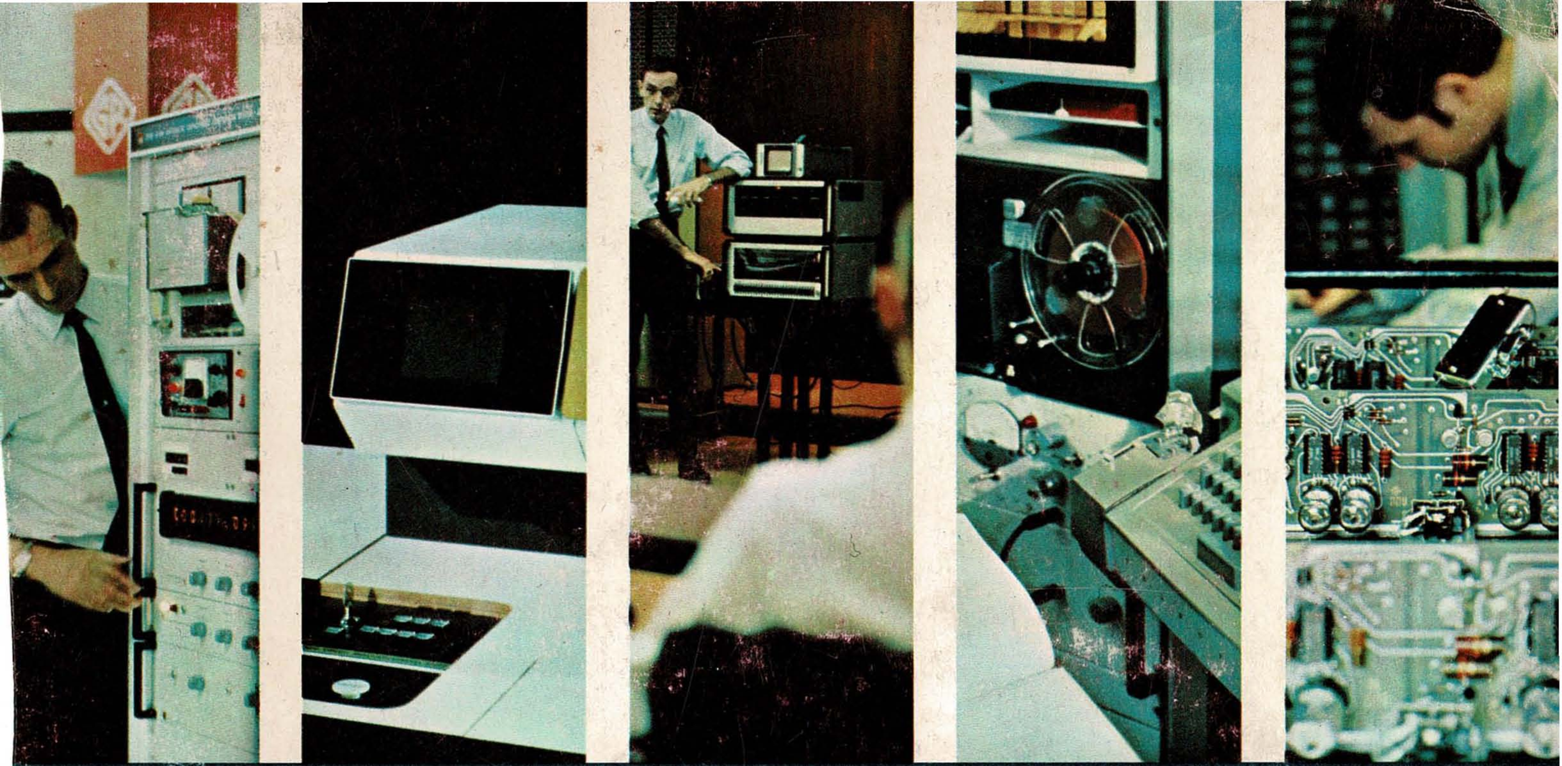


GENERAL RADIO · Catalog U

GENERAL RADIO

CATALOG U

FEBRUARY 1970

GENERAL RADIO COMPANY

West Concord, Massachusetts, U S A

NERALRADIO GENERALRADIO GENERALRADIO GENERALRADIO GENERALRADIO

GENERAL RADIO CANADA LIMITED
Toronto, Ontario, Canada

GENERAL RADIO COMPANY (OVERSEAS)
Zürich, Switzerland

GENERAL RADIO FRANCE
Paris, France

GENERAL RADIO GmbH
München, West Germany

GENERAL RADIO ITALIA S.p.A.
Milano, Italy

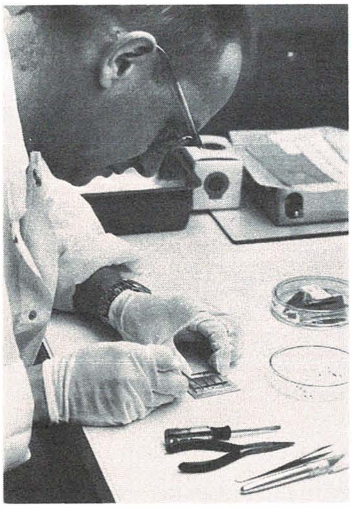
GENERAL RADIO COMPANY (U.K.) LIMITED
Bourne End, Buckinghamshire, England

TABLE OF CONTENTS

TABLE OF CONTENTS

(cont'd)

GENERAL RADIO is an employee-owned manufacturer of electrical and electronic measuring instruments for science and industry. Our administrative offices and plant are at West Concord, Massachusetts, and a second plant is located in Bolton, Massachusetts.



Because of the highly technical nature of our products, there is a high proportion of professional employees among the 1200-plus people who make up General Radio. We have been called "an engineer's company," and it is true that the engineering personality and discipline are present in most of the Company's operations.

Every employee is, directly or indirectly, a part owner of the Company and is jealous of his Company's reputation for quality. The extra reliability and years of life built into GR instruments are the result of both a deliberate corporate dedication to quality and an employee-by-employee commitment to the same principle.

General Radio sells standard, proprietary, off-the-shelf products, listed in this catalog. In addition, we custom-assemble a variety of systems, notably in the automatic-measurement area, including non-GR as well as GR products. We have also developed many special-purpose instruments, and we are always happy to explore ways of tailoring our capabilities to your needs.

What We Offer Our Customers

A Soundly and Imaginatively Designed Instrument

GR instruments are designed by engineers who draw on a unique combination of resources. First, there is a stockpile of Company experience in each of our product areas. Second, the breadth of GR's product line is reflected in a wide range of engineering activity, with constant exchange of ideas both within the Company and within the profession. By this environment and by education, the GR engineer is well equipped to make important technical contributions. The long list of early GR "firsts" is too well known to bear repeating. What GR engineers have done lately is no less impressive, including pioneering developments in the fields of automatic component-measuring systems and acoustic analyzer systems.

A Well Manufactured Instrument

GR has earned an envied reputation for making quality instruments, and it is one of our most cherished — and best guarded — possessions. It is a prime concern of our highly skilled instrument assemblers in the U.S.A. and in our new manufacturing facility in France.

Quality, of course, begins long before instrument assembly. Components must meet rigid standards, and, for closest control of quality, we make many of them ourselves.

After we put an instrument together, we test it thoroughly. By the time it crosses our shipping platform, we are so confident of its quality that we place a two-year warranty on it. It's a liberal warranty, but odds are better than 30 to 1 that you'll never use it.

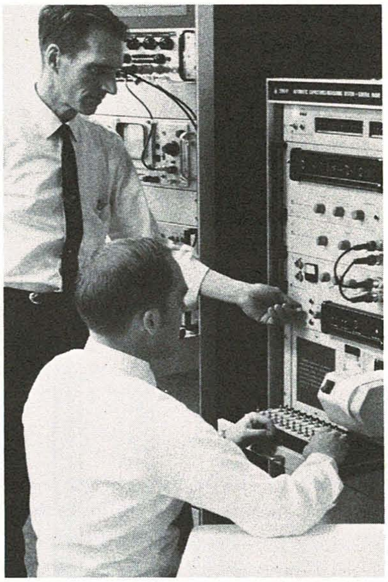
Prompt Delivery

Everything listed by type number in our catalog is on our shelf. At least that's our policy, even if occasionally orders exceed our expectations and we are caught with an empty shelf or two. To reduce delays, we stock instruments at several locations throughout the U.S., and we send all transcontinental shipments by air freight.

Solid Service

In the event that you do require service for your GR instrument, you'll get it fast, and it will be thorough and courteous.

GR service centers, staffed with factory-trained technicians, are located throughout the country and in Toronto, London, Paris, and Zurich. Even if an instrument needs only minor service, we give it a complete performance test and send it back to you with a one-year warranty that it will meet its original specifications.



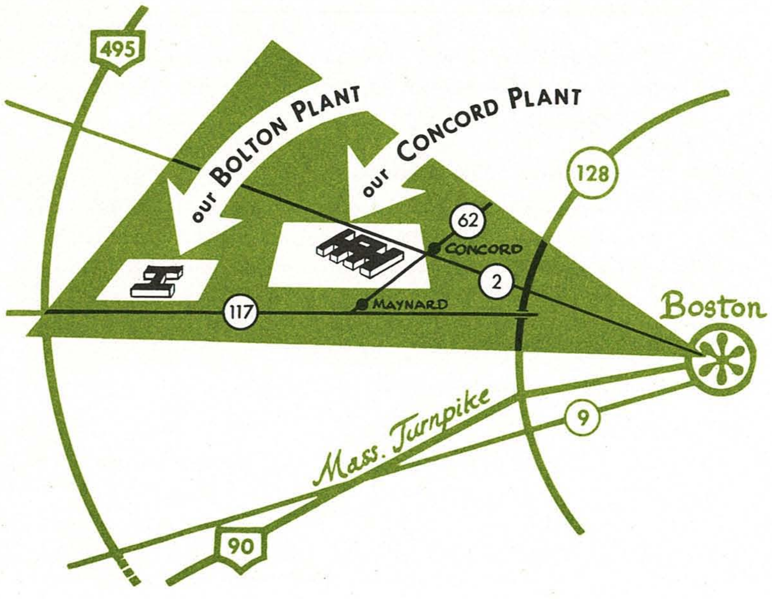
Expert Sales and Applications Engineering

Our sales engineers are salaried GR employees; most are graduate engineers and have completed a home-office training course in the commercial as well as the technical aspects of selling GR products. Selling an instrument line as broad as GR's, they are experts in instrumentation, well prepared to guide you in selecting the right instruments for your job.

GR sales engineers are located throughout the U.S. and Canada, from Seattle to Cocoa Beach, from San Diego to Boston. Where GR sales-engineering offices aren't, our traveling **Tourlabs** are. Abroad, the same expertise is available from our sales subsidiaries in London, Milan, München, Paris, and Zürich, and from representatives throughout the world.

To help you get the most out of your GR instruments, we publish a vast amount of technical literature, and we hope that you will take advantage of it. The long list includes **The Experimenter;** handbooks on noise and vibration measurement, stroboscopy, high-speed photography, textile applications for the stroboscope, and coaxial microwave measurements; student laboratory experiments and instrument notes; the periodicals **Noise Measurement** and **Strobotactics;** and many, many other bulletins and papers. Just drop us a line telling us what you want; we'll mail it out promptly.

If you have any questions on GR products, sales, or service, write us or phone your nearest GR sales engineer. Or, if you're in our neighborhood, stop by for a visit; you're always welcome.



Ordering and Service Information

WHERE TO ORDER

USA and Canada

Please address orders and other communications to any of the sales offices listed in the back of this catalog, or communicate directly with the Sales Engineering Office at West Concord, Mass.

Export Orders

Customers outside the United States and Canada are served by General Radio, its subsidiaries, and by various export representatives, all listed in the back of this catalog. All communications should be directed to the appropriate export representative. For countries not listed, inquiries should be addressed to General Radio Company, West Concord, Massachusetts 01781, U. S. A., or, for customers in Europe, to General Radio Company (Overseas), Postfach 124, CH 8034 Zurich.

HOW TO ORDER

Always order by type number, complete description, and catalog number, if included. AC-operated instruments are supplied wired for operation from 115-volt power, unless otherwise specified. Most instruments can also be supplied for operation from other common voltages and frequencies as indicated in the specifications under Power Required. Be sure to specify operating voltage and frequency if other than nominal 115 volts, 60 Hz.

For example:

Catalog No. 1900-9801, Type 1900-A Wave Analyzer, 230 V, 50 Hz, Bench Model

Special features and modifications not listed in the specifications (such as extra calibrations) are available at extra cost. Please include in your order information regarding any nonstandard features desired.

CONDITIONS OF SALE

Determination of prices, terms and conditions of sale and final acceptance of orders are made only at General Radio Company, West Concord, Massachusetts, USA, General Radio Canada Limited, Toronto, Canada, or General Radio Company (Overseas), Zurich, Switzerland.

USA and Canada: Net 30 days if credit has been arranged; otherwise, unless payment is received before shipment, shipment will be made COD.

Outside USA and Canada: Terms of payment for orders placed on General Radio representatives and on General Radio subsidiaries are those that are mutually agreed upon. If there is no representative in your area, the terms for orders placed directly on General Radio Company or on General Radio Company (Overseas) are full payment in advance of shipment or an irrevocable letter of credit, unless other terms have been previously arranged.

Quantity Discount

The following quantity discounts apply for identical units and packages purchased on a single order, normally for single shipment to one destination. All items are subject to these discounts.

Quantity	1	2-4	5-9	10-19	20-49	50-99	100
Discount	List	3%	7%	10%	13%	17%	20%

MINIMUM BILLING

The minimum billing per order is $10.00. This applies to all purchases except repair parts and cash-with-order transactions.

SOURCE-INSPECTION SURCHARGE

A surcharge of 1 percent ($2.50 minimum) applies on all orders requiring inspection at our plant. The inspection surcharge applies on each shipment inspected and covers only our costs.

SHIPPING INSTRUCTIONS

Unless specific instructions accompany the order, we shall use our judgment as to the best method of shipment. Shipments can be made by either air or surface transportation. For fast delivery, at a reasonable premium over other means, air shipment is generally recommended and will be employed on request.

PRICES

The prices listed in this catalog apply only on transactions originating in the USA, include the cost of domestic packing, are FOB our plant, West Concord, Massachusetts, and are exclusive of all taxes now in effect or that may be imposed hereafter by Federal, State, or local governments. Prices given are subject to change without notice. Formal price quotations remain in effect for 30 days. Export prices including the cost of packing are available from the offices or representatives listed in the back of this catalog. Canadian customers may obtain prices FOB Toronto from our subsidiary offices in Toronto or Montreal.

WARRANTY

We warrant that each new instrument manufactured and sold by us is free from defects in material and workmanship and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards, after examination by our factory, district office, or authorized repair agency personnel, will be repaired or, at our option, replaced without charge, except for tubes or batteries that have given normal service.

SPECIFICATION CHANGES

We reserve the right to discontinue any item without notice and to change specifications at any time without incurring any obligation to incorporate new features in instruments or parts previously sold.

SERVICE AND PARTS

The return of instruments for repair or recalibration and the ordering of repair parts should be arranged with your local General Radio office or representative. When arranging a return, be sure to give the catalog and type number, description, serial number of the instrument, date of original purchase, and details concerning the difficulty or the service desired.

When ordering repair parts, please specify the part number and description of the item as well as the type number and serial number of the instrument in which it is used. Advice on repairs to General Radio instruments may be obtained from any GR office or representative.

An instrument returned for credit will be subject to a restocking charge. If more than 6 months has elapsed since original purchase, an instrument will not be accepted for credit.

POWER-SUPPLY CONSIDERATIONS

General Radio ac-operated instruments will meet the published specifications when operated from power lines whose voltages and frequencies are within the limits stated in the specifications under the heading Power Required.

Most instruments have input voltage ranges of 100 to 125 and 200 to 250 volts and will therefore operate on nominal power-line voltages of 115, 220, 230, and 240 volts. The voltage range for which an instrument is wired is marked at the power-input plug or cord. Proper fuses for this voltage range are fitted in the fuse holders.

When the power-line voltage on which the instrument is to be operated is specified on the order, the necessary changes in connections, fuses, and name plate are made at the factory. Instruments equipped with line-voltage-selector slide switches are set for 115 volts when shipped.

Certain instruments are available for use only on power lines of 220, 230, and 240 volts (nominal).

For most instruments, the normal operating frequency range is 50 to 60 hertz.

All ac-operated instruments are supplied with three-wire power cords, designed for USA standard three-wire receptacles.

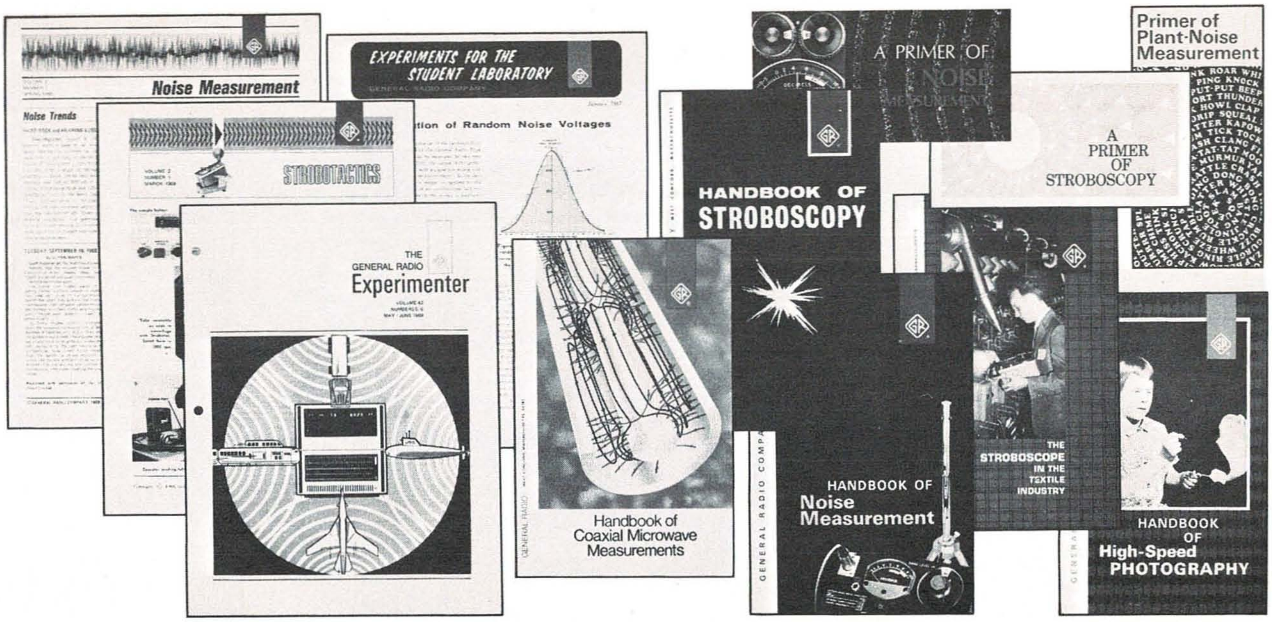
Battery Operation

Portable, battery-operated instruments are shipped with dry-cell batteries in place but disabled to prevent drain and leakage during shipment. To render the instrument operative, the user need only remove the yellow insulating disks from the battery terminals.

DIMENSIONS

Over-all dimensions are given for instruments except that the depth dimension for rack-mount instruments is actually depth behind panel, i.e., clearance required. However, no allowance is made for additional clearance that may be required for cables and connectors at rear panel.

PUBLICATIONS



The **General Radio Experimenter,** issued bimonthly, discusses new products and applications as well as general technical subjects. Sent free on request, this periodical is mailed to over 100,000 readers throughout the world.

For those especially interested in stroboscopic techniques and in sound and vibration measurements, two specialized magazines, **Strobotactics** and **Noise Measurement** are now published by GR.

Other GR publications include **Experiments for the Student Laboratory** with suggested experimental procedures for the electrical or physics laboratory in college, university, and technical schools, and a variety of handbooks: the **Handbook of Noise Measurement,** the **Handbook of Stroboscopy,** the **Handbook of High-Speed Photography,** and **The Stroboscope in the Textile Industry.** Also available are Instruments Notes, booklets, many reprinted articles on a wide range of technical subjects, and three primers: **A Primer of Noise Measurement, Primer of Plant-Noise Measurement,** and **A Primer of Stroboscopy.**

PATENTS

Many of our products are manufactured and sold under United States Letters Patent owned by the General Radio Company or under license grants from other companies. To simplify the listing of these patents they are given here in a single list and referred to at each instrument only by appropriate reference number.

1. "Certain vacuum-tube amplifier devices, electric wave filters, vacuum-tube oscillators, and sound-level meters are licensed by Western Electric Company, Inc., under all United States Letters Patent owned or controlled by American Telephone and Telegraph Company, or Western Electric Company, Inc., and any or all other United States patents with respect to which Western Electric Company, Inc., has the right to grant a license, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including engineering and industrial fields."

2. Patent 2,578,429
3. Patent 2,586,397
4. Patent 2,548,457
5. Patent 2,802,907
6. Patent 2,977,508
7. Patent 3,067,388
8. Patent Applied For
9. Patent Re 24,204
10. Patent 3,050,685
11. Patent 3,022,944
12. Patent 3,012,197
13. Patent 2,977,540
14. Patent 2,763,733
15. Patent D 187,740
16. Patent 2,970,258
18. Patent 2,581,133
19. Patent 2,872,639
20. Patent 2,943,277
21. Patent 2,942,172
22. Patent 2,966,257
24. Patent 2,702,736
25. Patent 2,715,718
26. Patent 2,786,140
27. Patent 3,156,870
28. Patent 3,300,731
29. Patent 3,286,199
30. Patent 3,339,108
31. Patent 3,177,425
32. Patent 3,227,893
33. Patent 3,238,442
34. Patent 3,327,071
35. Patent 3,328,564
36. Patent 3,378,701
37. Patent 3,382,443
38. Patent 3,422,422
39. Patent 3,426,187
40. Patent 3,435,366

SYSTEMS

SYSTEMS CAPABILITY
LOGIC-CIRCUIT ANALYZER

ENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO

SYSTEMS

FOR SPEED, HANDS-OFF TESTING, AND AUTOMATIC DOCUMENTATION

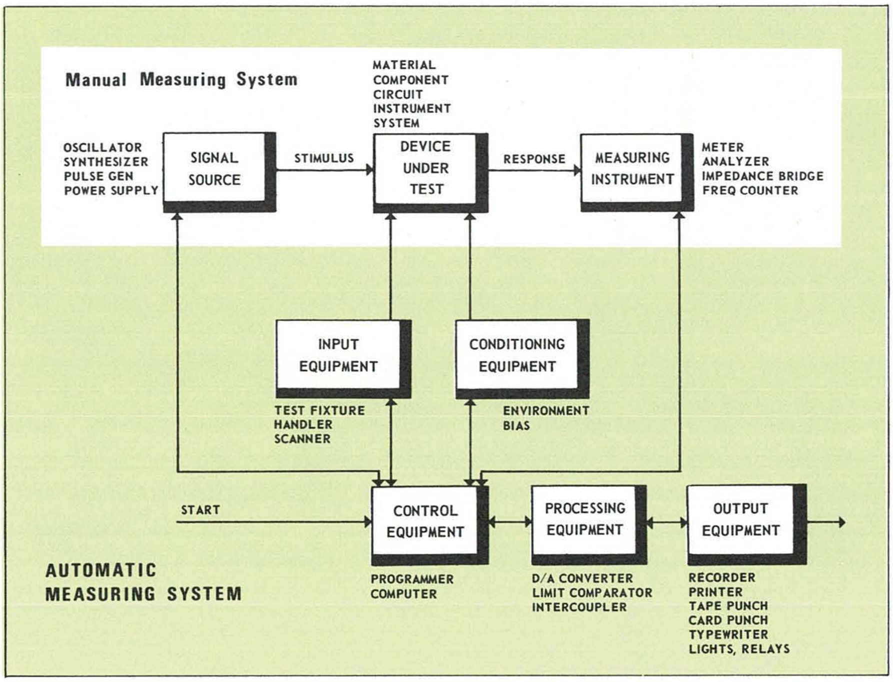
The advent of automatic measuring instruments with digital output has prompted the automation of many old and new measurement tasks. The diagram below shows the variety of functions to be found in an automatic measuring system.

The inner box contains the elements essential to any measuring system, manual or automatic. The device under test can range from a dielectric material or component to a complex system. The stimulus and response-measuring function are often combined in a single instrument.

The functions in the outer box can be added to automate all or part of the measurement task. Thus, one can add test fixtures and handlers, to assist the input function, or scanners for automatic connection of the devices under test to the measuring equipment. Processing equipment can operate on the measurement data and convert them to more useful forms; output equipment can be added to produce graphs, charts, or typewritten reports. Control equipment can perform various timing and switching operations. Many of these functions can be combined in a single unit.

As peripheral functions are added, the operator acts less as a mechanical part of the measurement process and can devote his attention to results rather than details of the measurement. If the results are used for automatic control of other equipment operating on the device under test, a closed-loop process-control system can be achieved.

Many General Radio instruments are useful in such systems. In addition to providing measuring instruments and peripheral system components, we welcome the opportunity to consider your entire measurement needs.



CUSTOM SYSTEMS

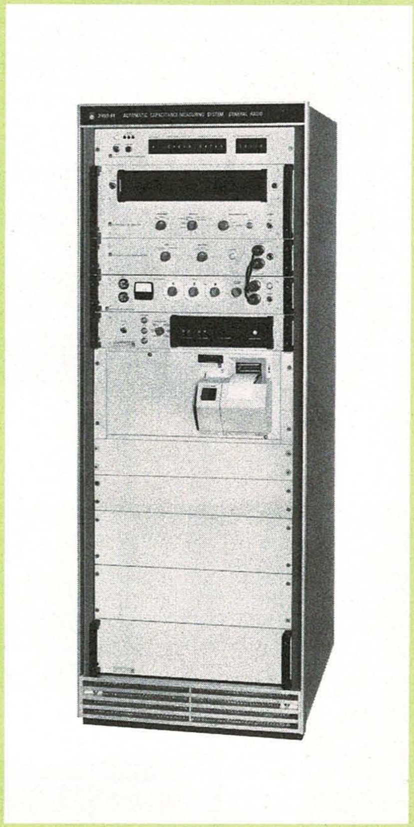
We define a "system" as a collection of instruments — some standard, some modified, some specially designed, some purchased — assembled to accomplish a specific measurement task.

This definition recognizes that a system is more than a group of catalog instruments and a few patch cords. The grouping must be carefully thought out, from both an electrical and mechanical standpoint. Interface problems must be identified and solved. Some instruments may have to be adapted to the requirements of the system. Others may have to be purchased or designed. Special cables, racks, and consoles may be necessary, along with special operating and maintenance instructions. The system must be thoroughly engineered; the whole must be greater than the sum of its parts.

Some typical examples of measurement systems, custom-built by GR, are shown on the next pages.

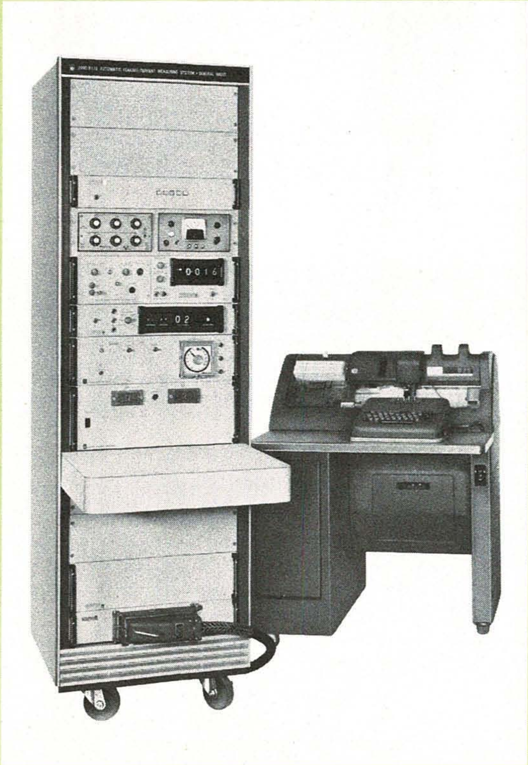
COMPUTER-CONTROLLED MEASUREMENTS

Install up to 100 capacitors on a test board, select the test frequency, type in the remaining test conditions, and push a button — 15 minutes later, including a 5-minute soak period, this system provides a complete printout of all tests of all capacitors. Capacitors from 0.1 pF to 1000 μF can be tested at frequencies of 120, 400, and 1000 Hz with electrification voltages up to 600 V and dc bias up to 50 V. Capacitance is measured with 0.1% basic accuracy, loss within 0.001, and leakage current from 2.200 nA to 2.200 mA full scale.



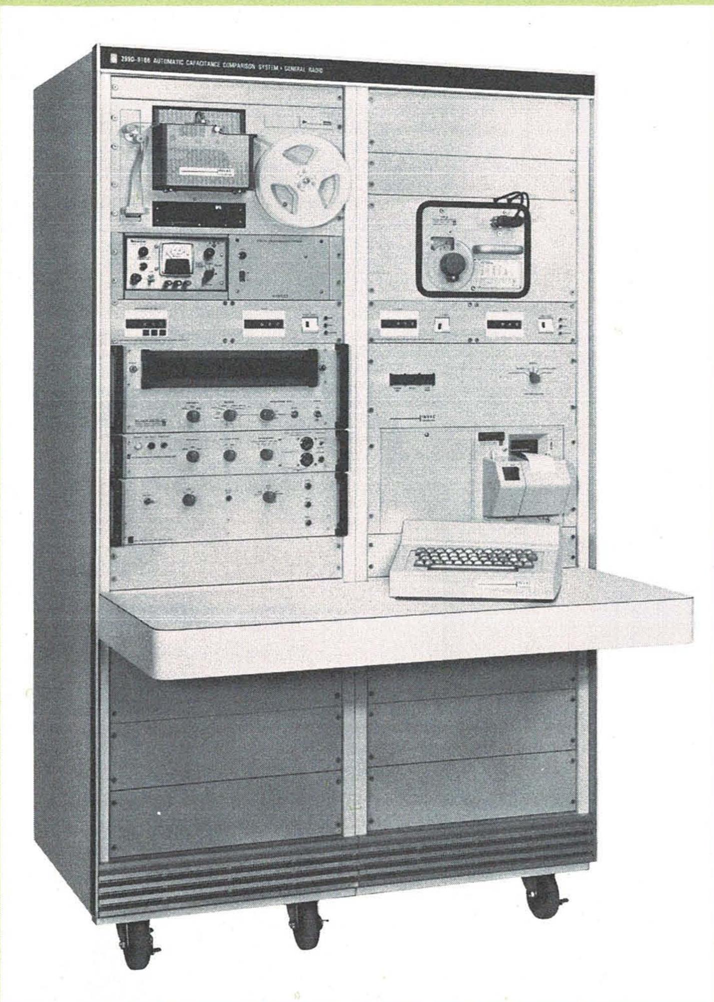
7000 GO-NO-GO TESTS PER HOUR

A scanner selects the component to be measured, a bridge measures both capacitance and loss, and a comparator compares the values to a set of preset limits — all automatically and at rates up to 7000 per hour. Measurements are made with dc bias and recorded on a data printer: in-tolerance values in black and out-of-tolerance values in red. The comparator is fully compatible with many automatic sorting devices so that the sorting process can be automatic also.



AUTOMATIC LEAKAGE-CURRENT MEASUREMENTS

Up to 45 components are sequentially measured for leakage by this system, which also produces permanent records in punched-card form. Electrification from 0 to 600 V dc is available, and currents from 2.200 nA to 2.200 mA full scale can be measured. The electrification and discharge times are preprogrammed and all measurements are fully automatic.



50-PPM COMPARISONS FULLY RECORDED

Comparisons of impedance magnitude and phase to a precision of 50 ppm are not only possible with this system, they are performed routinely and with full and automatic documentation, including a tape perforator for off-line processing. The measurements can be made with or without automatically stepped dc bias, supplemental data can be manually inserted by means of a keyboard, and an intercoupler can be added for use with an IBM Printing Summary Punch.

PLOTS OF CAPACITANCE VS VOLTAGE

Although a plotter was not included, this system provides the capability to plot the value of any capacitance from 0.01 pF to 1000 μF as a function of dc bias voltages up to 150 V, with 5-digit resolution.

RECORDED CAPACITANCE MEASUREMENTS

This is one of our simpler systems, yet it provides automatic capacitance measurements at rates up to two per second, with 0.1% accuracy. It also records capacitance and loss values along with serial numbers on a paper-tape printout.

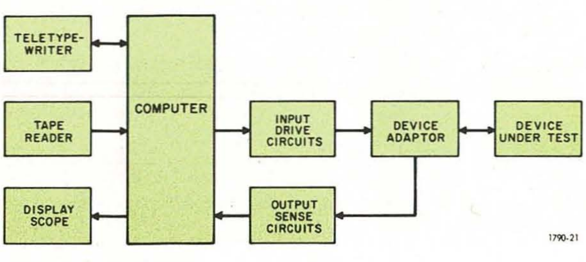
Type 1790 LOGIC-CIRCUIT ANALYZER

- up to 4000 tests per second
- go, no-go tests or complete analysis
- unique and easily-mastered test language
- standardized tooling
- no reference modules needed
- autoprogramming lets device determine outputs
- optional programmable logic levels

NEW

The 1790 is a computer-controlled functional and diagnostic test system for logic elements, be they simple devices, complex circuits, assemblies, or entire instruments. It accepts circuits with up to 96 inputs and 144 outputs, performs 1000 to 4000 tests per second, and provides typewritten, scope displayed, and bright-light results of any or all tests — at your command — in terms of a simple go/no-go indication or a detailed account of each test. The speed, low cost, and abundance of features, including a highly simplified yet very versatile test language, invite comparison. For $32,500 you get everything you'll probably need: the 1790, installation, and training. If you need more you can have that also — in the form of options such as additional memory and programmable logic levels.

Simple Setup The flexibility of the 1790 eliminates the need for costly special tooling, test fixtures, and documentation. For each circuit to be tested, only a simple device adaptor and test program are required. To write a program, a test technician analyzes the circuit and decides how it should be tested, much as he does for manual test procedures. But, instead of writing an involved test specification, he describes the tests to be performed in a GR-developed test language — so simple he can learn it in a few hours. The program is converted to a punched tape through the use of the built-in teletypewriter and computer. The program listing is the documentation.



High Test Speed The speed of the 1790 ensures that most test times will be limited only by the rate at which test devices can be connected to the system. For large production runs, this assures rapid sorting of good and bad devices and allows more time for trouble-shooting defective devices.

Lower Trouble-Shooting Costs The flexibility of the 1790 test language means that a great deal of diagnostic information can be included in the test program when it is initially prepared. When certain failures are encountered, the program can branch to detailed diagnostic routines and can display helpful suggestions or instructions to the operator. The technician can use the logic probe provided or an external oscilloscope and can control the mode of testing and the tests to be executed from the control panel and teletypewriter keyboard. In the SINGLE TEST mode, tests can be executed one at a time with a scope display of inputs and outputs. A RESTART ON FAIL mode provides continuous looping up to the test that failed. This mode and a keyboard-generated trigger pulse enable the use of an external oscilloscope for dynamic observation. To locate an intermittent failure, a RESTART ON GO mode continually tests a device until a failure occurs. It is also possible to use the teletypewriter to modify test programs on-line. This feature is useful for both initial program preparation and detailed diagnostic procedures.

Functional Design The desk console provides all controls and displays at an optimum location to minimize operator fatigue and to ensure highest production rates. The device adaptor sockets and accessory jacks are recessed into the broad desk top, which can be used for drawings or auxiliary test equipment. The teletypewriter is enclosed in the desk under a protective cover to provide additional work space and to reduce noise; it slides out to a typing position for use in the preparation of test programs. Two storage drawers allow storage for tapes or manuals, and full access to the computer controls is available by removal of the cover.

A storage-display oscilloscope is located at a convenient viewing angle and is used as the primary means of message display. While a hard copy of the error message is available from the teletypewriter by pressing the PRINTER pushbutton on the control panel, the display scope is much faster and eliminates the need for a heavy-duty teletypewriter. The high-speed optical tape reader located next to the display scope is used for rapid loading of programs. The LOAD TEST PROG pushbutton on the control panel initiates program loading; the operator does not have to manipulate the computer controls.

Control of system operation is through the pushbuttons on the control panel. The pushbuttons start the test program, continue the test program (after a programmed pause instruction or error message), and enable the test-program sequence to be modified by keyboard commands. The four indicator lights are GO, FAIL, PAUSE, and CONDITIONAL GO. The last indicates the device reached the end of the program but not all tests were executed (for example, when a keyboard instruction began a test in the middle).

specifications

Inputs to Device under Test: 96 max. Driver circuits are TTL 7440 power gates (programmable levels with option 3).

Outputs from Device under Test: 144 max. Sensor circuits are DTL 944 NAND gates. Device under test loaded by 12 kΩ to +5V (programmable levels with option 3).

Power Supplies: +5 V, − 15 V, and +15 V each at 1.25 A max, 250 V at 45 mA (programmable voltages with option 3).

Speed: 4000 tests/s/pin for 12 inputs-12 outputs (250 μs/test), 1100 tests/s/pin for 96 inputs-144 outputs (900 μs/test), slower with option 3.

Control: Control for any set of tests is by a test program, written once for the type of device under test and loaded into the computer at 300 characters per second by a high-speed optical tape reader. Tests can also be controlled by control-panel switches and teletype keyboard to allow changes in stimuli or test conditions and to permit diagnostic analysis.

Program: Written in easy-to-learn GR-originated test language and punched on tape by teletype, with an Editor program to simplify changes and a Translator program that provides a full set of error messages. A unique Autoprogramming Translator program stores the responses of a known-good device when it is inconvenient to write outputs into the test program. *Program length,* 900 test statements for 12 inputs-12 outputs, 130 test statements max for 96 inputs-144 outputs (increased approx 10 fold with option 2).

Display: Scope displays error messages, programmed diagnostic information, operator instructions, and test program during preparation. Teletype prints error messages and test-program listing. Indicator lamps show test results.

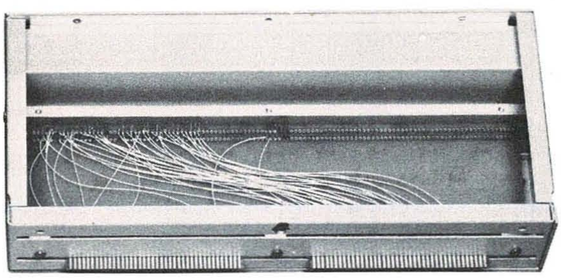
Interface: The device under test mates with a device adaptor that is easily inserted or removed by the action of a single lever. The *device adaptors* are configured by the addition of the sockets and wire-wrap connections necessary to meet, electrically and mechanically, the requirements of the device under test. Four kits are available; each contains a frame and circuit boards, with or without holes to mount a socket, for either 72 inputs-72 outputs or 96 inputs-144 outputs.

Power: 105 to 125 V, 60 Hz, 1000 W.

Supplied: Logic probe, three 1790-9602 Device Adaptor Kits, two-day training course at General Radio, and installation at customer's facility. *Standard System* consists of a computer with 4096 12-bit words of 1.6 μs-cycle core memory, interface and power-supply system, control panel, teletypewriter (including keyboard, reader, and punch), display oscilloscope, and optical tape reader. *Software* includes operating, programming, and maintenance manuals, and a full set of programs including Editor, Translator, Operating System, Combined Interactive System, Autoprogramming Translator, Diagnostic, Basic Loader, and computer maintenance and diagnostic programs.

Available: Additional device adaptor kits and custom device adaptors and test programs. **Option 1:** Rack Version. **Option 2:** Additional Memory (32k words). Increases program length to 8000 test statements max for 12 inputs-12 outputs, 1400 test statements max for 96 inputs-144 outputs. Housed in separate rack cabinet. **Option 3:** Programmable Logic Levels. *Input and output test levels* programmable by test statements from −30 to +30 V on 60-mV increments. *Power to device under test* programmable by test statements; three power supplies included, one from −20 to +20 V, 2 A max; two from −40 to +40 V, 1 A max. *Speed* is 2500 tests/s/pin for 12 inputs-12 outputs (400 μs/test) and 700 tests/s/pin for 96 inputs-144 outputs (1400 μs/test). Housed in separate rack cabinet.

Mechanical: Console or rack versions. *Dimensions* (w x h x d): Console, 74 x 48 x 34 in. (1880 x 1220 x 870 mm); rack. 23 x 72 x 44 in. (590 x 1830 x 1120 mm) plus separate pedestal for teletypewriter, 22 x 20 x 36 in. (560 x 510 x 910 mm); rack to house options 2 and 3, 23 x 48 x 29 in. (590 x 1220 x 740 mm).



Underside of 1790-9603 Device Adaptor Kit showing socket holes and typical wire-wrapped connections.

Description	Price in USA
1790 Logic-Circuit Analyzer, console version	**$32,500.00**
Option 1 Rack Version	(no extra charge)
Option 2 Additional Memory (32k words)	**add 11,500.00**
Option 3 Programmable Logic Levels	**add 9,500.00**
1790-9601 Device Adaptor Kit, without holes for socket, 72 inputs-72 outputs	**110.00**
1790-9602 Device Adaptor Kit, without holes for socket, 96 inputs-144 outputs	**160.00**
1790-9603 Device Adaptor Kit, with holes for socket, 72 inputs-72 outputs	**115.00**
1790-9604 Device Adaptor Kit, with holes for socket, 96 inputs-144 outputs	**165.00**

COMPLETE BROCHURE ON REQUEST

Two pages cannot explain adequately the full capabilities of the 1790. Before you spend 30 to 40 thousand dollars for our system or twice that for someone else's, call your nearest GR District Office or write us directly and request a full brochure on the 1790. This brochure discusses, in detail, the kind of performance and economy the 1790 offers, with specific examples.

A Total Solution

We've made it easy for you to write your own test programs. We provide training for your technicians, we install the 1790 at your facility, and we provide complete instructions and documentation for the equipment, the computer programs, and the device adaptors.

Also, at nominal cost, we will write test programs and build adaptors for your devices.

We have over 50 years of electronic know-how, sales and service offices throughout the world, and a full team of engineering and applications specialists. If you need help, you can get it — from us —quickly and expertly.

SOUND AND VIBRATION

METERS, TRANSDUCERS, and CALIBRATORS
SIGNAL ANALYZERS, PROCESSORS, and SYSTEMS
RECORDERS
NOISE GENERATORS

GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO

SOUND AND VIBRATION

General Radio offers a complete line of sound and vibration measuring instruments. Although these instruments are designed to operate by themselves, much thought was given to their use together in a variety of systems to solve specific measurement problems. The types of instruments available and their functions are summarized on the following pages. The chart at the bottom of the next page illustrates how they may be used together in systems. Our sales engineers will be glad to work with you in selecting the proper equipment for your application.

CALIBRATION

The first step in using any sound or vibration measuring equipment is calibration. Calibration insures that the instruments are functioning properly and reading correctly.

Calibrators page 29 ff

Acoustics — The Type 1559-B Microphone Reciprocity Calibrator is the heart of a laboratory microphone calibration system to provide primary calibration of microphone sensitivity from 20 Hz to 6 kHz.

The Type 1562-A Sound-Level Calibrator is a precision field calibration source that provides five test frequencies to calibrate acoustic instruments and systems.

Vibration — The Type 1557-A Vibration Calibrator is a handy source of 1 g of acceleration at 100 Hz. It provides a means of quickly checking vibration pickups and their associated instrumentation, either in the field or in the environmental test laboratory.

TRANSDUCERS

A transducer transforms energy from one form into another. In the case of microphones, it changes the pressure variation of an acoustic wave into an electrical signal proportional to that pressure variation. For vibration pickups, specifically accelerometers, it transforms the acceleration of a vibrating body into an electrical signal proportional to that acceleration.

Microphones page 25 ff

Acoustics — Ceramic and condenser microphones are offered. The ceramic microphones are noted for their ruggedness, insensitivity to humidity and temperature changes, and low cost. They are well suited for the bulk of acoustic measurements made. The condenser microphones feature somewhat smoother frequency responses.

Pickups page 28

Vibration — Accelerometers are the most popular type of vibration transducer. They offer a wide frequency response and are insensitive to the magnetic fields sometimes encountered when measurements are made on rotating machinery. Use of a control box permits measurement of velocity and displacement as well as acceleration. Three vibration pickup and control-box combinations are offered.

PREAMPLIFIERS

Preamplifiers are used between the transducer and the measuring instruments for two reasons; to amplify, and to match the transducer to connecting cables. A preamplifier makes possible the use of cables up to several thousand feet without significant signal degradation.

The Type 1560-P42 Preamplifier is a solid-state preamplifier designed for use with both ceramic and condenser microphones. It is supplied power by most of our analyzers and internally generates the polarizing voltage necessary for condenser microphones.

Preamplifier page 26

The Type 1560-P40 Preamplifier is a solid-state preamplifier designed for use with GR 15/16" ceramic microphones and vibration transducers.

TAPE RECORDER

Recorder page 56

Tape recorders are useful for a variety of sound and vibration measurement applications: to record field data for later analysis, to provide a permanent record, and to increase the duration of transient signals by the use of a tape loop. The Type 1525-A Data Recorder was specifically designed for acoustic measurements. It features a built-in sound-level meter, flat response, wide dynamic range and tape-loop adaptors.

SOUND-LEVEL METERS

Sound-Level Meters page 18 ff

The standard sound-level meter is the basic instrument for acoustic measurements.

The Type 1565-A Sound-Level Meter is a compact, low-cost, lightweight, easy-to-operate instrument. It is ideally suited for measurements in accordance with the noise control provisions of the Walsh-Healey Act.

The Type 1551-C Sound-Level Meter has gained wide acceptance as a general-purpose sound-level meter. Any of the GR vibration control boxes may be attached to the front of this instrument to convert it into a vibration measuring instrument. Its output can be used to drive many other GR instruments to obtain additional information about the noise or vibration being measured.

The Type 1561-A Precision Sound-Level Meter is for measurements requiring laboratory precision and for system applications. It meets the international standard IEC 179.

All the above instruments conform fully to the appropriate ANSI and IEC Standards.

VIBRATION METER

Vibration Meters page 22

The Type 1553-A Vibration Meter is the basic instrument for vibration measurement. With this instrument, one can measure acceleration, velocity, displacement or jerk of a vibrating body in terms of the peak, peak-to-peak or average value.

IMPACT ANALYZERS

Impact sound or vibration signals are characterized by a very high ratio of peak to rms level. Acoustic measurements of impact signals require an instrument specifically designed for this purpose. The Type 1556-B Impact Analyzer is such an instrument. It may be used with our sound-level meters, vibration meter and broad-band analyzers.

FREQUENCY ANALYZERS

Analyzers page 24

Frequency analyzers determine both the amplitude and frequency of sound, vibration and other electrical signals. Frequency analysis is usually a necessary step in the implementation of any noise-reduction program. The major difference between one analyzer and another is the bandwidth or selectivity of the filters used. Some analyzers may be used directly with transducers, while others require a preamplifier. The analyzers, bandwidth, and major application areas are listed below.

Type Number	Bandwidth	Major Application Area: Sound	Vibration	Other Electrical Signals
1558	Octave Band	X		
1564	1/3 and 1/10 Octave Band	X	X	
1568	1%		X	X
1900	3, 10, 50 Hz		X	X

GRAPHIC LEVEL RECORDER

The Type 1521-B Graphic Level Recorder provides permanent records of the levels measured by sound-level meters, frequency analyzers and vibration meters. It is offered in combination with the analyzers to produce automatic spectrum analysis of acoustic, vibration or electrical signals.

SIGNAL SOURCES

Signal sources of various types are required for acoustic and vibration testing. For example, random noise is required for measuring the transmission loss of materials; sinusoidal sources are used for frequency response testing of loud speakers; and tone bursts are used for transient response testing. GR offers sources to fulfill practically any acoustic requirement.

Analyzers page 34 ff

OTHER INSTRUMENTS

Recording Analyzers page 43 ff

The Type 1569 Automatic Level Regulator is designed to control the level in swept-frequency sound and vibration testing. It maintains a constant sound-pressure level for microphone response measurements, and a constant exciting force for swept-frequency vibration testing.

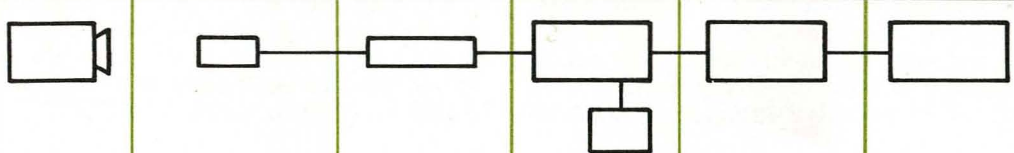
Noise Generators page 60 ff

The Type 1952 Universal Filter is a low-pass, high-pass, band-pass, or band-reject filter useful for filtering unwanted noise from signals, and for a variety of other applications.

Analyzers page 35 ff

REAL-TIME ANALYSIS

Real-Time analysis is a totally different concept in spectrum analysis. If you do large quantities of spectrum analysis work, work with non-stationary signals, or edit and process the analysis data, real-time analysis should be of interest to you.



	CALIBRATION	TRANSDUCERS	PREAMPLIFIERS	SOUND AND VIBRATION METERS, TAPE RECORDER AND IMPACT ANALYZER	FREQUENCY ANALYZERS	RECORDERS
Acoustic	1559-B 1562-A	1560-P5 1560-P7 1560-9531 1560-9532 1560-9533 1560-9534 1560-9535 1560-9536 1560-9537 1560-9538	1560-P40 1560-P42	1565 1551-C 1561 1525 1556	1558 1564 1568 1900	1521-B
Vibration	1557-A	1560-P52 1560-P53 1560-P54	1560-P40	1553 1556	1564 1568 1900	1521-B

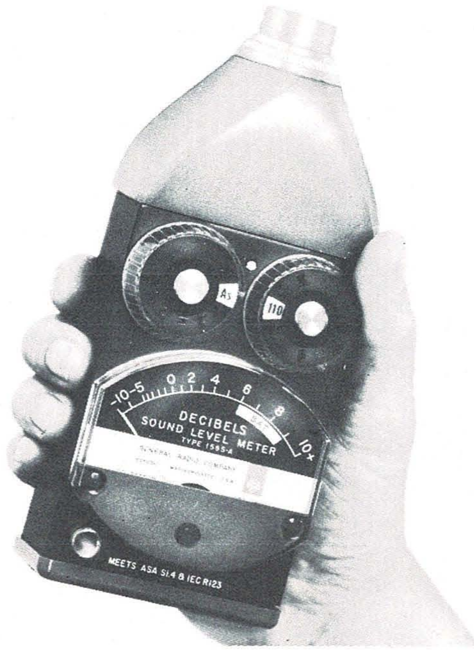
ANALYZER/RECORDER SYSTEMS

System Number	Instrument Numbers
1910	1900/1521-B
1911	1564/1521-B
1912	1564/1564-PI/1521-B
1913	1568/1521-B

Type 1565-A SOUND-LEVEL METER

- conforms to ANSI and international standards
- 40- to 140-dB measurement range
- ceramic microphone
- solid-state circuits

Sound-Level Meter in leather carrying case.



Although not so versatile in application as the Type 1551, this instrument is a standard sound-level meter capable of accurate noise measurements, in conformity with national and international standards. It is particularly useful for rapid surveys, for periodic checks on noisy environments, and for production testing of manufactured products.

The 1565-A Sound-Level Meter is a pocket-sized, lightweight instrument that can be held and operated with one hand. It includes most of the features usually found only in larger, more expensive instruments. With an adaptor in place of the microphone, the 1565 will accept a connector from a vibration pickup or other transducer or from a cable to a remotely placed microphone.

— See **GR Experimenter** for October-November 1964.

specifications

Sound-Level Range: 40 to 140 dB (re 20 $\mu N/m^2$).

Weighting: A, B, and C weighting in accordance with ANS Standard S1.4-1961 and IEC Publication 123, 1961.

Microphone: Lead-zirconate-titanate ceramic unit.

Output: At least 1.5 V behind 20 kΩ when meter reads full scale. Output can be used to drive a 1556 Impact-Noise Analyzer, 1558 Octave-Band Noise Analyzer, 1521 Graphic Level Recorder, or headphones. Harmonic distortion, 1% or less for frequencies above 100 Hz and 2% or less for frequencies below 100 Hz (panel meter at full scale).

Calibrator page 30

Meter: Rms response, and fast and slow meter speeds, in accordance with ANSI S1.4-1961 and IEC Publication 123, 1961.

Auxiliary Input Provision: A 1560-P96 Adaptor is available to allow connection to any source fitted with a male 3-terminal microphone connector. Input impedance is approximately 13 MΩ in parallel with 25 pF. For correct weighting, source impedance must be 380 pF ±5%.

Calibration: Sound-level meter can be pressure calibrated at 125, 250, 500, 1000, and 2000 Hz with a 1562 Sound-Level Calibrator or at any frequency from 20 to 2000 Hz with a 1559-B Microphone Reciprocity Calibrator.

Operating Temperature Range: 0 to 50°C.

Storage Temperature Range: —20° to 70°C (battery removed).

Operating Humidity Range: 0 to 90% R.H.

Temperature Coefficient of Sensitivity: Approx +0.03 dB/°C.

Effect of Magnetic Field: Equivalent C-weighted sound level of a 1-oersted (80 A/m) 60-Hz field is about 47 dB when meter is oriented for maximum indication.

Power Supply: One 1½-V size C flashlight cell. Battery life approx 35 hours for 2 h/day service.

Accessories Available: 1565-P1 Leather Carrying Case, 1562-A Sound-Level Calibrator, 1560-P96 Adaptor to adapt input to mate with three-terminal male microphone connector necessary for connection to vibration pickup, 1560-P95 Adaptor Cable to connect output to 1521-B Graphic Level Recorder or other devices fitted with jack-top binding posts on ¾-in. centers.

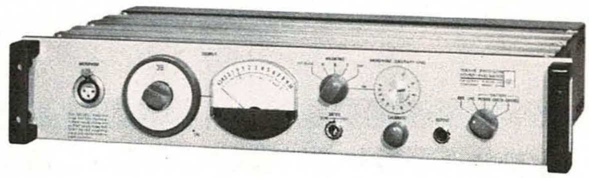
Dimensions (width x height x depth): 3⁵⁄₁₆ x 7⅜ x 2⅛ in. (78 x 190 x 54 mm).

Weight: Net, 1¾ lb (0.8 kg); shipping, 5 lb (2.3 kg).

Catalog Number	Description	Price in USA
1565-9701	**1565-A Sound-Level Meter**	**$345.00**
1565-9601	**1565-P1 Leather Carrying Case**	**15.00**
8410-0100	**Replacement Battery**	**.20**

Type 1561 PRECISION SOUND-LEVEL METER

- meets IEC 179 and ANSI S1.4
- rechargeable-battery operation
- rack model available
- external-filter connections



Rack Model

Industry standards for acoustical measurements are becoming more stringent. IEC Publication 179, 1965 requires greater accuracy of sound-level meters, particularly at frequencies above 1 kHz. The 1561 was designed to meet this requirement and the tighter low-frequency requirements of ANSI Standard S1.4-1961. It has the weighting characteristics, wide sound-level range, internal calibration facility, high-level output, and other capabilities of proven value in all the GR sound-level meters.

SPECIAL FILTERING

For special needs, the 1561 has provisions for the connection of an external filter to shape the frequency response as required. The GR 1952 Universal Filter is designed for such service.

CHOICE OF MOUNTING

For many applications, a rack-mounted sound-level meter is more appropriate than a portable instrument, e.g., in complete measuring systems. The 1561 is offered in both versions.

RECHARGEABLE BATTERY OPERATION

Either model of the 1561 can be powered by nickel-cadmium batteries; the portable model is available with two sets and separate battery charger or with dry cells; the rack model will operate from an ac line or from rechargeable batteries for which a charging circuit is built in.

— See **GR Experimenter** for April 1968.

specifications

Sound-Level Range (rms, dB re 20 μN/m^2):

Frequency Characteristic	With 1560-P7 Microphone and 10-ft cable	With 1560-P7 Microphone and 1560-P40 Preamplifier*
Flat	35 to 150 dB	31 to 130 dB
C Weighting	32 to 150 dB	27 to 130 dB
B Weighting	31 to 150 dB	26 to 130 dB
A Weighting	31 to 150 dB	27 to 130 dB

*Min obtained with ×10 preamp gain, max with ×1.

Allowance is made for a peak-to-rms ratio of 14 dB. When a sine-wave signal is applied to the 1560-P40, range is extended to 141 dB. The signal-to-noise ratio is at least 5 dB for the lower values given above.

Frequency Characteristics: A, B, and C weighting in accordance with ANSI Standard S1.4-1961, IEC Publication 123, 1961 and IEC Publication 179, 1965 for precision sound-level meters. Also provided is a flat response from 20 Hz to 20 kHz to permit measurement of sound-pressure level. Jacks are provided for insertion of an external filter.

Microphones: The GR 1560-P7 Precision Microphone is supplied with portable models (and available separately with rack models) with a 10-ft cable to permit microphone to be located away from instrument and observer to minimize diffraction and reflection effects (1561 gain is set to compensate for cable loss).

Sound-Level Indication: Reading is sum of meter and attenuator setting. Meter calibrated −6 to +10 dB; attenuator calibrated 30 to 140 dB (re 20 μN/m^2) in 10-dB steps.

Output (full-scale meter reading): 1.25 V behind 5500 Ω; harmonic distortion <0.5%.

Input Impedance: >100 MΩ, across 40 pF in portable model, across 90 pF in rack model.

Meter: Rms response; fast and slow meter speeds in accordance with above ANSI and IEC standards.

Calibration: Absolute calibration of the 1561 is set acoustically at 500 Hz and a level of 114 dB re 20 μN/m^2. Microphone response and sensitivity are measured in a free field 20 Hz to 15 kHz by comparison with a WE 640AA Laboratory Standard microphone with calibration traceable to the National Bureau of Standards. Complete electrical frequency-response measurements are made on each instrument. Panel adjustment provided for standardizing gain with internal calibration circuit, which has adjustment to permit calibration in terms of microphone sensitivity (control is internal and accessible through case of portable models, on front panel of rack models). The 1562 Sound-Level Calibrator or 1559 Microphone Reciprocity Calibrator can be used for making periodic over-all acoustic checks.

Calibrators page 29 ff

Temperature and Humidity Effects: The instrument will operate within specifications, for meter indications above 0 dB, over a range of 10 to 50°C and 0 to 90% relative humidity, when standardized by its internal calibration circuit or an external calibrator. No damage to microphone from −40 to +60°C and 0 to 100% relative humidity.

Magnetic-Field Effects: In a 60-Hz, 1-oersted (80 A/m) magnetic field and oriented for max reading, the rack model will indicate about 42 dB, the portable model about 53 dB (C weighting).

Accessories Supplied: Portable models include Precision Microphone Type 1560-P7, 10-ft microphone cable, and either one set of dry-cell batteries or two sets of rechargeable batteries and Battery Charger Type 1560-P60. Rack model includes power cord.

Accessories Available: 1952 Universal Filter and 1560-P40 Preamplifier (power supplied by 1561), 1560-P7 Microphone, and extension cables.

Universal Filter page 58

Power Required: The rack-mount 1561-R contains ac power supplies for operating the instrument and for recharging the batteries (not supplied) that can be used to power the instrument. This model operates from 100 to 125 or 200 to 250 V, 50 to 60 Hz, 2.5 W max.

The portable 1561 is supplied with either 3 Burgess type PM6 dry-cell batteries (or equivalent), which give about 15-h average operation, or with 2 sets of rechargeable nickel-cadmium batteries and the 1560-P60 Battery Charger. This unit will simultaneously recharge two sets of batteries (one set in the 1561, the other in the charger) from a power line of 105 to 125 or 210 to 250 V, 50 to 60 Hz, 5 W.

The nickel-cadmium batteries will provide about 20-h of operation and recharge in about 15-h; dry-cells about 15 h.

Mounting: The 1561-R is in a rack-mount cabinet, the portable model in a Flip-Tilt case; the charger in an aluminum case.

Dimensions (width x height x depth): Portable, 10¾ x 6⅛ x 5¾ in. (275 x 160 x 150 mm); rack, 19 x 3½ x 15 in. (485 x 89 x 385 mm); Battery Charger, 4¼ x 3¾ x 8 in. (110 x 96 x 205 mm).

Net Weight: Portable, 5½ lb (2.5 kg); rack, 15 lb (7.0 kg).

Shipping Weight: Portable, 10 lb (4.6 kg); rack, 23 lb (10.5 kg).

Catalog Number	Description	Price in USA
	1561 Precision Sound-Level Meter Portable Models, incl precision microphone and 10-ft cable	
1561-9700	with dry-cell batteries	$765.00
	with 2 sets rechargeable batteries and recharger	
1561-9701	for 115 volts	890.00
1561-9702	for 230 volts	890.00
1561-9703	**1561-R Precision Sound-Level Meter** Rack Model (no battery or microphone)	845.00
8410-3000	**Replacement Dry Cell,** 3 req'd	1.20
8410-1040	**Rechargeable Battery,** 2 req'd	12.00
1560-9607	**1560-P7 Precision Microphone** (no cable included, available only when ordered with 1561-R)	175.00

Type 1551-C SOUND-LEVEL METER

- 24- to 150-dB measurement range
- meets common standards:
  ANSI Standard S1.4-1961
  IEC Publication 123, 1961
- 20-Hz to 20-kHz amplifier response
- internal calibration system

The 1551-C is not only a convenient, highly accurate sound-level meter but is also the key instrument in a wide variety of sound and vibration measuring systems. In use as a sound-level meter alone, the 1551 is compact and easy to handle, rugged enough for severe environments, and simple to use.

A highly versatile instrument, it will, for example, serve as a calibrated preamplifier in combination with other, related instruments such as spectrum analyzers, special-purpose microphones, calibrators, and vibration pickups. Many other accessories, such as graphic level recorders and tape recorders, can be operated from the sound-level-meter output.

This sound-level meter can also be used as a portable amplifier, attenuator, and voltmeter for laboratory measurements in the audio-frequency range.

Many of its applications are described in detail in the Handbook of Noise Measurement, a copy of which is available to each user.

Description

The 1551-C consists of an omnidirectional microphone, a calibrated attenuator, an amplifier, standard weighting networks, and an indicating meter. The complete instrument, including batteries, is mounted in an aluminum case. The microphone can be used in several positions and, when not in use, folds down into a storage position, automatically disconnecting batteries. An ac power-supply unit is available.

— See **GR Experimenter** for August 1961.

Type 1553 VIBRATION METER

- direct reading in acceleration, velocity, displacement, and jerk
- 2 to 2000 Hz (120 to 120,000 rpm) to 20,000 Hz with suitable pickup
- portable, battery operated, simple to use

Analyzers page 34 ff

Vibration Pickups page 28

Vibration in a machine can cause faulty production, premature wear, structural fatigue, and human discomfort and fatigue.

The 1553, portable and simple to use and to read, is well suited to making rapid, repetitive measurements against vibration criteria, such as required in quality control product testing and preventive maintenance programs. With the 1553, periodic measurements of over-all vibration in a machine will quickly show any deteriorating performance trends and lead to early preventive maintenance.

This instrument gives readings in quantities that are physically meaningful: displacement (for clearance problems), velocity (for a criterion in preventive maintenance of machines), acceleration (a measure of the possibility of mechanical failure), and jerk (related to vehicular riding comfort).

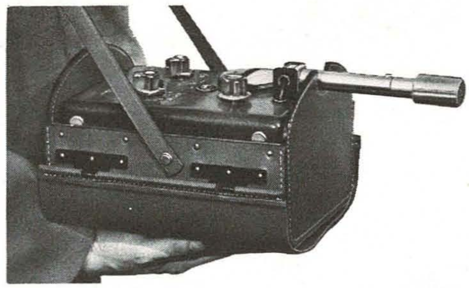
Its excellent low-frequency response permits the study of the operation of belt drives and of the effectiveness of mountings designed to reduce vibrations in adjacent structures.

Frequency analysis of vibrations aids in identifying their mechanical sources, diagnosing causes, and measuring the effect of remedies. The GR 1564-A Sound and Vibration Analyzer or the 1568-A or 1900-A Wave Analyzer is of great value in making such frequency analyses.

The 1553 Vibration Meter consists of an inertia-operated, lead-zirconate-titanate ceramic pickup, which delivers a voltage proportional to the acceleration of the vibratory motion; an adjustable attenuator; an amplifier; and an indicating meter. Networks can be switched to convert the output of the vibration pickup to a voltage proportional to displacement, velocity, or jerk (time rate of change of acceleration).

The 1553-A indicates directly in inches, in./s, in./s^2, or in./s^3. The 1553-AK indication is in metric units: mm, m/s, m/s^2, and m/s^3.

Filter jacks on the panel allow the use of external high-



(Left) Microphone in the storage position (batteries automatically disconnected). (Center) The sound-level meter operated in its leather carrying case, microphone in the horizontal operating position. (Right) The sound-level meter ac-operated with the Type 1262-B Power Supply, which plugs directly into the base of the sound-level meter.

specifications

Sound-Level Range: From 24 to 150 dB (re 20 μN/m^2).

Frequency Characteristics: Four response characteristics, A, B, C, or 20 kHz, as selected by panel switch. The A-, B-, and C-weighting positions are in accordance with ANSI Standard S1.4-1961 and IEC Publication 123, 1961. Frequency response for the 20-kHz position is flat from 20 Hz to 20 kHz, so that complete use can be made of very wide-band microphones.

Microphone: GR Type 1560-P5.

Sound-Level Indication: Sound level is indicated by the sum of the meter and attenuator readings. The clearly marked, open-scale meter covers a span of 16 dB with calibration from −6 to +10 dB. The attenuator is calibrated in 10-dB steps from 30 to 140 dB above 20 μN/m^2.

Calibration Accuracy: When amplifier sensitivity has been standardized, the absolute accuracy of sound-level measurements at 500 Hz is within ± 1 dB and at all frequencies is in accordance with the ANSI Standard.

Panel adjustment is provided for standardizing amplifier gain with internal calibration circuit.

Absolute acoustic sensitivity is factory calibrated at 500 Hz. Microphone response and sensitivity are measured in a free field from 20 Hz to 15 kHz by comparison with a WE 640AA laboratory-standard microphone with calibration traceable to the National Bureau of Standards. Complete electrical frequency-response measurements are made on each instrument.

The 1562-A Sound-Level Calibrator or the 1559-B Microphone Reciprocity Calibrator can be used for making periodic over-all acoustic checks.

Output: 1.4 V behind 7000 Ω (panel meter at full scale). The output can be used to drive analyzers, recorders, oscilloscopes, and headphones. Harmonic distortion (panel meter at full scale) <1%.

Input Impedance: 25 MΩ in parallel with 50 pF.

Meter: Rms response, and fast and slow meter speeds in accordance with ANS S1.4-1961 and IEC 123, 1961.

Environmental Effects

Temperature and Humidity: Microphone is not damaged at temperatures from −30 to +95°C and relative humidities from 0 to 100%. When standardized by its internal calibration system or a 1562 Sound-Level Calibrator, the instrument will operate within catalog specifications (for panel-meter indications above 0 dB) over the temperature range of 0 to 60°C and the relative humidity range of 0 to 90%.

Magnetic Fields: When exposed to a 60-Hz, 1-oersted (80 A/m) field, the sound-level meter will indicate 60 dB (C weighting) when oriented for maximum sensitivity to the magnetic field.

Electrostatic Fields: Aluminum case provides sufficient shielding, so that normally encountered electrostatic fields have no effect.

Vibration: Case is fitted with soft rubber feet and amplifier is resiliently mounted for vibration isolation. When the instrument is set on its feet on a shake table and vibrated at 10 mils pk-pk displacement over the frequency range of 10 to 55 Hz, the unwanted signals generated do not exceed an equivalent C-weighted sound-pressure level of 45 dB when motion is vertical, 60 dB when motion is lengthwise, or 40 dB when motion is sidewise.

GENERAL

Power Supply: Two 1½-V size D flashlight cells and one 67½-V battery (Burgess XX45 or equivalent) are supplied. An ac power supply, the Type 1262-B, is available.

Accessories Supplied: Telephone plug.

Accessories Available: 1551-P2 Leather Case (permits operation of instrument without removal from case), 1562 Sound-Level Calibrator, 1560-P95 Adaptor Cable for connecting output to 1521-B Graphic Level Recorder.

Calibrators page 29 ff

Mounting: Aluminum cabinet.

Dimensions (width x height x depth): 7¼ x 9¼ x 6⅛ in. (185 x 235 x 160 mm).

Weight, Net, 7¾ lb (3.6 kg); shipping, 16 lb (7.5 kg), batteries incl. Add 2 lb for leather case.

1262-B POWER SUPPLY

Attaches to the 1551-C Sound-Level Meter for ac-line operation.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 2 W.

Dimensions (width x height x depth): 5 x 7¼ x 3⅛ in. (130 x 185 x 80 mm).

Weight: Net, 2½ lb (1.2 kg); shipping, 8 lb (3.7 kg).

Catalog Number	Description	Price in USA
1551-9703	**1551-C Sound-Level Meter**	**$595.00**
8410-9499	**Set of Replacement Batteries**	**4.25**
1551-9602	**1551-P2 Leather Carrying Case**	**30.00**
	1262-B Power Supply	
1262-9702	115-V Model	**130.00**
1262-9705	230-V Model	**130.00**

PATENT NOTICE. See Note 12.

pass filters where it is desired to eliminate the frequency components below 30 or 70 Hz.

The vibration meter is portable and is mounted in a Flip-Tilt cabinet, which serves as protective cover and case in transit, and as a base on which the instrument can be operated in almost any position from vertical to horizontal.

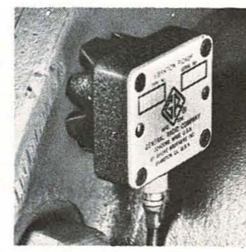
Accessories include various tips and a metal probe for the pickup to facilitate measurements in normally inaccessible places. Available at additional cost is the 1560-P35 Permanent-Magnet Clamp, which replaces the probe or tip when measurements are made under conditions where hand-held operation would not be satisfactory.

— See **GR Experimenter** for November 1961 and January 1963.

specifications

Ranges of Measurement:

Type No.	Quantity	Peak to Peak Min	Peak to Peak Max	Average Min	Average Max	Units	Frequency Range (Hz)
1553-A	Acceleration	0.3	300,000	0.03	30,000	in./s^2	2-2000
	Velocity	0.03	30,000	0.003	3,000	in./s	2-2000
	Displacement	3	300,000	0.3	30,000	mils	2-2000
	Displacement	0.03	30,000	0.003	3,000	mils	20-2000
	Jerk	30	300,000	3	30,000	in./s^3	2-20
1553-AK	Acceleration	0.01	10,000	0.001	1,000	m/s^2	2-2000
	Velocity	0.001	1,000	0.0001	100	m/s	2-2000
	Displacement	0.1	10,000	0.01	1,000	mm	2-2000
	Displacement	0.001	1,000	0.0001	100	mm	20-2000
	Jerk	1	10,000	0.1	1,000	m/s^3	2-20



Vibration pickup with permanent-magnet clamp

Accuracy: ±10% of full scale.

Input Impedance: 25 MΩ.

Voltage at Output Jack: 5 V rms, behind 75 kΩ for full-scale deflection.

Attenuators: A 10-step attenuator changes the meter-scale range by a factor of 100,000 to 1. Window readout indicates full-scale values and units (10 times full-scale for AVERAGE readings).

Calibration: Internal.

Allowable Pickup Sensitivity for Direct Reading: 30 to 150 mV/g.

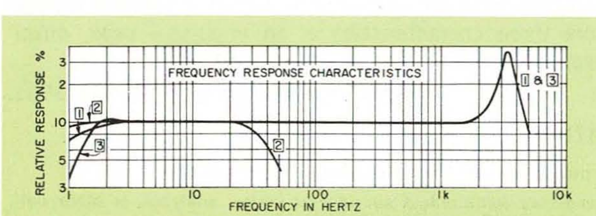
Terminals: A panel jack is provided for plugging in earphones, 1564-A Sound and Vibration Analyzer, 1556-B Impact-Noise Analyzer, 1538 or 1531 Strobotac® electronic stroboscope, 1568-A or 1900-A Wave Analyzer, or an oscilloscope.

Power Supply: Portable model, 3 size-D cells and one 67½-V battery (Burgess Type XX45 or equivalent) supplied. Typical battery life, 7 days at 8 h per day. For ac operation, use Type 1262-C Power Supply (listed below). Rack model, Type 1262-C Power Supply is included.

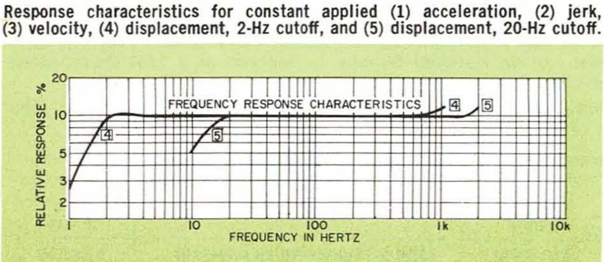
Accessory Supplied: 1560-P52 Vibration Pickup.

Accessories Available: 1560-P35 Permanent-Magnet Clamp; 1557-A Vibration Calibrator, high-frequency pickup 1560-P53, and high-sensitivity pickup 1560-P54.

Mounting: Flip-Tilt Case. Rack-mount versions also available.



Response characteristics for constant applied (1) acceleration, (2) jerk, (3) velocity, (4) displacement, 2-Hz cutoff, and (5) displacement, 20-Hz cutoff.

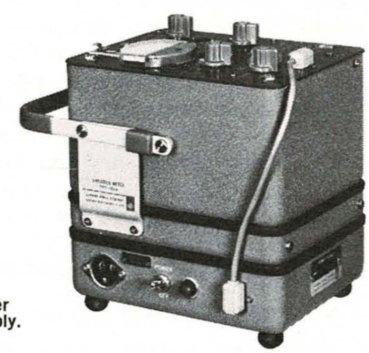


Dimensions (width x height x depth): Portable model, 8 x 9¼ x 7½ in. (205 x 235 x 190 mm); rack model, 19 x 10½ x 5 in. (485 x 270 x 130 mm).

Net Weight: Portable model, 10½ lb (4.8 kg); rack model, 14 lb (6.5 kg).

Shipping Weight: Portable model, 14 lb (6.5 kg); rack model, 31 lb (14.5 kg).

Type 1262-C Power Supply



Vibration meter with power supply.

Attaches to 1553 for ac operation. Included with rack model.

specifications

Power Required: 105 to 125 V, 50 to 400 Hz, 3 W, or 195 to 250 V, 50 Hz, 6 W.

Dimensions (width x height x depth): 7¼ x 9¼ x 3¼ in. (185 x 235 x 83 mm).

Weight: Net, 2¼ lb (1.1 kg); shipping, 8 lb (3.7 kg).

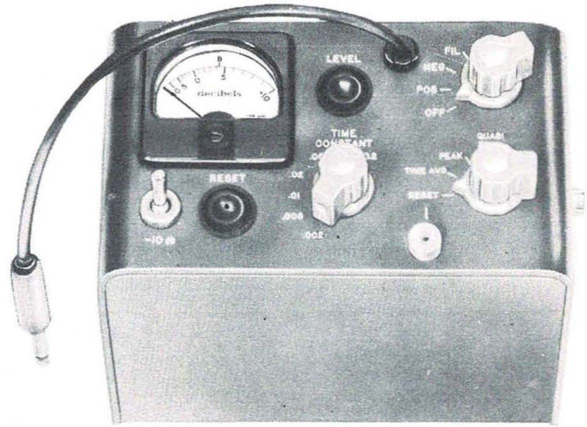
Catalog Number	Description	Price in USA
	1553-A Vibration Meter, English Units	
1553-9701	Portable Model, with batteries	**$ 990.00**
1553-9710	Portable Model with 115-V ac supply	**1185.00**
1553-9711	Portable Model with 230-V ac supply	**1185.00**
1553-9550	Rack Model with 115-V ac supply	**1200.00**
1553-9551	Rack Model with 230-V ac supply	**1200.00**
	1553-AK Vibration Meter, Metric Units	
1553-9819	Portable Model, with batteries	**990.00**
1553-9820	Portable Model with 115-V ac supply	**1185.00**
1553-9821	Portable Model with 230-V ac supply	**1185.00**
1553-9560	Rack Model with 115-V ac supply	**1200.00**
1553-9561	Rack Model with 230-V ac supply	**1200.00**
1262-9703	**1262-C Power Supply**	**195.00**
8410-9799	**Set of Replacement Batteries**	**4.45**
1560-9652	**1560-P52 Replacement Vibration Pickup**	**75.00**
1560-9635	**1560-P35 Permanent-Magnet Clamp**	**7.00**

PATENT NOTICE. See Note 12.

Type 1556-B IMPACT-NOISE ANALYZER

- measures electrical and acoustical noise peaks
- stores transient peak and time-average values
- 50-μs rise-time response

The 1556-B Impact-Noise Analyzer attaches to the 1551-C Sound-Level Meter as shown here.



Sound-Level Meters page 16 ff

1558 Analyzer page 50

This device evaluates the characteristics of impact-type sounds and electrical noise impulses, which cannot be satisfactorily measured with conventional noise-meters.

Impact Noises include those produced by punch presses, forging hammers, fire alarms, pile drivers, office machinery, and similar equipment. From the standpoint of hearing damage, some of these sounds constitute a serious problem for industry. They have hitherto been measurable only by complicated methods employing oscilloscopes.

The two characteristics of impact sounds that seem most significant are the peak amplitude and the duration, or decay time. This analyzer measures the:

- **peak value,** the maximum level reached by the noise,
- **"quasi-peak",** a continuously indicating measure of the high levels reached just before the time of indication, and
- **time-average,** a measure of the average level over a predetermined period of time, which, when subtracted from peak level, is a measure of the duration of the impact.

For these applications, the 1556-B operates from the output of a 1551, 1561, or 1565-A Sound-Level Meter or 1558 Octave-Band Noise Analyzer and, when a vibration pickup is used in place of the microphone, will measure vibration impacts. It will also operate from tape recorders, and vibration meters.

Electrical Noise Peaks in a wire communication circuit can be measured with this instrument as one of the tests to determine the adequacy of the circuit for transmitting data pulses. In such measurements, many peaks may be measured in a short time, and, after each peak, the stored signal must be erased before the next pulse occurs. To facilitate this a RESET pushbutton is provided, which can also be operated by an ordinary camera cable release.

Circuit. A battery-operated, degenerative, transistor amplifier simultaneously drives three ac voltmeter circuits, which comprise rectifiers, storage capacitors, and a dc electronic voltmeter. The electrical storage system (a capacitor charged by a rectifier) makes it possible to measure three characteristics of an impulse — peak, quasi-peak, and time-average — with a single meter.

— See **GR Experimenter** for September 1961.

specifications

Input: Any voltage from 1 to 10 V for normal range. Inputs below 1 V reduce the range of reading.

Input Impedance: Between 25,000 and 100,000 Ω, depending on the setting of the LEVEL control.

Frequency Range: 5 Hz to 20 kHz.

Level Indication: Meter calibrated in dB from −10 to +10. Attenuator switch increases range by 10 dB.

Peak Reading: Rise time is less than 50 μs for a value within 1 dB of peak value (for rectangular pulses). Storage time at normal room temperature is greater than 10 s for a 1-dB change in value.

Quasi-Peak Reading: Rise time of less than ¼ ms and decay time of 600 ±120 ms for rectifier circuit.

Time-Average Reading: Charge time of rectifier circuit selected by seven-position switch, having times of 0.002, 0.005, 0.01, 0.02, 0.05, 0.1, and 0.2 s for the resistance-capacitance time constant. Storage time at normal room temperature is greater than 1 min for a 1-dB change in value.

Input Terminals: Cord with phone plug at one end.

Accessory Required: A sound-level meter, analyzer, or other calibrated amplifier to supply 1556 input.

Batteries: One 1½-V size-D flashlight cell and one 45-V battery are supplied. Typical battery life is 100 hours.

Mounting: Aluminum cabinet; leather carrying case supplied. Cabinet can be fastened directly to one end of a 1551 Sound-Level Meter.

Dimensions (width x height x depth): 7½ x 6½ x 4½ in. (190 x 170 x 110 mm).

Weight: Net, 4½ lb (2.1 kg); shipping, 12 lb (5.5 kg).

Catalog Number	Description	Price in USA
1556-9702	**1556-B Impact-Noise Analyzer**	**$345.00**
8410-9590	**Set of Replacement Batteries**	**3.45**

MICROPHONES

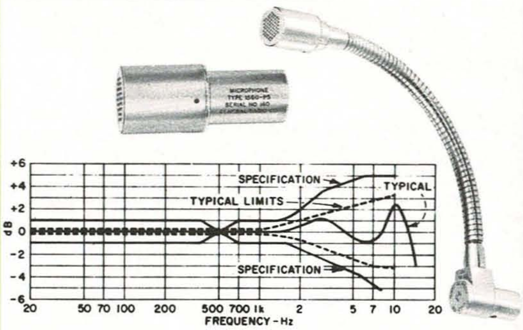
	Catalog Number	Price in USA

MICROPHONES

Types 1560-P5 and -P6 1-INCH CERAMIC MICROPHONES

— See **GR Experimenter** for May-June 1967.

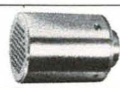
Frequency: Designed for flat random-incidence response (see curve). Typically flat, ± 1 dB, from 5 Hz to 20 Hz re the 500-Hz level. Time constant of pressure-equalizing leak is typically 0.08 s with a corresponding 3-dB roll-off at 2 Hz.
Sensitivity: −60 dB nominal, −62 dB min, re 1 V/μbar. *Temperature coefficient,* ≈ −0.01 dB/°C. *Maximum sound-pressure level,* at 150 dB SPL distortion is <1%; at >+ 174 and >−184 dB SPL peak, microphone fails.
Impedance: 1560-P5, 385 pF ± 15% at 23°C; 1560-P6, 405 pF ± 15% at 23°C. *Temperature coefficient of both,* 2.2 pF/°C from 0 to 50°C.
Environmental: No damage from −55 to +60°C, 0 to 100% RH; at 95°C, a 0.5-dB permanent sensitivity loss may occur.
Mechanical: *Terminals,* 3-terminal microphone connector; both terminals may be floated with respect to ground for hum reduction. *Dimensions,* cartridge only, 1⅛ in. (28.6 mm) long, 0.936 ± 0.002 in. (23.7 mm ± 50 μm) dia; 1560-P5 assembly, 2 5/16 (58.7 mm) long, 15/16 in. (23.7 mm) dia; 1560-P6 assembly, 11¾ in: (298 mm) long, 15/16 in. (23.7 mm) dia. *Weight,* 1560-P5, 2 oz (60 g) net, 1 lb (500 g) shipping; 1560-P6, 10 oz (300 g) net, 2 lb (900 g) shipping.



Type 1560-P5 and -P6 typical random response curve and tolerance.

	Catalog Number	Price in USA
1560-P5 Microphone	1560-9605	**$ 95.00**
1560-P6 Microphone Assembly	1560-9606	**115.00**

1560-9570 1-INCH CERAMIC MICROPHONE CARTRIDGE Same cartridge as 1560-P5 and -P6 above, with adaptor to fit 1560-P42 Preamplifier.



	Catalog Number	Price in USA
1-in. Ceramic Microphone Cartridge	1560-9570	**95.00**

NEW

The following microphone sets include a microphone cartridge, a 1560-P42 Preamplifier, all adaptors necessary to mate the cartridge to the preamplifier and to the 1562 Sound-Level Calibrator, and a carrying case for all components including the preamplifier. **Condenser Microphones:** All condenser microphones listed have a temperature coefficient of <±0.01 dB/°C from −50 to +60°C (except the ⅝-inch condenser microphones which are **−0.035 dB/°C**) and temperature range up to 150°C continuous, 250°C intermittent (except the ⅝-inch condenser microphones which operate only up to 100°C continuous).

Calibrator page 30

1560-9531 1-INCH CERAMIC MICROPHONE SET Uses same cartridge as 1560-P5 and -P6 Microphones above.

	Catalog Number	Price in USA
1-in. Ceramic Microphone Set	1560-9531	**270.00**

1560-9537 ⅝-INCH CONDENSER MICROPHONE SET, *normal level.* Random response typically ±3 dB from 20 Hz to 18 kHz with nominal sensitivity of −58 dB re 1 V/μbar and maximum sound-pressure level, with <1% distortion, of 135 dB to 1.5 kHz, 125 dB to 15 kHz and, with <10% distortion, of 155 dB to 1.5 kHz, 135 dB to 15 kHz.

	Catalog Number	Price in USA
⅝-in. Condenser Microphone Set	1560-9537	**345.00**

1560-9538 ⅝-INCH CONDENSER MICROPHONE SET, *high level.* Random response flat within ±2 dB from 20 Hz to 18 kHz with nominal sensitivity of −73 dB re 1 V/μbar and maximum sound-pressure level, with <1% distortion, of 150 dB to 1.5 kHz, 140 dB to 15 kHz and, with <10% distortion, of 170 dB to 1.5 kHz, 150 dB to 15 kHz.

	Catalog Number	Price in USA
⅝-in. Condenser Microphone Set	1560-9538	**375.00**

1560-9532 ½-INCH CONDENSER MICROPHONE SET, *flat perpendicular response.*

	Catalog Number	Price in USA
½-in. Condenser Microphone Set	1560-9532	**420.00**

1560-9533 ½-INCH CONDENSER MICROPHONE SET, *flat pressure response.*

	Catalog Number	Price in USA
½-in. Condenser Microphone Set	560-9533	**420.00**

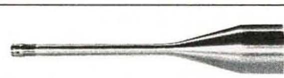
1560-9534 ¼-INCH CONDENSER MICROPHONE SET, *flat perpendicular response.*

	Catalog Number	Price in USA
¼-in. Condenser Microphone Set	1560-9534	**490.00**

1560-9535 ¼-INCH CONDENSER MICROPHONE SET, *flat pressure response.*

	Catalog Number	Price in USA
¼-in. Condenser Microphone Set	1560-9535	**490.00**

1560-9536 ⅛-INCH CONDENSER MICROPHONE SET, *flat pressure response.*



	Catalog Number	Price in USA
⅛-in. Condenser Microphone Set	1560-9536	**555.00**

PREAMPLIFIERS

	Catalog Number	Price in USA

PREAMPLIFIERS

1560-P40 PREAMPLIFIER

For ceramic microphones and vibration pickups.

The 1560-P40 Preamplifier is a high-input impedance, low-noise preamplifier. It is particularly well suited for amplifying the output of piezoelectric transducers, such as microphones and vibration pickups, and for use with GR sound-level meters and analyzers when a long cable must be used between microphone and instrument. It is also a useful probe amplifier for other electrical signals where its high input impedance and low noise are necessary. For example, it can increase the sensitivity and input impedance of analyzers, recorders, amplifiers and null detectors, counters and frequency meters, voltmeters, and low-frequency oscilloscopes.

The 1560-P40 is a three-stage negative-feedback amplifier that makes full use of the low-noise and high-input-impedance characteristics of a unipolar transistor (FET). The feedback can be switched by the user to obtain a voltage gain of either 1:1 to 10:1. A GR 1-inch ceramic microphone cartridge plugs directly onto the input end of the case. Output from the preamplifier is through a 3-terminal shielded connector. The required dc supply voltage is applied from one of these terminals to ground. This voltage can be obtained directly from the 1558, 1568, or 1564 Analyzers, the 1525 Recorder, 1561 Precision Sound-Level Meters, or from the 1560-9575 Power Supply.

Gain: 1:1 or 10:1 (20 dB) ±0.3 dB at 25°C; <±0.3-dB gain change from −50 to +50°C.

Frequency: (0.5-V pk-pk open-circuit output, −30 to +55°C):

	3 Hz – 5 Hz	5 Hz – 20 Hz	20 Hz – 250 kHz	250 kHz – 500 kHz
1:1 gain		±1 dB	±0.25 dB	
10:1 gain	±3 dB	±1.5 dB	±0.25 dB	±1.5 dB

Impedance: *Input capacitance,* 6 pF. *Input resistance,* >500 MΩ at low audio frequencies. *Output resistance:* 1:1 gain, ≈ 20 Ω in series with 3.3 μF; 10:1 gain, ≈ 100 Ω in series with 3.3 μF.

Noise: ≤2.5-μV equivalent input voltage, 400-pF source impedance, C-weighted, 10-kHz effective bandwidth.

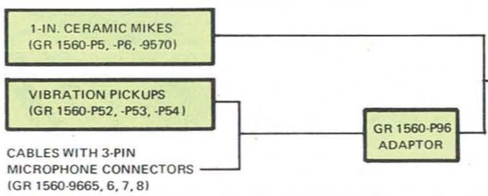
Distortion: <0.25% harmonic distortion at audio frequencies with 1-V pk-pk open-circuit output; 1% at 1 kHz with 5-V pk-pk capacitive-loaded output (0.01 μF which is equivalent to over 200 ft of cable); 1% at 10 kHz with 2-V pk-pk capacitive-loaded output.

Available: Ceramic microphones, vibration pickups, tripod, cables, and adaptors. 1560-P96 adaptor converts input to accept 3-terminal microphone connectors such as those used with 1560-P95 or -9665 through -9667 cables.

Power: +15 to 25 V, 1 to 2 mA dc; available directly from 1558, 1568, and 1564 analyzers, 1525 recorder, and 1561 Sound-Level Meter, or from 1560-9575 Power Supply when 1560-P40 Preamplifier is to be used with 1565 or 1551 Sound-Level Meters, 1553 Vibration Meter, and 1900 or 1910 analyzers.

Mechanical: *Dimensions:* 6⅞-in. long x 1.155 in. dia (175 x 30 mm). *Weight:* 9 oz (0.3 kg) net, 3 lb (1.4 kg) shipping.

Analyzers page 34 ff
Sound-Level Meters page 18 ff



	Catalog Number	Price in USA
1560-P40 Preamplifier	1560-9640	**$130.00**
1560-P96 Adaptor, to microphone connector	1560-9696	**25.00**

1560-P42 PREAMPLIFIER

For condenser microphones, ceramic microphones, and vibration pickups.

The 1560-P42 Preamplifier is a high-input impedance, low-noise preamplifier similar to the 1560-P40. It includes several additional features, however: a polarizing voltage for use with condenser microphones, higher output current so that longer cables can be driven, an insert voltage calibration capability for check-out convenience and a permanently-attached 10-foot cable.

It is a three-stage amplifier with a low-noise FET input stage, a class AB output stage, and full dc feedback for stability. Switched ac feedback selects ×1 or ×10 gain, and a self-contained oscillator supplies the polarizing voltage. This oscillator operates at a supersonic frequency to reduce interference and can be switched off when the preamplifier is used with ceramic microphones.

Gain: Same as 1560-P40.

Frequency: Same as 1560-P40.

Impedance: *Input capacitance,* 6 pF. *Input resistance,* >500 MΩ at low audio frequencies. *Output resistance* for 1:1 or 10:1 gain, 10 Ω in series with 3.3 μF.

Output: Signal, up to 12 V pk-pk into open circuit audio frequencies with 15-V supply. *Polarizing voltage,* +200 ±5 V dc, switch selectable (on for condenser microphones, off for ceramic microphones), temperature coefficient, 0.1%/°C.

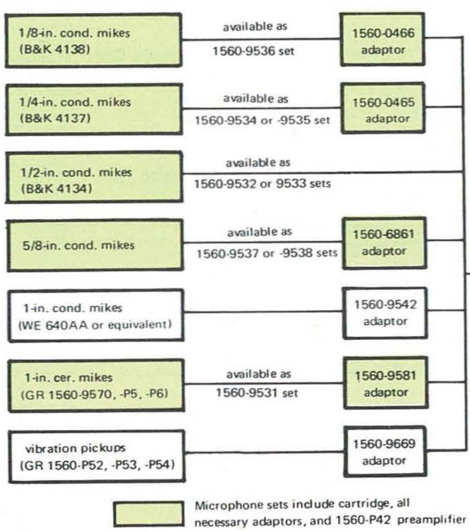
Noise: Same as 1560-P40.

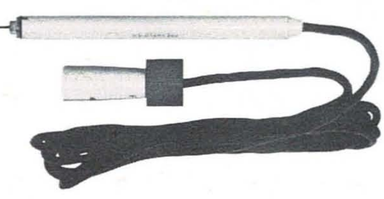
Distortion: <0.25% harmonic distortion at 1 kHz with 1-V rms open-circuit output; <1% at 10 kHz with 1 V rms into 0.1 μF.

Available: Condenser microphone kits, ceramic microphones, vibration pickups, tripod, cables and adaptors.

Power: +15 to 25 V dc, 2 to 5 mA idling.

Mechanical: *Dimensions* (less cable): 6.25-in. long x 0.5 in. dia (160 x 13 mm). *Weight* (with cable): 1 lb (0.5 kg) net, 3 lb (1.4 kg) shipping.





	Catalog Number	Price in USA
1560-P42 Preamplifier	1560-9642	**160.00**

TRANSDUCER ACCESSORIES

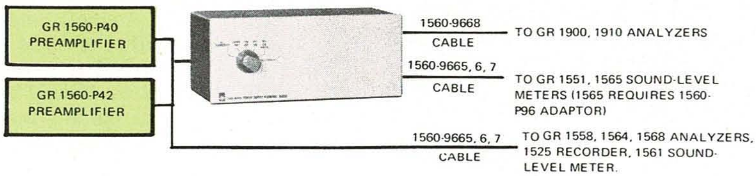
POWER SUPPLY

1560-9575 POWER SUPPLY Required with 1560-P40 or -P42 Preamplifiers when they are used with instruments that do not include a source of power such as the 1551 and 1565 Sound-Level Meters or 1900 and 1910 Analyzers. Also useful when long cables are to be driven at high levels and as a charger for rechargeable batteries in the 1561 Sound-Level Meter or 1952 Universal Filter.

A single front-panel control selects operating mode: OFF, CHARGE ONLY, CHARGE AND OPERATE, OPERATE ONLY, REMOTE (off or operate-only mode selected remotely by instrument such as 1561 or 1564 analyzer), and BATTERY CHECK. The batteries are easily removed by a slide-out clip and fit into the same type of holder used in the 1952 Universal Filter.

Input: 100 to 125 or 200 to 250 V, 50 to 60 Hz.
Output: 18 to 21 V, 15 mA max; automatic limiting protects supply and prevents deep battery discharge. *Ripple,* <5 mV rms in CHARGE-OPERATE mode. *Charge time,* 14 h for completely discharged battery, constant 22-mA battery-charging current. Rear-panel slide switch selects internal or external battery.
Interface: *Input,* power to, and signal from, preamplifier made by Cannon type 3-pin microphone connector. *Output,* signal from preamplifier and remote power control made by Cannon type 3-pin microphone connector.
Supplied: 1560-9665 4-ft cable to connect to 1551, 1561, 1564, etc; 4-ft adaptor cable to connect to 1900, 1910, etc, and cable to connect to 1561 charging terminals.
Mechanical: Convertible-Bench cabinet. *Dimensions* (w x h x d): 8½ x 3⅞ x 5½ in. (220 x 99 x 140 mm). *Weight:* 3 lb (1.4 kg) net, 5 lb (2.3 kg) shipping.

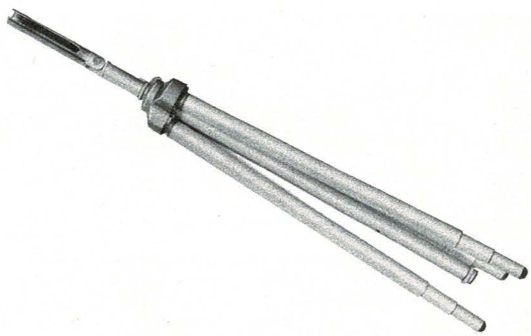
Analyzers page 34 ff
Sound-Level Meters page 18 ff
Universal Filter page 58
Calibrator page 30



	Catalog Number	Price in USA
Power Supply	1560-9575	$225.00

TRIPOD

1560-9580 TRIPOD This is a versatile tripod designed to accept a variety of equipment. A ¼-20 threaded stud fits all GR sound-level meters and electronic stroboscopes, a 1-in. sleeve accepts the 1560-P40 Preamplifier, and a ½-in. sleeve accepts the 1560-P42 Preamplifier. Also included are a locking nut, wrench, and spare setscrews.



	Catalog Number	Price in USA
Tripod	1560-9580	58.00

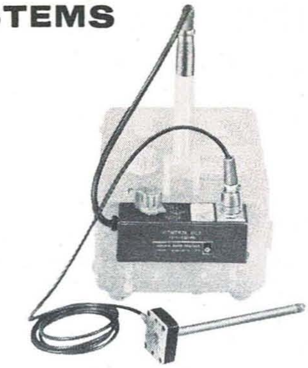
CABLES AND ADAPTORS

1560-9665 CABLE 4-ft shielded 3-wire cable terminated in Cannon type 3-pin microphone connectors, for use between preamplifier output and analyzer. Mates directly to input and output connectors of 1560-9575 Power Supply, 1558, 1564, or 1568 analyzers, 1525 recorder, or 1561 Sound-Level Meter.

Description		Catalog Number	Price in USA
1560-9665 CABLE (see above)	Cable, 4 ft	1560-9665	
1560-9666 CABLE 25-ft version of 1560-9665 cable above.	Cable, 25 ft	1560-9666	18.00
1560-9667 CABLE 100-ft version of 1560-9665 cable above.	Cable, 100 ft	1560-9667	30.00
1560-9561 COUPLER ADAPTOR SET Adapts ½, ¼, and ⅛-in. microphones to 1562 Sound-Level Calibrator.	Coupler Adaptor Set	1560-9561	28.00
1560-9581 ADAPTOR Adapts GR 1-in. ceramic microphone cartridge to the 1560-P42 Preamplifier.	Adaptor	1560-9581	15.00
1560-9669 ADAPTOR Adapts 1560-P42 Preamplifier input to Cannon type 3-pin microphone connector.	Adaptor	1560-9669	36.00
1560-9542 ADAPTOR Provides proper mechanical and acoustical coupling between a standard 1-inch condenser microphone, such as the Western Electric 640AA, and the 1560-P42 Preamplifier.	Adaptor	1560-9542	42.00

VIBRATION PICKUPS AND SYSTEMS

- accessories for sound-level meters
- select for:
  - high-frequency performance
  - high sensitivity
  - general application, economy



The 1560-P11B Vibration Pickup System with the 1551-C Sound-Level Meter.

For the measurement of solid-borne vibrations with the sound-level meter a vibration pickup is used in place of the microphone.

Each of these Vibration Pickup Systems consists of a vibration pickup, a control box, and a connection cable. The vibration pickup is an inertia-operated, ceramic device, which generates a voltage proportional to the acceleration of the vibrating body. By means of integrating networks in the control box, voltages proportional to velocity and displacement can also be delivered to the sound-level meter. The desired response is selected by means of a three-position switch on the control box. Conversion data are supplied for translating the decibel indications of the sound-level meter into the vibration parameters of displacement, velocity, and acceleration.

TYPE 1560-P11B

This system uses a lead-zirconate-titanate pickup, identical with that used on the 1553-A Vibration Meter. Probe and probe tips are provided. A permanent-magnet mount is also available.

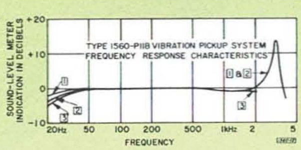
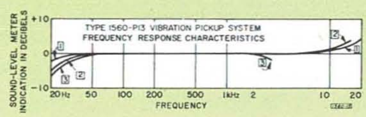
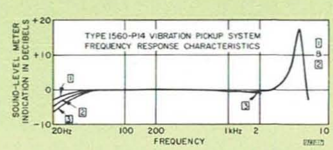
TYPE 1560-P13

For measurements at higher frequencies than the -P11B system affords, the -P13 combination is recommended, consisting of the 1560-P53 Vibration Pickup and the 1560-P23 Control Box. A small holding magnet is included.

This system with the Type 1551-C or -B Sound-Level Meter provides the flat frequency response and low-noise operation required by MIL-STD-740 (SHIPS) for vibration measurement. (The holding magnet is not used for measurements according to that standard.)

TYPE 1560-P14

The vibration pickup used in this system has approximately 10 times the sensitivity and 10 times the impedance of the 1560-P52.

Pickup Systems	General Purpose 1560-P11B Vibration Pickup System	High Frequency 1560-P13 Vibration Pickup System	High Sensitivity 1560-P14 Vibration Pickup System
Ranges of Measurement Rms Acceleration (in./s²)	0.1 to 39,000 (100 g)†	0.3 to 390,000 (1000 g)†	0.01 to 3900 (10 g)†
Rms Velocity (in./s)	0.001 to *	0.001 to 1000	0.0001 to *
Rms Displacement (in.)	0.00003 to *	0.00003 to 30	0.000003 to *
Frequency Range Response characteristics for constant applied (1) acceleration, (2) velocity, and (3) displacement.			
Net Weight of System (lb)	1¾ (0.8 kg)	1¾ (0.8 kg)	2 (1 kg)
Shipping Weight (lb)	5 (2.3 kg)	5 (2.3 kg)	5 (2.3 kg)
Catalog Number	1560-9922	1560-9613	1560-9614
Price: Vibration Pickup System	**$160.00** in USA	**$335.00** in USA	**$200.00** in USA

Pickup Characteristics

Pickup Type Number	1560-P52	1560-P53	1560-P54
Sensitivity (mV/g), nominal	70	70	700
Temp Coeff of Sens (dB/°C)	<−0.01	<0.02	0.01
Resonant Frequency (Hz)	3200	27,000	5000
Capacitance (pF)	10,000	350	700
Temperature Range (°C)	−18 to 100	−54 to 177	−18 to 120
Relative Humidity Range (%)	0 to 100	0 to 100	0 to 100
Cable Length (ft)	5 (1.55 m)	8 (2.5 m)	8 (2.5 m)
Dimensions (in.)	1⅝ × 1 7/16 × 5/16	⅝ (hex) × 0.7	1 3/16 (dia) × 1 1/16
(mm)	42 × 37 × 15	15.5 × 18	31 × 27
Net Weight (oz)	1.6 (45 grams)	1.1 (31 grams)	3.1 (90 grams)
Catalog Number	1560-9652	1560-9653	1560-9654
Price: Pickup Only	**$85.00** in USA	**$260.00** in USA	**$150.00** in USA

* Upper limit of displacement and velocity measurements depends upon frequency and is determined by the maximum acceleration possible before nonlinearity occurs (100 g for 1560-P11B, 10 g for 1560-P14).
† g = acceleration of gravity.

Type 1559-B MICROPHONE RECIPROCITY CALIBRATOR

- accuracy ±0.3 dB
- NBS traceable via WE 640AA microphone
- direct readout without calculations

This unique instrument employs the recognized method of performing the absolute calibration of laboratory standard microphones*: the closed-coupler (cylindrical cavity) reciprocity-calibration procedure. It will also serve as a sound-level calibrator or precision acoustical source for making rapid checks on microphones and sound-level meters or setting reference levels in analyzing systems.

The 1559-B contains the acoustic cavity and two transducers used in reciprocity calibration, interconnecting circuits and switching that obviate the need for physically moving the microphones during calibration, and an analog calculator that directly reads out microphone sensitivity after a simple 4-step voltage-matching procedure. A sound-level meter and nearly any general-purpose audio oscillator will serve as the required external detector and signal source.

* General Radio Types 1560-P3, 1560-P4, 1560-P5, 1560-P6, Western Electric 640AA or equivalent, and (with special adaptor) GR Type 1551-P1L.

BASIC PRINCIPLES

The analog calculator solves for the sensitivity of the unknown microphone from two quantities that the 1559-B measures by voltage matching: the ratio and the product of the sensitivities of the unknown and the internal reciprocal microphone.

— See **GR Experimenter** for December 1964.

specifications

AS MICROPHONE CALIBRATOR

Range: For microphone sensitivities between −35 dB and −75 dB re 1 V/μbar.

Accuracy:

Microphone Type	Accuracy	Frequency Range
GR 1560-P5,-P6 and WE 640AA	±(0.2 + 0.1 f_{kHz}) dB	20 Hz to 2.5 kHz
	±0.7 dB	2.5 to 6 kHz*
GR 1560-P3, -P4	±(0.2 + 0.1 f_{kHz}) dB	20 Hz to 2.5 kHz
	±0.7 dB	2.5 to 7 kHz*
GR 1551-P1L†	±(0.2 + 0.1 f_{kHz}) dB	20 Hz to 2.5 kHz
	±0.7 dB	2.5 to 5 kHz

* To 8 kHz with corrections. † Requires special adaptor.

AS PRECISION ACOUSTICAL SOURCE

Oscillators page 220 ff

Frequency Range: 20 Hz to 7 kHz.

Output: 92 dB re 20 μN/m² for excitation of 50 V.

Accuracy: At 92 dB, ±0.2 dB + error in determining microphone sensitivity.

AS SOUND-LEVEL CALIBRATOR

Frequency Range: 20 Hz to 2.5 kHz.

Output: 92 dB re 20 μN/m² when the input level in dB meter reads 92 dB.

Accuracy: ±0.7 dB at standard atmospheric pressure.

Note: The above specifications apply when the cavity is properly sealed. It may be necessary to apply a sealing compound (grease, etc) to the rim of the unknown microphone.

GENERAL

Accessories Required: Generator and detector. Generator to supply 5 V or more into a 2000-pF load, and 2.5 V or more into a 600-Ω load. The 1304-B Beat-Frequency Audio Generator, and the 1310-A Audio Oscillator are recommended. The 1551 or 1561 Sound-Level Meter, 1558 Octave-Band Analyzer, or 1564 Sound and Vibration Analyzer is recommended for the detector.

Accessories Supplied: 274-NP Patch Cord and an extension cable for connection to generator and detector; and adaptors for reciprocity and comparison calibration of the 1560-P5, 1560-P6, and Western Electric 640AA or equivalent microphones.

Mounting: Flip-Tilt Case. Also available in rack-mount version.

Dimensions (width x height x depth): Portable model, 10 x 8 x 7½ in. (255 x 205 x 190 mm); rack model, 19 x 10½ x 5 in. (485 x 270 x 130 mm).

Net Weight: Portable model, 13 lb (6 kg); rack model, 14 lb (6.5 kg).

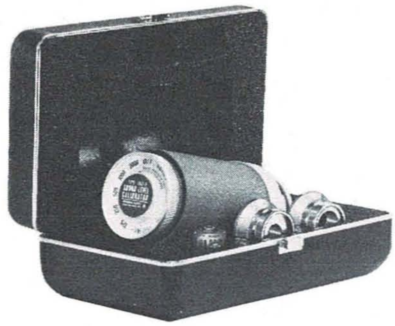
Shipping Weight: Portable model, 16 lb (7.5 kg); rack model, 25 lb (11.5 kg).

Catalog Number	Description	Price
	1559-B Microphone Reciprocity Calibrator	
1559-9702	Portable Model	**$750.00**
1559-9842	Rack Model	**750.00**

PATENT NOTICE. See Notes 15 and 22.

Type 1562-A SOUND-LEVEL CALIBRATOR

- 125 to 2000 Hz
- ±0.3-dB accuracy
- fits many microphones



The 1562 is a self-contained unit for making accurate field calibrations on microphones and sound-measuring instruments. It generates a precisely known sound-pressure level at five ANSI-preferred frequencies. With its several frequencies, improved accuracy, and built-in oscillator, the 1562 supersedes the 1552-1307 two-instrument combination.

The 1562 will calibrate the Western Electric 640AA and the GR 1560-P5, -P6, and -P7 microphones used with current instruments, the GR 1551-P1 Condenser Microphone System, and the older Types 1560-P3 and 1560-P4. Thus sensitivity and response tests can be made at several frequencies on a variety of instruments with microphones, including Types 1551, 1561, and 1565-A Sound-Level Meters, 1558 Octave-Band Analyzers, 1564-A Sound and Vibration Analyzer, 1555-A Sound-Survey Meter, and 1525-A Data Recorder.

An electrical signal output is provided for tests on instruments without microphones. An indicator lamp is provided to check for adequate battery voltage.

For even greater accuracy and NBS traceability, use the 1559-B Microphone Reciprocity Calibrator.

— See **GR Experimenter** for May-June 1967.

specifications

ACOUSTIC OUTPUT

Frequencies: 125, 250, 500, 1000, and 2000 Hz, ±3%.

Sound-Pressure Level: 114 dB re 20 μN/m².

Accuracy (at 23°C and 760 mm Hg):

	at 500 Hz	other frequencies
WE 640AA or equivalent	±0.3 dB	±0.5 dB
other microphones	±0.5 dB	±0.7 dB

Temperature Coefficient: Between 0 and −0.012 dB/°C.
Pressure Correction: Chart supplied.

ELECTRICAL OUTPUT

Voltage: 1.0 V ±20% behind 6000 Ω.

Frequency Characteristic: Output is flat ±2%.

Distortion: <0.5%.

Connector: Standard telephone jack.

GENERAL

Operating Environment: 0 to 50°C, 0 to 95% relative humidity.

Accessories Supplied: Carrying case, adaptors for 15/16-in. and 5/8-in. diameter microphones. (Fits 1 1/8-in. microphones without adaptor.) Battery included.

Battery: One 9 V Burgess PM6 or equal. 120 hours use.

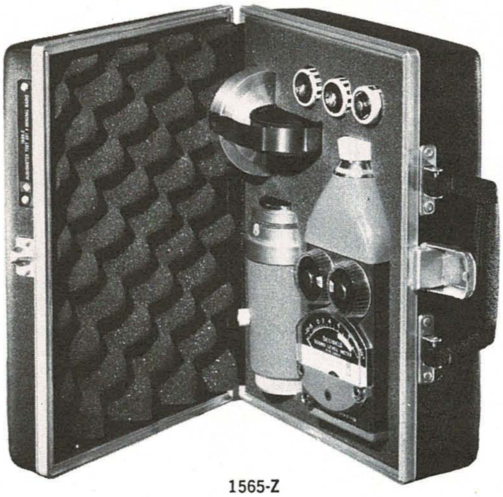
Dimensions: Length, 5 in. (130 mm); diameter, 2 1/4 in. (55 mm).

Weight: Net, 1 lb (0.5 kg); shipping, 4 lb (1.9 kg).

Catalog Number	Description	Price in USA
1562-9701	**1562-A Sound-Level Calibrator**	**$250.00**
8410-3000	**Replacement Battery,** 1 req'd	**1.20**

Type 1565-Z AUDIOMETER CALIBRATION SET

Type 1560-P82, -P83 EARPHONE COUPLER



1565-Z

1560-P83 Earphone Coupler

Faulty hearing or faulty audiometer? In 1963 a study[1] revealed that an audiometer only had a 50-50 chance of being accurate. Deficiencies included sound pressure at or beyond tolerance limits, faulty earphone performance, frequency outside limits, excessive harmonic distortion, and extraneous instrument noise.

With this fact in mind the 1565-Z Audiometer Calibration Sets were conceived — mini-systems with maxi-benefits for tight budgets. Each contains a sound-level meter and earphone coupler to measure the output level and frequency response of the audiometer, a sound-level calibrator to ensure accurate readings from the sound-level meter, a calibration chart, a full set of instructions, and a convenient carrying case to keep everything together.

[1]E. L. Eagles, S. M. Wishik, L. G. Doefler, W. Melnick, H. S. Levine, **Hearing Sensitivity and Related Factors in Children,** University of Pittsburgh Graduate School of Public Health. Published by **Laryngoscope,** St. Louis, Missouri, 1963.

*The 1560-P83 includes a microphone locating step for greater ease of use. A series of carefully controlled measurements with both NBS- and GR-type couplers indicates that this minor difference causes no discernible variation in coupler response.

EARPHONE COUPLERS

There are two versions of the 1565-Z Audiometer Calibration Set. One includes a 1560-P82 Earphone Coupler, which is an ANSI Type 1 coupler for 15/16-in.-diameter microphones such as the GR 1560-P5, -P6 and -P7 Microphones and Type L laboratory standard microphones such as the Western Electric 640AA. The other includes a 1560-P83 Earphone Coupler (mechanically* similar to the NBS type 9-A coupler) for the GR 1560-P5, -P6, and -P7 Microphones and WE 640AA microphone.

A third coupler, the 1560-P81 Earphone Coupler is available separately. It is an ANSI Type 1 coupler for 1⅛-in. microphones such as the older GR 1560-P3 and -P4 Microphones.

— See **GR Experimenter** for October 1966 and April 1968.

specifications

1560-P81 and -P82 EARPHONE COUPLERS

Type: ANSI Type 1.
Volume: 6 cm^3 including equivalent volume of microphone.
Axial Holding Force: 500 grams.
Frequency: 100 Hz to 6 kHz, ±1 dB; to 8 kHz, ±3 dB (with corrections for pressure response of microphone).
Dimensions: Coupler (diameter x height), 2¼ x 1 1/16 in. (57 x 26 mm); over-all (weight x height x depth), 2¼ x 3 x 3 in. (57 x 76 x 76 mm).
Weight: Net, 8 oz (230 g); shipping, 2 lb (1 kg).

1560-P83 EARPHONE COUPLER

Type: GR 9A (modified version of NBS type 9-A).
Volume: 5.642 cm^3, including volume added by microphone.
Axial Holding Force: 450 grams, nominal.
Frequency: 100 Hz to 8 kHz, within 1 dB of NBS 9-A response at audiometric test frequencies when used with TDH-39 or TDH-49 earphones with MX-41/AR ear cushions.
Dimensions: Coupler (diameter x height), 2 15/16 x 1¼ in. (75 x 32 mm); over-all height, 3½ in. (89 mm).
Weight: Net, 8½ oz (245 g); shipping, 2 lb (1 kg).

1565-Z AUDIOMETER CALIBRATION SET

Supplied: 1565-A Sound-Level Meter, 1562-A Sound-Level Calibrator, earphone coupler, spare batteries, storage case.
Dimensions: (width x height x depth): 11¼ x 4¼ x 10 in. (290 x 110 x 255 mm).
Weight: Net, 5 lb (2.3 kg); shipping, 12 lb (5.5 kg).

Catalog Number	Description	Price in USA
	1565-Z Audiometer Calibration Set	
1565-9900	with 1560-P82 Earphone Coupler	**$680.00**
1565-9901	with 1560-P83 Earphone Coupler	**680.00**
1560-9681	**1560-P81 Earphone Coupler,** ANSI type 1, 1⅛ in.	**45.00**
1560-9682	**1560-P82 Earphone Coupler,** ANSI type 1, 15/16 in.	**45.00**
1560-9683	**1560-P83 Earphone Coupler,** GR type 9A	**45.00**
8410-9591	**Set of Replacement Batteries**	**1.40**

Type 1557-A VIBRATION CALIBRATOR

- calibrates vibration pickups, meters
- generates 1 g at 100 Hz
- portable, battery-operated

The calibrator provides a single-frequency (100 Hz), single-level (1 g) check on the GR Vibration Pickups, the 1553 Vibration Meter, or any pickup whose total mass is 300 grams or less. It can provide on-the-spot calibration of vibration-measuring systems immediately before and after important measurements and can also be used to compare transducers or to calibrate working transducers against a standard transducer.

Operation of the calibrator is simple. A pickup of known mass is attached to the shaker, either in place of one of the removable 50-gram disks or to one of the disks by double-faced, pressure-sensitive tape. The user adjusts the LEVEL control until the panel meter, calibrated in grams, indicates the mass of the pickup. The pickup will then be automatically subjected to an acceleration of 1 g at 100 Hz.

The 1557-A is a small, battery-operated unit consisting of a transistorized electromechanical oscillator and a cylindrical shaker. The acceleration output of the calibrator appears at two pillbox-shaped, 50-gram disks mounted on an internal cylinder that projects through the sides of the instrument.

— See **GR Experimenter** for November 1960.

View of the calibrator with Type 1560-P52 Vibration Pickup attached.

specifications

OUTPUT

Acceleration: 1 g rms ±10%. 1 g = 386 in./s² (9.81 m/s²).

Velocity: 0.614 in./s (15.6 mm/s) rms.

Displacement: 0.000978 in. (0.0248 mm) rms; 0.00277 in. (0.0704 mm) pk-pk.

Frequency: 100 Hz ±1% for 50-gram load; 100 Hz +0, −2% for 300-gram load.

GENERAL

Batteries: Four RM-4 (or equivalent) mercury cells. Battery life is 100 hours of continuous operation. (Dry cells optional; please specify.)

Accessory Supplied: Leather carrying case.

Mounting: Aluminum case.

Dimensions (width x height x depth): 4 x 8 x 4 in. (105 x 205 x 105 mm).

Weight: Net, 3¼ lb (1.5 kg); shipping, 5¼ lb (2.4 kg).

Catalog Number	Description	Price in USA
1557-9701	**1557-A Vibration Calibrator**	**$360.00**
8410-1372	**Replacement Mercury Cell,** 4 req'd	**1.95**
8410-1050	**Replacement Dry Cell,** 1 req'd	**1.25**

ACCESSORIES FOR ACOUSTIC INSTRUMENTS

CONNECTORS

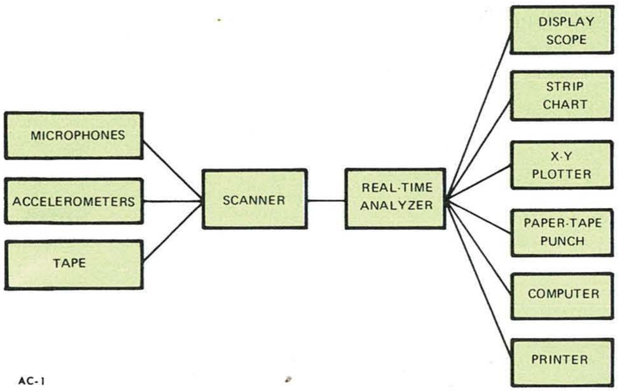
Many acoustic instruments are equipped with 3-terminal, shielded input connectors (female) that match or mate with connectors of the Switchcraft A3 type, Cannon XLR-3, or equivalent. GR microphones and vibration pickups are, of course, similarly equipped. Most instrument inputs also have a dc-supply voltage on the third connector pin to power the 1560-P40 Preamplifier when it is connected directly or through appropriate 3-conductor cable. Standard ¼-inch-shank 2-conductor phone jacks are used for most outputs and some inputs, so several cables are fitted with mating phone plugs.

		Catalog Number	Price in USA
CABLES			
Extension cable, 25 ft, with Switchcraft Type A3 female connector on one end and Type A3 male connector on the other end; for use between microphone or pickup and instrument input.	**1560-P73 Extension Cable**	1560-9673	**$ 20.00**
Extension cable, 100 ft, same cable, connectors, and uses as 1560-P73, above.	**1560-P73B Extension Cable**	1560-9982	**35.00**
Patch cord, 3 ft; shielded cable with phone plug on each end; general use.	**1560-P76 Patch Cord**	1560-2101	**3.00**
Adaptor cable, 3 ft; shielded cable with phone plug and double banana plug; for use from instrument outputs to binding-post inputs, general use.	**1560-P95 Adaptor Cable**	1560-9695	**4.00**
ADAPTORS			
Converts inputs of 1560-P40 Preamplifier and 1565 Sound-Level Meter (without microphones) to female microphone connector (jack).	**1560-P96 Adaptor**	1560-9696	**25.00**
Adaptor cable, phone plug to double banana plug; see 1560-P95, above.			
MISCELLANEOUS			
Tripod	**Tripod**	1560-9580	**58.00**
Magnet clamp for firm, temporary holding of vibration pickups on metal surfaces.	**1560-P35 Permanent-Magnet Clamp**	1560-9635	**7.00**
Battery charger, recharges nickel-cadmium batteries used with 1561 Precision Sound-Level Meter and 1952 Universal Filter.	**1560-P60 Charger,** 115 V 230 V	1560-9660 1560-9661	**125.00** **125.00**
Earphone couplers, for audiometric calibration, acoustically couple earphones to GR microphones.			page 31
Preamplifier, enhances measurement of low-level sound and vibration, permits use of microphones and pickups with long cables and direct connection to low-impedance and low-sensitivity inputs.			page 26
Microphones, GR-made, ceramic element; supplied with many GR instruments. Exceptional stability, frequency response, and ruggedness.			page 25
Vibration pickup systems; high-frequency, high-sensitivity, or general-purpose accelerometers, with or without integrating networks for velocity and displacement.			page 28

See also pages 291, 292.

ACOUSTIC SYSTEMS

Through the years, the measurement requirements in acoustics and vibration have become so complex that in many applications a single instrument is no longer adequate. To meet the more demanding situations, General Radio offers custom systems — groups of instruments fully integrated to provide a total solution to a specific measurement need.

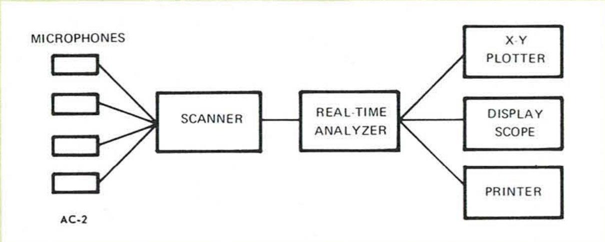


Some representative needs for such systems include:

- Product-noise analysis
- Preventative maintenance and production tests
- Loudness measurements
- Automotive-passby and aircraft-flyover measurements
- Acoustic-power measurements
- Vibration measurements
- ASHRAE ratings

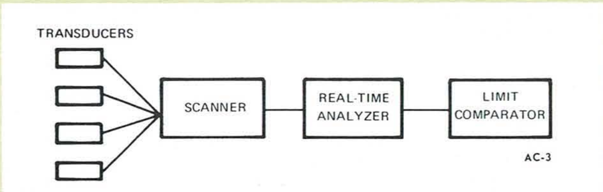
TYPICAL SYSTEMS

ACOUSTIC-POWER MEASUREMENTS



Acoustic-power measurements are simplified greatly when a system is employed, such as that shown. The scanner advances from one microphone to the next while the analyzer continuously stores and space-averages the spectrum in one-third-octave bands. At the end of the integration period, the entire acoustic-power spectrum is plotted and printed automatically.

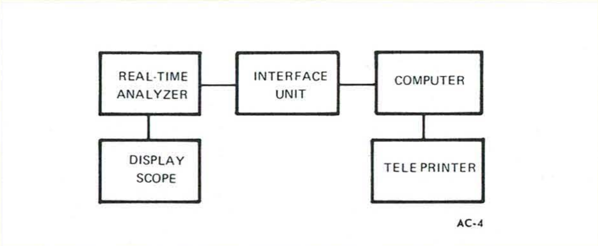
PREVENTATIVE MAINTENANCE AND PRODUCTION TESTS



Preventative maintenance and production testing require the analysis of a number of inputs. The analysis must be fast and automatic. One method is shown. A scanner switches from one transducer to the next and, in doing so, commands the analyzer to make a measurement. The attenuators in the analyzer are set to the inverse of the worst-case, but still acceptable, spectrum.

A limit comparator compares the output of each one-third-octave band to a preset limit and renders a go or no-go decision based on the results of the comparison. The transducers can be microphones or vibration pickups, and the data can be recorded first and analyzed later.

COMPLETE AUTOMATION



A computer greatly expands the usefulness of a system. With it you can automatically and directly

- perform one-third-octave analysis
- calculate octave data from one-third-octave data
- calculate loudness in sones or in phons from one-third-octave data
- calculate speech interference levels from one-third-octave data
- calculate PNL from one-third-octave data

REAL-TIME ANALYSIS

Description Real-time analyzers are more easily described by comparison with their counterparts, serial analyzers. A serial analyzer uses a single filter that is swept through the frequency range of interest. As the filter is swept, the voltage across it is read or plotted and the frequency spectrum is thus derived. Two factors must be controlled in this method of analysis, the speed at which the filter is swept and the input signal level. If the filter is swept too fast, the output data will be in error because the detector will not have enough time to respond to the applied voltage. And if the input signal level is not held constant, the spectrum obtained will not be representative of the input.

A real-time analyzer uses a number of filters in parallel. Since the detector for these filters measures all the filter channels in one measurement period, the real-time analyzer is as many times faster than a serial analyzer as the number of filters it contains for the desired frequency range.

Although a parallel bank of filters decreases the time required for a spectrum measurement, it increases the detection and display complexity. The filter channels all contain information simultaneously and some method of detecting and presenting the dB levels in each channel must be employed. One approach would be to use a number of detectors in parallel, one for each channel, and then sample the output of each detector to provide the required output. But this approach carries with it all the restrictions of conventional analog detectors: limited dynamic range, undefined integration time, and limited accuracy.

A better approach is that shown. The signal is connected to a preamplifier whose output is applied simultaneously to a number of attenuator-filter channels in a somewhat conventional manner. But, rather than parallel detectors, this system employs a multiplexer that samples each channel, one at a time, and delivers the samples to an analog-to-digital converter.

The converter changes the signal levels to binary numbers: From these numbers, *true* rms values are calculated and stored in memory. Then the information from each channel can be displayed on a front-panel digital readout or on analog and/or digital accessories connected to the analyzer. The result is an analyzer that is far superior to those using conventional, analog-detector methods. Consider, for example, these advantages:

At least 30 times faster — more data can be analyzed and measurements of non-stationary signals can be made without tape loops.

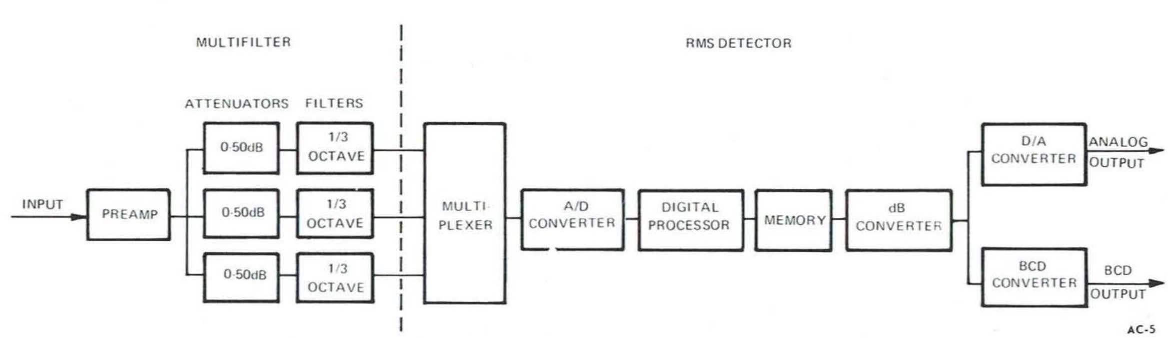
True rms detection — accuracy of ±0.5 dB means repeatable answers.

Exceptionally wide 70-dB range — permits analysis of low-level components in high-level signals.

Known and selectable integration times — ⅛ s to 32 s, allows measurement of the portion of interest in a signal and provides long integration times for statistically reliable measurements of random noise.

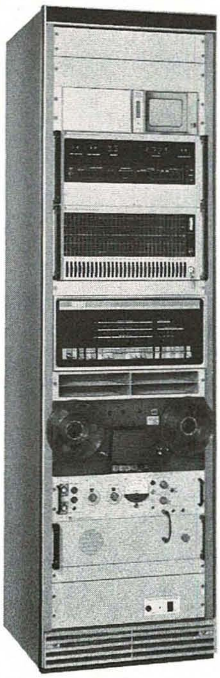
Adjustable attenuation — 50 dB, for dynamic-range extension, transducer flattening, subjective correlation, etc.

Programmable operation — lends it to systems applications and computer control.



REPRESENTATIVE SYSTEMS

The four systems on this page are but a small sample of the versatility of the "custom-product" approach.

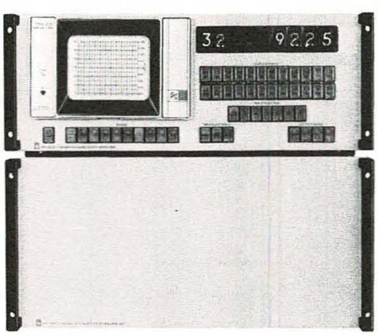


Right

Audiometer Calibration This kit provides everything necessary for complete audiometer calibrations in accordance with ANSI Standards Z24.5-1951, Z24.12-1952, and Z24.13-1953 — all contained in one moisture-proof, fiberglass carrying case. It includes an audiometric oscillator, sound analyzer, sound-level calibrator, microphone and preamplifier, earphone coupler, microphone adaptors, and all necessary accessories and instructions.

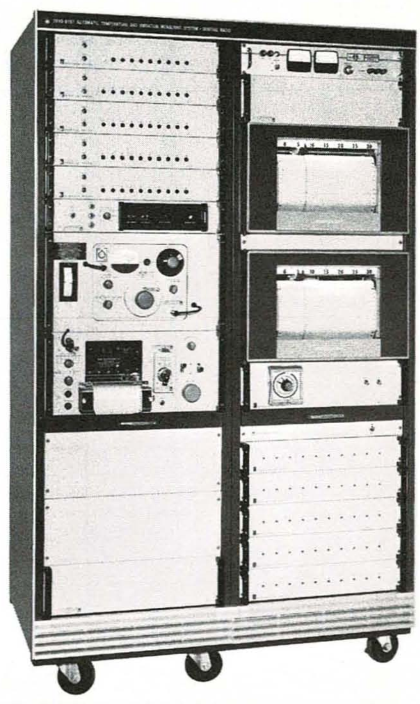
Left

Automatic Real-Time Noise Analysis This computer-controlled system provides on-line measurements and calculations of: spectrum comparisons in third-octave or octave bands, Stevens Loudness per ANSI S3.4-1968, ARF Loudness (per Society of Automotive Engineers Standards), Perceived Noise Levels as recommended by the FAA, Speech Interference Levels, Noise Criterion Levels, ARI Ratings per Air Conditioning and Refrigeraton Institute, AMCA Ratings, ASHRAE Measurements, and STC Ratings per American Society of Testing and Materials Standard E90-66T.



Left

Specialized Real-Time Analysis This is a special adaptation of our 1921 Real-Time Analyzer. It provides one-third-octave or octave-band analysis of signals from 100 Hz to 20 kHz and offers the advantages of true rms detection, including 70-dB dynamic range and 0.5-dB accuracy. It also incorporates a display oscilloscope and a built-in pink-noise calibration source.

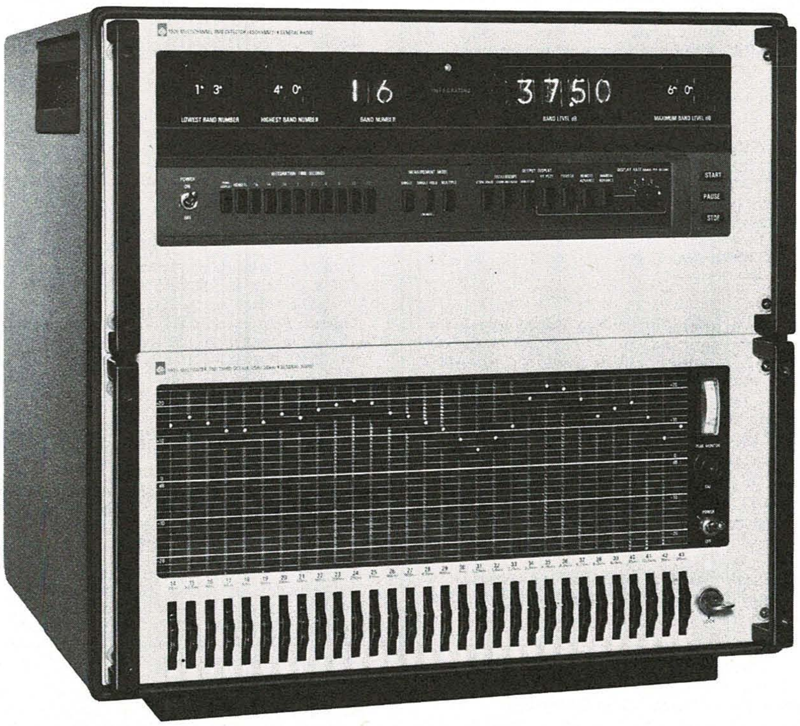


Right

Vibration and Temperature Monitoring A large automotive manufacturer uses this system to monitor vibration and temperature at up to 48 remote points in an automatic sequence. It provides sampled records of temperature and acceleration and provides visual and electrical indications when the measured values exceed selected limits. In additon, a detailed frequency analysis of acceleration can be made at any selected point.

Type 1921 REAL-TIME ANALYZER

- 3.15 Hz to 80 kHz
- 30 to 45 channels 1/1, 1/3, 1/10 octave bands
- 70-dB dynamic range
- 60-dB display range
- calibrated attenuators
- true rms detection
- 9 integration periods
- corrected spectrum displayed directly



The Type 1921 Real-Time Analyzer is a new-generation analyzer. It performs real-time one-third-octave spectrum analysis in the frequency range from 3.15 Hz to 80 kHz employing a unique digital detection scheme to achieve performance unattainable with analog techniques. The major components of the analyzer are the Type 1925 Multifilter and the Type 1926 Multichannel RMS Detector.

Filters in the 1925 conform to American and International standards. The Multifilter includes a calibrated attenuator in each filter channel to permit pre-whitening or weighting. The attenuators can also be used to correct transducer or tape-recorder errors or to extend the dynamic range of the analyzer. The attenuation is controlled by individual thumbwheels and indicated on a panel display. The Multifilter also includes A-, B-, and C-weighting networks.

The Type 1926 Multichannel RMS Detector is unique in that it processes the signal from the Multifilter digitally. The outputs of the filters are sampled, the sample data converted to digital binary form, and the binary numbers fed to a digital processor which computes root-mean-square level. There are several advantages in this method of rms detection as compared with analog methods. A very wide dynamic range can be realized while maintaining an accurate rms characteristic.

The averaging method is true (linear) integration with a choice of nine integration periods from 1/8 second to 32 seconds. A true integration scheme not only gives answers faster than the running average circuits found in analog devices (they "waste" time and are not very useful for transient signals) but also makes it possible to determine exactly what events in time have affected the answer. The computed band levels are stored in a digital memory to be retrieved at a rate limited only by the output recording or storage device. The analyzer simultaneously produces both digital (1-2-4-8 code) and analog outputs.

The 1921 is available in eight standard 30-channel versions including four versions with adjustable calibrated attenuators and four without. The four standard three-decade frequency ranges include bands extending down to 3.15 Hz and up to 80 kHz. A-, B-, and C-weighted sound level as well as a flat frequency-response channel are available for all versions. The analyzer's filter section (Type 1925 Multifilter) can also function as a spectrum synthesizer, equalizer, or shaper.

The 1921 Real-Time Analyzer has also been designed to allow great flexibility in the number and bandwidths of filters and for input and output devices. Custom versions with up to 45 channels, octave bands, mixtures of octave, one-third-octave, and one-tenth-octave bands, and special bandwidths can be supplied. Complete custom systems from transducer to final data storage (or even including a computer for rapid data storage, determining ratings, making comparisons, etc) can also be supplied.

— See **GR Experimenter** for May-June 1969.

specifications

OPERATIONAL CHARACTERISTICS

Frequency Range: 30 1/3-octave filter channels from 3.15 Hz to 80 kHz in standard models (see table).

Dynamic Range: 70 dB; 60-dB range is displayed, thus allowing a crest-factor margin of 10 dB at full scale.

Sensitivity: 0.1 V rms nominal for full scale. Can be increased to 5 mV full scale with GR 1560-P40 Preamplifier (power supplied by 1921).

INPUT

Impedance: 100 kΩ.

Voltage: AC component, ± 17 V pk max referred to dc component of input. DC component, ± 35 V max.

Gain Adjustment: 18 dB continuous, common to all channels.

Peak Monitor: A peak detector senses levels at two circuit points and drives a panel meter calibrated in dB referred to overload level. A signal proportional to meter deviation is available at an output jack for driving a dc recorder; 1 mA corresponds to full-scale reading.

FILTERS

Characteristics: One-third-octave effective (noise) bandwidths. Filters are six-pole Butterworth designs and meet current American and International standards: 1/3-octave filters conform to ANSI S1.11-1966 Class III (high attenuation) and IEC Recommendation Publication 225-1966.

Accuracy of Center Frequency: ±2%.

Passband Ripple: 0.5 dB max pk-pk.

Uniformity of Levels (at center frequencies, attenuator at +25 dB): ±0.25 dB at 25°C; ±0.5 dB, 0 to 50°C.

Noise: <15 μV equivalent input noise.

Harmonic Distortion (at band centers): For bands centered at 25 Hz and above, <0.1% at 1-V output. For bands below 25 Hz, <0.25% at 1-V output.

Weighting: A, B, and C characteristics of weighted channels conform to current American and International standards including ANSI S1.4, IEC R123, and IEC R179.

ATTENUATORS

Range: Gain in each filter channel adjustable in 1-dB steps over a range of 50 dB by front-panel controls.

Accuracy: ±0.25 dB relative to indicated +25-dB setting.

Readout: Panel display indicates attenuation in each channel and represents the transmission between input and summed output of multifilter. Display has standard 50-dB-per-decade scale factor; 10 dB per inch vertical, 5 inches per decade horizontal. Key lock on panel prevents accidental changes in attenuator setting.

DETECTOR

Characteristics: RMS with true (linear) integration. Choice of nine integration periods: ⅛, ¼, ½, 1, 2, 4, 8, 16 and 32 seconds.

Linearity: ±0.5 dB deviation from best straight-line fit over the top 50 dB of display range for any channel; ±1 dB over entire 60-dB range.

Sampling: Time between samples depends upon integration period selected. Sampling rate is swept over a range of about 1.8:1 during integration period to minimize coherence effects. 1024 samples are taken during integration periods of 1 to 32 seconds. Below 1-second integration period, the quantity of samples is reduced, in proportion to the integration period, to a minimum of 128.

Crest-Factor Capacity: 10 dB at full scale, increasing below full scale. Repeatability is better than 1 dB (one-σ limit) for tone burst with duty factor of 1/100 (equivalent to crest factor of approximately 23 dB) when rms levels are less than 13 dB below full scale.

Memory Duration: Unlimited while power is on.

OUTPUTS

Analog Output: Detected level output (Y axis) is linear in dB for a range in voltage of 0 to +1V ±10%, corresponding to 0 to 60 dB. Channel-number (X axis) data are linear with 0 to 1-V nominal output swing. Adjustable to 1-V swing, corresponding to quantity of output channels ranging from 10 to 45. Channels are designated by ANSI Standard Band Numbers. Overload in any channel is indicated by a "jitter" superimposed on the "level" voltage for that channel.

Digital Output: Levels in dB from 0 to 159 dB (in 0.25-dB steps) are represented by five BCD digits. Band number is reported by two BCD digits. Logic is standard 5-V TTL (positive true) for both level and band number. Overload in any channel is indicated by presence of an 8 or 9 as the most significant digit in the level indication corresponding to the channel number.

Display: Five neon readout tubes display band level in dB. Two neon readout tubes display standard band numbers (per ANSI S1.6 and S1.11).

Calibration: Full-scale and zero-level self calibration provided in two auxiliary channels. Front-panel controls allow a calibration factor to be added to digital output; full-scale indication is adjustable from 60 to 159 dB in 1 dB steps.

GENERAL

Accessories: Synchronizing and control signals provided for CRT display, automatic recorders, scanners, data printers, and computers. Interfaces specifically designed for GR 1522 DC Recorder, GR 1921-P1 Storage Display Unit, Houston Instruments 6400-024-series plotters, and Mohawk Data Sciences model 800 High-Speed Printer. 1925-9670 Transmission Record Sheets, thin mylar sheets, same size and with same scale as 1925 display window; used to record position of dots in window with grease pencil or other marker; attaches to window with self-contained adhesive strip.

Programmability: All panel-control functions except output display rate are programmable by contact closures or solid-state switches to ground.

Power Required: 100 to 125 or 200 to 250 V, 50 to 60 Hz, 135 W.

Mounting: Rack or bench (mounted in single metal cabinet).

Dimensions (width x height x depth): Bench, 19½ × 19 × 20 in. (495 × 485 × 510 mm); rack, 19 × 17½ × 16 in. (485 × 445 × 410 mm).

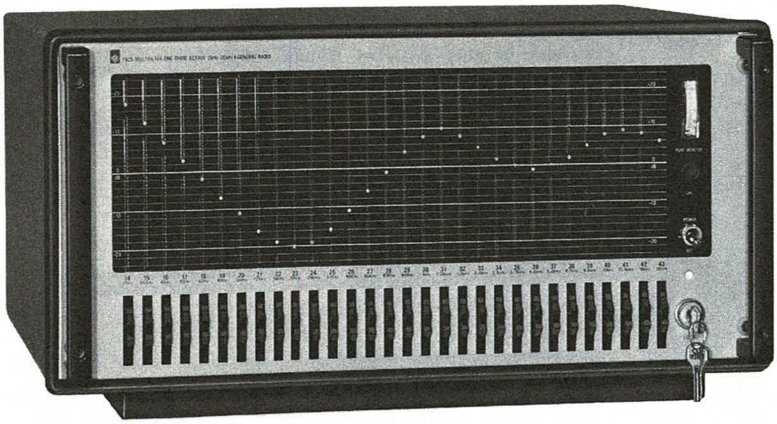
Weight: Bench, 95 lb (44 kg) net, 190 lb (87 kg) shipping; rack, 80 lb (37 kg) net, 120 lb (55 kg) shipping.

Catalog Number					Price in USA	
With Attenuator		Without Attenuator			With	Without
Bench	Rack	Bench	Rack	Description	Attenuator	Attenuator
				1921 Real-Time Analyzer One-Third-Octave Bands		
1921-9700	1921-9701	1921-9708	1921-9709	25 Hz to 20 kHz	**$9275.00**	**$8925.00**
1921-9702	1921-9703	1921-9710	1921-9711	12.5 Hz to 10 kHz	**9355.00**	**9005.00**
1921-9704	1921-9705	1921-9712	1921-9713	3.15 Hz to 2.5 kHz	**9455.00**	**9105.00**
1921-9706	1921-9707	1921-9714	1921-1915	100 Hz to 80 kHz	**9225.00**	**8875.00**

Description	Price in USA
1925-9670 Transmission Record Sheets, pack of ten	**$15.00**

Type 1925 MULTIFILTER

- 3.15 Hz to 80 kHz
- 1/3-octave or octave bands
- calibrated channel attenuators
- display with standard scale factor
- scanned, parallel, and summed outputs



The GR 1925 Multifilter contains up to 30 channels of parallel octave-band or one-third-octave-band filters included in the frequency range from 3.15 Hz to 80 kHz. The instrument is offered in several options of frequency range and filter bandwidth, and with or without calibrated channel attenuators.

APPLICATIONS

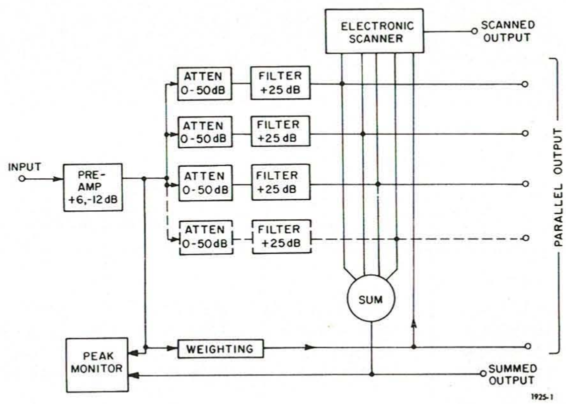
The 1925 can be supplied with or without attenuators that permit independent control of the gain in each filter channel. With the attenuators, it can be used as an equalizer or spectrum shaper to simulate or to compensate for irregularities in the frequency response of electrical or acoustical transmission systems or transducers. With or without the attenuators, the 1925 Multifilter can be used in a serial or parallel frequency analyzer system.

OUTPUTS

The outputs from the individual filter channels are presented simultaneously in parallel, summed in a single output, and selected individually by manual switching, external switch closure, or by a remote Type 1771 Scanner Contol. Additional outputs provide the unfiltered input signal and the signal with A, B, and C weighting imposed. Peak detectors located both before and after the filters drive a metering circuit which selects the highest peak and indicates in decibels referred to the overload level.

ATTENUATORS

Although the 1925 can be supplied without them, calibrated attenuators for each filter channel broaden the Multifilter's usefulness. Each attenuator gives 50 dB of gain control with 1-dB-per-step resolution. Attenuation is controlled by individual thumb wheels and indicated by a panel display that represents the "transmission" of the instrument. The display has a horizontal scale of 5 in./decade and a vertical scale of 10 dB/in. (the same scale as chart paper 1521-9463 supplied for use with the Type 1564-A Sound and Vibration Analyzer). A key-operated lock guards against unintended changes in the attenuator control settings.



FILTER CHARACTERISTICS

The filters, built on plug-in etched boards (three per board) for easy interchange, are available with either octave or one-third-octave bandwidths that conform to both American and international standards. Both meet the IEC Recommendation Publication 225-1966; the third-octave characteristic meets the ANSI Standard S1.11-1966 Class III (high attenuation), the octave meets the same standard, Class II (moderate rate — highest for octave-band filters).

The A, B, and C weighting characteristics also conform to the requirements of the various standards for sound-level meters.

— See **GR Experimenter** for May-June 1969.

specifications

FILTERS

Characteristics: See curve. Both octave-band and one-third octave-band filters are six-pole Butterworth designs. Specified bandwidths are effective bandwidths, i.e. bandwidths for noise. Filters meet all current American and international standards: 1/3-octave conforms to ANSI S1.11-1966 Class III (high attenuation), the octave filters to ANSI S1.11-1966 Class II (moderate rate but highest for octave-band filters). Both octave and third-octave characteristics conform to IEC Recommendation Publication 225-1966.

Accuracy of Center Frequency: ±2%.

Passband Ripple: 0.5 dB max peak to peak.

Uniformity of Levels: At center frequencies (attenuator at +25 dB) ± 0.25 dB at 25°C; ± 0.5 dB, 0 to 50°C.

Noise: <15 μV equivalent input noise.

Distortion: For bands centered at 25 Hz and above, harmonic distortion at band center is <0.1% at 1 V out. For bands with center frequency below 25 Hz, distortion at band center is <0.25% at 1 V out.

ATTENUATORS

Range: Gain in each channel adjustable in 1-dB steps from +25 dB to −25 dB relative to nominal 0-dB gain by means of panel control.

Accuracy: ±0.25 dB relative to +25-dB attenuation setting.

Readout: Panel display indicates attenuation in each channel and represents transmission between input and summed output. Display has standard 50-dB-per-decade scale factor; 10 dB per inch vertical, 5 inches per decade horizontal. Lock on panel prevents accidental changes in attenuator settings.

CHASSIS (accepts up to 30 filters)

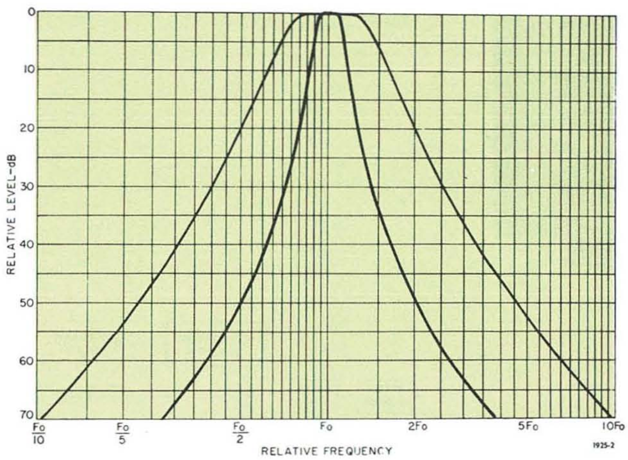
Over-all Gain: 0 dB nominal.

Gain Adjustment: +6 to −12 dB, common to all channels.

Input Impedance: 100 kΩ.

Input Voltage: AC component, ±17 V pk max referred to dc component of input. DC component, ±35 V max.

Scanner: Any single filter output is selected by a rear-panel pushbutton, external switch closure, or by use of a Type 1771 Scanner Control (available on special order), which displays and outputs (BCD) the channel number.



Peak Monitor: A peak detector senses levels at two circuit points and drives a panel meter calibrated in dB referred to overload level. A signal proportional to meter indication is available at an output jack for driving a dc recorder; 1 mA corresponds to full-scale reading.

OUTPUTS

Channel Outputs (Parallel Output: *Impedance:* 20 Ω nominal. *Voltage:* ±4.2 V max (3 V rms sine wave). *Load Impedance:* 3 kΩ minimum for max output voltage.

Scanned Output: *Impedance:* 20 Ω nominal. *Voltage:* ±4.2 V max (3 V rms sine wave). *Load Impedance:* 3 kΩ minimum for max output voltage. Two chassis can be wired in parallel for up to 60 scanned channels.

Summed Output (For equalizing and shaping applications): *Impedance:* 600 Ω. *Voltage:* ±4.2 V max, open circuit. *Load Impedance:* Any. Will not affect linear operation of output.

Weighted and Unfiltered Outputs: *Impedance:* 20 Ω nominal. *Load Impedance:* 3 kΩ minimum for max output voltage. *Gain:* 0 dB nominal at 1 kHz. *Weighting:* A, B, and C characteristics conform to requirements of current American and international standards including ANSI S1.4, IEC R123, and IEC R179.

GENERAL

Accessories Supplied: Power cord, 36-terminal plugs (2), Handbook of Noise Measurement.

Accessories Available: 1925-9670 Transmission Record Sheets, thin mylar sheets, same size and with same scale as 1925 display window; used to record position of dots in window with grease pencil or other marker; attaches to window with self-contained adhesive strip.

Power Required: 100-125 V or 200-250 V, 50-60 Hz, 17 W.

Mounting: Rack-bench mount.

Dimensions (w x h x d): Bench, 19¾ x 9⅛ x 14 in. (500 x 235 x 355 mm); rack, 19 x 8¾ x 12¼ in. (485 x 225 x 315 mm).

Weight: Bench, 49 lb (42.5 kg) net, 58 lb (27 kg) shipping; rack, 39 lb (18 kg) net, 47 lb (21.5 kg) shipping.

Catalog Number					Price in USA	
With Attenuator		Without Attenuator			With	Without
Bench	Rack	Bench	Rack	Description	Attenuator	Attenuator
				1925 Multifilter		
				One-Third-Octave Bands		
1925-9700	1925-9701	1925-9712	1925-9713	25 Hz to 20 kHz	**$3500.00**	**$3150.00**
1925-9702	1925-9703	1925-9714	1925-9715	12.5 Hz to 10 kHz	**3580,00**	**3230.00**
1925-9704	1925-9705	1925-9716	1925-9717	3.15 Hz to 2.5 kHz	**3680.00**	**3330.00**
1925-9706	1925-9707	1925-9718	1925-9719	100 Hz to 80 kHz	**3450.00**	**3100.00**
				Octave Bands		
1925-9708	1925-9709	1925-9720	1925-9721	31.5 Hz to 16 kHz	**2110.00**	**1990.00**
1925-9710	1925-9711	1925-9722	1925-9723	4 Hz to 2 kHz	**2210.00**	**2090.00**

Note: Rack and bench versions of any model are priced the same.

Type 1926 MULTICHANNEL RMS DETECTOR

The Type 1926 Multichannel RMS Detector is the digital detector section of the 1921 Real-Time Analyzer. The 1926 is available separately for use with the 1925 Multifilter or other multichannel filters where real-time analysis is required. It is also useful as a multichannel true-rms detector in other applications such as monitoring the sound pressure at a number of points or measuring the electrical noise of multichannel systems.

specifications

Input: *Channels,* 30 or 45. *Sensitivity,* 1 V full scale ±10%, 1 mV to 1 V rms range of ac component, 0.1 V max dc component, 3 V max peak ac component for linear operation. *Input impedance,* ≈ 5kΩ; 0 to 30-Ω allowable source impedance.

Analog Output: *Level* (X axis), linear in dB, 0 to +1 V ±10% corresponds to 0 to 60 dB; overload indicated by jitter superimposed on level. *Channel number* (Y axis), linear, adjustable to 1 V corresponding to a quantity of output channels ranging from 10 to 45.

Digital Output: *Level,* 0 to 159 dB in 0.25-dB steps represented by 5 BCD digits; overload indicated by 8 or 9 as the hundreds digit. *Channel number,* 2 BCD digits. *Logic levels,* standard 5-V TTL (15-V DTL available on special request), positive true. *Output period,* advance from one channel to the next is automatic at 720 μs to 45 s for 45 channels or manual by pushbutton or external command.

Dynamic Range: 70 dB; 60 dB is displayed, 10 dB at full scale is crest-factor margin, increasing below full scale. Repeatability for tone burst with 1/100 duly factor (equivalent to crest factor of ≈ 23 dB) is better than 1 dB (1 δ limit) when rms levels are lower than 13 dB below full scale.

Sampling: 1024 samples taken for integration periods of 1 to 32 s, reduced in proportion to integration period for periods <1 s to a minimum of 128; time between samples depends on integration period; rate is swept over a range of 1.8 to 1 during integration period to reduce coherence effects.

Detection: Rms with true (linear) integration. *Integration periods,* nine, ⅛, ¼, ½, 1, 2, 4, 8, 16, 32 s. *Linearity,* ±0.5-dB deviation from best straight-line fit over top 50-dB display range for any channel, ±1 dB over entire 60-dB range. *Memory duration,* unlimited while power is on.

Frequency: Lower 3-dB point is <1 Hz for channels 1 to 10, <6 Hz for all others; error in frequency response is <1 dB at 100 kHz.

Display: 5 neon read-out tubes for band level in dB, 2 for channel number (or Standard Band Number if desired).

Calibration: Full-scale and zero self-level calibration provided in 2 auxiliary channels; front-panel controls allow a calibration factor to be added to digital output. Indicated level range is adjustable in 1-dB steps from 60 to 159 dB.

Programmability: All panel-control functions except output display time are programmable by standard DTL or TTL logic elements or closures to ground.

Power: 100 to 125 or 200 to 250 V, 50-60 Hz, 135 W.

Mechanical: Rack model only. *Dimensions* (w x h x d): 19 x 8¾ x 17$\frac{7}{16}$ in. (485 x 225 x 444 mm). *Weight:* 46½ lb (102 kg) net, 55 lb (25 kg) shipping.

Catalog Number	Description	Price in USA
	1926 Multichannel RMS Detector, Rack Model	
1926-9701	30 Channels	**$5775.00**
1926-9703	45 Channels	**6275.00**

Type 1566 MULTICHANNEL AMPLIFIER

NEW

- 16 channels
- manual or remote channel selection
- 2-Hz to 100-kHz response
- 55-dB gain, manually or remotely adjusted
- calibration noise source built in

Many sound and vibration measurements can be simplified by use of a scanner that connects, in sequence or in any arbitrary order, the outputs from a number of transducers to a single analyzer. A scanner system can be set up to measure signals individually or to average all signals.

The 1566 scans up to 16 channels (up to 99 with a special additional unit), amplifies each by up to +55 dB, and provides a built-in pink-noise calibration source that speeds not only the check out of the scanner but also that of any analyzer connected to it. The 1566 is particularly useful with the 1921 Real-Time Analyzer. This combination can automatically analyze the spectrum from each transducer scanned or it can measure radiated sound power (average) using 2, 4, 6, 8, 10, 12, or 16 microphones.

specifications

Channels: 16 plus 1 for calibration, expandable to 99 (additional channels housed in a special unit). *Control:* Active channel is selected manually or by external 1-2-4-8 BCD signal, or automatically scanned in sequence with range of channels to be scanned selected by thumbwheel switches; dwell time adjustable from 100 ms to 10 s or infinity (channel advance initiated by external signals); scan set to occur once or repetitively and started, stopped on active channel, or reset to lowest channel by pushbuttons or external closures to ground. *Display:* Two, high-intensity neon readout tubes display active channel.

Frequency: 2 Hz to 100 kHz, flat within ±0.5 dB.

Sensitivity: 1.8 mV to 1.6 V for 1-V output; gain set in 1-dB increments by panel control or 1-2-4-8 BCD signal at standard DTL levels (logic 0 ≈ ground, logic 1 ≥ + 3 V). Rear-panel adjustment provides 10-dB continuous control of gain for all channels for calibration. Each channel includes a 6-dB gain adjustment for transducer sensitivity equalization.

Impedance: *Input,* 100 kΩ. *Output,* 600 Ω.

Noise: <10 μV equivalent input noise in each channel when gain is maximum and source impedance is ≤ 100 Ω.

Calibration: Built-in pink-noise (±0.5 dB) source with symmetrical Gaussian distribution from 2 Hz to 100 kHz. Spectrum-level slope is −3 dB per octave. Noise signal applied to internal calibration channel is adjustable from 30 to 100 mV rms. Rear-panel noise output is fixed at 100 mV rms and can be loaded by 0.05 μF without affecting spectrum up to 100 kHz.

Supplied: Power cord, two 24-pin data plugs.

Available: 1560-P40 and -P42 Preamplifiers (1566 provides power for up to 99 of either), microphones, vibration pickups.

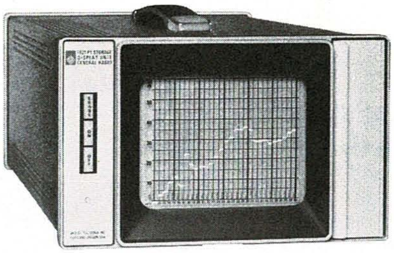
Transducers, Preamplifiers, page 25

Power: 100 to 125 or 200 to 250 V, 50 to 60 Hz, 30 W.

Mechanical: Bench or rack mount. *Dimensions* (w x h x d): Bench, 19½ x 5 x 20 in. (495 x 130 x 510 mm); rack, 19 x 3½ x 18½ in. (485 x 89 x 470 mm). *Weight:* Bench, 32 lb (15 kg) net, 47 lb (21.5 kg) shipping; rack 26 lb (12 kg) net, 41 lb (19 kg) shipping.

Catalog Number	Description	Price in USA
1566-9701	**1566 Multichannel Amplifier**	**price on request**

Type 1921-P1 STORAGE DISPLAY UNIT



NEW

An accessory for the GR 1921 Real-Time Analyzer, the 1921-P1 is a storage oscilloscope on which the results of the spectrum analysis can be displayed. The display functions of the unit are programmable and necessary control and deflection voltages are produced by the Real-Time Analyzer.

The 1921-P1 is a slightly modified Tektronix type 601 Storage Display Unit. It has all-solid state circuits, a 5-inch bistable storage CRT, built-in vertical and horizontal deflection amplifiers, and Z-axis modulation capability. It is supplied with interconnecting cable for the 1921 analyzer and graticules marked with 1/3 octave standard band numbers, center frequencies, and a decibel scale.

specifications

Frequency Response: Useful to 100 kHz for displaying waveforms on Y versus T plot. Not more than 1° phase shift between X and Y up to 100 kHz.

Z Axis: On time should be ≥9 μs to ensure good storage.

Cathode Ray Tube: 5-inch flat-faced bistable storage tube, phosphor similar to P1.

Display Size: 8 cm vertically and 10 cm horizontally.

Display Linearity: No more than 5% difference horizontally or 2% vertically between any two centimeters.

Line-Writing Speed (stored): >5 cm/ms.

Viewing Time: Up to 15 min recommended; erasure becomes more difficult if information is stored longer.

Erase Time: 200 ms.

Power Required: 90 to 136 or 180 to 272 V, 48 to 440 Hz, 57 W.

Mounting: Rack or bench.

Dimensions (width x height x depth): Bench, 8½ x 6 x 17½ in. (220 x 155 x 445 mm); rack, 19 x 7 x 17½ in. (485 x 180 x 445 mm).

Weight: Net, 17½ lb (8 kg); shipping, 25 lb (11.5 kg).

Catalog Number	Description	Price in USA
	1921-P1 Storage Display Unit	
1921-9720	Bench Model	**$1345.00**
1921-9721	Rack Model	**1395.00**

RECORDING ANALYZERS
(cont'd)

	Catalog Number	Price in USA

1912 THIRD-OCTAVE RECORDING ANALYZER

The 1912 will make chart records of stepped third-octave analyses of sound and vibration as called for in such standards as Military Standard-740B(SHIPS), ASHRAE 36A-63, and others. In stepped analysis, the analyzer steps from frequency to frequency and dwells a specified time at each while the recorder chart paper feeds continuously. The result is a synchronized, calibrated plot of time-averaged levels in each third-octave band for ease of analysis.

Frequency can also be swept continuously, giving more detailed information than when stepped. See individual descriptions of 1564-A, 1564-P1, and 1521-B.

The 1912 is supplied completely assembled in a cabinet and includes a storage drawer and a system power control, which switches the analyzer battery supply as well as the ac line.

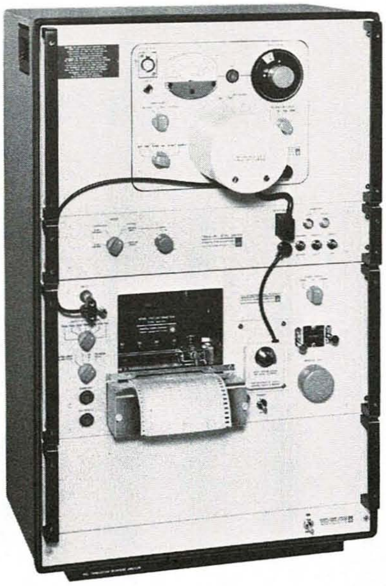
The 1912 includes the following:
- **1564-A Sound and Vibration Analyzer,** rack model
- **1564-P1 Dial Drive**
- **1521-B Graphic Level Recorder** with **40-dB Potentiometer** (1521-9602) and medium-speed motor
- **Chart Paper,** 10 rolls (1521-9460), for stepped analysis

Accessories Available: 1560-P40K Preamplifier and Microphone Set, Chart Paper 1521-9469 for continuous-mode analysis, 80-dB potentiometer, choice of GR microphones and vibration pickups for direct vibration or acoustic analysis.

Mounting: Assembled in cabinet.

Dimensions (width x height x depth): 19¾ x 31¼ x 18½ in. (500 x 800 x 470 mm).

Weight: Net, 120 lb (55 kg); shipping, 175 lb (80 kg).



	Catalog Number	Price in USA
1912 Third-Octave Recording Analyzer (for 115-V, 60-Hz supply)	1912-9700	**$3870.00**

1913 RECORDING WAVE ANALYZER — 1% Bandwidth

This constant-percentage-bandwidth recording analyzer will make high-resolution spectrum plots from 20 Hz to 20 kHz. It is easy to use, having automatic range switching and few controls. Wide dynamic range and the 80-dB potentiometer reduce the need to change sensitivity manually to accommodate widely varying amplitudes. Narrow bandwidth permits separation of closely spaced low frequencies without forfeiting high-frequency resolution; typically, the fiftieth harmonic can be identified. See description of 1568-A Wave Analyzer for more details.

The 1913 is supplied assembled and includes a storage drawer and system power control, which switches the analyzer battery supply as well as the ac line.

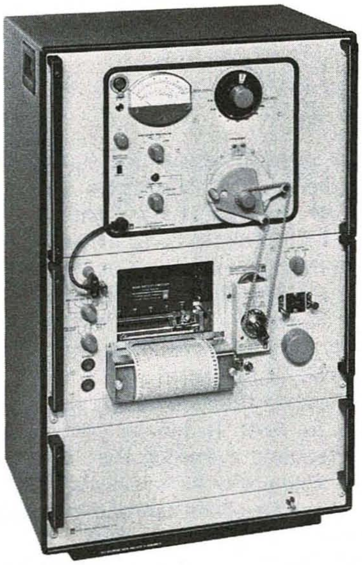
The 1913 includes the following:
- **1568-A Wave Analyzer,** rack model, and accessories
- **1521-B** (or -BQ1 for 50-Hz supply) **Graphic Level Recorder** with **40-dB Potentiometer** (1521-9602) and medium-speed motor
- **1521-P3 80-dB Potentiometer** (1521-9603)
- **1521-P10B Drive Unit** (1521-9467)
- **1521-P15 Link Unit** (1521-9615), with 16-tooth sprocket installed (standard 24-tooth sprocket also included)
- **Chart Paper,** 10 rolls (1521-9475), scale 2-20 log, normalized

Accessories Available: 1560-P40J Preamplifier and Adaptor Set.

Mounting: Assembled in cabinet.

Dimensions (width x height x depth): 19¾ x 31¼ x 15¾ in. (500 x 800 x 400 mm).

Weight: Net, 110 lb (50 kg); shipping, 165 lb (75 kg).



	Catalog Number	Price in USA
1913 Recording Wave Analyzer, 1% Bandwidth		
for 115-V, 60-Hz supply	1913-9700	**$3515.00**
for 230-V, 50-Hz supply	1913-9701	**3515.00**

FREQUENCY-RESPONSE & SPECTRUM RECORDER ASSEMBLIES

Several GR instruments can be used with the 1521-B Graphic Level Recorder for automatic plotting of the frequency response of devices or the frequency spectrum of acoustic or electrical noise or of a complex electrical waveform. Automatic plotting with these instruments replaces tedious point-by-point manual methods and provides much more information in the form of finer-resolution curves. Listed below are several such assemblies that can be ordered under a single catalog number and include all accessories normally needed. Or the component items can be ordered individually to convert existing equipment into fully automatic recording assemblies.

Custom assemblies of GR analysis equipment and sound and vibration instruments can be built to order to meet a variety of special requirements.

— See **GR Experimenter** for Sept 1964 and Nov-Dec 1967.

RECORDING ANALYZERS

1910-A RECORDING WAVE ANALYZER

The 1910-A is particularly useful in analyzing and recording the frequency components present in mechanical vibrations, acoustic signals, and in complex electrical signals including random noise. Its linear frequency scale, 20-Hz to 54-kHz range, three bandwidths (3, 10, and 50 Hz), and 80-dB dynamic range permit higher-order, closely spaced and weak components to be found with ease.

The complete assembly includes the following:

- **1900-A Wave Analyzer,** including **1560-P95 Adaptor** cable and other accessories
- **1521-B** (or -BQ1 for 50-Hz supply) **Graphic Level Recorder** with **40-dB Potentiometer** (1521-9602) and medium-speed motor
- **1521-P3 80-dB Potentiometer** (1521-9603)
- **1521-P10B Drive Unit** (1521-9467) (installed)
- **1900-P1 Link Unit** (1900-9601) (installed)
- **1900-P3 Link Unit** (1900-9603)
- **Chart Paper,** 10 rolls (1521-9464), scale 0-10 kHz
- **Chart Paper,** 10 rolls (1521-9465), scale 0-50 kHz

Accessories Available: 1560-P40H Preamplifier and Power Supply Set; choice of vibration pickups or microphones.

Mounting: Rack-Bench Cabinets; includes end frames for bench use and supports for rack mounting.

Dimensions (width x height x depth): Bench, 19 x 25¼ x 15¼ in. (485 x 645 x 390 mm); rack, 19 x 24½ x 13¼ in. (485 x 625 x 340 mm).

Weight: Net, 116 lb (53 kg); shipping, 227 lb (104 kg).

	Catalog Number	Price in USA
1910-A Recording Wave Analyzer, (for 60-Hz supply)	1910-9701	**$4870.00**
1910-AQ1 Recording Wave Analyzer, (for 50-Hz supply)	1910-9494	**4870.00**

1911-A RECORDING SOUND AND VIBRATION ANALYZER

This assembly will generate continuous frequency plots of the 1/3- or 1/10-octave spectrum of sound and vibration signals over the range of 4.5 Hz to 25 kHz. Thus 1/3-octave measurements can be made in accordance with several common military and industrial noise-control specifications. While the third-octave bandwidth is convenient for testing compliance to a specification for maximum allowable noise or vibration level, the 1/10-octave bandwidth permits identification of individual frequency components, leading to their reduction or elimination. The analyzer will accept signals from a sound-level meter, vibration meter, or other stable amplifier, or directly from a microphone or vibration pickup. It includes a storage drawer and power system control.

The 1911-A consists of the following:

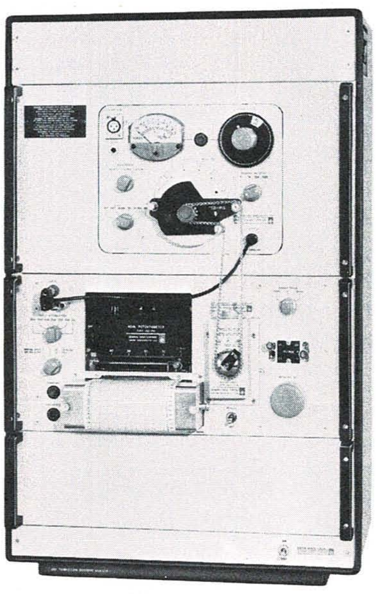
- **1564-A Sound and Vibration Analyzer,** rack model
- **1521-B** (or -BQ1 for 50-Hz supply) **Graphic Level Recorder** with **40-dB Potentiometer** (1521-9602) and medium-speed motor
- **1521-P10B Drive Unit** (1521-9467)
- **1521-P15 Link Unit** (1521-9615), with 16-tooth sprocket installed (standard 24-tooth sprocket also included)
- **Chart Paper,** 10 rolls (1521-9469), calibrated 2.5-25 normalized, logarithmic
- **Adaptor Cable,** double plug to offset phone plug.

Accessories Available: 1560-P40K Preamplifier and Microphone Set; 80-dB potentiometer; choice of vibration pickups.

Mounting: Completely assembled with end frames for bench use. Hardware for rack mounting is supplied.

Dimensions (width x height x depth): 19¾ x 31¼ x 15¾ in. (500 x 800 x 400 mm).

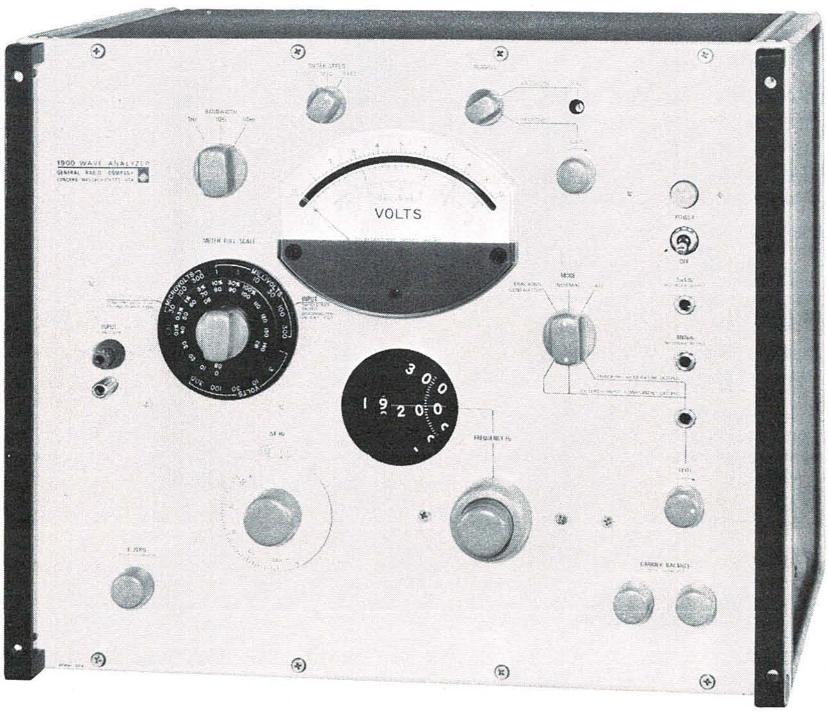
Weight: Net, 101 lb (47 kg); shipping, 158 lb (72 kg).



	Catalog Number	Price in USA
1911-A Recording Sound and Vibration Analyzer (for 60-Hz supply)	1911-9701	**$3460.00**
1911-AQ1 Recording Sound and Vibration Analyzer (for 50-Hz supply)	1911-9494	**3460.00**

Type 1900-A WAVE ANALYZER

- 20 to 54,000 Hz, linear frequency scale
- 3-, 10-, and 50-Hz bandwidths
- 30 μV to 300 V, full scale — 3 μV with preamp
- 80-dB recording analyzer with 1521 recorder
- outputs: filtered or BFO, 100 kHz and dc recorder
- 1-megohm input impedance on all ranges



The wave analyzer is used for measuring the components of, or analyzing the spectra of, complex electrical signals, acoustic noise, or mechanical vibrations

Individual components of periodic complex waveforms such as harmonic or intermodulation distortion are readily separated and measured, owing to the excellent selectivity.

Automatic frequency control enables the 1900-A to remain tuned to a slowly varying component that might otherwise drift out of the 50-Hz bandwidth.

This analyzer is particularly suited for analyzing noise, because its bandwidth in hertz is independent of the center frequency. The required averaging time is, therefore, constant, and the calculation of spectrum level is simple. Furthermore, when the 50-Hz bandwidth is used, the averaging time required is reasonably short.

Preamplifier page 26

For automatic analysis, outputs are provided for driving the 1521 Graphic Level Recorder as well as dc recorders.

The 1560-P40H Preamplifier and Power Supply Set is available to extend the full-scale sensitivity to 3 microvolts and to increase the input impedance.

TUNABLE FILTER USE

The analyzer can also be used as a tunable filter, so that the individual components of a complex input signal can be used to drive other instruments, such as frequency counters, when a highly accurate measure of the component frequencies is desired, or to drive earphones. When a wide-band noise generator drives the analyzer, the output is a tunable narrow band of noise. Such a signal is useful in a number of psychological and architectural-acoustics tests.

AS A TRACKING GENERATOR

In the "tracking generator" mode of operation the output is a sine-wave signal tunable over the 54-kHz range and always in tune with the analyzer. When this signal is used to drive a bridge or other network, the output can be measured by the analyzer, whose selectivity reduces the interference from extraneous noise, hum, and distortion.

DESCRIPTION

The 1900-A is a heterodyne type of voltmeter. The intermediate-frequency amplifier at 100 kHz includes a highly selective quartz-crystal filter whose bandwidth can be switched to 3, 10, and 50 Hz. The use of a heterodyne system makes it possible to vary the response frequency although the filter frequency is fixed. The 100-kHz output of the filter is indicated on a meter and is also available at the panel. In one mode of operation the output is also heterodyned back to the original frequency. In another mode the local oscillator beats with a 100-kHz quartz-crystal oscillator to function as a beat-frequency oscillator. These two outputs are also available at panel terminals as FILTERED INPUT COMPONENT and INDICATED FREQUENCY, respectively.

— See **GR Experimenter** for April 1964.

specifications

FREQUENCY

Range: 20 to 54,000 Hz. The frequency is indicated on a counter and a dial with a linear graduation, 10 Hz per division.

Accuracy of Calibration: ±(½% + 5 Hz) up to 50 kHz; ±1% beyond 50 kHz.

Incremental-Frequency Dial (ΔF): ±100 Hz. Accuracy is ±2 Hz below 2 kHz, ±5 Hz up to 54 kHz.

Automatic Frequency Control: At frequencies below 10 kHz, total range of frequency lock is 400 Hz for the 50-Hz band and 150 Hz for the 10-Hz band, as defined by 3-dB drop in response from full-scale deflection. At 50 kHz, the lock ranges decrease to one-half of these values.

SELECTIVITY Three bandwidths (3, 10, and 50 Hz).

Effective bandwidth for noise equal to nominal bandwidth within ±10% for 10- and 50-Hz bands and ±20% for 3-Hz band.

3-Hertz Band: At least 30 dB down at ±6 Hz from center frequency, at least 60 dB down at ±15 Hz, at least 80 dB down at ±25 Hz and beyond.

10-Hertz Band: At least 30 dB down at ±20 Hz, at least 60 dB down at ±45 Hz, at least 80 dB down at ±80 Hz and beyond.

50-Hertz Band: At least 30 dB down at ±100 Hz, at least 60 dB down at ±250 Hz, at least 80 dB down at ±500 Hz and beyond.

INPUT

Impedance: 1 MΩ shunted by 30 pF on all ranges.

Voltage Range: 30 μV to 300 V, full scale, to 3 μV with preamp, in 3, 10 series. A decibel scale is also provided.

Voltage Accuracy: After calibration by internal source, the accuracy up to 50 kHz is ±(3% of indicated value + 2% of full scale) except for the effects of internal noise when the attenuator knob is in the maximum-sensitivity position. From 50 to 54 kHz, the above 3% error becomes 6%.

Residual Modulation Products and Hum: At least 75 dB down.

OUTPUT

100-kHz Output: Amplitude is proportional to amplitude of selected component in analyzer input signal. With the 1521 Graphic Level Recorder connected, full-scale output is at least 3 V. Dynamic range from overload point to internal noise is >80 dB with attenuator knob fully clockwise.

Recording Analyzer: See the 1910-A Recording Analyzer and 1521-B Graphic Level Recorder.

1521 Recorder page 51

DC Output: 1 mA in 1500 Ω, full scale, one side grounded.

Filtered Input Component: Output at least 1 V across 600-Ω load for full-scale meter deflection with output control at max.

Tracking Analyzer (Indicated Frequency): 20 Hz to 54 kHz; output is at least 2 V across 600-Ω load with output control at max.

GENERAL

Terminals: Input, binding posts; output, telephone jacks.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 40 W.

Accessories Supplied: 1560-P95 Adaptor Cable, phone plug, power cord.

Preamplifier page 26

Accessories Available: 1900-P1 and 1900-P3 Link Units for coupling to 1521 Graphic Level Recorder, 1560-P40H Preamplifier and Power Supply Set.

Mounting: Rack-Bench Cabinet.

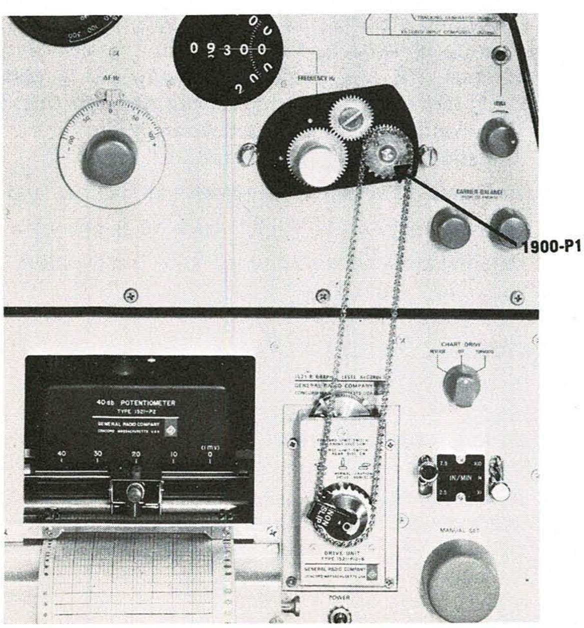
Dimensions (width x height x depth): Bench model, 19 x 16¼ x 15¼ in. (485 x 415 x 390 mm); rack model, 19 x 15¾ x 13¼ in. (485 x 400 x 340 mm).

Weight: Net, 56 lb (26 kg); shipping, 140 lb (64 kg).

Catalog Number	Description	Price in USA
	1900-A Wave Analyzer	
1900-9801	Bench Model, 115 V	**$2950.00**
1900-9811	Rack Model, 115 V	**2950.00**
1900-9802	Bench Model, 230 V	**2950.00**
1900-9812	Rack Model, 230 V	**2950.00**

PATENT NOTICE. See Notes 1, 15, and 18.

AUTOMATIC WAVE ANALYSIS



The 1900-A Wave Analyzer can be used in conjunction with the GR 1521 Graphic Level Recorder to produce, automatically, permanent graphic records of high-resolution spectrum analyses. The necessary coupling mechanisms and chart papers are available for frequency scales of 50, 500, or 5000 Hz per inch. A choice of 3 recorder potentiometers permits selection of 20, 10, or 5 dB per inch, so that virtually any combination of horizontal and vertical scale resolution is possible.

The 1900-P1 and 1900-P3 Link Units mount on the wave analyzer in place of the manual frequency-tuning dial providing mechanical coupling to the recorder. The 1900-P3 permits selection of 500 or 50 Hz per inch scale factors with a lever; the 1900-P1 provides 5000 or 500 Hz per inch by the interchanging of sprocket wheels.

An assembly of the 1900-A Wave Analyzer, 1900-P1, and 1521-B Graphic Level Recorder is available as the 1910-A Recording Wave Analyzer.

1910 Assembly page 42

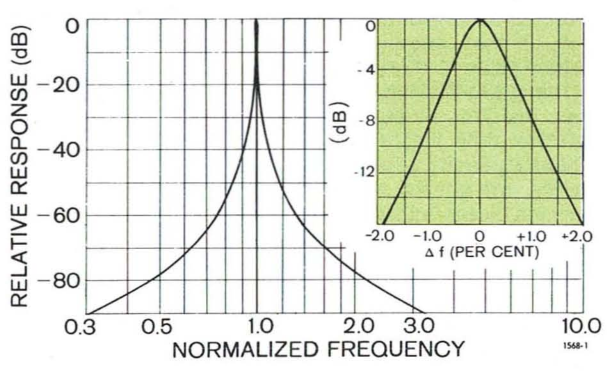
Catalog Number	Description	Chart Paper	Price in USA
1900-9601	**1900-P1 Link Unit**	1521-9464, 500 Hz/in. 1521-9465, 5000 Hz/in.	**$45.00**
1900-9603	**1900-P3 Link Unit**	1521-9464	**80.00**

Type 1568-A WAVE ANALYZER

- 20 Hz to 20 kHz
- 1% constant-percentage bandwidth
- portable, battery-operated
- 85-db rejection

The 1568-A is an important new instrument for high-resolution frequency analyses, whether for measuring vibration and noise components or the spectrum of a complex electrical signal. Recent design advances combine the excellent filter shape of a wave analyzer with the convenient, simple operation of constant-percentage-bandwidth analyzers in a portable, low-cost instrument.

The voltage sensitivity and input impedance, adequate for most uses, can be improved to 10 microvolts full-scale and > 500 megohms, respectively, by the use of a 1560-P40 Preamplifier. Power for it is supplied at the input connector.



Attenuation characteristics of the filter.

HIGH RESOLUTION

Narrow bandwidth permits separation of closely spaced frequencies; wide dynamic range, high stop-band attenuation, and low distortion allow measurement of small components in the presence of components up to 80 dB larger. These capabilities are vital to the identification of unwanted vibration and noise components and to the measuring of discrete frequencies in complex electrical waveforms. At low frequencies bandwidth is narrower, stability better, and calibration more accurate than those of fixed-bandwidth heterodyne wave analyzers.

The 1568 will excell in such applications as

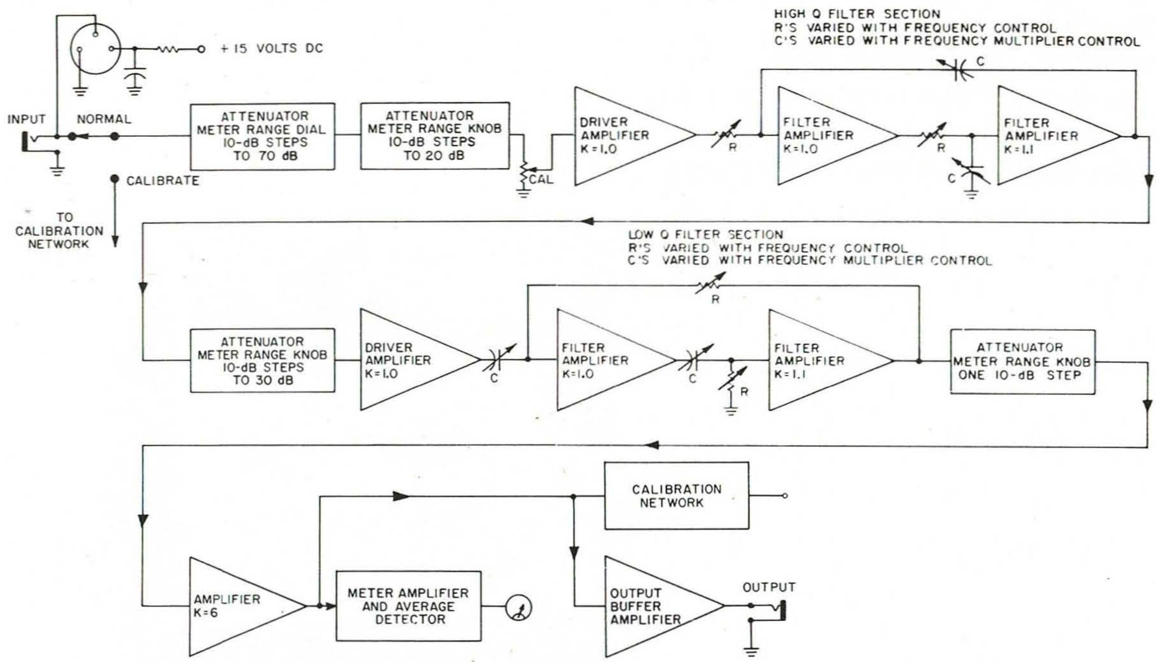
- harmonic distortion measurements at low frequencies
- harmonic analysis — 1% bw yields 50 components
- detailed analysis of machinery noise and vibration
- separation of close, discrete, low frequencies

AUTOMATIC ANALYSIS

In combination, the 1568-A and 1521-B Graphic Level Recorder produce spectrum plots with as much as a 70-dB recording range. Automatic range switching is included for ease and speed in making spectrum analyses. The analyzer and recorder are available mounted in a cabinet, interconnected, and mechanically coupled as a complete system, the 1913 Recording Wave Analyzer.

— See **GR Experimenter** for September 1966.

specifications



FREQUENCY

Range: 20 Hz to 20 kHz in six half-decade bands.

Dial Calibration: Logarithmic.

Accuracy of Frequency Calibration: 1%.

Filter Characteristics: Bandwidth between 3-dB points on selectivity curve is one percent of selected frequency.

Attenuation at 20% above and at 20% below selected frequency is greater than 50 dB referred to the level at the selected frequency. Attenuation at twice and at one-half the selected frequency is at least 75 dB referred to the level at the selected frequency. Ultimate attenuation is greater than 85 dB.

Uniformity of filter peak response with tuning is ±1 dB from 20 Hz to 6.3 kHz and ±2 dB from 20 Hz to 20 kHz.

INPUT

Impedance: 100 kΩ.

Voltage Range: 100 μV to 300 V, full scale, in 3-10 series steps. Power is supplied at input socket for the 1560-P40 Preamplifier, which extends the sensitivity to 10 μV, full scale, and increases the input impedance to more than 500 MΩ.

Distortion: Input-circuit distortion is lower than −80 dB relative to input-signal level.

OUTPUT

Impedance: 6000 Ω. Any load can be connected.

Voltage: At least one volt open circuit when meter reads full scale.

Crest-Factor Capacity: Greater than 13 dB.

Output Meter: In addition to normal-speed mode, meter has slow-speed mode for manual measurements of noise.

GENERAL

Analyzing Range: 80 dB. Components of an input signal that differ in amplitude by as much as 80 dB can be measured.

Automatic Recording: Automatic range switching is provided to allow convenient, continuous spectrum plotting when the 1521 Graphic Level Recorder is used. Medium-speed motor is recommended. Chart paper is Catalog No. 1521-9475. Frequency scale is logarithmic, 10 inches per decade; vertical scale is 4 inches for 20, 40, or 80 dB, depending on the potentiometer used in the recorder.

Amplitude Calibrator: A built-in, feedback-type calibration system permits amplitude calibration at any frequency.

Accessories Supplied: Power cord; 1568-2090 Detented Knob and Dial Assembly, used to facilitate measuring the components of an input signal as a percentage or in decibels with an arbitrary voltage reference.

Accessories Available: Preamplifier and Adaptor Set 1560-P40J; Link Unit 1521-P15, with Sprocket Kit 1521-P16 for mechanical coupling to 1521-B Graphic Level Recorder equipped with Drive Unit 1521-P10B; Chart Paper 1521-9475.

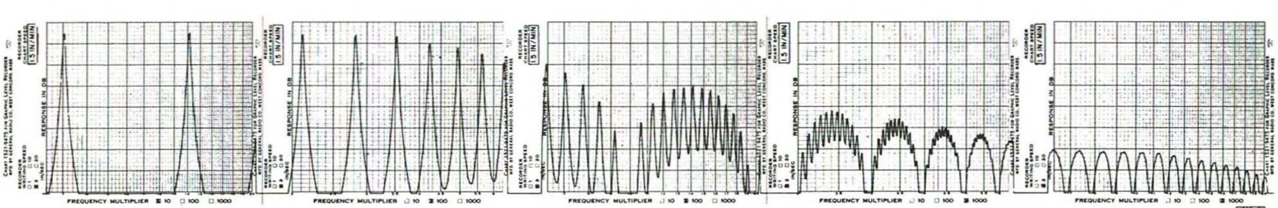
Power Supply: 100 to 125 or 200 to 250 V, 50 to 60 Hz. 2 W for normal operation, 3.5 W for battery charging. A rechargeable nickel-cadmium battery is supplied. Battery provides about 20 hours of operation when fully charged and requires 16 hours for charging. Internal charger operates from the power line.

Mounting: Flip-Tilt case, rack model available.

Dimensions (width x height x depth): Portable, with case closed, 13¼ x 13 x 8¼ in. (340 x 330 x 210 mm); rack, 19 x 12¼ x 5 in. (485 x 310 x 130 mm).

Weight: Net, 21½ lb (10.0 kg); shipping, 27 lb (12.5 kg).

Catalog Number	Description	Price in USA
	1568-A Wave Analyzer	
1568-9701	Portable Model, 115 V ac	**$1550.00**
1568-9702	Portable Model, 230 V ac	**1550.00**
1568-9820	Rack Model, 115 V ac	**1570.00**
1568-9821	Rack Model, 230 V ac	**1570.00**
1560-9510	**1560-P40J Preamplifier and Adaptor Set**	**200.00**
1521-9615	**1521-P15 Link Unit**	**30.00**
1521-9616	**1521-P16 Sprocket Kit**	**20.00**
1521-9475	**Chart Paper**	**3.00**
8410-0410	**Replacement Battery**	**20.00**



Frequency spectrum analysis of a 1.0-ms pulse at a 70-Hz repetition rate. The 1% bandwidth yields high resolution at low frequencies, shows the envelope at high frequencies.

Type 1564-A SOUND AND VIBRATION ANALYZER

- 2.5 Hz to 25 kHz
- 2 bandwidths: 1/3- and 1/10-octave
- use direct from microphone or vibration pickup
- ac or portable battery operation
- automatic spectrum plots with 1521 recorder

The 1564-A Sound and Vibration Analyzer is designed primarily for measuring the amplitude and frequency of the components of complex sound and vibration spectra. Its 1/3-octave (23%) and 1/10-octave (7%) noise bandwidths provide the flexibility needed for analysis of both the noise and its causes.

INPUT SOURCES

The high input impedance of the analyzer permits direct connection of piezoelectric transducers for measuring sound pressures from 44 to 150 dB re 20μN/m^2 and acceleration from 0.0007 g to 100 g.

The 1560-P40 preamplifier is available to extend the full scale sensitivity of the analyzer by 20 dB (10:1) and to allow use of the transducer at the end of a long extension cable. Alternatively, for higher sensitivity, the analyzer can be driven from a sound-level meter or vibration meter.

AUTOMATIC ANALYSIS

1521 Recorder page 51

Automatic range switching is provided so that the 1521-B Graphic Level Recorder can record automatically the spectrum of a signal under analysis. The combination of analyzer and recorder is available as the 1911-A Recording Sound and Vibration Analyzer for continuous spectrum plots. For both stepped and continuous 1/3-octave analysis, the recorder and analyzer are coupled by the 1564-P1 Dial Drive; this system is available as the 1912 Third-Octave Recording Analyzer.

NOISE FILTER

The analyzer can be used in conjunction with the 1390-B, 1381, or 1382 random-noise generators for transfer and reverberation measurements using 1/3- or 1/10-octave bands of random noise.

DESCRIPTION

The 1564-A consists of a high impedance amplifier, a continuously tunable filter having a noise bandwidth of either 1/3 or 1/10 octave, an output amplifier, and a meter. The center frequency of the filter is continuously adjustable. An all-pass, or flat, characteristic permits measurement of the over-all signal amplitude.

— See **GR Experimenter** for September-October 1963.

specifications

FREQUENCY

Range: 2.5 Hz to 25 kHz in four decade ranges.

Dial Calibration: Logarithmic.

Accuracy of Calibration: ±2% of frequency-dial setting.

Filter Characteristics: Noise bandwidth is either ⅓ octave or 1/10 octave. One-third-octave characteristic has at least 30-dB attenuation at one-half and twice the selected frequency. One-tenth-octave characteristic has at least 40-dB attenuation at one-half and twice the selected frequency. Ultimate attenuation is 70 dB or greater for both characteristics. For both bandwidths, peak response is uniform ±1 dB from 5 Hz to 10 kHz and ±1.5 dB from 2.5 Hz to 25 kHz. An ALL-PASS, or flat, characteristic is also included.

INPUT

Impedance: 25 MΩ in parallel with 80 pF (independent of attenuator setting).

Voltage Range: 0.3 mV to 30 V full scale in 10-dB steps.

Microphone: 1560-P6 Microphone Assembly or the 1560-P40K Preamplifier and Microphone Set is recommended.

OUTPUT

Voltage: At least 1.0 V open circuit, when meter reads full scale.

Impedance: 6000 Ω. Any load can be connected.

Meter: Three scales, 0 to 3 V; 0 to 10 V; −6 to +10 dB.

Recording Analyzer: Automatic range switching at the end of each frequency decade allows convenient continuous recording of spectra with the 1521-B Graphic Level Recorder.

GENERAL

Amplitude Calibration: Built-in, feedback-type calibration system permits amplitude calibration at any frequency.

Detector: Rms with three averaging times. Faster two speeds conform with ANS standard for sound-level meters.

Power Required: Operates from 105 to 125 or 210 to 230 V, 50-60 Hz, or from nickel-cadmium battery supplied. Battery provides 25 h of operation when fully charged and requires 14 h for charging.

Accessories Supplied: Power cord, shielded cable, and detented knob and dial assembly.

Accessories Available: 1560-P6 Microphone Assembly, 1560-P52, -P53, -P54 Vibration Pickups, 1560-P40 Preamplifier (power for preamp available at input connector), 1564-P1 Dial Drive for coupling to 1521 recorder for stepped third-octave analysis.

Mounting: Flip-Tilt Case. Rack-mount version also available.

Dimensions (width x height x depth): Portable model, 10¼ x 8⅛ x 8 in. (260 x 210 x 205 mm); rack model, 19 x 10½ x 6 in. (485 x 270 x 155 mm).

Net Weight: Portable model, 14½ lb (7 kg); rack model, 15½ lb (7.5 kg).

Shipping Weight: Portable model, 17 lb (8 kg); rack model, 28 lb (13 kg).

Catalog Number	Description	Price in USA
	1564-A Sound and Vibration Analyzer	
1564-9701	Portable Model, 115 V	**$1575.00**
1564-9820	Rack Model, 115 V	**1595.00**
1564-9702	Portable Model, 230 V	**1575.00**
1564-9821	Rack Model, 230 V	**1595.00**
8410-0410	**Replacement Battery**	**20.00**

PATENT NOTICE. See Notes 12, 15, and 22.

Type 1564-P1 DIAL DRIVE

Noise and vibration measurement criteria often call for "stepped" frequency analysis in which the analyzer, rather than sweeping continuously through its frequency range, dwells briefly at each specified frequency. Stepped one-third-octave analysis is widely used for noise measurements to check compliance with various criteria such as Military Standard-740B(SHIPS), ASHRAE 36A-63, and others.

The 1564-P1 synchronizes the 1564 analyzer and the 1521-B Graphic Level Recorder for producing automatic third-octave-analysis plots. This complete system is available as the 1912 Third-Octave Recording Analyzer, or the 1564-P1 can be added to existing units.

The dial drive automatically sets the analyzer to the one-third-octave center frequencies designated by ANSI as Preferred Frequencies for Acoustical Measurements in Standard S1.6-1960 and in S1.11-1966.

The dwell time in each band is adjustable to permit averaging the noise level over a desired time interval and is controlled by an internal timer (set by front-panel control) or by a synchronizing signal. This signal is normally generated by the contactor attached to the graphic level recorder. Alternately, a tape loop containing a recorded signal for analysis could trigger a sensing device to generate the synchronizing signal, thus making the dwell time equal to the time for one "pass" of the tape loop.

The 1564-P1 also permits the analyzer frequency to be continuously swept for more detailed analysis of a noise.

— See **GR Experimenter** for May-June 1967.

specifications

STEPPING CHARACTERISTICS

Stepping Motion: 0.75°/step; 40 steps (30°) per one-third octave; controlled to step in sequence of 4 pulses = 3°.

Stepping Time: Stepped positions, approx 0.35 s/30°; continuous positions, 6 s/30° or 20 s/30°, both synchronized to 60-Hz line.

Dwell Time (per ⅓-octave band): Dwell time plus stepping time is 1, 3, 10 or 30 s, when controlled by 1521-B Graphic Level Recorder with medium-speed motor installed. These times can be increased by a factor of 2 or 4 with cam adjustment. Dwell time can also be controlled by front-panel knob over a range of about 1 to 60 s.

GENERAL

Temperature Range: Operating, 0 to 50°C; storage, −40 to +70°C.

Humidity Range: 0 to 95% relative humidity.

Synchronization: To 1521 Graphic Level Recorder in both stepped and continuous modes.

Recording System: Output from 1564-A Sound and Vibration Analyzer can be connected to any recording system with an input impedance of 10 kΩ or more and a sensitivity of at least 10 mV.

Power Required: 100 to 125 or 200 to 250 V, 60 Hz.

Accessories Supplied: Adaptor-cable assembly, power cord, end-frame set (bench model) or rack support set (rack model).

Accessories Available: Chart paper for use with 1521 Graphic Level Recorders: 1521-9460 for stepped analysis and 1521-9469 for continuous analysis.

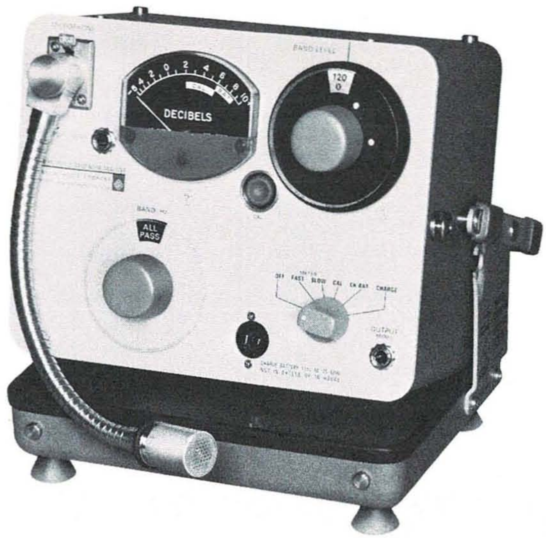
Dimensions (width x height x depth): Relay-rack section, 19 x 3½ x 12½ in. (485 x 89 x 320 mm); stepper motor, 4¼ (dia) x 5⅛ in. (110 x 135 mm); contactor assembly, 3 x 4¹⁄₁₆ x 2⅛ in. (77 x 105 x 54 mm).

Weight: Total shipping, 36 lb (16.5 kg); net, relay-rack section, 14½ lb (7 kg); stepper motor, 1½ lb (0.7 kg); contactor assembly, 8 oz (230 g).

Catalog Number	Description	Price in USA
1564-9771	**1564-P1 Dial Drive,** Bench Model	**$650.00**
1564-9772	**1564-P1 Dial Drive,** Rack Model	**650.00**
1521-9460	**Chart Paper** (for stepped mode)	**3.00**
1521-9469	**Chart Paper** (for continuous mode)	**3.00**

Type 1558 OCTAVE-BAND NOISE ANALYZER

- 44 to 150 dB direct from microphone to 24 db with preamplifier
- meets ANSI Standards
- A-weighting available in 1558-BP
- portable, battery-operated
- internal calibration circuit



The 1558-BP Octave-Band Noise Analyzer with optional 1560-P6 Microphone Assembly

Octave bandwidth. The 1558 is used for rapid analysis of broadband noise where a knowledge of individual frequency components is not desired. It is particularly useful for: studies of environmental noise as related to hearing damage; measurement of environmental noise, as in offices and factories, where speech-interference level is important; measurement of aircraft, vehicle, and machinery noise; loudness determinations; and acoustical studies of rooms and materials.

It comes in two models: The **1558-BP** has octave bands centered at ANS Preferred Frequencies (ANS Standard S1.6-1960, also specified by ISO Recommendation 266 and German Standard DIN45-401) and conforms to the current ANS Standard Specification for Octave, Half-Octave, and Third-Octave-Band Filter Sets S1.11-1966 for Type E, Class II octave-band filters. And it includes an A-weighted filter that eliminates the need for a separate sound-level meter in some cases. The **1558-A** has octave bands as specified by the older ANS Standard for Octave-Band Filters Z24.10-1953, as well as bandpass filters that extend the range at both ends beyond that specified in the standard.

Expandable. The high input impedance and preamplification permit the use of piezoelectric microphones and vibration pickups. The 1560-P6 Microphone Assembly is recommended as are the1560-P40 and -P42 Preamplifiers and their accessories (useful when the microphone is used at the end of a long cable). For vibration analysis, the 1560-P52, -P53, and -P54 Vibration Pickups are available.

— See **GR Experimenter** for October 1962.

specifications

Range: 1558-BP (center frequencies; conforms to ANS S1.11-1966 for octave, half-octave, and third-octave-band filter sets): 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 Hz; plus ALL PASS, A-weighting. **1558-A** (frequency range; conforms to ANSI Z24.10-1953 for octave-band filters): 18.75 to 37.5, 37.5 to 75, 75 to 150, 150 to 300, 300 to 600, 600 to 1200, 1200 to 2400, 2400 to 4800, 4800 to 9600, and 9600 to 19,200 Hz; plus ALL PASS and low pass with 75-Hz upper cutoff frequency.

Filters: Attenuation measured with signal applied to INPUT (SLM) terminals and with respect to center frequency for bands from 63 to 8000 Hz:

¼ × center	½ × center	nominal cutoff	center frequency	nominal cutoff	2 × center	4 × center
≥50 dB	≥30 dB	3.5±1 dB	±1 dB	3.5±1 dB	≥30 dB	≥50 dB

The 75-Hz low-pass filter in 1558-A is ≥35 dB down at 200 Hz and ≥50 dB down at 400 Hz.

Input: At MIKE terminals: 44 to 150 dB re 20μN/m^2 with microphone (24 to 130 dB with preamp) or 40 μV to 8 V (4 μV to 0.8 V with preamp) into 50 MΩ∕∕50pF. At SLM terminals: 0.5 mV to 1 V (3 V max) into 100 kΩ.

Output: ≥1 V behind 6 kΩ, meter at full scale, any load permissible.

Meter: Rms response and fast and slow speeds meet ANSI S1.4-1961.

General: Amplifier frequency characteristic can be set to C weighting to meet ANSI S1.4-1961 for sound-level meters or to 20-kHz for an essentially flat response. Built-in reference allows gain to be calibrated for use with piezoelectric microphones with sensitivities of −52 to −62 dB re 1V/μbar. Absolute accuracy for ALL PASS is then within 1 dB over a wide range of atmospheric conditions.

Accessories Supplied: Carrying strap, power cord for charging battery, shielded cable for connection to sound-level meter.

Accessories Available: 1560-P6 Microphone Assembly, 1560-P40K preamplifier and Microphone Set (powered by 1558). Preamplifier page 26 Sound-Level Meters page 18

Power Required: 105 to 125 or 210 to 230 V, 50-60 Hz, or internal NiCd battery that provides 30-h operation; requires 14 h to charge.

Mounting: Flip-Tilt case; rack model available.

Dimensions (width × height × depth): Portable model, 10¼ x 9¼ x 7¼ in. (260 x 235 x 185 mm); rack model, 19 x 8¾ x 5 in. (485 x 225 x 130 mm).

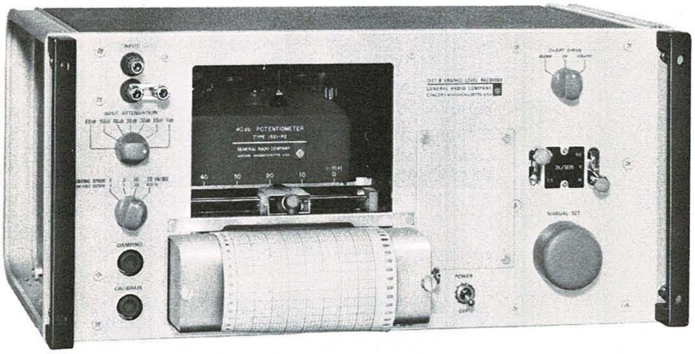
Weight: Portable model, 8¾ lb (4 kg) net; 12 lb (5.5 kg) shipping; rack model, 9 lb (4.1 kg) net; 22 lb (10 kg) shipping.

Catalog Number	Description	Price in USA
	Octave-Band Noise Analyzer 1558-BP, Current Standard Frequencies	
1558-9890	Portable Model	**$1050.00**
1558-9848	Rack Model	**1050.00**
	1558-A, Old Standard Frequencies	
1558-9701	Portable Model	**1050.00**
1558-9820	Rack Model	**1050.00**
1560-9606	**1560-P6 Microphone Assembly**	**115.00**
8410-0410	**Replacement Battery, 1 req'd.**	**20.00**

PATENT NOTICE. See Notes 15 and 22.

Type 1521-B GRAPHIC LEVEL RECORDER

- 7 Hz to 200 kHz
- 1-mV ac sensitivity
- linear dB plot of rms ac-voltage level
- 20-, 40-, or 80-dB range
- convenient, disposable pens



The 1521-B is a completely transistorized, single-channel, servo-type recorder. It produces a permanent, reproducible strip-chart record of ac-voltage level as a function of time or some other quantity.

Most often these are records of the frequency response of a device or of the frequency spectrum of noise or of a complex electrical signal. The Graphic Level Recorder can be mechanically or electrically coupled to various GR analyzers and oscillators to synchronize the frequency scale of the chart record with the instrument's calibrated tuning-control dial. Such combinations of instruments are available factory assembled or as individual components to add to existing equipment.

Owing to the high stability of its reference voltage and amplifier gain, the 1521 can be calibrated and used as a recorder of absolute level.

With a sound-level meter, the recorder can plot sound levels over a wide dynamic range as a function of time. The writing speed is sufficiently high for the measurement of reverberation time and other transient phenomena.

The wide range of paper speed facilitates long-period studies of the noise produced by traffic and machinery, as well as of short-duration transients.

The frequency response can be extended downward to 4.5 Hz at the slower writing speeds. Writing speeds and low-frequency cutoff are selected by a single switch.

Changes of range are easily accomplished by use of a 20-dB or an 80-dB potentiometer in place of the standard 40-dB unit. With the 80-dB unit, the maximum writing speed is 300 dB/second. The slow writing speeds filter out abrupt level variations, yielding a smoothed plot without loss of accuracy.

A linear potentiometer is available, which can be used for dc recording and is easily substituted for the logarithmic ac potentiometers.

— See **GR Experimenter** for September 1964.

specifications

Recording Range: As supplied, 40 dB full-scale; 20-dB and 80-dB ranges are also available. For dc recording, 0.8 to 1 V (0.8 to 1.0 mA) full-scale, with zero position adjustable over full scale.

Frequency Response and Writing Speed

Level Recording: High-frequency response ±2 dB to 200 kHz. Low-frequency sine-wave response depends on writing speed, as shown in following table:

Writing Speed (approx) in./s with 0.1-inch overshoot	Low-Frequency Cutoff Hz (less than 1 dB down)
20	100
10	20
3	7 (3 dB down at 4.5 Hz)
1	7 (3 dB down at 4.5 Hz)

Dc Recording: 3 dB down at 8 Hz (pk-pk amplitude less than 25% of full scale).

Potentiometer Linearity

20-, 40-, 80-dB Potentiometers: ±1% of full-scale dB value plus a frequency error of 0.5 dB at 100 kHz and 1.5 dB at 200 kHz.

Linear Potentiometer: ±1% of full scale.

Resolution ±0.25% of full scale.

Max Input Voltage: 100 V ac.

Input Attenuator: 60 dB in 10-dB steps.

Input Impedance: 10,000 Ω for ac level recording; 1000 Ω for dc recording.

Max Sensitivity: 1 mV at 0 dB for level recording; 0.8 or 1 V full-scale for dc recording.

Paper Speeds

High-speed motor (normally supplied): Paper speeds of 2.5, 7.5, 25, 75 in./min. Used for high-speed-transient measurements and with Type 1304 Beat-Frequency Audio Generator.

Medium-speed motor (supplied on request): Paper speeds of 0.5, 1.5, 5, 15 in./min. Used with analyzers and in level-vs-time plots; must be used with 1564-P1 Dial Drive.

Low-speed motor (supplied on request): Paper speeds of 2.5, 7.5, 25, 75 in./h. Used for level-vs-time measurements from 1 to 24 h.

External Dc Reference: An external dc reference voltage of from 0.5 to 1.5 V can be applied internally to correct for variations of up to 3 to 1 in the signal source of the system under test.

Detector Response: Rms within 0.25 dB for multiple sine waves, square waves, or noise. Detector operating level is 1 V.

Chart Paper: 4-inch recording width on 5-inch paper. All rolls are 100 feet long. See full list of charts below.

Accessories Supplied: 40-dB potentiometer, 12 disposable pens with assorted ink colors, 1 roll of 1521-9428 chart paper, power cord, 1560-P95 Adaptor Cable (phone to double plug).

Accessories Available: Potentiometers, chart paper, pens, high-, medium-, and low-speed motors, drive and link units.

Power Required: 105 to 125 or 210 to 250 V, 50 or 60 Hz, 35 W.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench model, 19 x 9 x 13½ in. (485 x 230 x 345 mm); rack model, 19 x 8¾ x 11¼ in. (485 x 225 x 290 mm).

Weight: Net, 50 lb (23 kg); shipping, 62 lb (29 kg).

Catalog Number	Description	Price in USA
	Graphic Level Recorder	
1521-9812	**1521-B**, Rack Model (for 60-Hz supply)	**$1450.00**
1521-9802	**1521-B**, Bench Model (for 60-Hz supply)	**1450.00**
1521-9507	**1521-BQ1**, Rack Model (for 50-Hz supply)	**1450.00**
1521-9506	**1521-BQ1**, Bench Model (for 50-Hz supply)	**1450.00**

PATENT NOTICE. See Notes 1 and 18.

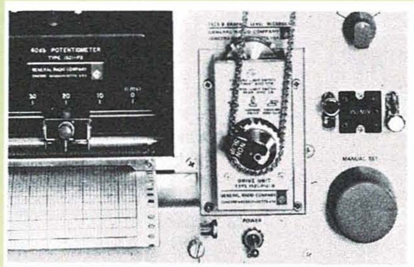
Graphic Level Recorder Accessories

	Catalog Number	Price in USA

DRIVE AND LINK UNITS FOR COUPLING TO GENERATOR AND ANALYZERS

1521-P10B Drive Unit

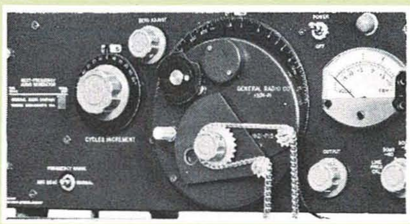
Provides mechanical-drive output from 1521-B to operate any link unit.



	Catalog Number	Price in USA
1521-P10B Drive Unit	1521-9467	$95.00

1521-P15 Link Unit

For mechanical coupling to 1304-B oscillator or to 1564 or 1568 analyzers. Fitted with 24-tooth sprocket. Includes chain.



	Catalog Number	Price in USA
1521-P15 Link Unit	1521-9615	30.00

1521-P16 Sprocket Kit,

contains 5 sizes of interchangeable sprockets for 1521-P15: 40, 36, 32, 20, and 16 teeth. Provides choice of scale factor in proportion to that with normal 24-tooth sprocket. Includes chain.

INDUSTRY SCALE FACTORS

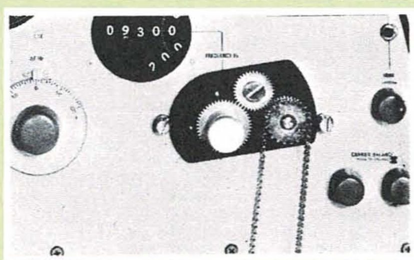
Industry Standard	Scale Factor (dB/decade)	Decade Length (inches) for Type 1304 Generator	Sprocket (teeth)	Pot (dB)
Institute of High Fidelity Manufacturers	20	2.0	16	40
Proposed International Standard	25	2.5	20	40
Electronic Industries Association	30	3.0*	24	40
Institute of High Fidelity Manufacturers	20	4.0	32	20
Hearing Aid Industry	45	4.5	36	40
Proposed International Standard	50	5.0	40	40
Proposed International Standard	50	5.0**	16	40

* Chart paper available for Type 1304-B Beat-Frequency Audio Generator.
** Decade length applies to Type 1564-A Sound and Vibration Analyzer; chart paper available.

	Catalog Number	Price in USA
1521-P16 Sprocket Kit	1521-9616	20.00

1900-P1 Link Unit

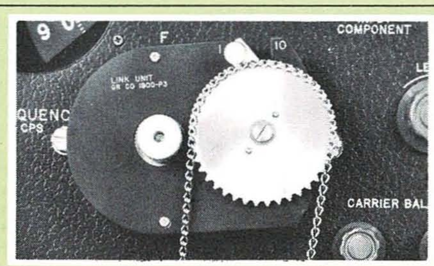
For coupling to 1900-A Wave Analyzer. Use with chart paper 1521-9464 for scale of 10 kHz per 20 in. and with 1521-9465 for scale of 50 kHz per 10 in. Chain included.



	Catalog Number	Price in USA
1900-P1 Link Unit	1900-9601	45.00

1900-P3 Link Unit

For coupling to 1900-A Wave Analyzer. Use with chart paper 1521-9464 for scale factors of 10 kHz per 20 in. or expanded 1 kHz per 20 in.



	Catalog Number	Price in USA
1900-P3 Link Unit	1900-9603	80.00

Graphic Level Recorder Accessories (cont'd)

1564-P1 Dial Drive

Electromechanical coupler between 1521-B recorder and 1564-A Sound and Vibration Analyzer. Generates chart records of "stepped" one-third octave analysis. Keeps synchronism between continuous chart-paper feed and stepped analyzer motion, i.e., where 1564 dwells for selected interval at each third-octave center frequency. Also provides for continuous swept-frequency analysis. Uses chart paper 1521-9460 for stepped mode, 1521-9469 for continuous analysis.

See page 49 for full details on 1564-P1.

	Catalog Number	Price in USA
Bench Model	1564-9771	$650.00
Rack Model	1564-9772	650.00

CHART PAPERS

Associated Instrument	Calibration Horizontal	Calibration Vertical (Div)	Chart Length (in.) Cal.	Chart Length (in.) Blank	Catalog Number	Price in USA
1304-B Generator	20 Hz to 20 kHz, log	80	8⅞	7½	1521-9470*	3.00
1304-B Generator	20 Hz to 20 kHz, log	40	7½	3¾	1521-9473*	3.00
1350-A Generator-Recorder Assembly	20 Hz to 20 kHz, log	80	8⅞	7½	1521-9470*	3.00
1350-A Generator-Recorder Assembly	20 Hz to 20 kHz, log	40	7½	3¾	1521-9473*	3.00
1911-A Recording Analyzer. Requires special link unit, available on special order, to use 1521-9471 paper.	Third-octave bands 3.15 Hz to 25 kHz	40	4 2½ in. sections	½	1521-9471	3.00
1900-A Analyzer with **1900-P1** or **1900-P3 Link Units**	0-1 or 0-10 kHz, linear	40	20	0	1521-9464	3.00
1900-A Analyzer with **1900-P1 Link Unit**	0-50 kHz, linear	40	16	0	1521-9465	3.00
1564-A Analyzer with **1521-P15 Link Unit** and 24-tooth sprocket	2.5-25 normalized, log	40	7½	1½	1521-9493	3.00
1564-A Analyzer with **1521-P15 Link Unit** and 16-tooth sprocket or with **1564-P1 Dial Drive** (continuous mode)	2.5-25 normalized, log	40	5	1	1521-9469	3.00
1564-A Analyzer with **1564-P1 Dial Drive** (stepped mode)	Third-octave bands 3.15 Hz-25 kHz	40	10	0	1521-9460	3.00
1568-A Analyzer with **1521-P15 Link Unit**	2-20 normalized, log	40	10	2	1521-9475	3.00
1554-A Analyzer	2.5 Hz-25 kHz, log	40	18	3	1521-9463	3.00
760-B Analyzer	25-7500 Hz, log	40	12½	1	1521-9429	3.00
General use	Continuous ¼-in. div	40	Continuous		1521-9428	3.00
1136-A D/A Converter	Continuous ⅝-in. div	50	Continuous		1521-9466	3.00

* Use -9470 with 40-dB potentiometer and use -9473 with 80-dB potentiometer. Both have 50-dB per decade scale factor required by many testing standards, particularly the ANSI S3.8-1967, "Method of Expressing Hearing Aid Performance."

POTENTIOMETERS

*Normally supplied with the recorder

	Catalog Number	Price in USA
1521-P1 20-dB Potentiometer	1521-9601	75.00
1521-P2 40-dB Potentiometer*	1521-9602	95.00
1521-P3 80-dB Potentiometer	1521-9603	155.00
1521-P4 Linear Potentiometer (for dc)	1521-9604	70.00

OPTIONAL MOTORS **

			Chart Speeds	Catalog Number	Price in USA
High-Speed Motors	Used for high-speed-transient measurements and with **1304 Beat-Frequency Audio Generator.** Not for use with 1900-A, 1564-A, and 1568 analyzers.	**1521-P19** (for 60-Hz supply) normally supplied in recorder**	2.5-75 in./min	1521-9619	80.00
		1521-P21B (for 50-Hz supply)	2.5-75 in./min	1521-9921	80.00
Medium-Speed Motors	Used with analyzers and in level-vs-time plots; must be used with 1564-P1 Dial Drive.	**1521-P23** (for 60-Hz supply)	0.5-15 in./min	1521-9623	80.00
		1521-P24 (for 50-Hz supply)	0.5-15 in./min	1521-9624	80.00
Low-Speed Motors	Used for level-vs-time measurements 1-24 hours.	**1521-P20B** (for 60-Hz supply)	2.5-75 in./h	1521-9513	80.00
		1521-P22B (for 50-Hz supply)	2.5-75 in./h	1521-9514	80.00

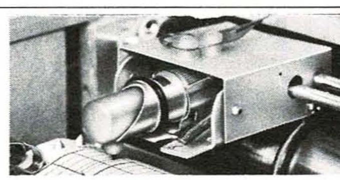
** Recorder can be supplied with low- or medium-speed motor installed, at same price as with standard motor.

fastrak® PEN SETS AND CONVERSION KIT

The pen used in the 1521-B recorder combines ink reservoir and writing point in a single disposable unit, eliminates refilling. Each cartridge has about twice the life of one old-style pen refill and can outlast three rolls of chart paper. The pen consists of a sealed plastic cartridge with a fiber plastic point that requires only about 2 grams of force to operate properly.

The pens are available with red, green, and blue ink and are supplied in sets of twelve pens. A set of assorted colors is included with the recorder and with the conversion kit.

For converting older 1521-A and 1521-B recorders to use the improved pen, a kit is available that contains a pen holder, set of 12 assorted-color pens, and conversion instructions.

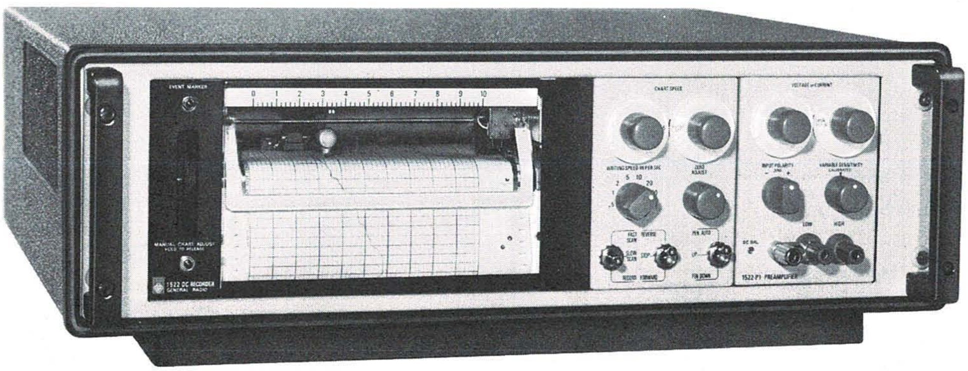


	Catalog Number	Price in USA
fastrak Marker Set, Red	1521-9446	15.00
fastrak Marker Set, Green	1521-9447	15.00
fastrak Marker Set, Blue	1521-9448	15.00
fastrak Marker Set, Assorted Colors	1521-9449	15.00
fastrak Recorder Marker Conversion Kit	1521-9439	25.00

Type 1522 DC RECORDER

- 2-mV/inch and 0.2-μA/inch sensitivity
- 65-inch/second writing speed
- 0.25% linearity, 0.5% accuracy
- programmable writing functions
- plug-in versatility: grounded or differential input

NEW



Bench model shown with 1522-P1 Preamplifier.

Imagine an automatic testing system that is programmed by its own analog recorder. As the output data are plotted, the recorder programs test conditions and measurement ranges, activates and synchronizes other recording devices, and controls its own writing functions. Triggered by timing marks printed on the chart paper, the GR 1522 DC Recorder will control companion instruments and itself, changing chart speed, rewinding the chart for overplotting, quickly advancing to a fresh graph, all the while remembering to lift the pen when not plotting. With optional limit switches, the 1522 can operate sort/select mechanisms, activate additional recorders, or alert an operator if the plotted data exceed preset high or low limits.

As an accessory to the GR 1921 Real-Time Analyzer, for example, the 1522 Recorder will plot the band levels against frequency much faster than conventional X-Y plotters. Operating synchronously with the 1921, the recorder pauses briefly as each band level is selected to allow the pen to settle, producing a neat bar graph with a standard scale factor.

The 1522 is a fine program director; it is first a superb dc recorder, combining accuracy, high sensitivity, and fast writing speed. It will plot a full-scale (5-inch) transient in under 100 ms, respond to a 200-μV or 20-nA change with a 1-division deflection, and remain linear to within ⅛ of a division (0.25%).

The recorder accepts one of two plug-in preamplifiers. The 1522-P1 Preamplifier provides a wide range of voltage and current measurements at an economical price. The 1522-P2 Differential Preamplifier provides the same versatility with the added feature of a differential input so that measurements from ungrounded sources can be made. This plug-in offers up to 180-dB of common-mode rejection at inputs up to $\pm$500 volts.

DESCRIPTION

The 1522 is convenient. A chart take-up reel is included, but the chart paper can feed directly out for immediate inspection and use. Controls are few and obvious; the pen, for instance, is lifted electrically by a manual switch and automatically when the chart is being positioned in either its fast-scan or slow-scan mode. For reliability, there are no gears or clutches; speed changes and control of the stepping drive motor are all done with integrated circuits.

The pen in the GR 1522 is the General Radio fastrak® marker with the fibre plastic point for clog-free operation in a disposable cartridge that eliminates messy refilling. Cartridges are easily interchanged and come in three colors.

specifications

INPUT WITH 1522-P1 PREAMPLIFIER

Ranges: Controlled by range switches, polarity switch, and continuous control with calibrated position that operates on all ranges. *DC Voltage,* 2 mV/in. to 100 V/in.; 15 ranges, 1-2-5 sequence. *DC Current,* 0.2 μA/in. to 100 mA/in.; 18 ranges, 1-2-5 sequence.

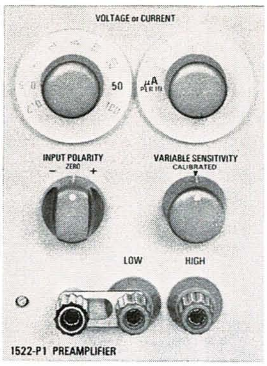
Accuracy: $\pm$0.5% of full scale.

Stability: $<$0.01%/day drift typical in 0.2 V/in. range after warmup.

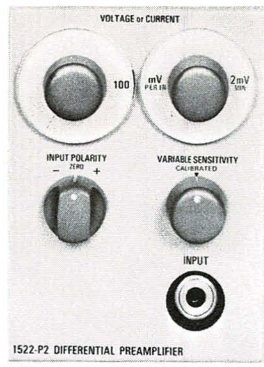
Input Resistance: 1 MΩ.

Input Isolation: $>$1000 MΩ dc from LOW to GROUND terminal typical at 200 V dc; 0.22 μF ac. *Voltage,* 200 V max dc or peak ac.

Common-Mode Rejection: 70 dB dc typical with 1-kΩ source impedance; 40 dB ac typical at 60 Hz.



1522-P1 Preamplifier



1522-P2 Differential Preamplifier

Offset and Drift: *Voltage,* Adjustable to zero. *Drift,* ±25 μV/°C from 0 to 50°C after warmup; warmup drift <0.5 mV. *Current* (bias), 0.1 nA at 25°C; doubles each rise of 11°C.

INPUT WITH 1522-P2 DIFFERENTIAL PREAMPLIFIER

Ranges: Controlled by range switches, polarity switch, and continuous control with calibrated position that operates on all ranges. *Voltage,* 2 mV/in. to 100 V/in.; 15 ranges, 1-2-5 sequence. *Current,* 0.2 μA/in. to 100 mA/in.; 18 ranges, 1-2-5 sequence.

Accuracy: ±0.5% of full scale.

Linearity: ±0.25% of full scale.

Input Resistance between HIGH and LOW terminals: *Voltage,* 1 MΩ. *Current,* 0.11 to 50.06 Ω depending on scale as follows:

Input Isolation: $\geq 10^{11}$ Ω from GUARD terminal to ground, in parallel with <500 pF. *Voltage,* V dc or peak ac.

Common-Mode Rejection: 160 dB dc, 80 dB 60 Hz, undriven guard, typical; 180 dB ac up to 20 kHz, driven guard, typical.

Offset and Drift: *Voltage,* Adjustable to zero. *Drift,* ± (25 μV/°C from 0.005% of full scale/°C) from 0 to 75°C. *Current* (bias), 0.1 nA at 25°C; doubles each rise of 11°C.

Scale	Resistance
0.2 μA/in. to 0.2 mA/in.	$\leq \dfrac{10\ \mu\text{V/in.}}{\text{scale in }\mu\text{A/in.}} + 0.06\ \Omega$
0.5 mA/in. to 10 mA/in.	$\dfrac{20\ \text{mV/in.}}{\text{scale in mA/in.}}$
20 mA/in. to 100 mA/in.	1 Ω

RECORDER RESPONSE

Fast Writing Speed: 65 in./s with <2% overshoot.

Slow Writing Speeds:	60	30	20	10	5	2	1	0.5 in./s
Servo Bandwidth (3 dB) (for ¼-in. excursions)	30	20	15	7.5	4	1.5	0.75	0.4 Hz

Linearity: ±0.25% of full scale.

Deadband: ±0.15% of full scale.

Zero Adjustment: 10-turn pot, can be set over full range.

Chart Speeds: 0.5, 1, 2, 5, 10, 20 seconds, minutes, hours per inch; 18 speeds.

Chart-Speed Synchronization: Sync outputs permit other 1522 recorders to run at identical speed or at other standard speeds in synchronization with master recorder.

Programmability: All chart control functions fully programmable and outputs provided for full system integration.

Remote-Control Functions: Require switch or solid-state closure to ground. Controls: pen lift; two event markers; 18 chart speeds; chart start, stop, forward, reverse; fast scan (2 in/s) with pen-lift; slow scan (2 in./min) with pen-lift; record command (drops pen, starts chart at selected speed); pen motion stopped in position by servo blanking.

Remote-Control Outputs: Start, stop, forward, reverse, servo-position error voltage, retransmitting potentiometer, three independent solid-state closures corresponding to lines printed on paper.

Other Outputs: Power for two additional stepper motors, power for externally controlled dc reference voltage.

Accessories Supplied: 274-NQ 3-ft double-plug patch cord, fastrak® Marker Set of 12 assorted-color pens, Event-Marker Set of 4 red, 4 black pens, 2 chart-paper rolls type 1522-9640, 2 potentiometer contacts, 2 paper cap assemblies, power cord, spare fuses.

Accessories Available: 1522-P11 Limit-Switch Set provides two adjustable limit stops; pen at limit closes reed-relay contacts with 50-V, 500-mA dc rating, 117-V, 100-mA ac rating, 210-V breakdown rating.

Power: 100 to 125 or 200 to 250 V, 50-60 Hz, 90 W.

Mechanical: Bench or rack cabinets. *Dimensions* (w x h x d): Bench, 19½ x 7 x 17 in. (495 x 180 x 435 mm); rack, 19 x 5¼ x 15¼ in. (485 x 135 x 370 mm). *Weight:* Bench, 42.5 lb. (19.5 kg) net, 58 lb (27 kg) shipping; rack, 38.5 lb (17.5 kg) net, 54 lb (24.5 kg) shipping; -P1, 1.5 lb (0.7 kg) net, 8 lb (3.7 kg) shipping; -P2, 3.25 lb (1.5 kg) net, 10 lb (4.6 kg) shipping.

Description	Price in USA
1522 DC Recorder, less preamplifier	
Bench Model	**$1950.00**
Rack Model	**1915.00**
1522-P1 Preamplifier	**250.00**
1522-P2 Differential Preamplifier	**475.00**
1522-P11 Limit-Switch Set, for two adjustable limit stops	**60.00**
1522-9613 Extender Board Kit, for servicing ease	**85.00**
1522-9670 Cable Set, for connection to 1921	**35.00**
1522-9612 Event-Marker Set, 4 black, 4 red pens	**10.00**
fastrak® Marker Sets	
1522-9446 Red, 12 pens	**15.00**
1522-9447 Green, 12 pens	**15.00**
1522-9448 Blue, 12 pens	**15.00**
1522-9449 Assorted, 4 of each color	**15.00**

Chart Paper Ideal for use with 1921 Real-Time Analyzer; 140-ft rolls with 25-dB/decade scale factors. Inch-ruled charts have 2.08-in/decade abscissas, centimeter-ruled charts have 5-cm/decade abscissas. Bands are ANSI preferred ⅓-octave.

Chart	Ordinate Scale	Abscissa Bands	Abscissa Frequencies	
1522-9640	*Linear	Linear, 5 div/in.		**5.00**
1522-9647	*10dB/in.	30 bands—not marked		**5.00**
1522-9646	12dB/in.	30 bands—not marked		**5.00**
1522-9652	12dB/in.	5-34	3.15 Hz-2.5 kHz	**5.00**
1522-9648	12dB/in.	5-49	3.15 Hz-80 kHz	**5.00**
1522-9645	12dB/in.	11-40	12.59 Hz-10 kHz	**5.00**
1522-9644	12dB/in.	14-43	25 Hz-20 kHz	**5.00**
1522-9658	5dB/cm	30 bands—not marked		**5.00**
1522-9656	5dB/cm	5-34	3.15 Hz-2.5 kHz	**5.00**
1522-9654	5dB/cm	5-49	3.15 Hz-80 kHz	**5.00**
1522-9657	5dB/cm	11-40	12.59 Hz-10 kHz	**5.00**
1522-9655	5dB/cm	14-43	25 Hz-20 kHz	**5.00**

* Total ordinate range is 60 dB, except for -9640 which is linear 50 div and -9647 which is 50 dB.

Type 1525-A DATA RECORDER

- 15 Hz to 16 kHz
- built-in sound-level meter
- 2 channels, 2 speeds
- wide dynamic range

Tailored by GR specifically for acoustic-noise measurements, this instrument is both a sound-level meter and audio tape recorder. With it you can make on-location measurements and calibrated recordings for unhurried and detailed laboratory analysis later or make a permanent record of once-only events. The 1525-A permits recording with a flat frequency-response characteristic, recommended for recording noise and not available with speech and music recorders. Dual channels, simultaneous playback and recording, two-speed drive, and accessory tape-loop guides add versatility.

MAIN CHANNEL

The main-channel recording amplifier doubles as the sound-level-meter amplifier and, for its dual role, contains an accurate step attenuator and several weighting networks: those prescribed by ANSI for a sound-level meter, NAB equalization, and constant-current (flat) response. The high input impedance of this amplifier will accommodate a variety of high-impedance transducers. The GR 1560-P5 Microphone is recommended; with it, sound-level-meter performance conforms to ANSI Standard S1.4-1961 and IEC 123-1961. The 1562 Sound-Level Calibrator is recommended as a source of standard sound level for the calibration of recording levels.

The GR 1560-P40 Preamplifier can be used to drive either channel; power for its operation is supplied at both input connectors.

SECOND CHANNEL

The second channel lets you record timing signals or a narration of test program and conditions. Or you can play back a prerecorded test signal (e.g., swept tone, tone bursts, or filtered noise) into a system whose output is being recorded on the main channel. This method simplifies many measurements, room reverberation for one. Acoustical noise, too, can be recorded on channel 2 with the aid of an external sound-level meter or preamplifier.

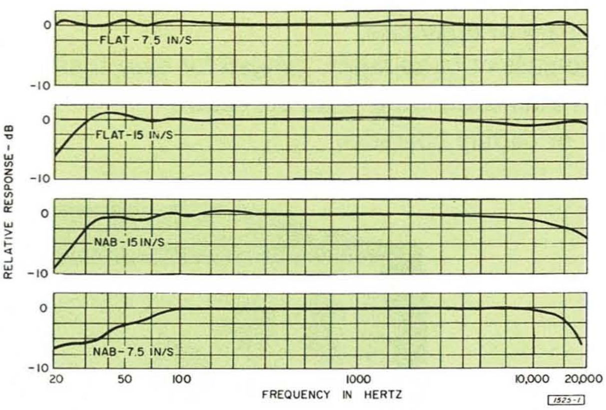
PLAYBACK AND MONITORING

Identical playback amplifiers monitor both channels and provide outputs that are always available, even during recording. In addition, the monitor amplifier that drives the panel meter and supplies an additional output can be switched to monitor the output of any of the recording or playback amplifiers. A peak-responding monitor light, sensing recording levels in the main channel after equalization, warns you against saturating the tape, with resultant distortion.

VERSATILE OPERATION

In addition to recording and storing data for later use, the 1525-A can serve many other purposes. Short-duration, varying, or once-only sounds can be made continuous or repetitive by playback of the recording as a tape loop, guides for which are supplied. Frequency of a noise may be doubled or halved by playback at a tape speed that is twice or half that used for recording, thus similarly scaling the effective bandwidth of an analyzer and of the recorder itself. Time can also be scaled or reversed, a convenience in graphic recording of transients.

— See **GR Experimenter** for Oct 1966 and Reprint A142.



Typical over-all frequency response characteristics.

specifications

Frequency Response (over-all):

At 15 in./s (38.1 cm/s)

Constant Current: ±2 dB, 50 to 15,000 Hz.
+2, −4 dB, 30 to 18,000 Hz.

NAB equalization: ±2 dB, 50 to 15,000 Hz.

At 7½ in./s (19.05 cm/s)

Constant Current: ±2 dB, 20 to 10,000 Hz.
+2, −4 dB, 15 to 16.000 Hz.

NAB equalization: +2, −4 dB, 50 to 15,000 Hz.

Signal-to-Noise Ratio:

NAB equalization: Over 54 dB below 2% distortion point as measured according to NAB standard (A weighting).

Constant Current: Over 45 db below 2% distortion point for noise band from 20 to 15,000 Hz (over 65 dB for octave band at 1 kHz) with input channel #1 more than 10 mV.

INPUT

Channels: 2 channels with separate record and playback amplifiers and separate channel erase.

Measurement Range (Input Level): 10 μV to 1 V on channel #1 (40 to 140 dB sound-pressure level for microphone sensitivity of −66 dB re 1 V/μbar). About 0.7 V on channel #2 for full-scale meter indication. (For high sensitivity, channel #2 can be driven by the output of a separate sound-level meter.)

Impedance: Channel #1: approx 20 pF shunted by 400 MΩ.
Channel #2: > 100 kΩ.

Weighting Characteristics: NAB, constant current, A, B, and C weighting (standard sound-level-meter characteristic) and one having decreasing response with increasing frequency above 1 kHz of 20 dB per decade of frequency, for record channel #1. Constant current for record channel #2.

RECORDING

Flutter and Wow: Below 0.2%, rms.

Bias and Erase Frequency: 95 kHz nominal; separate erase for each channel; cleans tape greater than 60 dB.

Tape Speeds: 15 in./s (38.1 cm/s).
7½ in./s (19.05 cm/s).

OUTPUT

Weighting Characteristics: NAB and constant current for both playback amplifiers.

Monitoring: Electronic voltmeter with 16-dB range and sound-level-meter ballistic characteristics, switchable to monitor record or playback level on either channel. Peak monitor on record channel #1.

Levels: When meter reads +10 dB, monitor output is approx 1.5 V, open circuit, and playback outputs are approx 0.5 V, open circuit.

Impedance: Source impedance for monitor output is 330 Ω; for playback outputs it is 10,000 Ω. Any load can be connected to the output.

GENERAL

Tapes: ¼-inch, professional quality, 7-inch reel (max).

Power Required: 105 to 125 V, 60 Hz, 135 W.

Accessories Supplied: Guides for tape loop: 1560-P99 Adaptor Cable; line power cord; transport power cord; roll of tape; take-up reel; 2 reel-lock knobs; maintenance kit; rack-mount accessories.

Accessories Available: 1562-A Sound-Level Calibrator, 1560-P5 Microphone and 1560-P34 Tripod and Extension Cable for sound measurements and recording. 1560-P40K Preamplifier and Microphone Set for sound measurements and recording at levels below 50 dB where the best signal-to-noise ratio must be maintained (the recorder supplies the necessary power to operate a 1560-P40 Preamplifier). For sound and noise analysis, 1900-A Wave Analyzer, 1564-A Sound and Vibration Analyzer, 1568-A Wave Analyzer, 1558 Octave-Band Noise Analyzers.

Microphones, Preamplifier page 25 ff

Analyzers page 42 ff

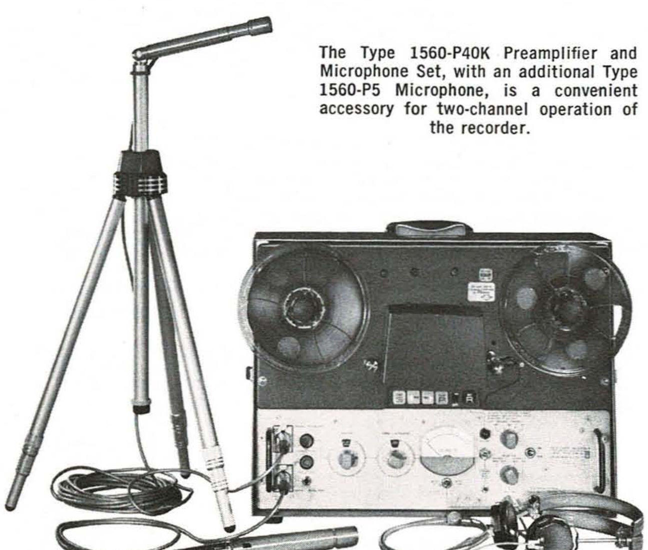
Mounting: Luggage carrying case or rack.

Dimensions (width x height x depth): Portable, 21 x 16 x 9 in. (540 x 410 x 230 mm); rack, 19 x 14 x 7 in. (485 x 355 x 180 mm).

Net Weight: Portable, 53 lb (25 kg); rack, 50 lb (23 kg).

Shipping Weight: 60 lb (28 kg).

Catalog Number	Description	Price in USA
1525-9701	**1525-A Data Recorder**	**$2750.00**



The Type 1560-P40K Preamplifier and Microphone Set, with an additional Type 1560-P5 Microphone, is a convenient accessory for two-channel operation of the recorder.

Type 1952 UNIVERSAL FILTER

- 4-Hz to 60-kHz tuning
- low-pass or high-pass,
  band-pass or band-reject, ganged for easy tuning
- high attenuation rate — 30 db/octave
- line or battery operation

The 1952 Universal Filter will perform as a low-pass, high-pass, band-pass, or band-reject filter at the turn of a panel switch. It consists of a low-pass and a high-pass filter that can be employed singly, in cascade, or in parallel, to provide the assortment of over-all characteristics. The cut-off frequencies of the two filters can be controlled independently or ganged together to provide constant-percentage bandwidth for band-pass or band-reject tuning.

Noise Generators page 60

This filter is of value in many signal-conditioning applications. For example, it can be used to control system bandwidth for reduction of extraneous signals or to evaluate the effect of limited bandwidth upon signal intelligibility and data-transmission accuracy. As a high-pass filter it can reduce power-line-related components, as a low-pass filter control high-frequency noise, or as a notch filter eliminate single-frequency components. The 1952 can also act as part of a spectrum analyzer or distortion meter and, with a random-noise generator, produce controlled bands of noise as test signals. It is recommended as an accessory for the GR 1142 Frequency Meter and Discriminator and the 1561-R Precision Sound-Level Meter.

— See **GR Experimenter** for April 1968.

specifications

FREQUENCY RANGE

Cut-off Frequencies: Adjustable 4 Hz to 60 kHz in four ranges.

Pass-Band Limits: Low-frequency response to dc (approx 0.7 Hz with ac input coupling) in LOW PASS and BAND REJECT modes. High-frequency response uniform ±0.2 dB to 300 kHz in HIGH PASS and BAND REJECT modes.

Controls: Log frequency-dial calibration; accuracy ±2% of cut-off frequency (at 3-dB points).

FILTERS

Filter Characteristics: Filters are fourth-order (four-pole) Chebyshev approximations to ideal magnitude response. The nominal pass-band ripple is ±0.1 dB (±0.2 dB max); nominal attenuation at the calibrated cut-off frequency is 3 dB; initial attenuation rate is 30 dB per octave. Attenuation at twice or at one-half the selected frequency, as applicable, is at least 30 dB.

Tuning Modes: Switch selected, LOW PASS, HIGH PASS, BAND PASS, and BAND REJECT.

Ganged Tuning: The two frequency controls can be ganged in BAND PASS and BAND REJECT modes so the ratio of upper to lower cut-off frequencies remains constant as controls are adjusted. Range overlap is sufficient to permit tuning through successive ranges without the need to reset frequency controls if ratio of upper to lower cut-off frequencies is 1.5 or less.

Minimum Bandwidth: 26% (approx ⅓ octave) in BAND PASS mode.

Null Tuning: In BAND REJECT mode, setting the frequency controls for a critical ratio of upper to lower cut-off frequency (indicated on dials) gives a null characteristic (point of infinite attenuation) that can be tuned from 5 Hz to 50 kHz.

INPUT

Gain: 0 or −20 dB, switch selected. Accuracy of gain is ±1 dB, of 20-dB attenuator is ±0.2 dB.

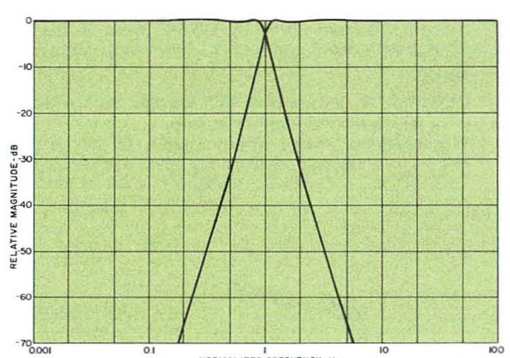
Impedance: 100 kΩ.

Coupling: Ac or dc, switch selected. Lower cut-off frequency (3 dB down) for ac coupling is about 0.7 Hz.

Max Voltage: Max sine-wave input is 3 V rms (8.4 V pk-pk) or 30 V rms with input attenuator at 20 dB. Max peak input voltage for dc coupling is ±4.2 V. For ac coupling max peak level of ac component must not exceed ±4.2 V and dc component must not exceed 100 V. Input can tolerate peak voltages of ±100 V without damage. An LC filter at input limits bandwidth to 300 kHz, thus reducing danger of overloading active circuits at frequencies above normal operating range.

GENERAL

Output: 600-Ω impedance. Any load can be connected without affecting linear operation of output circuit. Temperature coefficient of output offset voltage is between 0 and +4 mV/°C.



Low-pass and high-pass filter characteristics.

Noise: <100 μV in an effective bandwidth of 50 kHz.

Distortion: Max harmonic distortion, with all components in the pass band, for a linear load, is less than 0.25% for open-circuit voltages up to 3 V and frequencies up to 50 kHz.

Power Required: 100 to 125 or 200 to 250 V (switch selected), 50 to 60 Hz, 2.5 W. Or 19.2 V, approx 20 mA from rechargeable nickel-cadmium batteries (not supplied), about 10-h operation. Connections for external battery.

Accessories Supplied: Power cord, bench- or rack-mount hardware.

Accessories Available: Rechargeable batteries (two required) and 1560-P60 Battery Charger.

Dimensions (width x height x depth): Bench, 19 x 3⅞ x 15 in. (485 x 99 x 385 mm); rack, 19 x 3½ x 11¾ in. (485 x 89 x 300 mm); charger, 4¼ x 3¾ x 8 in. (110 x 96 x 205 mm).

Weight: Net, 20½ lb (9.5 kg); shipping, 25 lb (11.5 kg).

Catalog Number	Description	Price in USA
	1952 Universal Filter	
1952-9801	Bench Model	**$1075.00**
1952-9811	Rack Model	**1075.00**
8410-1040	**Rechargeable Battery** (2 req'd)	**12.00**
	1560-P60 Battery Charger	
1560-9660	115 volts	**125.00**
1560-9661	230 volts	**125.00**

Type 1569 AUTOMATIC LEVEL REGULATOR

- 2 Hz to 100 kHz
- 50-dB control range
- acoustic-system accessory

The 1569 Automatic Level Regulator is intended as an accessory for an oscillator or for a source of narrow-band noise. Its primary function is to control the signal level in swept-frequency sound and vibration tests.

The regulator senses a control voltage from a microphone, accelerometer, or other transducer monitoring the sound or vibration to be controlled and adjusts its output to maintain constant level (see diagram). Output level is indicated by a panel meter with a linear-dB scale, showing the operator where in its 50-dB control range the regulator is operating. Regulation is such that a level variation (without the regulator) of 25 dB, for instance, is compressed to a variation of 1 dB. The control rate is adjustable by means of a panel control to suit the operating frequency and magnitude-phase conditions in the control loop.

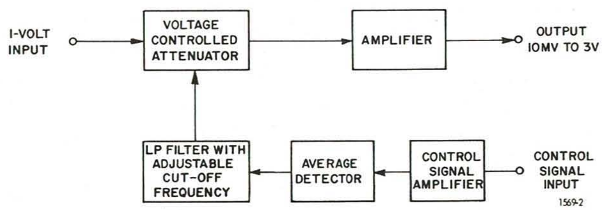


Diagram of 1569 Automatic Level Regulator

The 1569 can also be used to regulate voltage from an oscillator or other signal source. In this mode, the control range is limited to 15 dB.

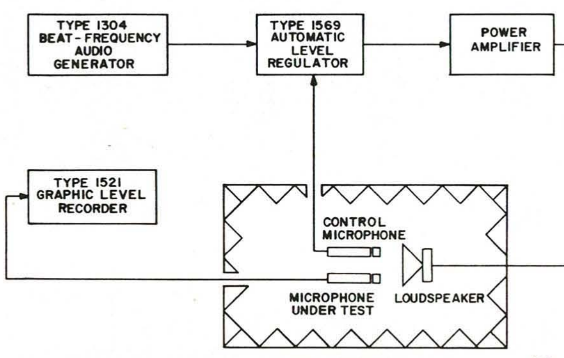
— See **GR Experimenter** for April 1968.

specifications

Frequency Range: 2 Hz to 100 kHz.
Control Range: 50 dB.
Compression Ratio: 25 (0.04 dB per dB).

DRIVE (INPUT)
Voltage Required (for normal operation): 1 V.
Impedance: 100 kΩ.

OUTPUT
Voltage: 3 V max to 10 mV min.
Impedance: 600 Ω. Any load impedance can be connected without affecting linear operation of output circuit.



Typical Measurement System Using 1569

Noise: Typically better than 65 dB below 3 V in 100-kHz band.
Harmonic Distortion: $<$1% total for $<$1-V output level.
Automatic "Shut-Down": A loss of drive (input) voltage from signal source causes the output voltage to drop to zero to protect equipment connected to output.

CONTROL-SIGNAL INPUT
Voltage: 5 mV to 4 V required.
Impedance: 25 MΩ.
Control Rates and Corresponding Min Operating Frequencies:

1000 dB/s	300 dB/s	100 dB/s	30 dB/s	10 dB/s	3 dB/s
600 Hz	200 Hz	60 Hz	20 Hz	6 Hz	2 Hz

Power Required: 100 to 125 or 200 to 250 V (switch selected), 50 to 60 Hz, 4 W.
Accessories Supplied: Power cord, mounting hardware with rack or bench models.
Accessories Available: GR 1560-P40 Preamplifier (power for preamplifier available at rear-panel input connector); 1304 Beat-Frequency Audio Generator, 1521 Graphic Level Recorder; microphones and vibration pickups.

Preamplifier page 26

Mounting: Rack-Bench Cabinet.
Dimensions (width x height x depth): Bench model, 19 x 3⅞ x 13 in. (485 x 99 x 330 mm); rack model, 19 x 3½ x 10½ in. (485 x 89 x 275 mm).
Weight: Net, 13 lb (6 kg); shipping, 30 lb (14 kg).

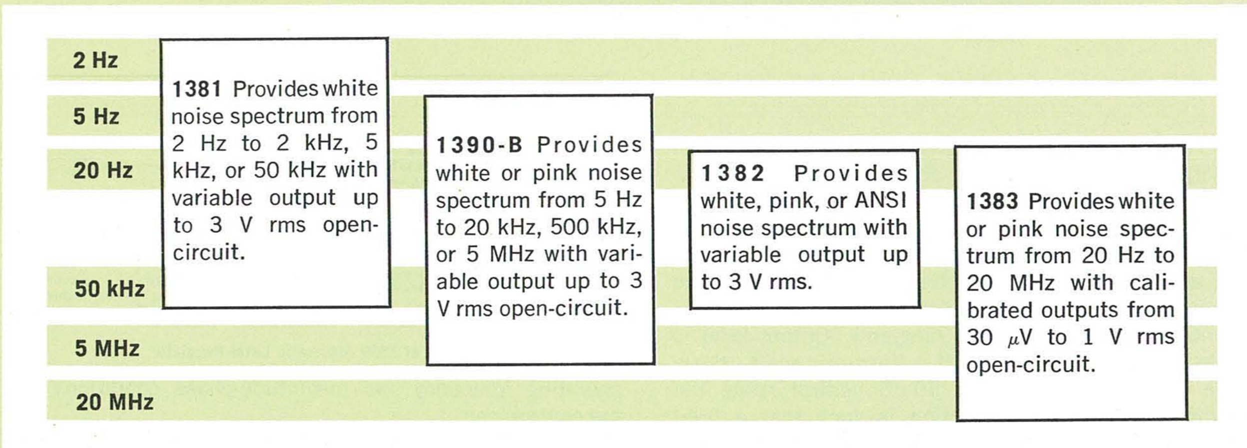
Catalog Number	Description	Price in USA
	1569 Automatic Level Regulator	
1569-9700	Bench Model	**$595.00**
1569-9701	Rack Model	**595.00**

RANDOM-NOISE GENERATORS

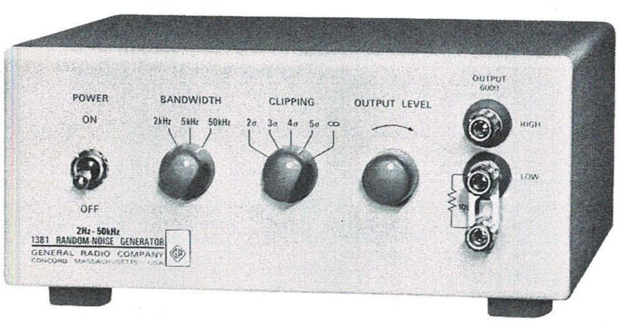
Electrical noise is, by definition, any unwanted disturbance and its reduction in communications circuits is a constant aim of the engineer. Noise from a controlled source, however, is useful in studying the effectiveness of systems for detecting and recovering signals in noise. Well defined random noise is, moreover, a remarkably useful test signal that has, for many measurements, properties that are more useful than those of a single-frequency signal. Its wide frequency content sometimes permits one test with random noise to replace a series of single-frequency tests. Noise is also useful in simulating speech, music, or communications circuit traffic.

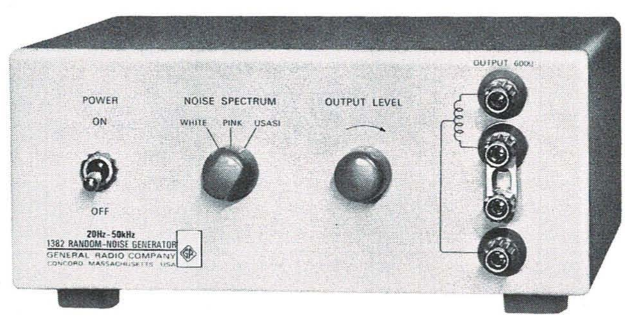
Noise is called random if its instantaneous amplitude at any future instant is unpredictable. Random noise is specified by its amplitude distribution and by its spectrum. Many types of naturally occurring electrical noise have the same distribution of amplitudes as do errors that normally occur in experimental measurements — the normal or Gaussian distribution. In general-purpose noise generators the design objective is random noise that is Gaussian and has a uniform spectrum level over the specified frequency range.

The General Radio random-noise generators produce electrical noise at high output levels, each model having been designed for specific uses. The 1381 is useful for many audio-frequency applications, and also in vibration testing as its spectrum extends well into the subaudio range. The 1382 is intended for audio-frequency electrical, acoustical, and psychoacoustical applications. The 1390-B is useful at higher frequencies because its spectrum extends to 5 MHz. The 1383 generates wide-band noise of uniform spectrum level and is particularly useful for tests in video- and radio-frequency spectrums.



RANDOM-NOISE GENERATORS — Type 1381, Type 1382





Type 1381

- 2 Hz to 2, 5, or 50 kHz, Gaussian distribution
- adjustable clipping
- 3-V rms output

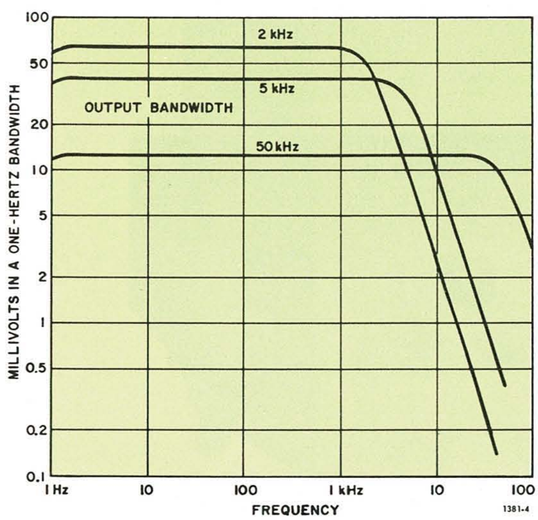
Type 1382

- 20 Hz to 50 kHz, Gaussian distribution
- white, pink, or ANSI spectra
- 3-V rms output, balanced, unbalanced, or floating

The 1381 and 1382 are companion instruments that generate truly random noise from a semiconductor source. Special precautions are taken to ensure a symmetrical, Gaussian amplitude distribution. Output level is adjustable from below 3 millivolts to 3 volts rms behind a 600-ohm source impedance. Each model is constructed in a 3½-inch-high, half-rack-width cabinet, convenient for bench use and two can be mounted side-by-side in a relay rack.

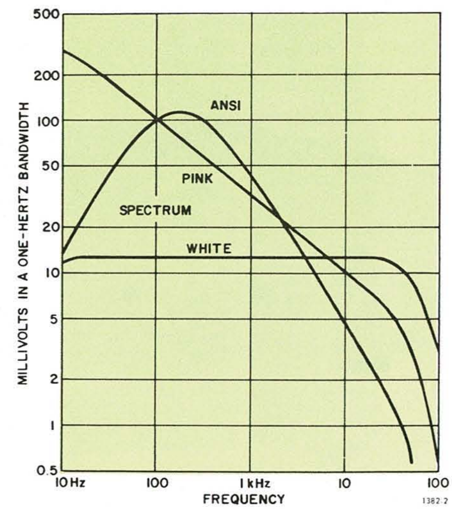
Either of these noise generators can be used for simulation of noise in signal paths, as test-signal sources, or for demonstrations of statistical and correlation principles. The different features of the two offer a choice to match your needs.

— See **GR Experimenter** for January 1968.



Type 1381

The 1381 generates noise that is flat down to 2 Hz and is intended for random-vibration tests and for general-purpose use in the audio and sub-audio range. The upper-frequency limit (at —3 dB) can be switched to 2, 5, or 50 kHz. The output signal can be clipped symmetrically at 2, 3, 4, or 5 times the rms amplitude.



Type 1382

The 1382 generates noise in the 20-Hz to 50-kHz band and is intended for electrical, acoustical, and psycho-acoustical tests. It offers three spectra, white (flat), pink (—3 dB per octave), and ANSI (see specifications). The output can be taken balanced or unbalanced, floating or grounded.

specifications

SPECTRUM

1381: Flat (constant energy per hertz of bandwidth) ±1 dB from 2 Hz to 1, 2.5, or 25 kHz; upper-cutoff frequency (3-dB point) can be switched to 2, 5, or 50 kHz. Spectral density at 3-V output and for 1-Hz bandwidth is approx 64, 40, and 13 mV, respectively, for 2-, 5-, and 50-kHz upper cutoff. Upper cutoff slope is 12 dB/octave. See curve.

1382: Either (a) white noise (constant energy per hertz bandwidth) ±1 dB, 20 Hz to 25 kHz, with 3-dB points at approx 10 Hz and 50 kHz; (b) pink noise (constant energy per octave bandwidth) ±1 dB, 20 Hz to 20 kHz; or (c) ANSI noise, as specified in ANSI Standard S1.4-1961. See curve.

Waveform:

Voltage	Gaussian Probability-Density Function	Amplitude-Density Distribution of 1381/1382
0	0.0796	0.0796 ± 0.005
$\pm\sigma$	0.0484	0.0484 ± 0.005
$\pm 2\sigma$	0.0108	0.0108 ± 0.003
$\pm 3\sigma$	0.000898	0.000898 ± 0.0002
$\pm 4\sigma$	0.0000274	0.0000274 ± 0.00002

These data measured in a "window" of 0.2σ, centered on the indicated values; σ is the standard deviation or rms value of the noise voltage.

Clipping: The output of the 1381 can be clipped internally to remove the occasional wide extremes of amplitude. Clipping, if desired, is adjustable to approx 2, 3, 4, or 5σ. Such clipping has negligible effect on the spectrum or the rms amplitude.

Output Voltage: >3 V rms max, open-circuit, for any bandwidth.

Output Impedance: 600 Ω. Can be shorted without causing distortion. 1381 output is unbalanced; 1382 output is floating, can be connected balanced or unbalanced.

Amplitude Control: Continuous adjustment from full output to approx 60 dB below that level.

Terminals: 1381 output at front-panel binding posts and rear-panel BNC connector; 1382 output at front-panel binding posts and rear-panel jacks for double plugs.

Accessories Supplied: Power cord, rack-mounting hardware with rack models.

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 6 W.

Mounting: Convertible-Bench Cabinet.

Dimensions (width x height x depth): Bench, 8½ x 3⅞ x 9⅞ in. (220 x 99 x 250 mm); rack, 19 x 3½ x 9 in. (485 x 89 x 230 mm).

Weight: Net, 7 lb (3.2 kg); shipping, 10 lb (4.6 kg).

Catalog Number	Description	Price in USA
	Random-Noise Generator	
1381-9700	2 Hz to 50 kHz, Bench Model	**$395.00**
1381-9701	2 Hz to 50 kHz, Rack Model	**420.00**
1382-9700	20 Hz to 50 kHz, Bench Model	**395.00**
1382-9701	20 Hz to 50 kHz, Rack Model	**420.00**

Type 1383 RANDOM-NOISE GENERATOR

20 Hz - 20 MHz

- 20 Hz to 20 MHz, ±1.5 dB
- 30-μV to 1-V output, open-circuit
- 50-ohm output impedance
- meter and 10-dB-per-step attenuator

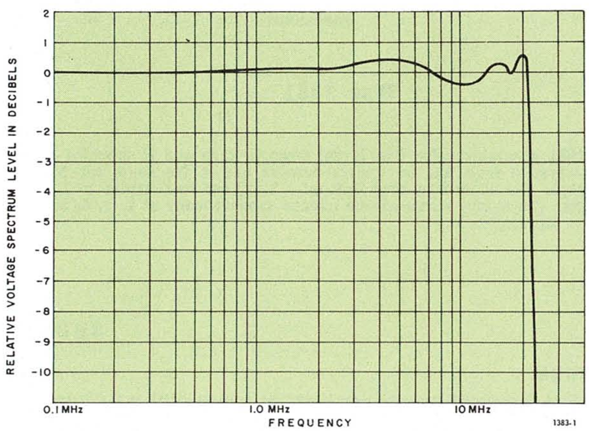
This instrument generates wide-band noise of uniform spectrum level, particularly useful for tests in video- and radio-frequency systems.

The maximum output is one volt open circuit from a 50-ohm source. An 8-step attenuator of 10 dB per step permits reduction of the output level to 30 μV.

Use the 1383 as a broad-band noise source for

- Intermodulation and cross-talk tests.
- Simulation of noise in carrier systems.
- Noise-interference tests in radar and telemetry.
- Determining noise bandwidth.
- Measuring noise figure.
- Setting transmission levels in communication circuits.
- Statistical demonstrations in classroom and lab.
- Determining meter response characteristics.
- Measuring noise temperature.

— See **GR Experimenter** for March-April 1969.



Typical spectrum of 1383 Random-Noise Generator output; energy-per-Hz bandwidth vs frequency.

specifications

Spectrum: Flat (constant energy per hertz of bandwidth) ±1 dB from 20 Hz to 10 MHz, ±1.5 dB from 10 MHz to 20 MHz.

Waveform: Table shows amplitude-density-distribution specifications of generator compared with the Gaussian probability-density function, as measured in a "window" of 0.2σ, centered on the indicated values:

Voltage	Gaussian Prob. Dens. Function	Amplitude-Density Dist. of 1383 Random-Noise Gen.
0	0.0796	0.0796 ±0.005
$\pm\sigma$	0.0484	0.0484 ±0.005
$\pm 2\sigma$	0.0108	0.0108 ±0.003
$\pm 3\sigma$	0.000898	0.000898 ±0.0003

(σ is the standard deviation or rms value of the noise voltage.)

Output Voltage: Full output 1 V rms min, open circuit.

Output Meter: Indicates open-circuit output voltage ahead of 50Ω.

Amplitude Control: Continuous control and 8-step, 10 dB-per-step attenuator.

Output Impedance: 50Ω. Can be shorted without causing distortion.

Output Terminals: GR874® coaxial connector that can be mounted on either front or rear panel.

Accessories Supplied: Lamp, power cord.

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 40 W.

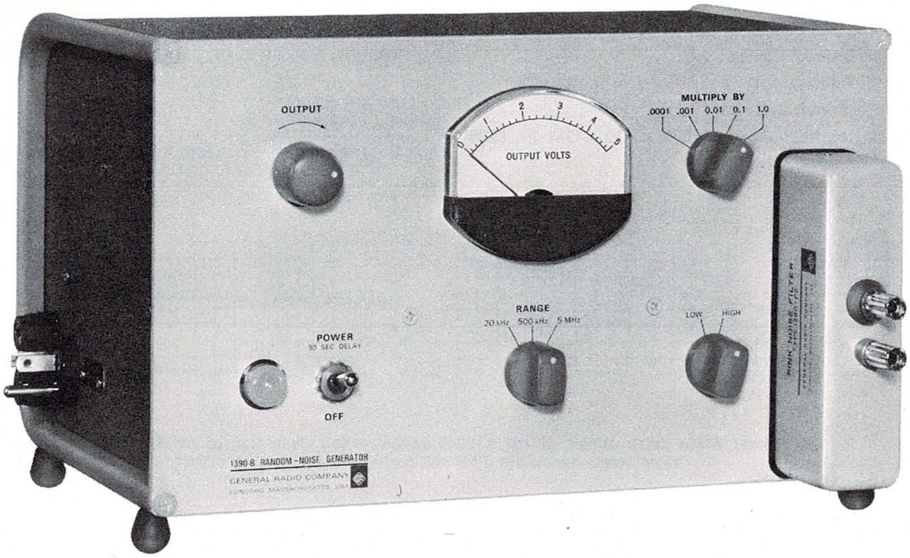
Dimensions (width x height x depth): Bench: 17 x 3⅞ x 12¾ in. (435 x 99 x 325 mm); rack, 19 x 3½ x 10¾ in. (485 x 89 x 275 mm).

Weight: Net, 14 lb (6.5 kg); shipping, 21 lb (10 kg).

Catalog Number	Description	Price in U.S.A.
	1383 Random-Noise Generator	
1383-9700	Bench Model	**$825.00**
1383-9701	Rack Model	**845.00**

Type 1390-B RANDOM-NOISE GENERATOR

- 5 Hz to 5 MHz
- 30-μV to 3-V output
- $\pm$1-dB audio-spectrum-level uniformity



This instrument generates wide-band noise of uniform spectrum level, particularly useful for noise and vibration testing in electrical and mechanical systems. The noise output of a gas-discharge tube is amplified and shaped with low-pass filters to provide ranges to 20 kHz, 500 kHz, and 5 MHz.

The output level is controlled by a continuous attenuator followed by a 4-step attenuator of 20-dB per step and is metered from over 3 volts to below 30 microvolts. When the attenuator is used, the output impedance remains essentially constant as the output level is adjusted.

Use the 1390-B as a broad-band signal source for:

- frequency response — drive device under test with 1390-B and analyze output with any of several GR analyzers, manually or with the GR 1521-B Graphic Level Recorder.
- intermodulation and cross-talk tests.
- simulation of telephone-line noise.
- measurements on servo amplifiers.
- noise interference tests on radar.
- determining meter response characteristics.
- setting transmission levels in communication circuits.
- statistical demonstrations in classroom and lab.

acoustic measurements:

- frequency response.
- reverberation — use 1390-B with a GR analyzer as source of narrow-band noise. **Analyzers** page 35
- sound attenuation of ducts, walls, panels, or floors.
- acoustical properties of materials.
- room acoustics.

or use with an amplifier to drive:

- a loudspeaker for structural fatigue tests in high-level acoustic fields.
- a vibration shake-table.

— For more information, request GR Reprint E-110.

specifications

Frequency Range: 5 Hz to 5 MHz.

Output Voltage: Max open-circuit output is at least 3 V for 20-kHz range, 2 V for 500-kHz range, and 1 V for 5-MHz range.

Output Impedance: Source impedance for max output is approx 900 Ω. Output is taken from a 2500-Ω potentiometer. Source impedance for attenuated output is 200 Ω. One output terminal is grounded.

Range	Typical Spectrum Level (with 1-V rms output)	Spectrum Level Uniformity *
20 kHz	5 mV for 1-Hz band	within $\pm$1 dB, 20 Hz to 20 kHz
500 kHz	1.2 mV for 1-Hz band	within $\pm$3 dB, 20 Hz to 500 kHz
5 MHz	0.6 mV for 1-Hz band	within $\pm$3 dB, 20 Hz to 500 kHz; within $\pm$8 dB, 500 kHz to 5 MHz

* Noise energy also present beyond these limits. Level is down 3 dB at 5 Hz. See plot.

specifications (cont'd)

Waveform: Noise source has good normal, or Gaussian, distribution of amplitudes for ranges of the frequency spectrum that are narrow compared with the band selected. Over wide ranges the distribution is less symmetrical because of dissymmetry introduced by the gas tube. Some clipping occurs on the 500-kHz and 5-MHz ranges.

Voltmeter: Rectifier-type averaging meter measures output. It is calibrated to read rms value of noise.

Attenuator: Multiplying factors of 1.0, 0.1, 0.01, 0.001, and 0.0001. Accurate to ±3% to 100 kHz, within ±10% to 5 MHz.

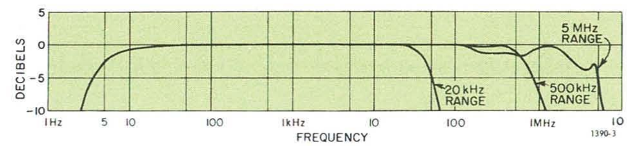
Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 50 W.

Accessories Supplied: CAP-22 Power Cord.

Accessories Available: Rack-adaptor set (19 x 7 in.); 1390-P2.

Mounting: Convertible-Bench Cabinet.

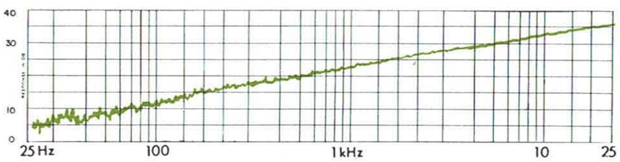
Dimensions (width x height x depth): 12¾ x 7½ x 9¾ in. (325 x 190 x 250 mm).

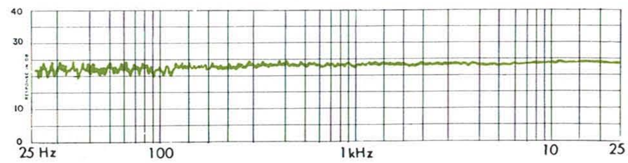


Typical spectrum-level characteristics.

Weight: Net, 12 lb (5.5 kg); shipping, 16 lb (7.5 kg).

Catalog Number	Description	Price in USA
1390-9702	**1390-B Random-Noise Generator**	**$395.00**





(Left curve) White noise output of the 1390-B Random-Noise Generator as measured by a one-third octave-bandwidth filter and (right curve) pink-noise output.

Type 1390-P2 PINK-NOISE FILTER

When white noise is used for frequency-response measurements in conjunction with a constant-percentage bandwidth analyzer (such as the GR 1564-A Sound and Vibration Analyzer or 1568-A Wave Analyzer), the amplitude-frequency characteristic of a flat system appears to slope upward with increasing frequency at a rate of 3 dB per octave, owing to the constantly increasing bandwidth (in hertz) of the analyzer. The 1390-P2 converts the audio-frequency output of the 1390-B from white noise to pink noise, which has constant energy per octave. Thus it flattens the response curves made with a constant-percentage-bandwidth analyzer.

— See **GR Experimenter** for July 1962.

specifications

Frequency Response: Sloping —3 dB per octave from 20 Hz to 20 kHz, —6 dB per octave above 20 kHz. Output voltage is approx —5 dB with respect to the input voltage at 20 Hz and —35 dB at 20 kHz. It lies within 1 dB of the straight line connecting these two points on a graph of output in decibels vs log frequency.

Over-all Output Level: When the filter is used with the random-noise generator set for the 20-kHz range, the output voltage of the filter is approx 30 dB below its input, and the voltage level in each one-third-octave band is approx 17 dB below that. Thus, when the output meter of the generator indicates 3 V, the output of the filter is approx 0.1 V, and the level in each one-third-octave band is approx 15 mV.

Input Impedance: The filter should be driven from a source whose impedance is 1 kΩ or less. Input impedance is variable from 6.5 kΩ + load resistance at zero frequency to 6.7 kΩ at high frequencies.

Output Impedance: The filter should not be operated into a load of less than 20 kΩ. Internal output impedance is variable from 6.5 kΩ + source resistance at low frequencies to approx 200 Ω at high frequencies.

Max Input Voltage: 15 V rms.

Terminals: Input terminals are recessed banana pins on ¾-in. spacing at rear of unit. Output terminals are jack-top binding posts with ¾-in. spacing.

Dimensions (width x height x depth): 1⅜ x 5 x 2⅞ in. (35 x 130 x 73 mm).

Weight: Net, 6 oz (0.2 kg); shipping, 4 lb (1.9 kg).

Catalog Number	Description	Price in USA
1390-9602	**1390-P2 Pink-Noise Filter**	**$ 50.00**
0480-9842	**480-P412 Relay-Rack Adaptor Set**	**11.00**

PATENT NOTICE. See Note 15.

IMPEDANCE

IMPEDANCE BRIDGES

CAPACITANCE BRIDGES and STANDARDS

INDUCTANCE BRIDGES and STANDARDS

RESISTANCE BRIDGES and STANDARDS

DETECTORS

ENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO

IMPEDANCE MEASUREMENT

Null methods have long been recognized as the most precise way to measure all types of impedances — resistive and reactive, inductive and capacitive, from low frequencies to uhf. Most null-type instruments evolved from the century-old Wheatstone Bridge, still the fundamental circuit for measuring dc resistance. Other null circuits, such as the admittance meter and transfer-function bridge, have been developed by General Radio to meet the diverse requirements of modern measurement. In all, GR produces bridges that cover virtually the entire field of impedance measurement. Some of these bridges include built-in generator and detector and are thus complete, self-contained measurement systems. Others are available in combination with various General Radio oscillators and detectors, as complete assemblies.

DC BRIDGES

The Wheatstone bridge measures an unknown resistance, R_X, in terms of calibrated standards of resistance connected as shown in Figure 1. The relation is:

$$R_X = \frac{R_N R_B}{R_A} \tag{1}$$

which is satisfied when the voltage across the detector terminals is zero.

AC BRIDGES

The Wheatstone bridge circuit is easily adapted to ac measurement. With complex impedances, two balance conditions must be satisfied, one for the resistive component and one for the reactive component. At balance:

$$Z_X = R_X + jX_X = Z_N Y_A Z_B \tag{2}$$

or

$$Y_X = G_X + jB_X = Y_N Z_A Y_B \tag{3}$$

Equation (2) expresses the unknown in terms of impedance components; equation (3) expresses the unknown as an admittance. To satisfy these equations, at least one of the three arms A, B, or N must be complex.

The reactance X_X can be measured in terms of a similar reactance in an adjacent arm (Figure 2) or an unlike reactance in the opposite arm (Figure 3).

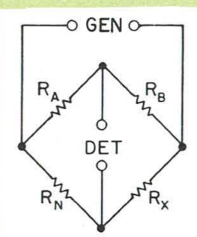
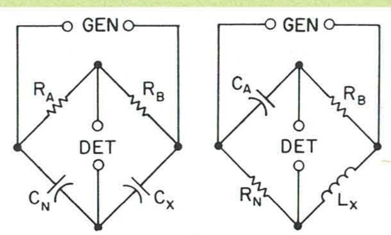


Figure 1. The general Wheatstone bridge circuit.



Figures 2 and 3. Circuits for capacitance bridges in which like reactances (left) or unlike reactances (right) are compared.

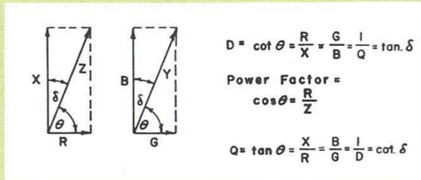


Figure 4. Vector diagram showing the relations between factors D and Q, and angles θ and δ

The complex arm required to satisfy the balance conditions of equation (2) or (3) is a combination of a resistance and a reactance, in series or in parallel. With a **series** combination in an arm **adjacent** to the unknown or a **parallel** combination in the arm **opposite** the unknown, the bridge measures the equivalent series components of the unknown. Conversely, an adjacent parallel or an opposite series combination will yield a measurement of equivalent parallel components. (Every impedance can be expressed in terms of either series or parallel equivalents, as discussed below.)

If both components of this complex arm are adjustable, the balances for the real and imaginary parts of the unknown will be independent of each other and orthogonal. If only one component of the combination is adjustable, this component will be proportional to either the D or the Q of the unknown impedance. If the adjustable component is the more prominent of the two, as it is when very low-Q inductors are measured, the balance convergence is slow, if not impossible. The general-purpose 1650 Impedance Bridge and the 1617 Capacitance Bridge use a mechanical ganging of the bridge controls (called Orthonull®) to facilitate convergence.

D AND Q

An important characteristic of an inductor or a capacitor, and often of a resistor, is the ratio of resistance to reactance or of conductance to susceptance. The ratio is called dissipation factor, D, and its reciprocal is storage factor, Q. These terms are defined in Figure 4 in terms of phase angle θ and loss angle δ. Dissipation factor is directly proportional to energy dissipated, and storage factor to energy stored, per cycle. Power factor ($\cos\theta$ or $\sin\delta$) differs from dissipation factor by less than 1% when their magnitudes are less than 0.1.

In Figure 4, R and X are series resistance and reactance, and G and B are parallel conductance and susceptance, of the impedance or admittance involved.

Dissipation factor, D, which varies directly with power loss, is commonly used for capacitors. Storage factor, Q, is more often used for inductors because it is a measure of the voltage step-up in a tuned circuit. Q is also used for resistors, in which case it is usually very small.

Most General Radio capacitance and inductance bridges also measure D or Q.

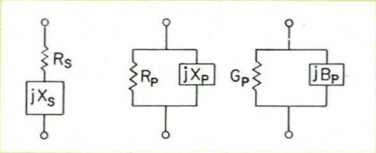


Figure 5. Series and parallel components of impedance.

SERIES AND PARALLEL COMPONENTS

Many GR impedance bridges give the user the option of measuring the unknown in terms of either its series or parallel equivalents. The choice is a matter of convenience for the problem at hand. Since the distinction between series and parallel equivalents is sometimes overlooked in texts, we will briefly summarize the relationships here.

Regardless of physical configuration, every impedance can be expressed, for any given frequency, as either a series or a parallel combination of resistance and reactance, as shown in Figure 5. The relations between the elements of Figure 5 are:

$$R_P = \frac{1}{G_P} = \frac{R^2_S + X^2_S}{R_S} = R_S(1 + Q^2)$$

$$X_P = \frac{1}{B_P} = \frac{R^2_S + X^2_S}{X_S} = X_S(1 + D^2)$$

In terms of series and parallel capacitive and inductive reactances, these relations become:

$$C_P = C_S\left(\frac{1}{1 + D^2}\right)$$

$$C_S = C_P\,(1 + D^2)$$

$$L_P = L_S\left(1 + \frac{1}{Q^2}\right)$$

$$L_S = L_P\left(\frac{Q^2}{1 + Q^2}\right)$$

Where:

$$Q = \frac{X_S}{R_S} = \frac{R_P}{X_P} = \frac{B_P}{G_P} = \frac{\omega L_S}{R_S} = \frac{R_P}{\omega L_P} = \frac{1}{D}$$

and

$$D = \frac{1}{Q} = \frac{R_S}{X_S} = \frac{X_P}{R_P} = \frac{G_P}{B_P} = \omega R_S C_S = \frac{1}{\omega R_P C_P} = \frac{1}{Q}$$

If Q is 10 or more (or if D is 0.1 or less), the difference between series and parallel reactance is no more than 1%. For very low Q's or high D's, however, the difference is substantial; when $Q = 1$, X_P is twice X_S. If there were no losses in the reactive elements (i.e., $D = 0$), X_S and X_P would be equal.

SUBSTITUTION METHODS

In many ac bridges, the unknown is connected in series or in parallel with the main adjustable component, and balances are made before and after the unknown is connected. The magnitude of the unknown then equals the change made in the adjustable component, since the total impedance of the unknown arm remains constant. The chief advantage of this substitution technique is that its accuracy depends only on the calibration of the adjustable arm and not on the other bridge arms (as long as they are constant). The substitution principle can also be used to advantage with any bridge if the balances are made with an external, calibrated, adjustable component.

BRIDGES WITH ACTIVE ELEMENTS

If a potentiometer-amplifier combination is connected as a bridge element, fixed capacitance and conductance standards can be used, with current adjusted by variation of voltage rather than of impedance magnitude. The principle is used in the Type 1633-A Incremental-Inductance Bridge, which can accurately measure nonlinear elements.

THE TRANSFORMER RATIO-ARM BRIDGE

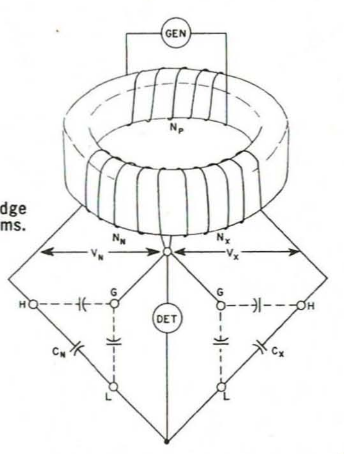
Transformer ratio arms, introduced almost a century ago, have recently come into considerable favor because of certain outstanding advantages. Ratio accuracies of a few parts per million are possible, even for transformer ratios of up to 1000 to 1, and the ratio is virtually unaffected by age, temperature, or voltage. Examples of the transformer bridge are the 1615 Capacitance Bridge and the 1680 and 1682 Automatic Capacitance Bridges.

Figure 6 shows a transformer bridge in elementary form. The balance condition for capacitance is

$$\frac{C_X}{C_N} = \frac{N_N}{N_X}$$

Figure 6 also explains the exceptional ability of the transformer bridge to make three-terminal measurements without the use of a guard circuit or auxiliary balance. Capacitances from the H terminals appear across the low-impedance transformer winding, while those from the L terminals are across the detector, where they do not enter

Figure 6. A capacitance bridge with transformer ratio arms.



the balance expression. These capacitances are thus excluded from the measurement of direct capacitance, C_x, between H and L terminals. Because this type of bridge can tolerate relatively large capacitances from both sides of the unknown to the guard point, long cables with guard shields can be used for remote measurement, and circuit capacitances can often be measured **in situ.**

Conventional bridges can also be adapted for three-terminal measurements (although they generally cannot tolerate as low an impedance to guard). On the Types 1650 and 1608 Impedance Bridges and 1617 Capacitance Bridge any stray capacitance is in parallel with a standard capacitor of at least 0.1 μF and usually has negligible effect. On the Type 1654 Impedance Comparator an electronic amplifier provides a guard point.

LIMIT BRIDGES AND COMPARATORS

In limit bridges, the unbalance voltage of the bridge actuates a meter, which indicates the degree of deviation of one impedance from another. The Type 1662 Resisance Limit Bridge, which includes an adjustable standard resistor, can limit-test resistors over a wide range. The Type 1654 Impedance Comparator indicates the magnitude and phase differences between the unknown and an external standard. On this instrument, the availability of several sensitive ranges enables the user to measure small differences very accurately.

THE AUTOMATIC BRIDGE

The ultimate in convenience is a bridge that balances itself. The 1680-A Automatic Capacitance Bridge Assembly, the 1682 Automatic Capacitance Bridge, and the 1683 Automatic RLC Bridge fully automate the balance procedure — selecting range, balancing, and presenting readout in both visual and digital data form.

The implications of such automatic measurement are far-reaching. The conversion of bridge-measured data into digital and binary-coded form gives the bridges access to the whole modern arsenal of data-processing equipment — computors, printers, tape-punchers, sorters, etc. Speed is one obvious byproduct of automatic equipment: GR's new automatic bridges take about one-half second to achieve balance.

COAXIAL-LINE INSTRUMENTS

The Slotted Line

The upper-frequency limit of conventional bridge circuits using lumped-parameter elements depends on the magnitude of the residual impedances of the elements and leads. The corrections for these usually become unmanageable at frequencies above a few hundred megacycles, and circuits based on coaxial-line techniques are more satisfactory.

One of the basic methods of measuring the impedance of a coaxial device is the measurement of the standing-wave ratio it introduces in a uniform line. The measurement is best made by a slotted line. General Radio offers two slotted lines: the Type 874-LBB, for general impedance measurements, and the highly accurate Type 900-LB, the most advanced slotted line available commercially.

The Admittance Meter

The GR 1602-B UHF Admittance Meter and 1609 UHF Bridge use adjustable loops to sample the currents flowing in three coaxial lines fed from a common source and terminated, respectively, in the unknown, a standard conductance, and a standard susceptance. The loops are adjusted so that the combined output from them is zero (a null balance). Scales associated with the three loops give the value of the unknown directly, in terms of admittance.

GENERATORS AND DETECTORS

Several GR bridges includes both generator and detector. Some others — the Type 1615-A Capacitance Bridge and the Types 1632 and 1633 Inductance Bridges — are available as complete measuring assemblies, with generator, detector, interconnecting cables, relay rack, and other accessories. Unless one obtains such a complete system, he must carefully choose generator and detector to ensure satisfactory measurement results. (Even with a complete system, the user may at times wish to connect a different generator or detector to the bridge, and almost all GR bridges include panel connectors for such use.)

The chief generator requirements are good frequency stability, adequate power output, and low harmonic content. A wide choice of GR oscillators is available, covering the frequency range from audio to microwave.

Desirable detector characteristics are

(1) High sensitivity, preferably the ability to detect a few microvolts or less.

(2) High selectivity, to reject harmonics, noise, and other interfering signals. This is particularly important in measurements on iron-core coils and other nonlinear elements.

(3) Logarithmic or nearly logarithmic response, to minimize gain adjustment during the balancing procedure.

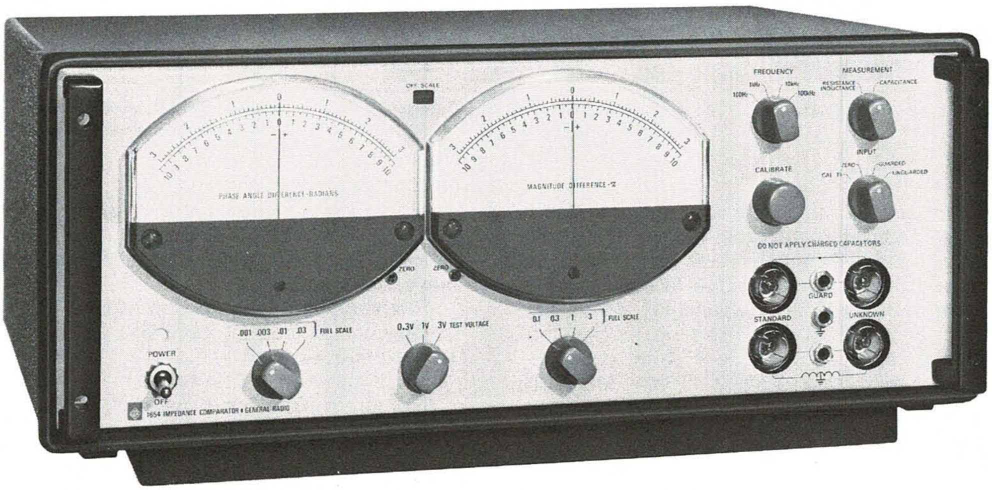
(4) Good shielding, to prevent errors from extraneous pickup.

At audio frequencies, GR's Type 1232-A Tuned Amplifier and Null Detector is recommended for its high sensitivity and for its general versatility in the lab. Crystal mixers are available for both the detectors, extending their frequency ranges to about 60 MHz. At these and higher frequencies, the heterodyne type of detector is preferred, because of its wide frequency range and excellent shielding. Type DNT and 1241 detectors operate from 70 kHz to 2000 MHz.

One of the most popular generator-detector combinations, the Type 1311-A Audio Oscillator (50 Hz to 10 kHz) with the Type 1232-A Tuned Amplifier and Null Detector, is now available in a single assembly as the Type 1240-A Generator-Detector Assembly.

Type 1654 IMPEDANCE COMPARATOR

- 0.003% impedance-difference resolution
- 100 Hz to 100 kHz — 4 fixed frequencies
- wide impedance ranges:
  - 2Ω to 20 MΩ
  - 0.1 pF to 1000 μF
  - 20 μH to 1000 H
- stable solid-state circuits
- fast sorting >4000/h, with accessory limit comparator



The GR 1654 Impedance Comparator indicates on large panel meters and by analog output voltages the difference in magnitude and phase angle between two external impedances, usually a standard and an unknown. Owing to its speed and percent-deviation readout, the 1654 is of great value in the sorting, selecting, and adjusting of components in production and inspection applications.

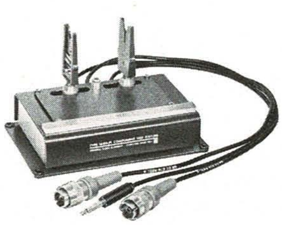
ACCURATE

Because the 1654 measures differences to an accuracy of 3% of full scale, the measurement accuracy and resolution as a percent of the total impedance are considerably better, with comparison precisions to ±0.003%. In addition, the magnitude channel of the 1654 has been linearized to ensure accurate readings without correction for up to 30% impedance differences. Solid-state circuits are used in the 1654 so that drift of the meter zero is negligible, permitting more certain accuracy and fewer interruptions for readjustment.

VERSATILE

Test voltage, frequency, and measurement ranges of impedance and phase-angle differences are all selected by front-panel controls. Test voltage and measurement ranges are related and their panel switches interlocked to reflect this relationship. Four measurement ranges can be used with each test voltage. The largest test voltage, 3 volts, gives the greatest sensitivity: 0.1% and 0.001 radians, full scale. The lower voltages, 1.0 and 0.3 volts, permit measurement of more fragile components, allow easy voltage-coefficient tests, and, while limiting maximum sensitivity, extend large-difference capability to 30% and 0.3 radians, full scale.

Wide ranges of impedance, resistance, capacitance, and inductance can be compared with the 1654. Since it is a transformer bridge, the 1654's accuracy is little affected by loading or by stray impedances for most measurements. A guard terminal is provided for making three-terminal connections to minimize the effects of stray jig and cable capacitance.



1680-P1 Test Fixture.

HIGH-SPEED SORTING, SYSTEMS EXPANSION

The 1654 measures the difference between two externally connected components. For comparison measurements you need a standard. For rapid sorting you need either a limit comparator or an alert operator who can mentally juggle up to six numbers simultaneously. You can solve these problems neatly by adding to the basic impedance comparator or, more neatly yet, by letting us do the adding in the form of one of several models of the 1654-Z Sorting System.

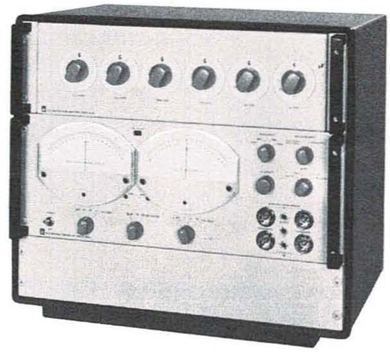
One model of the 1654-Z contains, in addition to the 1654 Impedance Comparator, our newest and one of our best decade capacitors. A second model contains a versatile limit comparator especially designed for the 1654, and a third model contains both.

The 1413 Precision Decade Capacitor provides a range of from 0 to 1.11111 μF, an accuracy of 0.05%, and a resolution of 1 pF. Any value in its range is set easily by six in-line readout dials, and it may be connected to either the front or the rear of the 1654. 1413 page 106

The 1782 Analog Limit Comparator provides four limits that you may use as your needs dictate: a high and low limit for both magnitude and phase, two values of magnitude only or phase only, or four high limits to sort components into five categories (say 5, 10, 20 and 30% and 1782 page 71

NEW

1654-Z1 Sorting System includes limit comparator for additional limits.



1654-Z2 Sorting System contains precise capacitance decade standard.

1654-Z3 Sorting System includes both a limit comparator and capacitance decade standard.

reject). All limits can be set to an accuracy of within ±2% of full scale and bright-light panel indicators provide results of the comparison in terms of go or no go. The 1782 is available also with a relay option to control automatic sorting mechanisms. The components can be applied manually or automatically at rates up to four per second. For special applications, up to 16 limit comparators can be connected to the 1654. Call your local GR District Office for further details on incorporating additional limit comparators or other automatic measuring and sorting equipment.

TYPICAL USES

Rapid sorting and matching of precision components, subassemblies, and networks, manually or with automatic equipment.

Measuring the effects of time and environment on components, with high precision and continuous indication.

Rapid testing of the tracking of ganged potentiometers and variable capacitors.

Studying the frequency dependence of components.

Easy comparison of quantities usually requiring laboratory techniques, such as:

Small impedance differences.
D of low-loss dielectric materials.
D $\left(=\frac{1}{Q}\right)$ of inductors.
Q or phase angle of wire-wound resistors or potentiometers.
Balance of transformer windings.
Semiconductor capacitances.
Capacitance drift with temperature.

specifications

Frequencies: Internal only 100 Hz, 1, 10, and 100 kHz, ±1%.
Ranges: 0.1% to 30% full-scale impedance difference; 0.001 to 0.3 radians full-scale phase-angle difference. Available ranges depend on test voltage selected as shown in the following table.

Test Voltage	Impedance Difference Full-scale Range — %						Phase-Angle Difference Full-scale Range — Radian					
	0.1	0.3	1	3	10	30	0.001	0.003	0.01	0.03	0.1	0.3
0.3 V			x	x	x	x			x	x	x	x
1 V		x	x	x	x			x	x	x	x	
3 V	x	x	x	x			x	x	x	x		

Impedance Ranges (0.3-V test voltage*):

	Resistance	Capacitance	Inductance
Full useful range	2Ω — 20 MΩ	50 pF** — 1000 μF	20 μH — 1000 H
at 100 Hz	2Ω — 20 MΩ	1000 pF — 1000 μF	5 mH — 1000 H
at 1 kHz	2Ω — 2 MΩ	50 pF** — 100 μF	500 μH — 100 H
at 10 kHz	2Ω — 200 kΩ	50 pF** — 10 μF	50 μH — 1 H
at 100 kHz	10Ω — 10 kΩ	50 pF** — 0.1 μF	20 μH — 10 mH

*Low R and L limits are increased and upper C limit decreased by 10:1 for 1-V test voltage and by 100:1 for 3-V.
**To 0.1 pF by substitution method.

Resolution: Meter, 0.003% and 0.00003 radian. Analog-voltage output, 0.001% and 0.00001 radian.

Accuracy: 3% of full scale.

Voltage Across Standard and Unknown: 0.3, 1, or 3 V selected by front-panel control. Test voltage of 2 V (with 0.6 and 6 V) can be obtained on special order.

Analog-Voltage Outputs: Voltages proportional to meter deflections at two rear-panel connectors: ±10 V full scale behind < 10Ω for 1782 Analog Limit Comparator; ±3 V or ±10 V (depending on range) full scale behind 2 kΩ for DVM, A-D converter or other use.

Test Speed: About 1 component per second with meter, max. With analog output voltage, about 4 components per second, except about 1 component per second at 100 Hz.

Power: 105 to 125 or 210 to 250 V, 50-60 Hz, 15 W for 1654 and 1654-Z2, 35 W for -Z1 and -Z3.

Supplied: Multiple-contact connector and power cord.

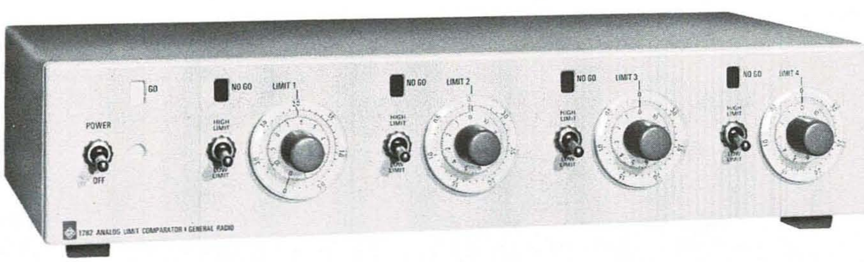
Available: 1782 Analog Limit Comparator (supplied with -Z1 and -Z3); 1413 Precision Decade Capacitor (supplied with -Z2 and -Z3) and other GR decade boxes and standards of resistance, capacitance, and inductance; 1680-P1 Test Fixture for rapid connection of components (includes connecting cables); 1654-9600 Adaptor Kit for components with ¾-in. spaced leads; 874-MB Coupling Probes for components with 1¼-in. spaced leads; and 874-R33 Patch Cords for connection to GR874®-terminated standards or unknowns.

Mechanical: 1654, bench or rack models; 1654-Z, all units mounted in a single cabinet with necessary interconnections made. *Dimensions* (w x h x d): 1654 bench, 19½ x 8¾ x 15 in. (495 x 225 x 385 mm); 1654 rack, 19 x 7 x 13½ in. (485 x 180 x 345 mm); 1654-Z1, 12 x 19½ x 15 in. (305 x 225 x 385 mm); 1654-Z2, -Z3, 17½ x 19½ x 15 in. (445 x 225 x 385 mm). *Weight:* 1654 bench, 40 lb (19 kg) net, 60 lb (28 kg) shipping; 1654 rack, 25 lb (12 kg) net, 40 lb (19 kg) shipping; 1654-Z1, 51 lb (23.5 kg) net, 63 lb (29 kg) shipping; 1654-Z2, 66 lb (30 kg) net, 79 lb (36 kg) shipping; 1654-Z3, 77 lb (35 kg) net, 90 lb (41 kg) shipping.

Description	Price in USA
1654 Impedance Comparator	
Bench Model	**$1300.00**
Rack Model	**1250.00**
Sorting System	
1654-Z1 With limit comparator	**1865.00**
1654-Z2 With decade capacitor	**2230.00**
1654-Z3 With limit comparator and decade capacitor	**2805.00**
Option 6 Relay Output for -Z1 or -Z3	**add 75.00**
1680-P1 Test Fixture	**105.00**
1654-9600 Adaptor Kit	**20.00**
874-MB Coupling Probe, 2 req'd for each terminal pair	**7.50**
874-R33 Patch Cord, 2 req'd for each terminal pair	**9.00**

Type 1782 ANALOG LIMIT COMPARATOR

- accessory to 1654 Impedance Comparator
- 4 independent limits — use for high or low
- 2% of full scale accuracy
- GO/NO GO lights, optional contact closures



The GR 1782 Analog Limit Comparator increases the speed at which the 1654 Impedance Comparator will operate in sorting applications. It compares the analog-voltage output of the 1654 against high and low limits set on the 1782 front panel and displays GO or NO GO lights for manual sorting. Optional relay-equipped models will operate external automatic-sorting devices. Up to 4 components per second can be measured with the two instruments together.

Four controls on the front panel permit the limits to be set to 1% resolution; each control can act as either a high limit or a low limit as selected on an adjoining switch and for $\triangle Z$ or $\triangle \theta$ as selected by a rear-panel switch.

The 1782 is shown here with the 1654 Impedance Comparator to form one version of the 1654-Z Sorting System.

specifications

INPUT

Analog Voltage: ±10 V full scale

Resistance (of each comparator)**:** 66 kΩ, approx.

OUTPUT

Analog Voltage: Identical to input.

Decision Outputs: Visual or relay contacts.
Visual: NO-GO lamp for each limit; GO lamp indicates measurement is within all limits.
Relay Contacts (optional): 5 SPDT contacts, 115 V rms, 0.1 A rms, max.

Accuracy: ±2% of full scale.

Limit Controls: Four independent limits; can be set for + (high) or — (low) with switch adjoining each control. Dual controls: inner scale calibrated 0 to 100 (each division corresponds to 100 mV), outer scale calibrated 0 to 30 (316 mV per division).

Test Speed: Approx 10 tests per second, max.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz, 20 W.

Accessories Supplied: 24-contact connector with relay models only, input-signal cable, power cord

Mounting: Convertible bench cabinet.

Dimensions (width x height x depth): Bench, 17 x 3⅞ x 9⅞ in. (435 x 99 x 250 mm); rack, 19 x 3½ x 8⅝ in. (485 x 89 x 220 mm).

Weight: Net, 9 lb (4 kg); shipping, 15 lb. (7 kg).

Catalog Number	Description	Price in USA
	1782 Analog Limit Comparator	
1782-9700	Bench Model, without relays	**$550.00**
1782-9701	Rack Model, without relays	**570.00**
1782-9702	Bench Model, with relays	**625.00**
1782-9703	Rack Model, with relays	**645.00**

Type 1683 AUTOMATIC RLC BRIDGE

- Resistance: 1 $\mu\Omega$ to 2 MΩ
- Inductance: 0.1 nH to 2000 H
- Capacitance: 0.01 pF to 0.2 F
- 0.1% basic accuracy
- up to 20 measurements per second

NEW

The 1683 Automatic RLC Bridge is a fully-automatic, low-frequency, five-terminal impedance bridge that measures capacitors, inductors, and resistors with loss expressed as a series element. It is a true bridge whose accuracy depends on stable passive standards. The automatic nature of the bridge allows unskilled personnel to make precision measurements at the push of a button.

The accuracy and rapid speed of balance make the 1683 a natural choice for incoming inspection, quality control, and high-volume production applications where a large number of components must be measured in as short a time as possible. The wide range of the 1683 enables it to measure almost any type of component.

The data-output option enables the user to retrieve, record, analyze, and utilize volumes of data in a minimum of time. The bridge is designed to interface with scanners, comparators, card- and tape-punch machines, recorders, and computers, all of which can be supplied by GR separately or as a system.

The programming option allows for external control of the bridge functions. This is desirable for fully-automated testing where a master computer may be controlling one or more bridges and other accessory equipment. The computer would function as controller, data retriever, data analyzer, and decision maker to reduce the possibility of error. Such a controlled system would provide for extremely fast, accurate, and economical component evaluation.

The five-terminal feature provides the user with the ability to measure accurately low-impedance and high-impedance components far removed from the bridge. The Kelvin-type connection lessens the effects of lead impedance and enables milliohms of impedance to be measured at the end of several feet of cable. The special cable provided decreases the effect of mutual inductance when low impedances are measured, and the fifth terminal decreases the effect of stray capacitances when high impedances are measured. This is especially useful when several small-valued capacitors are sequenced with a scanner system.

The bias feature and leakage option provide the ability to characterize large-valued tantalums and electrolytic-class capacitors at one station. The ESR option provides the user with another means to express loss in capacitor measurements as required by some MIL specifications.

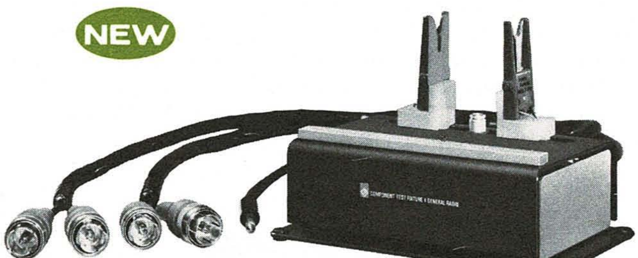
The many features incorporated in the 1683 Automatic RLC Bridge allow the user to accomplish fast, accurate, and economical testing of resistors, inductors, and capacitors in a number of applications ranging from laboratory use to the most sophisticated of computer-controlled systems.

Measurement	Range at 120 Hz	Range at 1 kHz	Accuracy (% of reading)
CAPACITANCE With concurrent loss measurement (that can be displayed as dissipation factor or equivalent series resistance) and optional go, no-go leakage-current test.	0000.1 pF to 1999.9 μF 02.000 mF to 199.99 mF	000.01 pF to 199.99 μF 0200.0 μF to 19.999 mF	0.1% ± 1 count 1% ± 10 counts
INDUCTANCE With concurrent loss measurement expressed as series resistance.	00.001 μH to 199.99 μH 0200.0 μH to 1999.9 H	0000.1 nH to 19.999 μH 020.00 μH to 199.99 H	1% ± 20 counts 0.1% ± 2 counts
RESISTANCE Simple resistance, or series resistance with inductance measurements.	00.001 mΩ to 199.99 mΩ 0200.0 mΩ to 1999.9 kΩ		1% ± 10 counts 0.1% ± 1 count
DISSIPATION FACTOR (D) Concurrent with capacitance measurements.	0.0000 to 1.9999		1% ± 0.001
EQUIVALENT SERIES RESISTANCE (Option 4) Concurrent with capacitance measurements.	00.001 mΩ to 1999.9 kΩ		1% ± 10 counts
LEAKAGE CURRENT (Option 3) Go, no-go indication concurrent with capacitance measurement.	1 μA to 25 mA		2%

Display: Reactive and resistive readouts, each with 5-digit resolution, high-intensity neon readout tubes, decimal point, and unit of measurement. Display also indicates measurement frequency, unbalanced condition, manual- or remote-ranging condition, and go or no-go result of leakage current measurement.

Speed: Measurement rate at 1 kHz is ≈ 20 measurements per second for ± 1% of full-scale change in unknown, 16/s for ± 10% change, and 8/s for ± 100% change; at 120 Hz rates 10 times slower. Interval between measurements can be infinite (measurements initiated by front-panel pushbutton or external closure to ground) or from ≈ 20 ms to 1s as set by front-panel control so that measurements are repetitive. Speed may be decreased slightly when D is measured near the low end of each range.

NEW



Terminals: Five; 4-terminal connection minimizes errors due to lead impedance and ground terminal minimizes error due to stray capacitance. Connections to unknown are made by coaxial cables at the front and the rear of the instrument. A 1683-P1 Test Fixture is available for the rapid connection of axial-lead components and contains a start button to initiate the measurements. Stray capacitance up to 2 pF across the test fixture can be cancelled by an adjustment on the rear of the 1683.

Ranges: Nine for all measurements except five for leakage current. Ranging can be automatic, manual, or remote except leakage current which has no automatic ranging.

Oscillator Level: Voltage applied to unknown can be reduced from the normal 2.2 V rms for special applications.

Sensitivity: Can be manually or remotely reduced from maximum, with consequent loss of resolution, to overcome problems with non-linear or rapidly changing unknown or external noise or hum pickup.

Bias: 0 to 3 V internal, manually or remotely set; 600 V max, external; 2995-9158 Bias Supply provides up to 50 V and 40 mA. Bridge fully protected from possible damage by charged or shorted capacitors.

Bias Supply page 85

Leakage-Current Test (Option 3): No-go limit can be manually set with 2% accuracy or remotely measured with 1% accuracy from 1 μA to 25 mA. External monitoring of leakage current or of a dc voltage proportional to leakage current provided.

Interface:

Low-Level Data Output (Option 5A): 50-pin Amphenol Type 57 connector provides 11 digits of measurement data (5 for reactance, 5 for resistance, 1 for range) plus various control inputs and outputs for systems use. Digits are 1-2-4-8-weighted BCD at standard TTL logic levels (logic "0" ≈ ground with 10-mA sink capability, logic "1" ⩾ 3.5 V).

High-Level Data Output (Option 5B): Same as low-level except all outputs are 15-V swing (logic "0" ≈ ground with 10-mA sink capability, logic "1" ≈ + 15 V behind 12 kΩ).

Remote Programmability (Option 2): 50-pin Amphenol Type 57 connector provides terminals for external remote programming of all control functions except line-voltage control. Functions are controlled by closures to ground or standard TTL levels.

Accessories Supplied: Power cord.

Accessories Available: 1683-P1 Test Fixture, 2995-9158 Bias Supply, printers, recorders, card-punch couplers, scanners.

Power: 100 to 125 and 200 to 250 V, 50-60 Hz, 110 W.

Mechanical: Bench or rack models. *Dimensions* (w x h x d): Bench, 19 x 7⅞ x 25⅜ in. (485 x 200 x 640 mm); rack, 19 x 7 x 23¾ in. (485 x 180 x 610 mm). *Weight:* Bench, 60 lb (28 kg) net, 74 lb. (34 kg) shipping; rack, 50 lb (23 kg) net, 67 lb (31 kg) shipping.

Description	Price in USA
1683 Automatic RLC Bridge	
Bench Model	**$4250.00**
Rack Model	**4215.00**
Option 2 Remote Programmability	**add 200.00**
Option 3 Leakage Current	**add 100.00**
Option 4 ESR Readout	**add 225.00**
*Option 5A Low Level Data Output	**add 200.00**
*Option 5A Low-Level Data Output	**add 200.00**
1683-P1 Test Fixture for axial leads	**165.00**

* Not available together in the same instrument.

PATENT NOTICE. See Note 8.

Type 1656 IMPEDANCE BRIDGE

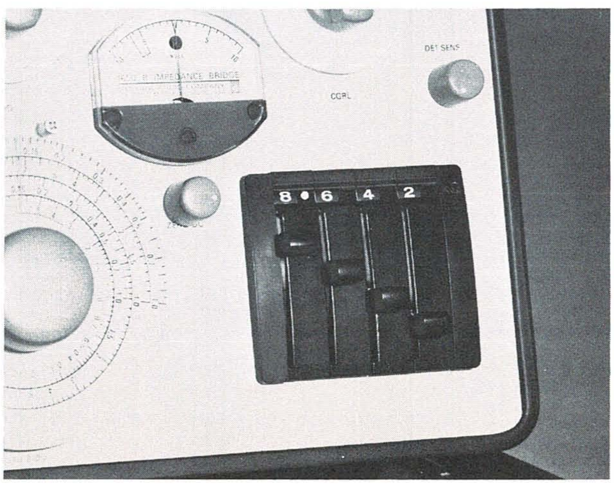
- measures C, L, R, and G
- 0.1% basic accuracy
- convenient lever switches
- digital main readout
- portable, self-contained

NEW

The 1656 is particularly well suited for measurements of the high-precision electrical components now coming into common use. Lever-arm adjustments for the main readout not only provide a rapid means of balance but reduce reading errors as well. Its 0.1% accuracy makes it a valuable laboratory instrument, its low cost and ease of balance adapts it to production testing, and its portability lends it to field measurements.

An all-around performer, it measures capacitance and loss (D), inductance and loss (Q), resistance, and conductance — all with equal ease. Capacitance and inductance measurements can be expressed as series or parallel elements and resistance and conductance measurements can be made at ac or dc. It is an exceptionally fine dc bridge because of its sensitive detector and wide resistance and conductance ranges.

The ability of the 1656 to measure D with an accuracy of 0.001 can easily be as important in the measurements of precision networks as its ability to measure capacitance with an accuracy of 0.1%. Provisions are also made for measurements at frequencies from 20 Hz to 20 kHz, by means of an external oscillator and detector.



Lever-arm switches permit fast balances and easy-to-read answers.

specifications

Range	Resolution (one digit on lowest range)	Accuracy* Frequencies ≤1 kHz and small phase angle (fs = full scale)	Accuracy* Frequencies >1 kHz or large phase angle Typical additional error terms
Capacitance: 0.1 pF to 1100 μF Series or parallel, 7 ranges	0.1 pF	±(0.1% of reading + 0.01% of fs + 0.2% of reading on highest range)	$\pm(0.2\ Df_{kHz} + 0.5\ D^2 + 0.002\ f^2_{kHz})\%$
Inductance: 0.1 μH to 1100 μF Series or parallel, 7 ranges	0.1 μH	±(0.1% of reading + 0.01% of fs + 0.2% of reading on lowest range)	$\pm(0.2\ f_{kHz}/Q + 0.5/Q^2 + 0.002\ f^2_{kHz})\%$
Resistance: 0.1 mΩ to 1.1 MΩ Ac or dc, 7 ranges	0.1 mΩ	±(0.1% of reading + 0.01% of fs + 0.2% of reading on lowest range)**	$\pm(Qf_{kHz} + 0.003\ f^2_{kHz})\%$**
Conductance: 0.1 n℧ to 1.1℧ Ac or dc, 7 ranges	0.1 n℧	±(0.1% of reading + 0.01% of fs + 0.2% of reading on highest range)**	$\pm(Qf_{kHz} + 0.003\ f^2_{kHz})\%$**
Dissipation Factor, D: series capacitance **0 to 1**	. . .	±(0.001 ±5% of reading)	$\pm(0.001\ f_{kHz}$ + 5% of reading)
parallel capacitance **0.1 to 50**	. . .	±5% of reading (sliding null at high D)	± 5% of reading
Storage Factor, Q: series inductance **0.02 to 10**	. . .	±5% of reading (sliding null at low Q)	± 5% of reading
parallel inductance **1 to ∞**	. . .	±(5% of reading + 0.001) for 1/Q	$\pm$(5% of reading + 0.001 f_{kHz}) for 1/Q

* Full accuracy applies from 15 to 35°C, <85% RH (useful from 0 to 45°C). Residual terminal impedances of ≈0.3 pF, 0.15 μH, and 1 mΩ must be corrected to obtain specified accuracy.

** Terms apply to ac measurements when external phase balance is properly adjusted; otherwise accuracy is 0.5% of reading.

Generator: Internal, 1 kHz ±2% ac, 1.5 V dc. External, 20 Hz to 20 kHz ac; Type 1310 or 1311 Oscillator recommended.

Detector: Internal, 1 kHz ac with >20-dB rejection at 2nd harmonic or flat, meter indication; 10-μV/mm dc meter sensitivity. External, Type 1232 Tuned Amplifier and Null Detector recommended.

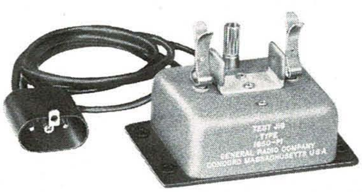
Bias: 600 V max on capacitors; small currents allowable on inductors and resistors; external only.

Terminals: ¾-in.-spaced binding posts for unknown; pin jacks for external ac generator and capacitor for ac phase balance; phone jacks for external detector, bias, and DQ adjustment.

Supplied: Batteries.

Oscillators pages 223, 226

Detector page 134



Flip-Tilt case provides complete protection.

Available: 1650-P1 Test Jig for rapid and convenient connection of axial-lead components to bridge. Permits 3-terminal connection for negligible zero capacitance, introduces 80-mΩ total lead resistance (which only affects measurements on very low impedances), and adds a D or 1/Q error of less than 0.007.

Power: 5 D-cells, supplied; battery checks provided.

Mechanical: Flip-Tilt cabinet. *Dimensions* (w x h x d): Portable, 13¼ x 12⅞ x 6$^{11}/_{16}$ in. (337 x 327 x 170 mm); rack, 19 x 12¼ x 5¾ in. (483 x 311 x 146 mm). *Weight*: Portable, 14.5 lb (7 kg) net, 21 lb (10 kg) shipping; rack, 15.5 lb (7.5 kg) net, 28 lb (13 kg) shipping.

Catalog Number	Description	Price in USA
	1656 Impedance Bridge	
1656-9701	Portable Model	**$700.00**
1656-9702	Rack Model	**735.00**
1650-9601	**1650-P1 Test Jig**	**35.00**

WHICH BRIDGE?

GR now offers three manual CRL bridges with differing accuracy, price, and features. While a study of their individual specifications should determine which is required, a few general guidelines may be helpful in making this choice:

1650-B: 1%, lowest priced. Orthonull® permits high-D and low-Q measurements without sliding null. Recommended for general measurements of components and particularly adaptable to measurements of networks, transformers, and other impedances where the phase angle may be unusually large.

1656: 0.1%, medium priced. The 0.1% accuracy applies to R, L, C, and G. This bridge is the obvious choice for measurements of precision components. In addition, it is well suited for incoming-inspection and quality-assurance applications. Where it is desirable to reduce the band of uncertainty to a minimum (0.1%), this bridge provides the best compromise between accuracy and price.

1608-A: 0.05%, highest priced. Its ac R and G bridges have phase (Q) balances so that any passive impedance can be measured without a bad sliding null; dc bridge supplies variable voltages up to 300 V on highest range. This bridge is often referred to as a "standards lab in a box." Recommended for highest accuracy (of loss as well as value) for ac measurements on networks and resistive devices.

Type 1650-B IMPEDANCE BRIDGE

- measures L, C, and loss; R and G
- 1% accuracy
- 20 Hz to 20 kHz, internal 1 kHz and dc
- portable, self-contained, battery-operated

The 1650 Impedance Bridge will measure the inductance and storage factor, Q, of inductors*, the capacitance and dissipation factor, D, of capacitors, and the ac and dc resistance or conductance of resistors.

In the laboratory it is extremely useful for measuring the circuit constants in experimental equipment, testing preliminary samples, and identifying unlabeled parts. In the shop and on the test bench it has many applications for testing and component sorting.

Three-terminal measurements can be made in the presence of considerable stray capacitance to ground.

Flip-Tilt case provides protection when bridge is not in use.

DESCRIPTION

This bridge is completely self-contained and portable. Battery-powered, low-drain transistor oscillator and detector are included. The panel meter indicates both dc and ac bridge unbalances.

The measured quantities, R, G, L, C, D, and Q, are indicated directly on dials with constant-percentage-accuracy logarithmic scales. Multiplier and the units of measurement are indicated by the range setting.

The bridge circuit elements are high-quality, stable components that ensure long-term accuracy. The Orthonull® balance finder, a patented mechanical-ganging device, is used to make a low-Q (high-D) balance possible without a sliding null. This mechanism, which may be switched in or out as desired, adds accuracy as well as convenience to low-Q measurements that are practically impossible on other impedance bridges.

The Flip-Tilt case provides a handle and a captive, protective cover that allows the bridge panel to be tilted and held firmly at any angle.

— See **GR Experimenter** for May 1968 and Aug-Sept 1968.

* Including such low-Q inductors as rf coils measured at 1 kHz.

specifications

RANGES OF MEASUREMENT / **ACCURACY**

	20 Hz to 20 kHz†	DC	Residuals
Capacitance 1 pF to 1100 μF, series or parallel, 7 ranges	±1% ±1 pF		≈0.5 pF
Inductance 1 μH to 1100 H, series or parallel, 7 ranges	±1% ±1 μH		≈0.2 μH
Resistance ac or dc, 1 mΩ to 1.1 MΩ, 7 ranges	±1% ±1 mΩ	±1%, 1 Ω to 100 kΩ, ext supply or detector required >100 kΩ and <1 Ω.	≈1 mΩ
Conductance ac or dc, 1 nanomho to 1.1 mhos, 7 ranges	±1% ±1 nanomho	±1%, 10 micromhos to 1 mho, ext supply or detector required <10 micromhos.	
Dissipation Factor, D, at 1 kHz, 0.001 to 1 of series C, 0.1 to 50 of parallel C.	±5% ±0.001 at 1 kHz and lower		
Storage Factor, Q, at 1 kHz, 0.02 to 10 of series L, 1 to 1000 of parallel L.	$\frac{1}{Q}$ accurate to ±5% ±0.001 at 1 kHz or lower		

† Bridge operates up to 100 kHz with reduced accuracy.

GENERAL

Generator: Internal; 1 kHz ±2%. Type 1310 or 1311 Oscillator recommended if external generator is required. Internal dc supply, 6 V, 60 mA, max.

Detector: Internal or external; internal detector response flat or selective at 1 kHz; sensitivity control provided. Type 1232-A Tuned Amplifier and Null Detector is recommended if external detector is required. Combination of 1311 oscillator and 1232 detector is available as the Type 1240 Bridge Oscillator-Detector.

DC Polarization: Capacitors can be biased to 600 V from external dc power supply for series capacitance measurements.

Power Required: 4 size-D cells, supplied.

Accessories Required: None. Earphones can be used for high precision at extremes of bridge ranges.

Accessories Available: Type 1650-P1 Test Jig.

Mounting: Flip-Tilt Cabinet.

Dimensions (width x height x depth): Portable, 13 x 6¾ x 12¼ in. (330 x 175 x 315 mm); rack, 19 x 12¼ x 4⅛ in. (485 x 315 x 105 mm).

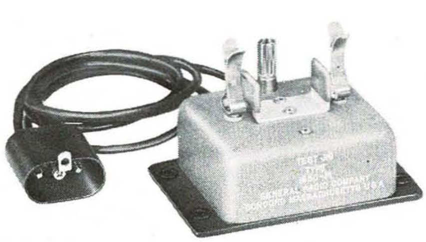
Net Weight: Portable, 17 lb (8 kg); rack, 18 lb (8.5 kg).

Shipping Weight: Portable, 21 lb (10 kg); rack, 30 lb (13.5 kg).

Catalog Number	Description	Price in USA
	1650-B Impedance Bridge	
1650-9702	Portable Model	**$525.00**
1650-9703	Rack Model	**560.00**
8410-0200	**Replacement Battery,** 4 req'd	**0.20**

PATENT NOTICE. See Notes 15 and 22.

Type 1650-P1 TEST JIG



This test-jig adaptor is used to connect components quickly to a pair of terminals and can be placed on the bench directly in front of the operator. Thus, the test jig and 1650-B or 1608-A Impedance Bridge make a rapid and efficient component sorting device when the panel meter of the bridge is used as a limit indicator.

The test jig makes a three-terminal connection to the bridge, so that the residual zero capacitance is negligible.

The lead resistance (0.08 ohm total) has effect only when very low impedances are measured, and the lead capacitance affects only the measurement of the Q of inductors, introducing a small error in D $\left(\text{or } \frac{1}{Q}\right)$ of less than 0.007.

Weight: Net, 10 oz (285 grams); shipping, 4 lb (1.9 kg).

Catalog Number	Description	Price in USA
1650-9601	**1650-P1 Test Jig**	**$35.00**

Type 1608-A IMPEDANCE BRIDGE

- measures C, R, L, and G with digital readout
- ±0.05% accuracy
- 20 Hz to 20 kHz (external generator)
- internal 1-kHz oscillator and detector
- measures impedance of any phase-angle
- accurate D and Q readings

This wide-range bridge will measure precision components to an accuracy of 0.05% — capacitance, inductance, and ac as well as dc resistance and conductance. An almost error-free readout and rapid-balance adjustments allow accurate and fast laboratory or production tests. Six bridge circuits cover all possible phase angles so that any network can be measured, even such "black boxes" as filters, transducers, and equalizers.

In ac resistance and conductance measurements, a Q adjustment for precise balancing gives phase information useful in predicting high-frequency behavior. This capability is also useful for measuring lossy reactances, such as rf chokes, without a sliding null. The high phase precision of ±0.0005 radian makes D or Q measurements meaningful on low-loss reactances, which must often have tight D or Q tolerances for use in precision networks.

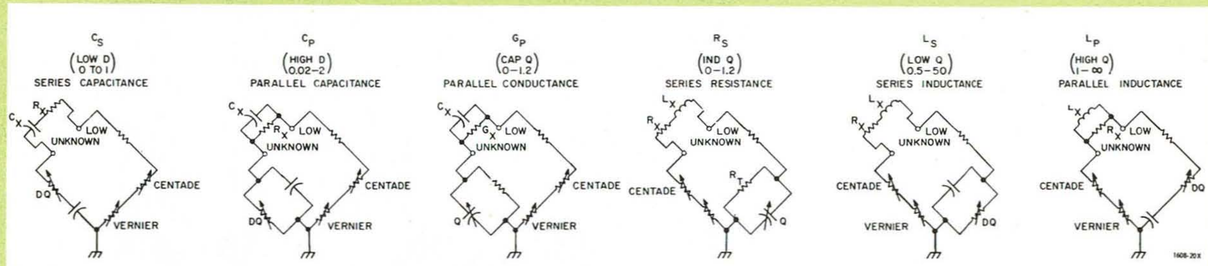
It will measure resistors at EIA-specified dc voltages, three-terminal capacitors and small capacitors remotely located, voltage-biased capacitors or current-biased inductors and resistors. Almost any impedance is measurable over the audio-frequency range.

The ability to measure small capacitances by a three-terminal connection makes possible the measurement of the capacitance between components, wires, or mounting structures. Long, shielded cables can be used without significantly affecting the accuracy of the measurement.

For production testing of components, a test jig, Type 1650-P1, is available.

DESCRIPTION

This self-contained bridge system includes six bridges, along with suitable ac and dc sources and detectors. The



Elementary schematics of the capacitance, conductance, resistance, and reactance bridges.

bridge elements are precision units. The wire-wound resistors are similar to those used in GR decade resistance boxes; the standard capacitor is a combination silver-mica and stabilized-polystyrene unit, with a low temperature coefficient.

The readout system is digital for C, R, L, and G, as well as for the Q of resistors. D and Q for capacitors and inductors are read from a dial with the correct scale illuminated. Decimal points and units are indicated automatically, and there are no multiplying factors for any quantity at 1 kHz or dc.

The C-R-L-G readout has both coarse and fine adjustments controlled by concentric knobs.

The 1-kHz frequency-selective networks for the internal oscillator and tuned detector are on a plug-in module, which can be easily replaced with modules available for other internal test frequencies. Provision is made for use with an external oscillator and detector. Three dc supplies are included to obtain maximum sensitivity over a wide range of resistance.

— See **GR Experimenter** for March 1962.

specifications

RANGES

Capacitance: 0.05 pF to 1100 μF in seven ranges, series or parallel.

Inductance: 0.05 μH to 1100 H in seven ranges, series or parallel.

Resistance: (series) 0.05 milliohm to 1.1 megohms, ac or dc.

Conductance: (parallel) 0.05 nanomho to 1.1 mhos, ac or dc (20,000 megohms to 0.9 ohm).

D: (of series capacitance) — 0.0005 to 1 at 1 kHz.
(of parallel capacitance) — 0.02 to 2 at 1 kHz.

Q: (of series inductance) — 0.5 to 50 at 1 kHz
(of parallel inductance) — 1 to 2000 at 1 kHz.
(of series resistance) — 0.0005 to 1.2 inductive at 1 kHz.
(of parallel conductance) — 0.0005 to 1.2 capacitive at 1 kHz.

Frequency: 1 kHz with internal oscillator module supplied; 20 Hz to 20 kHz with external oscillator.

ACCURACY

C, G, R, L

At 1 kHz: ±0.05% ±0.005% of full scale except on lowest R and L ranges and highest C and G ranges, where it is ±0.2% ±0.005% of full scale.

Additional % error terms for high frequency and large phase angle:

C and L: ($\pm 0.001 f^2_{kHz} \pm 0.1 D f_{kHz} \pm 0.5 D^2$)% of measured value.
R and G: ($\pm 0.002 f^2_{kHz} \pm 0.000001 f^4_{kHz} \pm 0.1 Q$)% of measured value.

Residual Terminal Impedance: $R \simeq 0.001\ \Omega$, $L \simeq 0.15\ \mu$H, $C \simeq 0.25$ pF.

DC Resistance and Conductance: Same as for 1-kHz measurement, except that accuracy is limited by sensitivity at the range extremes. Balances to 0.1% are possible from 1 ohm to 1 megohm with the internal supply and detector.

D $\left(\text{or } \frac{1}{Q}\right)$ of C or L: ±0.0005 ±5% at 1 kHz or lower.
$\pm 0.0005 f_{kHz} \pm 5\%$ above 1 kHz.

Q of R or G: $\pm 0.0005 f_{kHz} \pm 2\%$.

GENERAL

Generator: Internal, 1 kHz ±1% module normally supplied; plug-in modules for other frequencies available on special order. Level control provided. With external generator, frequency range of bridge is 20 Hz to 20 kHz. Type 1310-B or the 1210-C Oscillator recommended if external generator required. Internal dc supply 3.5, 35, and 350 V, adjustable; power limited to 1/3W or less.

Test Jig page 77

Detector: Internal or external; ac; can be used either flat or selective at frequency of plug-in module (normally 1 kHz); other frequencies available; second-harmonic rejection of 25 dB. Sensitivity control provided. Type 1232-A Tuned Amplifier and Null Detector recommended when external generator is used.

1310 Oscillator page 223

1232 Detector page 134

Dc Bias: Capacitors can be biased to 500 V from external source; bias current can be applied to inductors up to 40 mA.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz; 10 W.

Accessories Supplied: Power cord, spare indicator lamps.

Accessories Available: 1650-P1 Test Jig.

Mounting: Rack-Bench Cabinet.

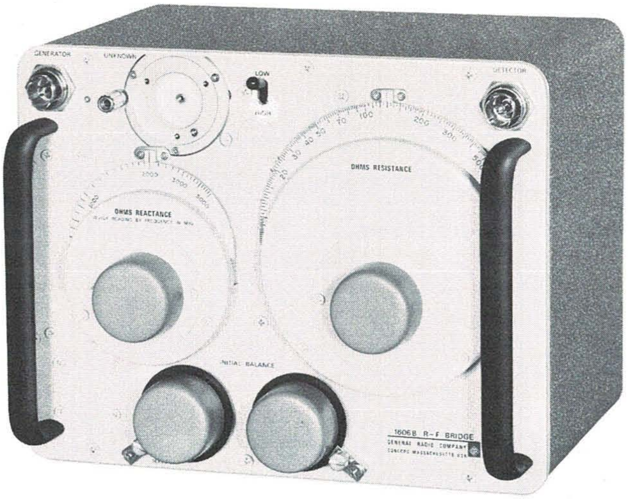
Dimensions (width x height x depth): Bench model, 19 x 12½ x 11½ in. (485 x 320 x 295 mm); rack model, 19 x 12¼ x 10 in. (485 x 315 x 255 mm).

Weight: Net, 36½ lb (17 kg); shipping, 54 lb (24.5 kg).

Catalog Number	Description	Price in USA
	1608-A Impedance Bridge	
1608-9801	Bench Model, 115 V	**$1550.00**
1608-9802	Bench Model, 230 V	**1550.00**
1608-9811	Rack Model, 115 V	**1550.00**
1608-9812	Rack Model, 230 V	**1550.00**

Type 1606-B RADIO-FREQUENCY BRIDGE

- 400 kHz to 60 MHz
- direct reading in ohms
- adaptable to coaxial connectors
- accurate, compact, simple operation



The 1606-B accurately and easily measures the resistance and reactance of antennas, transmission lines, networks, and components. It is particularly well suited for measuring low values of impedance of rf devices. Its range can be extended by means of an external parallel capacitor to measure high impedances.

PRECISION COAXIAL CONNECTIONS

In this latest model of the popular 1606 RF Bridge, the UNKNOWN terminals are adaptable to coaxial connectors, in particular the GR900. This is a significant advantage that not only permits the measurement of components having coaxial fittings but also ensures better repeatability and more accurate definition of the measurement plane. This permits the 1606 to be precision calibrated against coaxial standards such as the 1406 Coaxial Capacitance Standards and the various GR900® precision components; open- and short-circuits, 50-, 100-, and 200-ohm Standard Terminations, and the various lengths of precision air line.

ACCESSORY ADAPTOR KIT

With the 1606-P2 adaptor kit, the 1606-B can be fitted to accept GR900 and GR874® connectors (the adaptors include compensation to match 50-ohm standards and components); it will also accept a 14-mm flange connector (a GR900 flange is included to convert GR900 connectors), or it can be adapted to other common connectors (N, BNC, TNC, etc) by the use of GR900 adaptors.

DESCRIPTION

Measurements are made by a series-substitution method in which the bridge is first balanced with a short circuit across the unknown terminals. The short is then removed, the unknown impedance connected, and the bridge rebalanced.

The entire mechanical design is such that the instrument can operate under difficult environmental conditions similar to those specified for testing military electronics equipment, which makes the 1606-B bridge an excellent instrument for field use.

— See **GR Experimenter** for September 1967.

specifications

RANGES OF MEASUREMENT	ACCURACY
Reactance: ±5000 Ω at 1 MHz. This range varies inversely as the frequency; at other frequencies the dial reading must be divided by the frequency in MHz.	**Reactance:** At frequencies up to 50 MHz, ±2% ±(1 + 0.0008 Rf)Ω where R is the measured resistance in ohms and f is the frequency in MHz.
Resistance: 0 to 1000 Ω.	**Resistance:** At frequencies up to 50 MHz, $\pm\left[1\% + 0.0024f^2\left(1+\frac{R}{1000}\right)\% \pm \frac{10^{-4}X}{f}\,\Omega + 0.1\,\Omega\right]$ (where X is the measured reactance in ohms). Subject to correction for residual parameters.

Frequency: 400 kHz to 60 MHz.

Satisfactory but somewhat less accurate operation can be obtained at frequencies as low as 100 kHz and somewhat above 60 MHz.

Generator: External only (not supplied), to cover desired frequency range. Recommended, Type 1211-C and Type 1215-C Unit Oscillators, Type 1330-A Bridge Oscillator, Type 1310-A Oscillator, Type 1003 Standard-Signal Generator.

Detector: External only (not supplied). A heterodyne detector, Type DNT-5 or DNT-6, is recommended. A well shielded radio receiver is also satisfactory.

Accessories Supplied: 2 leads of different lengths to connect unknown impedance to bridge terminals; ½-in. spacer and ¾-in. screw to mount component to be measured directly on bridge terminals; 874-R22LA Patch Cord.

Accessories Available: Luggage-type carrying case, 1606-P2 Precision Coaxial Adaptor Kit.

Mounting: Welded aluminum cabinet.

Dimensions (width x height x depth): 12½ x 9½ x 10¼ in. (320 x 245 x 260 mm).

Weight. Net, 23 lb (10.5 kg), with case, 29 lb (13.5 kg); shipping, 30 lb (14 kg), with case, 31 lb (14.5 kg).

specifications for 1606-P2

Capacitance Added: By adaptor to GR900, 0.38 pF at reference plane (less fringing capacitance); by flange adaptor, 0.18 pF.

Weight: Net, 10 oz (270 g); shipping, 12 oz (340 g).

Catalog Number	Description	Price in USA
1606-9702	**1606-B Radio-Frequency Bridge**	**$1295.00**
1606-9601	**1606-P1 Luggage-Type Carrying Case**	**30.00**
1606-9602	**1606-P2 Precision Coaxial Adaptor Kit**	**120.00**

CAPACITANCE BRIDGES

TWO-TERMINAL AND THREE-TERMINAL CONNECTIONS

Most capacitors can be represented by the three capacitances shown in Figure 1: the direct capacitance C_{HL}, capacitance between the plates of the capacitor and the two terminal capacitances, C_{HG} and C_{LG}, which are capacitances from the corresponding terminals and plates to the capacitor case, surrounding objects, and to ground (to which the case is connected either conductively or by its relatively high capacitance to ground).

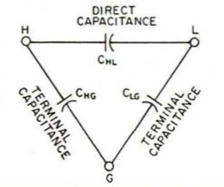
In the two-terminal connection, the capacitor has the L and G terminals connected together, i.e., the L terminal is connected to the case. The terminal capacitance, C_{LG}, is thus shorted, and the total capacitance is the sum of C_{HL} and C_{HG}. Since one component of the terminal capacitance C_{HG} is the capacitance between the H terminal and surrounding objects, the total capacitance can be changed by changes in the environment, particularly by the introduction of connecting wires. Such changes can cause uncertainties of a few tenths of a picofarad in the calibration of two-terminal capacitors that use banana pins for the connection. More accurate two-terminal calibrations, with connection uncertainties no more than a few femtofarads (thousandths of a picofarad) can be made by use of precision coaxial connectors such as the GR900® connectors used on Type 1406 Coaxial Capacitance Standards. For accuracy at high frequencies, i.e. around 1 MHz, such precision two-terminal connections are necessary. At lower frequencies, i.e. around 1 kHz, precision two-terminal connections are useful, but here most of the connection uncertainties can be eliminated by the use of three-terminal capacitors and measurements[1].

A three-terminal capacitor (Figure 1) has connected to the G terminal a shield that completely surrounds at least one of the terminals (H), its connecting wires, and its plates except for the area that produces the desired direct capacitance to the other terminal (L). Changes in the environment and the connections can vary the terminal capacitances, C_{HG} and C_{LG}, but the direct capacitance C_{HL} is determined only by the internal geometry.

This direct capacitance can be calibrated by three-terminal measurement methods, which use guard circuits or transformer-ratio-arm bridges to exclude the terminal capacitances.

The direct capacitance can be made as small as desired, since the shield between terminals can be complete except for a suitably small aperture. The losses in the direct capacitance can also be made very low because the dielectric losses in the insulating materials can be made a part of the terminal impedances. When the three-terminal capacitor is connected as a two-terminal, the two-terminal capacitance will exceed the calibrated three-terminal value (C_{HL}) by at least the terminal capacitance C_{HG}.

Figure 1.



Measurements on very large capacitors are subject to uncertainties due to series impedance that can be avoided by four-terminal measurements, a technique regularly used in precision measurement of low resistance.

AUTOMATIC BRIDGES

GR automatic bridges combine the accuracy and stability of classical bridge techniques with digital logic circuits to form automatic instruments which permit high-speed measurements of impedance. The basic instruments feature short measurement time, completely automatic operation, and accuracies sufficient for most high-volume testing of components. They provide coded data outputs for automatic error-free recording of data and for use in completely automatic systems.

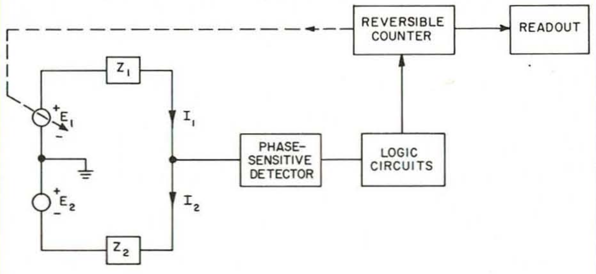


Figure 2. Generalized Diagram of Automatic Bridges.

The basic bridge circuit (Figure 2) of GR 1680 and 1682 automatic bridges is similar to that of the transformer-ratio-arm bridge.[2]

In this circuit the bridge is at balance when $I_1 = I_2$. If the bridge is unbalanced and, say, current I_1 is greater than I_2, the phase-sensitive detector and logic circuitry cause the reversible counter to count in a reverse direction. This counter controls electronic switches to decrease the value of the voltage E_1 until balance is achieved. At balance the counter displays the value of the unknown.

Only one set of controls has been shown — actually there are two which simultaneously balance the in-phase and quadrature components of the signal. When a null in both components is achieved, the bridge simultaneously displays the value of both the reactive and resistive parts of the component's impedance.

This bridge method is superior to the direct-measurement method which was in use before automatic bridges were first introduced in 1964. In the direct method, an

[1] John F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," General Radio Experimenter, July 1959.

[2] M. C. McGregor, J. F. Hersh, R. D. Cutkosky, F. K. Harris, and F. R. Kotter, "New Apparatus at the National Bureau of Standards for Absolute Capacitance Measurements," IRE Transactions on Instrumentation, vol. I-7, pp 253-261; December, 1958. Also available as General Radio Reprint A-78.

ac voltage is applied directly to the component under test and the resulting current is measured with a phase-sensitive detector and digital voltmeter. While simple in principle, it is very difficult to build a phase detector with the required characteristics. To measure accurately a capacitor's dissipation factor of 0.001, for example, requires the accurate measuring of a signal in the presence of an out-of-phase signal 1000 times larger. Very small phase shifts could cause severe errors so that time-consuming adjustments were often necessary to attain the required accuracy. In GR automatic bridges, the phase detector is used only to control the direction of balance — its amplitude and exact phase characteristics are not important. In common with other bridge circuits, the accuracy is determined by the value of stable, passive impedance standards.

In the 1683, a bridge circuit using active elements provides a much wider impedance range than is possible with the transformer-ratio-arm circuit described above. This arrangement also makes it convenient to measure resistance and inductance as well as capacitance. Accurate measurements of impedance as low as a few milliohms (capacitances as high as 200,000 μF) cannot be made on a transformer-ratio-arm bridge because the low impedance would load the ratio transformer to the point where it would no longer appear as an ideal voltage source. The use of precision dividers and "ideal" amplifiers in the bridge circuit provides the necessary isolation so that wide variations in impedance level do not affect accuracy. The amplifiers are "ideal" in the sense they have high enough open-loop gain so that their transfer function essentially depends only upon the ratio of two fixed passive components. The high open-loop gain also permits their input and output impedances to appear infinite or zero (depending upon their use in the bridge) compared with the impedance levels of adjacent circuitry. These amplifiers also make possible the display of the loss term for capacitance measurements in terms of dissipation factor (D) or equivalent series resistance (ESR). Finally, the use of active circuitry in the bridges makes possible four- and five-terminal connections that enable measurements with micro-ohm resolution.

MANUAL OR AUTOMATIC?

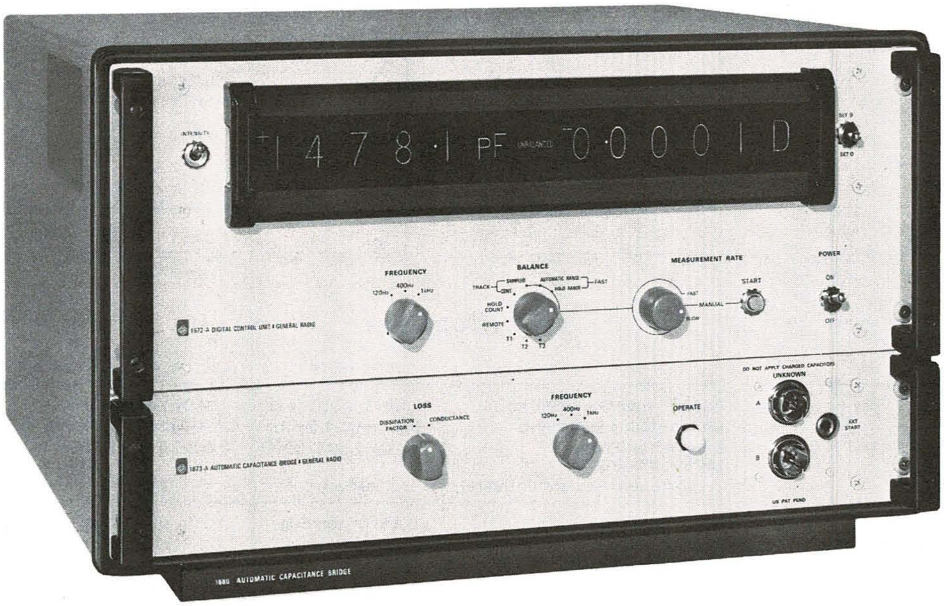
	Manual Bridges	Manual Impedance Comparators	Automatic Bridges	Automatic Bridge Systems
Measurement Rate	<300/h	300 to 3000/h		>3000/h
Data Recording and Sorting Decisions	Manual			automatic
Absolute Values Deviation from Standard	R, L, C —	— R, L, C	C, G R, L, C	
Operator Skill Needed	moderate	low		
Equipment Costs	**<$1000**	**$1000**	**$5000**	**$7000 and up**

APPLICATION AREAS

Application Area	1680-A	1682	1683
Capacitance Measurements General use, mica, plastic, paper	Direct reading in C and D or G over 7 decade ranges, 4 measurements per second.	Direct reading in C and G over 4 decade ranges, 16 measurements per second	Direct reading in C and D over 9 decade ranges, 20 measurements per second
Ceramics	1-kHz, 1-V signal	1-MHz, 0.5 to 500-mV signal	1-kHz, 0 to 2.2-V signal
Low-loss plastic and glass	D accuracy 0.001	G resolution 0.01 μV	D accuracy 0.001
Semiconductor	1-kHz, 1-V signal, no errors due to strays	1-MHz, low-level signal, adjustable dc bias, no errors due to strays or lead impedances	1-kHz, low-level signal, adjustable dc bias, no errors due to strays or lead impedances
Electrolytics	Useful to 1000 μF, 5-second balance at 120 Hz, reads parallel capacitance	———	Accurate to 200,000 μF, <1-second balance at 120 Hz, reads series ESR and tests leakage current, no errors due to lead impedances
Inductance Measurements	Reads negative capacitance	———	Direct reading in inductance
Resistance Measurements	Reads conductance	Reads conductance	Direct reading in resistance
Sorting, Inspection, QC	Wide range, fast and simple operation, data output		
Material Studies	Fast, automatic operation, 120, 400, 1000 Hz	Fast, automatic operation, 1 MHz, adjustable signal level and dc bias	Fast, automatic operation, 120, 1000 Hz, adjustable signal level and dc bias
Temperature Coefficient and Life Tests	Direct reading to 0.1%, can read ΔC to 100 ppm, tracking mode over all ranges		
Process Control	Programmable controls, data output, rapid balances, tracking mode over all ranges		

Type 1680 AUTOMATIC CAPACITANCE BRIDGE ASSEMBLY

- 0.01 pF to 1000 μF
- $\pm$0.1% of reading accuracy
- 120, 400, 1000 Hz
- ½-second automatic balance at 1 kHz
- true bridge circuit — 3-terminal connection
- BCD output data



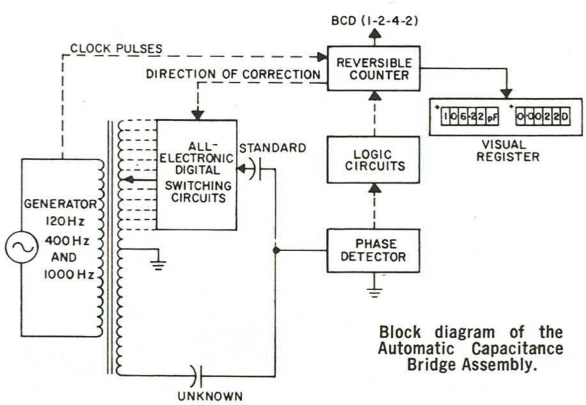
The Automatic Capacitance Bridge Assembly is a fully automatic, all-solid-state three-terminal, capacitance bridge. It is a true bridge, relying on stable, passive standards for its accuracy.

USES

The 1680-A is an accurate, fast, and economical test device for production and laboratory applications where a great many capacitance measurements are needed. Its range and accuracy cover most capacitor-measurement requirements.

In component-inspection applications, measurement rate is up to ten times faster than is possible with manually balanced bridges.

In capacitor production applications, this bridge can be used as an integral part of automatic manufacturing processes to monitor production automatically.



Block diagram of the Automatic Capacitance Bridge Assembly.

In qualification testing, quality control, and reliability studies, freedom from stray-capacitance effects permits accurate measurements at the end of long cables, such as those necessary to connect to capacitors in environmental chambers. Lead resistance is negligible in the measurement of all but very large capacitors (see accuracy curves).

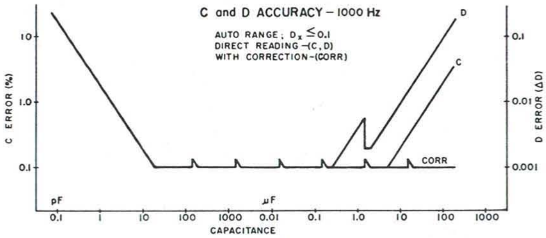
ACCESSORY EQUIPMENT

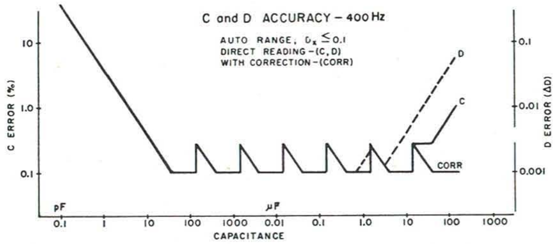
Many devices are available for more fully automated measurements with the 1680. Up to 100 components can be connected to the bridge in sequence, automatically, with the 1770 Scanner System. An integral part of an automatic sorting system is the 1781 Digital Limit Comparator. Data from the bridge can be collected fast and accurately on an 1137 Data Printer, an analog recorder, or other equipment such as card- and tape-punch machines.

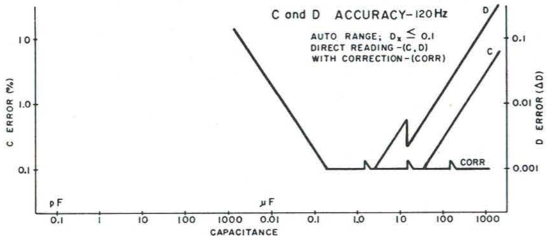
DESCRIPTION

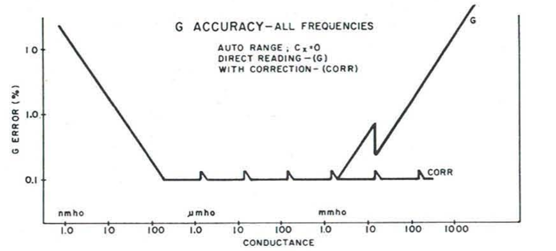
The circuit is a transformer-ratio-arm bridge. It is in balance when the currents through the standard capacitor and the unknown capacitor are equal so that the current in the phase detector is zero. The phase detector compares currents in the unknown and standard arms and produces an error signal that controls a reversible counter, which changes the voltage on the standard capacitor, in the proper direction to equalize the two currents and produce a null. At balance, the value of the unknown is displayed on an in-line digital readout, which indicates capacitance, dissipation factor or conductance, decimal points, and units. This information is also presented in binary-coded-decimal form for use with printers and other data-handling equipment.

— See **GR Experimenter** for June-July 1968.









specifications

		At 120 Hz	At 400 Hz	At 1000 Hz
RANGES	**Capacitance (parallel)*:**	0.0001 μF-1000 μF	0.01 pF-100 μF	0.01 pF-100 μF
	Conductance (parallel):	0.1 μmho-1.0 mho	0.0001 μmho-1.0 mho	0.0001 μmho-1.0 mho
	Dissipation Factor (direct reading)	0.0001-1.00 (100%)	0.0001-1.00 (100%)	0.0001-1.00 (100%)
	(Measured as conductance):	0 to ∞	0 to ∞	0 to ∞
BASIC ACCURACY (see curves)	**Capacitance:**	0.1% of reading	0.1% of reading	0.1% of reading
	Conductance:	0.1% of reading	0.1% of reading	0.1% of reading
	Dissipation Factor:	1% of reading ±0.001	1% of reading ±0.001	1% of reading ±0.001
SPEED OF BALANCE (approx) (Speed may be somewhat lower than that listed when dissipation factor is measured near the low end of each range.)	**Fast Modes:**			
	No range changes	2.5 seconds	0.35 second	0.25 second
	With range changes	5.0 seconds	0.6 second	0.5 second
	Tracking Modes:			
	10-count change	1.0 second	0.1 second	0.1 second
	100-count change	2.0 seconds	0.35 seconds	0.2 second
	1000-count change	11.0 seconds	2.6 seconds	1.1 seconds

* For series capacitance measurements a correction (chart supplied) can be used: If $D_x = 0.1$ (10%), correction = 1%. If $D_x = 0.03$ (3%), correction = 0.1%.

EFFECTS OF LEADS: There is no error introduced by stray capacitance if shielded cables are used. Series resistance of leads can cause errors on the highest range. Accuracy curves include the effects of up to 50 mΩ of external cable.

Voltage Across Unknown: At 120 Hz, 1 V to 1.5 μF, 100 mV to 15 μF, 10 mV to 150 μF, 1 mV to 1000 μF; at 400 and 1000 Hz, 1 V to 150 nF, 100 mV to 1.5 μF, 10 mV to 15 μF, 1 mV to 100 μF. Voltage can be set internally to as little as 1/10 these values with proportionate loss in resolution.

DISPLAY: Two 5-digit banks of bright-light, numerical indicators, with decimal points and units of measurement. Lamp burnout does not affect instrument operation or coded output. Lamps can be replaced from front panel.

DC BIAS: Can be introduced from external source.

REMOTE CONTROL: Start and balance controls can be activated remotely by contact closures.

OUTPUT SIGNALS

Numerical Data: 10 digits BCD 1-2-4-2 code (1-2-4-8 available).

Range Code (1 to 7): 1 digit BCD 1-2-4-2 code (1-2-4-8 available).

Print Command at Completion of Balance: Change from "1" level to "0" level — returns to "1" level at end of display interval.

Signal Levels: "1" level, 0 V; "0" level, −12 V; both with respect to reference line, which is at +6 V above chassis ground. Impedance of lines = 12 kΩ.

MEASUREMENT RATE: Panel control allows adjustment of measurement rate so that display time between measurements is between approx 0.1 and 5 s. The rate can be set manually (or remotely) at any rate compatible with balance time.

OPERATION AT OTHER MEASUREMENT FREQUENCIES: With internal modification, the measurement frequencies can be changed to any frequency between 100 Hz and 2 kHz.

DIFFERENCE MEASUREMENTS: By the addition of a suitable standard to terminals provided, the bridge can be made to indicate the deviation, either positive or negative, from a nominal value.

GENERAL

Power Required: 105 to 125 V, 195 to 235, or 210 to 250 V, 50 to 60 Hz, 100 W. Internal 120-Hz oscillator is locked to power line for 60-Hz operation.

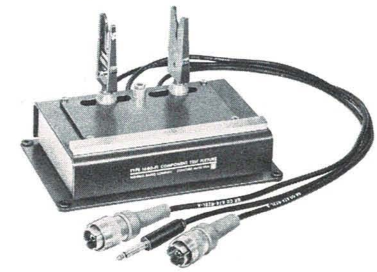
Auxiliary Controls: A rear-panel sensitivity control can be used to minimize balance time by a decrease in resolution.

Dimensions (width x height x depth): 19½ x 12 x 19 in. (495 x 305 x 485 mm).

Weight: Net, 77 lb (35 kg); shipping, 150 lb (70 kg).

Catalog Number	Description	Price in USA
	1680-A Automatic Capacitance Bridge Assembly	
1680-9702	115 V, 60 Hz, Bench	**$5250.00**
1680-9703	115 V, 60 Hz, Rack	**5250.00**
1680-9704	115 V, 50 Hz, Bench	**5250.00**
1680-9705	115 V, 50 Hz, Rack	**5250.00**
1680-9706	220 V, 50 Hz, Bench	**5250.00**
1680-9707	220 V, 50 Hz, Rack	**5250.00**
1680-9708	230 V, 50 Hz, Bench	**5250.00**
1680-9709	230 V, 50 Hz, Rack	**5250.00**
1680-9601	**1680-P1 Test Fixture**	**105.00**

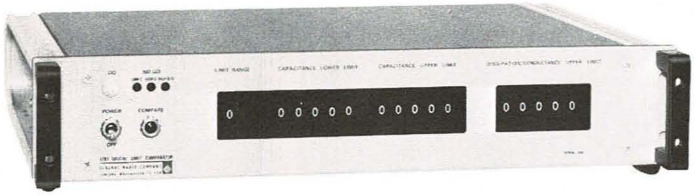
PATENT NOTICE. See Note 8.



1680-P1 Test Fixture facilitates connection of capacitors to the bridge. Capacitor leads are inserted in the clips and the bridge balances when bar marked PRESS is pressed.

Type 1781 DIGITAL LIMIT COMPARATOR

- 0.1% sorting with automatic capacitance bridge
- compares capacitance and loss with manually preset limits
- GO-NO GO visual indication and relay contacts



The digital limit comparator automatically compares the BCD output of the 1680, 1682, and 1683 Automatic Capacitance Bridges with limits for high and low C and high D or G that are preset (with appropriate range) on front-panel thumbwheels. Panel lights show if the capacitor under test is in tolerance or, if not, the reason: HIGH C, LOW C, or HIGH D or G. Relay contacts are provided to actuate external GO-NO GO indicators or automatic sorting mechanisms. Several comparators can be used together for multiple-tolerance sorting.

— See **GR Experimenter** for November-December 1966.

specifications

RANGE OF LIMIT SETTINGS: 00000 to 19999 for both C and D/G.
ACCURACY: Same as that of data source.

INPUT
Data: 11 digits, BCD, 1-2-4-2 (1-2-4-8 optional).

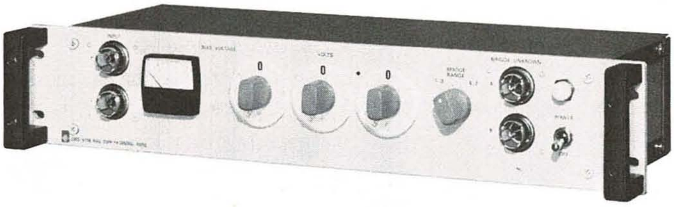
OUTPUT
Data: Identical to input.
Comparison Result: BCD digit, behind 10 kΩ.
Print Command: Logic 1 to logic 0 transition, behind 2.2 kΩ.
Relay Contacts: Internal contact protection provided for 115 V, ac, rms, 0.1 A max. Contacts rated for 500 V max, 2 A max, 100 VA with appropriate contact protection.

GENERAL
Accessories Supplied: Power cord, signal cable to connect comparator to measuring instrument.
Accessories Required: If sorting equipment is used, 4205-1010 cable is also needed.
Power Required: 105 to 125 or 210 to 250 V (195 to 235 V also available), 50 to 60 Hz, 10 W.
Cabinet: Rack-bench.
Dimensions (width x height x depth): Bench, 19 x 4 x 16½ in. (485 x 105 x 420 mm); rack, 19 x 3½ x 16 in. (485 x 89 x 410 mm).
Weight: Net, 20 lb (9.5 kg); shipping, 30 lb (14.0 kg).

Catalog Number	Description	Price in USA
	1781 Digital Limit Comparator	
1781-9801	Bench Model	$1700.00
1781-9811	Rack Model	1700.00
4205-1010	**Accessory Cable** (to sorting equipment)	65.00

2995-9158 BIAS SUPPLY

NEW



- 0 to 50 V, up to 40 mA
- programmable

The measurement of capacitors under dc bias has become more than an occasional task for the Type 1680 Automatic Capacitance Bridge, and we have responded to this and other requirements with a companion bias supply, the 2995-9158.

This supply provides a bias voltage adjustable from 0 to 50 volts in increments as small as 0.1 volt. (Several supplies can be used in series to permit a combined bias voltage up to 150 V.) Voltages can be remotely programed or manually set, and a panel meter serves to indicate the output level. The 2995-9158 also protects the GR 1680 and handling equipment from large current surges by instantaneously limiting the current whenever a charged or shorted capacitor is inadvertently connected for measurement.

An additional feature of this bias supply is the very low series impedance it presents to the bridge test signal. This eliminates the need for corrections to the GR 1680 readings on all but the highest capacitance range.

specifications

Voltage: 0 to 50 V, adjustable in 0.1-V increments with 3 in-line-readout dials.
Accuracy: ±(0.2% + 10 mV) typical. *Stability,* ±(0.1% + 1 mV) typical for 8 h. *Regulation,* ±(0.2% + 10 mV) from 100 to 125 V ac line. *Ripple,* <100 μV rms.
Current: 40 mA positive, 10 mA negative. Transient current limited to <100 mA within 2 μs.
Impedance: <0.2 Ω, up to 1 kHz. Added 3-terminal capacitance <1 pF. Limit impedance 1 kΩ + 100 Ω/V.
Programming: 100-Ω/V, connected between two rear-panel connectors.
Environmental: Operating temperature 0 to 50°C. Temperature coefficient of voltage ±(0.1% + 1 mV)/°C typical.
Accessories Supplied: Power cord, two locking GR874® coaxial connectors, and two 2994-1007 one-foot coaxial cables.
Mechanical: Rack mount only. *Dimensions* (w x h x d) 19 x 3½ x 6⅜ in. (485 x 89 x 165 mm). *Weight,* 10¼ lb (4.7 kg) net, 12¼ lb (6 kg) shipping.

Catalog Number	Description	Price in USA
2995-9158	**Bias Supply**	**$800.00**

Type 1682 AUTOMATIC CAPACITANCE BRIDGE 1 MHz

- 0.001 pF to 0.02 μF
- 0.1% basic accuracy
- 20 measurements per second
- 0 to 100 V built-in bias

NEW

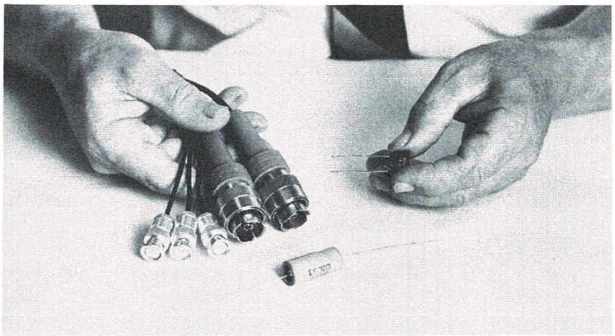
1682 Automatic Capacitance Bridge
with optional 1682-P1 Test Fixture

Why measure capacitance at 1 MHz? Whatever your reason, you'll find that with the GR 1682 it is as easy at 1 MHz as at much lower frequencies. Use of 1 MHz as the test frequency permits accurate measurement of small values of capacitance in the presence of large values of shunt conductance as found in many semiconductor devices and in rf networks. Many military and commercial test specifications require 1-MHz measurement of small solid-dielectric capacitors, like ceramics, whose capacitance may vary with frequency.

The 1682 is a true bridge with transformer ratio arms and precision impedance standards for high accuracy and ensured long-term stability. Five-terminal connection for the unknown minimizes the effects of lead impedances. The 1682 is a second-generation automatic GR bridge that is fast and reliable.

The 1682 provides five-digit resolution for capacitance measurements and four-digit resolution for concurrent loss measurements, expressed as parallel conductance. All measurements can be made with internal bias voltages from 0 to 100 V or any external bias voltage up to 200 V. The signal level on the unknown can be reduced on the lower two ranges (0.001 pF to 200 pF) to accommodate the more voltage sensitive devices.

A continuous-tracking mode is provided for voltage- and temperature-coefficient studies. Full programmability is available with an array of inputs and outputs for such enhancements as data printing, card punching, computer control, and scanner inputs.



Five Wires for a Two-Terminal Device?

Yes! The four-terminal (Kelvin) connections minimize lead-impedance effects and preserve the accuracy of the bridge *at the component* even with low-impedance unknowns. And the fifth, or ground, terminal provides a similar safeguard with high impedances whose measurement might otherwise be affected by stray capacitance to ground.

specifications

Measurement	Range	*Accuracy (% of reading)
CAPACITANCE With concurrent loss measurement displayed as parallel conductance	00.001 to 1999.9 pF	0.1% ± 1 count
	02.00 to 19.99 nF	1% ± 1 count
CONDUCTANCE Concurrent with capacitance measurement	00.01 to 1999 μ℧	1% ± 1 count
	02.0 to 19.9 m℧	10% ± 1 count

* Specified at the end of a 4-foot cable to unknown.

1682-P1 Test Fixture for axial-lead components

Display: 5-digit capacitance readout (4 digits on highest range, 0.001 to 20 nF) and 4-digit conductance readout (3 digits on highest range, 1 to 20 m℧); each with high-intensity neon readout tubes, decimal point, and unit-of-measurement. Display also indicates unbalanced condition.

Speed: Measurement rate is ≈20 measurements per second for ±10% of full-scale change in unknown, 6/s for full-scale change, and 3/s with range changes. Interval between measurements can be infinite (measurements initiated by front-panel pushbutton front-panel control so that measurements are repetitive. A or external closure to ground) or from ≈ 1 to 0.02 s as set by *tracking mode* provides continuous balances to monitor changing unknowns.

1682-P2 Test Fixture with GR900® terminals

Terminals: Five-terminal connection that minimizes errors due to lead impedance and stray capacitance to ground are made by coaxial cables at the front of the instrument. A 1682-P1 Test Fixture is available for the rapid connection of axial-lead components and contains a start button to initiate the measurements. A 1682-P2 Text Fixture is available for the connection of GR900® connector-terminated components such as the GR 1405, 1406, and 1407 Coaxial Capacitance Standards. A 1682-P3 Test Fixture is available for the connection of GR 874®-connector-terminated components such as the GR 1403 Standard Capacitors or, by means of a 777-Q3 Adaptor, to any component with ¾-in.-spaced binding posts. *Stray capacitance:* Up to 5 pF on lowest range and 0.5 pF on next-to-lowest range across the test fixtures can be cancelled by an adjustment on the rear of the 1682.

Ranges: Four. Ranging can be automatic, manual, or remote.

1682-P3 Test Fixture with GR874® terminals

Oscillator Level: Voltage applied to unknown can be reduced from the normal 500 and 50 mV rms on the lower two ranges to 50 and 25 mV, with a 1-digit resolution loss, for special applications.

Sensitivity: Can be manually or remotely reduced from maximum, with consequent loss of resolution, to overcome problems with nonlinear or rapidly changing unknowns, or external noise or hum pickup.

Bias: 0 to 100 V internal, source impedance 100 kΩ, manually or remotely set; 200 V max external. A BNC connector is provided to monitor the level.

Interface: *Low-level Data Output,* 50-pin Amphenol Type 57 connector provides 10 digits of measurement data (5 for capacitance, 4 for conductance, 1 for range) plus various control inputs and outputs for systems use. Digits are 1-2-4-8-weighted BCD at standard TTL logic levels (logic "0" ≈ ground with 10-mA sink capability, logic "1" ≧+3.5 V). *High-level Data Output,* same except all outputs are 15-V swing (logic "0" ≈ ground, with 10-mA sink capability, logic "1" ≈ +15V behind 12 kΩ). *Remote Programmability — Option 2,* 50-pin Amphenol Type 57 connector provides terminals for external remote programming of all control functions except line-voltage control. Functions are controlled by closures to ground or standard TTL or DTL signals.

Accessories Supplied: Power cord.

Accessories Available: 1682-P1, -P2, and -P3 Test Fixtures, printers, recorders, card-punch couplers, scanners, limit comparators.

Power: 100 to 125 and 200 to 250 V, 50-60 Hz, 60 W.

Mechanical: Bench or rack mount.

Dimensions (w x h x d): Bench, 19 x 7⅞ x 24¾ in. (485 x 200 x 630 mm); rack, 19 x 7 x 23⅛ in. (485 x 180 x 590 mm).

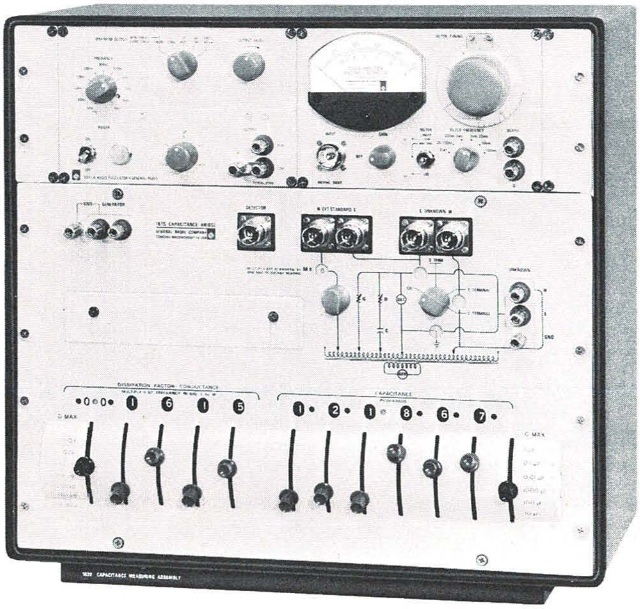
Weight: Bench, 59 lb (27 kg) net, 74 lb (34 kg) shipping; rack, 50 lb (23 kg) net, 67 lb (31 kg) shipping.

Description	Price in USA
1682 Automatic Capacitance Bridge (1 MHz)	
Bench Model	**$3975.00**
Rack Model	**3940.00**
Option 2 Remote Programmability, not available without option 5A or 5B	add **200.00**
*Option 5A Low-Level Data Output	add **200.00**
*Option 5B High-Level Data Output	add **200.00**
1682-P1 Test Fixture, for axial leads	**110.00**
1682-P2 Test Fixture, GR900® terminals	**110.00**
1682-P3 Test Fixture, GR874® terminals	**75.00**

* Not available together in the same instrument.

Type 1620-A CAPACITANCE-MEASURING ASSEMBLY

- 10^{-5} pF to 11.1 μF, 2 or 3 terminal
- 0.01% accuracy, 1 ppm resolution
- lever balance, in-line readout
- reads dissipation factor or conductance



1620-A Capacitance-Measuring Assembly including: 1615-A Capacitance Bridge, 1311-A Oscillator, 1232-A Tuned Amplifier and Null Detector

The 1620-A is a self-contained assembly of the GR 1615-A Capacitance Bridge with appropriate oscillator and null detector for measurements at 11 frequencies between 20 Hz and 20 kHz. For applications requiring other or higher frequencies, to 100 kHz, the 1615-A bridge can be supplied separately and the oscillator and detector selected as needed.

The 1620-A is intended for

- accurate and precise measurements of capacitance and dissipation factor
- measurement of circuit capacitances
- dielectric measurements
- intercomparison of capacitance standards differing in magnitude by as much as 1000:1

The 1615-A Capacitance Bridge brings to the measurement of capacitance, to the intercomparison of standards, and to the measurement of dielectric properties an unusual degree of accuracy, precision, range, and convenience.

High accuracy is achieved through the use of precisely wound transformer ratio arms and highly stable standards fabricated from Invar and hermetically sealed in nitrogen. For calibration these standards can be intercompared.

TWO- OR THREE-TERMINAL CONNECTION

Accurate three-terminal measurements can be made even in the presence of capacitances to ground as large as 1 μF as might be encountered with the unknown connected by means of long cables. The bridge has the necessary internal shielding to permit one terminal of the unknown to be directly grounded, so that both true two-terminal and three-terminal measurements can be made over the whole capacitance range.

CONVENIENT OPERATION

For both capacitance and dissipation factor, the balance controls are smoothly operating, lever-type switches. The readout is digital, and the decimal point is automatically positioned. Each capacitance decade has a -1 position to facilitate rapid balancing.

The circuit, shown here in elementary form, is also clearly delineated on the panel. Changes in connections and grounds are automatically indicated as the bridge terminals are switched for different measurement conditions.

EXTEND RANGE TO 11.1 μF

With the 1615-P1 Range-Extension Capacitor the 1615-A will measure to a maximum of 11.11110 μF. It plugs into front-panel bridge terminals and can be adjusted for calibration to the bridge.

— See **GR Experimenter** for August-September 1962.

specifications

(see 1615 for performance specifications)

Frequency: 50, 60, 100, 120, 200, 400, 500, 1000, 2000, 5000, and 10,000 Hz. For use below 100 Hz, 1620-AP (with preamplifier) should be used for resolution beyond 0.01% or 0.01 pF.

Generator: 1311-A Oscillator.

Detector: 1232-A Tuned Oscillator and Null Detector. 1232-P2 Preamplifier added in 1620-AP.

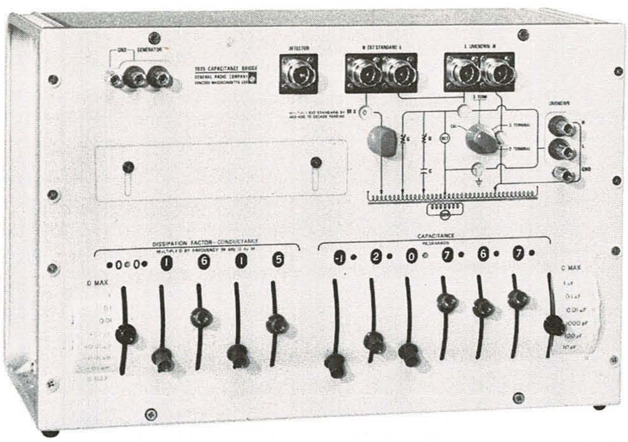
Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 22 W for oscillator. Null detector and preamplifier operate from internal battery.

Mounting: Assembled in cabinet.

Weight: Net, 59 lb (27 kg); shipping, 96 lb (44 kg).

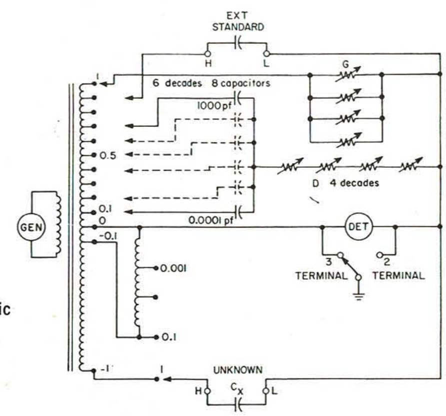
Catalog Number	Description	Price in USA
1620-9701	**Capacitance-Measuring Assembly 1620-A**	**$2700.00**
1620-9829	**1620-AP, with 1232-P2 detector preamplifier**	**2790.00**
8410-1372	**Replacement Battery,** 9 req'd	**1.95**

Type 1615-A CAPACITANCE BRIDGE



The 1615-A is an accurate, high-precision bridge for the measurement and intercomparison of standard capacitors, circuit component capacitors, or dielectric materials. It is available with oscillator and detector in the 1620 assembly listed on the previous page. Or, to take full advantage of its wide frequency range, the bridge can be ordered separately for use with oscillator and detector especially selected for the purpose or already in hand.

— See **GR Experimenter** for August-September 1962.



Elementary schematic diagram of the capacitance bridge.

specifications

RANGES OF MEASUREMENT	ACCURACY
Capacitance, 10 aF to 1.11110 μF (10^{-17} to 10^{-6} farad) in 6 ranges, direct-reading, 6-figure resolution; least count 10^{-17} F (10 aF). With Range-Extension Capacitor, upper limit is 11.11110 μF.	At 1 kHz, $\pm$(0.01% + 0.00003 pF). At higher frequencies and with high capacitance, additional error is $[\pm 3 \times 10^{-5}\% + 2 \times 10^{-3}\% (C_{\mu F}) \pm 3 \times 10^{-7}\,\mathrm{pF}] \times f^2_{kHz}$. At lower frequencies and with low capacitance, accuracy may be limited by bridge sensitivity. Comparison, accuracy, unknown to external standard, 1 ppm.
Dissipation Factor, D, At 1 kHz, 0.000001 to 1, 4-figure resolution; least count, 0.000001; range varies directly with frequency.	$\pm[0.1\%$ of measured value $+ 1 \times 10^{-5} (1 + f_{kHz} + 5\, f_{kHz}\, C_{\mu F})]$
Conductance, G, 10^{-6} μ℧ to 100 μ℧, 2 ranges +, 2 ranges —, 4-figure resolution, least count 10^{-6} μ℧ independent of frequency; range varies with C range.	$\pm[1\%$ of measured value $+ 1 \times 10^{-5}\ \mu$℧ $+ 6 \times 10^{-2} f_{kHz} C_{\mu F} \times (1 + f_{kHz} + 5\, f_{kHz}\, C_{\mu F})\ \mu$℧$]$

FREQUENCY: Approx 50 Hz to 10 kHz. Useful with reduced accuracy to 100 kHz. Below 100 Hz, resolution beyond 0.01% or 0.01 pF requires preamplifier or special detector.

GENERAL

Standards: 1000, 100, 10, 1, 0.1, 0.01, 0.001, 0.0001 pF. Temperature coefficient of capacitance is less than 5 ppm/°C for the 1000-, 100-, and 10-pF standards, slightly greater for the smaller units.

Generator: Type 1310-A or 1311-A oscillator recommended. Max safe generator voltage 30 x f_{kHz} volts, 300 V max. If generator and detector connections are interchanged, 150 to 500 V can be applied, depending on switch settings.

Detector: Type 1232-A Tuned Amplifier and Null Detector recommended. For increased sensitivity needed to measure low-loss small capacitors (on lowest C and D ranges simultaneously) at frequencies below 1 kHz, use 1232-AP.

Accessories Supplied: 874-WO Open-Circuit Termination, 874-R22A Patch Cord, 274-NL Patch Cord.

Accessories Available: Type 1615-P1 Range-Extension Capacitor. 1615-P2 Coaxial Adaptor converts 2-terminal binding-post connection on 1615 bridge to GR900 Precision Coaxial Connector for highly repeatable connections; enables measurements with adaptor to be direct-reading by compensating for terminal capacitance.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench model, 19 x 12¾ x 10½ in. (485 x 325 x 270 mm); rack model, 19 x 12¼ x 8½ in. (485 x 315 x 220 mm); 1615-P1, 3-1/16 in. dia. x 4⅞ in. (78 x 125 mm).

Weight: Net, 38½ lb (17.5 kg); shipping, 58 lb (27 kg).

Catalog Number	Description	Price in USA
	1615-A Capacitance Bridge	
1615-9801	Bench Model	**$1795.00**
1615-9811	Rack Model	**1795.00**
1615-9601	**1615-P1 Range-Extension Capacitor**	**65.00**
1615-9602	**1615-P2 Coaxial Adaptor, GR900 to binding posts**	**75.00**

Oscillators page 220 ff

1232 Detector page 134

Type 1617-A CAPACITANCE BRIDGE

- 1 pF to 1.1 farads
- 20 Hz to 1 kHz
- 1% accuracy
- 2-, 3-, or 4-terminal connections

SELF-CONTAINED BRIDGE

The 1617-A was specifically designed for measuring capacitance, dissipation factor, and leakage current of electrolytic capacitors, but it will also find considerable use as a general-purpose 1% bridge. It is completely self-contained, including a 120-Hz generator, null detector, dc polarizing-voltage supply, and metering for bias voltage and leakage current. At frequencies other than 120 Hz, an external oscillator is needed.

Calibrate with 1426 page 111

MULTITERMINAL CONNECTIONS

An unknown capacitor can be connected to the bridge by means of three- or four-terminal connections, as well as the usual two-terminal. The four-terminal connection permits accurate measurement of large capacitance by reducing the effect of the resistance and inductance of leads and connections. Correct readings of small capacitances are assured by the three-terminal connection, which reduces the effect of stray lead capacitance. These multiterminal configurations are necessary for accurate measurement of capacitors connected by long cables as, for instance, in tests on capacitors in an environmental chamber.

This bridge includes an Orthonull® balance finder, which speeds up measurements of high-dissipation-factor capacitors by eliminating troublesome sliding balance. The operator's safety is assured by warning lights indicating the presence of voltage on the bridge terminals.

— See **GR Experimenter** for June 1966.

specifications

Quantity	Frequency	Range	Accuracy *
Capacitance	120 Hz internal	0 to 0.11 F	±1% ±1 pF, smallest division 2 pF; residual ("zero") capacitance approx 4 pF
		0.11 F to 1.1 F	±2%
	40 Hz to 120 Hz external (useful down to 20 Hz with reduced accuracy)	0 to 1.1 F	Same as above with suitable generator
	120 Hz to 1 kHz external	0 to 1 F $\left(\frac{100}{f_{Hz}}\right)^2$	±1% ±1 pF with suitable generator and precautions
Dissipation Factor	120 Hz internal or 40 Hz to 120 Hz	0 to 10 $\frac{f_{Hz}}{120}$	±0.001 ±0.01 C ±2%
	120 Hz to 1 kHz	0 to 10	(±0.001 ±0.01 C) $\frac{f_{Hz}}{120}$ ±2%

* C is expressed in farads.

Lead-Resistance Error (4-terminal connection): Additional capacitance error of less than 1% and D error of 0.01 for a resistance of 1Ω in each lead on all but the highest range, or 0.1Ω on the highest range.

FREQUENCY RANGE

Internal Test Signal: 120 Hz (synchronized to line) for 60-Hz model; 100 Hz for 50-Hz model. Selectable amplitude less than 0.2 V, 0.5 V, or 2 V. Phase reversible.

External Test Signal: 20 Hz to 1 kHz with limited range (see above).

DC VOLTAGE AND CURRENT

Internal DC Bias Voltage and Voltmeter: 0 to 600 V in 6 ranges.

Voltmeter Accuracy: ±3% of full scale.

Internal DC Bias Current: Approx 15 mA max.

Ammeter Range: 0 to 20 mA in 6 ranges. Can detect 0.5-μA leakage.

Ammeter Accuracy: ±3% of full scale.

External Bias: 800 V max.

GENERAL

Power Required: 105 V to 125 V or 210 V to 250 V, 60 Hz, 18 W max. Models available for 50-Hz operation.

Accessories Supplied: Four-lead and shielded two-lead cable assemblies.

Accessories Required: None for 120-Hz measurements. The 1311-A Oscillator is recommended for measurement at spot frequencies, the 1310-A Oscillator for continuous frequency coverage.

Oscillators page 220 ff

Mounting: Flip-Tilt Case. Rack model also available.

Dimensions (width x height x depth): Portable, 16¼ x 15 x 9 in. (415 x 385 x 230 mm); rack, 19 x 14 x 6⅛ in. (485 x 355 x 160 mm).

Net Weight: Portable model, 26 lb (12 kg); rack model, 28 lb (13 kg).

Shipping Weight: Portable model, 34 lb (15.5 kg); rack model, 43 lb (20 kg).

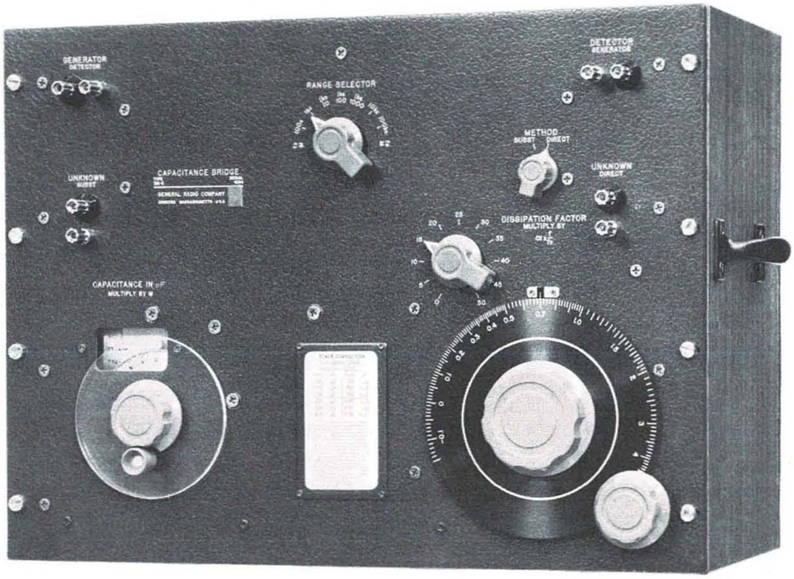
Catalog Number	Description	Price in USA
	1617 Capacitance Bridge	
1617-9701	Portable Model (115 V, 60 Hz)	**$1325.00**
1617-9286	Portable Model (230 V, 60 Hz)	**$1325.00**
1617-9206	Portable Model (115 V, 50 Hz)	**$1325.00**
1617-9266	Portable Model (230 V, 50 Hz)	**$1325.00**
1617-9820	Rack Model (115 V, 60 Hz)	**$1325.00**
1617-9296	Rack Model (230 V, 60 Hz)	**$1325.00**
1617-9216	Rack Model (115 V, 50 Hz)	**$1325.00**
1617-9276	Rack Model (230 V, 50 Hz)	**$1325.00**

The 1617 Capacitance Bridge is designed especially for measuring these large-valued capacitors, as well as other electrolytic types, most of which require the special measurement conditions prescribed by MIL or EIA specifications:

Specification and Capacitor Type	Frequency	AC Level	Accuracy C	Accuracy Loss	DC Polarizing Voltage
MIL C-3965-C MIL C-39006-A Tantalum Foil and Sintered Slug Capacitors	120 ± 5 Hz	Less than 30% of dcwv or 1 V, pk, whichever is smaller (Less than 1V rms for 39006A)	2%	R or P.F. 2% (P.F. 2% for -39006A)	C—Sufficient for no reversal of polarity. D—"Polarized Capacitance Bridge" Sum of ac and dc shall not exceed DCWV (Less than 2.2 V for 39006A)
MIL C-26655-B MIL C-39003 Solid Tantalum Capacitors MIL C-39018 Aluminum Oxide Capacitors	120 ± 5 Hz	Limited to 1V, rms	2%	D, 10% (2% for -39003 and -39018)	C—Max bias 2.2 V. D—"Polarized Bridge", 2.2-V dc max.
RS 228 Tantalum Electrolytic Capacitors	120 Hz	Small enough not to change value	±2½%	D, 5%	Optional
MIL C-62 B Polarized Aluminum Capacitors	120 ± 5 Hz	Limited to 30% of DCWV or 4 V, whichever is smaller	2%	D, 2%	No bias required if ac voltage less than 1 V. However, if bias causes differences, measurements with bias shall govern.
RS 154 B Dry Aluminum Electrolytic Capacitors	120 Hz	Small enough not to change value	±2½%	R or RC	Optional, but if substantial difference occurs, rated dc should be used.
RS 205 Electrolytic Capacitors for use in Electronic Instruments	120 Hz	Small enough not to change value	±2½%	D	Optional

Type 716-C CAPACITANCE BRIDGE

- 30 Hz to 300 kHz
- C: 0.1 pF to 1.1 μF, $\pm$0.1%
- D: 0.00002 to 0.56, $\pm$2%



The 716-C is a modified Schering bridge that measures capacitance and dissipation factor by either direct or substitution method.

This capacitance bridge is particularly well suited to the measurement of the dielectric properties of insulating materials and to the measurement of small values of capacitance and/or large values of dissipation factor at high and low frequencies. With corrections, accurate results can be obtained to 1 MHz.

By substitution methods, one can measure the inductance and Q of large inductors, the inductance and resistance of cables, the resistance and parallel capacitance of high-valued resistors, and the conductance and parallel resistance of electrolytes.

specifications

RANGES OF MEASUREMENT	ACCURACY
Capacitance (direct-reading) 100 pF to 1.1 μF at 1 kHz, 100 pF to 1150 pF at 100 Hz, 10 kHz, and 100 kHz.	At 30 Hz to 300 kHz $\pm$0.1% $\pm$(0.6 pF $\times$ capacitance multiplier setting) when D $<$0.01. Residual C is approx 1 pF.
Capacitance (substitution) 0.1 pF to 1050 pF with internal standard. 0.1 pF up to value of available standard with external standard.	$\pm$1.2 pF. Correction chart for the precision capacitor is supplied, which allows a substitution measurement accuracy of $\pm$0.05% or $\pm$0.6 pF. With additional Precision Calibration of standard capacitor, $\pm$0.05% or $\pm$0.2 pF.
D (direct reading) 0.00002 to 0.56	$\pm$0.0005 or $\pm$2% of dial reading, whichever is larger.
D (substitution) 0.00002 to 0.56 $\times \frac{C_{STD}}{C_{UNK}}$	$\pm$0.00005 or $\pm$2% for the change in D when the change is less than 0.06. Corrections are supplied for greater D's.

GENERAL

Temperature and Humidity Effects: Bridge accuracy not significantly affected by variations of temperature from 65 to 95°F. Precise measurements of dissipation factor should not be attempted when the bridge has been exposed to abnormally high relative humidity, unless it is first dried by heat or a desiccant.

Generator: External only (not supplied); 30 Hz to 300 kHz; 1 W max, which allows 200 V at 1 kHz or 50 V at 60 Hz. If generator and detector connections are interchanged, 700 V can be applied at 1 kHz and lower. Type 1311-A or 1310-A Oscillator recommended.

Detector: External only (not supplied). Type 1232-A Tuned Amplifier and Null Detector recommended for audio range; for higher frequencies, add 1232-P1 Mixer and local oscillator.

Accessories Supplied: 274-NL Shielded Patch Cord, 874-R34 Patch Cord.

Accessories Available: Type 1422 Precision Capacitor, 1409 Fixed Capacitors, and 1423 Precision Decade Capacitor as balancing capacitors for substitution measurements. Type 1690-A Dielectric Sample Holder for dielectric measurements.

Mounting: Wooden cabinet or relay rack.

Dimensions (width x height x depth): Bench model, 21¾ x 14¼ x 11¼ in. (555 x 365 x 290 mm); rack model, 19 x 14 x 9 in. (485 x 360 x 230 mm).

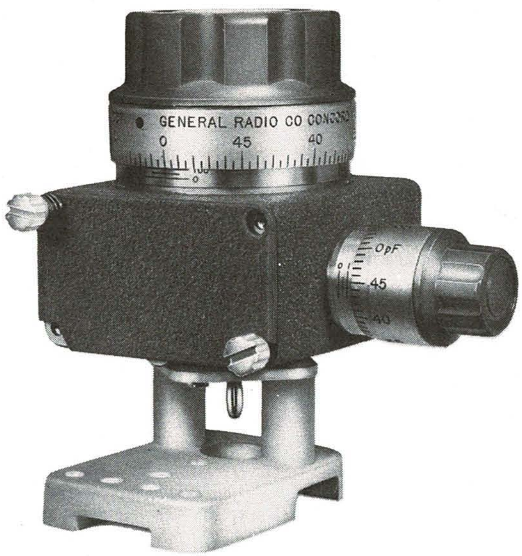
Net Weight: Bench model, 40½ lb (18.5 kg); rack model, 30½ lb (14 kg).

Shipping Weight: Bench model, 55 lb (25 kg); rack model, 45 lb (20.3 kg).

Catalog Number	Description	Price in USA
	716-C Capacitance Bridge	
0716-9803	Bench Model	**$1250.00**
0716-9483	with Precision Calibration	**1330.00**
0716-9813	Rack Model	**1200.00**
0716-9484	with Precision Calibration	**1280.00**

PATENT NOTICE. See Note 15.

Type 1690-A DIELECTRIC SAMPLE HOLDER



- micrometer-electrode-type for dielectric disks
- wide frequency range; fits many instruments
- calibration corrects for fringing and strays
- stable mounting, complete shielding

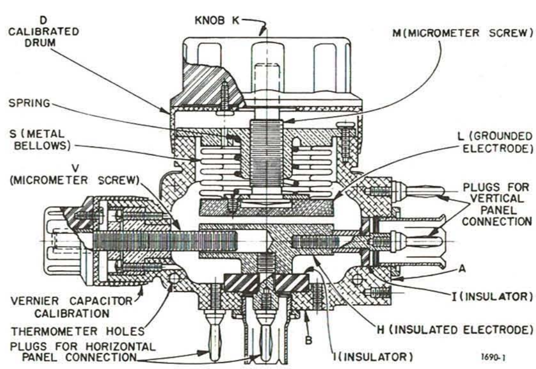
The 1690-A is a sample-holder of the Hartshorn and Ward type,* used for the measurement of dielectric constant, dissipation factor, and volume resistivity of 2-inch-diameter, or less, disks of dielectric material in accordance with ASTM test method D-150. It is suitable for any flat sample whose largest diameter is not over 2 inches and whose thickness is not over 0.3 inch.

It can be used with resonant circuits for susceptance-variation or frequency-variation measurements, with the Types 1615-A and 716-C Capacitance Bridges, the 874-LBB and 900-LB Slotted Lines, the 1602-B and 1609 immittance meters, and the 1644-A Megohm Bridge.

A precision micrometer screw, M, with large instrument knob, K, drives the movable grounded electrode, L, with respect to a fixed, insulated electrode, H. An accurately divided drum, D, indicates the electrode spacing. The micrometer screw is electrically shunted by a metal bellows, S, to assure a positive, low-resistance connection. A release mechanism automatically disengages the drive to prevent damage when the electrodes are in contact. The movable electrode adjusts itself to the plane of the specimen surface.

The vernier capacitor with micrometer screw, V, is for use in the susceptance-variation method of measurement, and for precise C balance with low-loss samples.

The assembly is mounted in a rugged aluminum casting, B, which shields it on four sides. Two removable cover plates, which permit access to the electrodes, complete the shielding. The holder can be mounted on either horizontal or vertical panels.



* L. Hartshorn and W. H. Ward, Proceedings of the Institution of Electrical Engineers, Vol. 79, pp. 597-609 (1936).

specifications

Electrodes: Diameter, 2.000 in. ± 0.0025 in. Surfaces ground optically flat within a few wavelengths.

Electrode Spacing: Adjustable from zero to 0.3 in., indicated by micrometer reading in mils.

Vernier: Incremental capacitance is 5 pF, nominal.

Calibration: For main capacitor, a chart gives calculated air capacitance as a function of spacing. Correction curve gives the measured deviations from calculated values over range from 300 mils to 10 mils spacing. In accordance with recommended ASTM practice, calibration is referred to the calculated geometric value at a spacing of 100 mils. Accuracy is ±0.2% ±0.1 mil.

For vernier capacitor, correction chart is provided, from which capacitance differences can be determined to an accuracy of ±0.004 pF.

Zero Capacitance: Approx 11 pF.

Operating Temperature: Up to 100°C.

Frequency: No significant error occurs at frequencies below 100 MHz.

Accessories Supplied: 1690-P1 Adaptor Assembly for mounting to 1615-A and 716-C Capacitance Bridges; hardware for mounting sample holder on 1644-A Bridge and 1862-C Megohmmeter.

Accessories Available: 1690-P2 Adaptor Assembly to 874-LBB Slotted Line or 1602-B UHF Admittance Meter; 900-Q874 Adaptor to 900-LB Precision Slotted Line and 1609 UHF Immittance Bridge.

Mechanical Data: Carrying and storage case supplied.

Dimensions: 6¼ x 5¾ x 4½ in. (160 x 150 x 115 mm).

Weight: Net, 3¾ lb (1.8 kg); shipping, 13 lb (6 kg).

Catalog Number	Description	Price in USA
1690-9701	**1690-A Dielectric Sample Holder**	**$695.00**
1690-9602	**1690-P2 Adaptor Assembly (for connecting to GR874 coaxial equipment)**	**50.00**

RESISTANCE MEASURING

This section describes a completely self-contained resistance-limit bridge, megohm bridge, and three megohmmeters, one of which measures up to 200 TΩ. These instruments are but a part of our total resistance-measuring capability. Five other instruments are offered: These are impedance bridges capable of capacitance and inductance measurements as well as resistance measurements. They are shown in the tinted blocks below and are more fully described earlier in this catalog. Of particular interest to those engaged in production testing or incoming inspection is the Type 1662 Resistance-Limit Bridge, capable of up to 4 measurements per second.

50 100 μΩ | 1 mΩ | 1 2 Ω | 1 50 kΩ | 1.1 2 20 111 MΩ | 200 1000 TΩ

1608: *±0.1% accuracy,* comparison precision within 10 ppm. Measurements can be made at dc or from 50 Hz to 10 kHz. Features 6-digit resolution by means of in-line readout dials with automatic decimal point.

1656: *±0.1% accuracy.* Measurements can be made at dc or 1 kHz. Balance is achieved by 4 in-line readout lever switches. Portable, low-cost, high-precision bridge.

1683: *±0.1% accuracy, automatic bridge.* Measurements can be made at 120 Hz or 1 kHz. Fully automatic bridge with 5-digit resolution and provisions for full systems use. 5-terminal connections to unknown.

1650-B: *±1% accuracy.* Measurements can be made at dc or 1 kHz. Completely self-contained, battery operated. Excellent low-cost, general-purpose bridge.

1662: *±0.01% comparison accuracy.* Measures resistance difference from self-contained standard with meter calibrated in percent. Also contains high and low limit settings with go, no-go lamps.

1654: *±0.003% comparison accuracy.* Measures resistance differences with meter calibrated in ohms. 1654 systems include standard and limit comparator.

1644: *±1% accuracy.* Megohm bridge with 7 test voltages and self-checking internal standards. Resistance difference measurements accurate to ±0.2%.

1862-C, 1863, 1864: *Up to 3% accuracy.* Megohm meters from 2 to 200 different test voltages (10 to 1000 V) depending on type.

Type 1662 RESISTANCE LIMIT BRIDGE

- Resistance range from 1 Ω to 111 MΩ
- Deviation range from ±0.01 to ±30%
- 0.01% comparison precision
- go, no-go indications
- up to 4 measurements per second
- four-terminal Kelvin connections

NEW

Limit bridge shown with 1662-P1 Test Fixture for rapid connection of axial-lead components

When GR introduced the 1652 Resistance Limit Bridge seventeen years ago, it not only met industry's requirements for a fast and accurate method of sorting resistors, it also proved a valuable tool for matching pairs of resistors or comparing them to a standard sample. With so much in its favor, it seemed unlikely that anything more than imaginary improvements would be made. But time, state-of-the-art advances, and imaginative engineering caught up with the 1652 and it has been replaced by a worthy successor, the 1662.

The 1662 provides greater accuracy, go, no-go limits, increased deviation-resolution, accuracy, and resistance range, four-terminal measurement capability, and much greater reliability. And to these improvements are added a test fixture for greater convenience and speed, increased comparison resolution for more precise temperature-coefficient measurements, and outputs for auxiliary equipment to permit automatic or semi-automatic sorting or control of thin-film trimming processes.

Although the basic elements of the 1662 are simple, each is very carefully designed for the best possible combination of features. The dc generator is guarded and shielded to reduce stray leakage paths to ground and to preserve the accuracy even at range extremes. The Kelvin bridge consists of exceptionally stable resistors adjusted to an accuracy of better than 0.01%. It is an active bridge, linearized to measure the resistance deviations as a percent of the standard. The preamplifier is a highly sensitive photo-chopper amplifier that provides high gain but low noise and drift, and its gain is stabilized by feedback around the over-all system. In addition to driving a large front-panel meter with center-scale zero, the preamplifier output is used by a set of analog limit-comparator circuits that compare the deviation to a preset voltage level. The result of the comparison is then indicated by front-panel lamps and made available at a rear connector for use by auxiliary equipment.

When resistance measurements are required, the 1662 is a natural, either as a complete self-contained instrument or as the nucleus of a larger, more sophisticated system.

specifications

Resistance Range: 1Ω to 111.1111 MΩ, controlled by 4-position multiplier switch and 7 in-line readout dials with decimal point.

Resistance Accuracy: ±(0.02% + 2 mΩ + 0.02% long-term); long-term factor can be removed by calibration.

Deviation Range: ±0.01 to ±30%, controlled by 5-position range switch with full-scale ranges of 0.3, 1, 3, 10, and 30%.

Deviation Accuracy: ±3% of full-scale deviation range (e.g., on 0.3% range, accuracy is ±0.01%).

Bridge Multiplier (R_x/R_s)	0.1	1	10	100
Range of Unknown	1 to 111 kΩ	10 to 1.11 MΩ	100 to 11.1 MΩ	10 kΩ to 111 MΩ
Voltage on Unknown*	0.11 V	0.2 V	1.1 V	10.1 V
Voltage on Standard	1.1 V	0.2 V	0.11 V	0.101 V
Resistance Resolution	0.01 Ω	0.1 Ω	1 Ω	10 Ω

* Varies with deviation from nominal; current is held constant. Power dissipated in unknown is <12 mW from 1Ω to 111 MΩ.

Display: Meter indicates percent deviation. Limit lamps indicate high, go, or low condition. *High and low limits* independently adjustable from 0 to 100% of deviation range with a direct accuracy of ±2% of full scale.

Speed: 1 measurement/s using meter indication, 4/s using limit indication.

Interface: *Unknown connection* is by means of a 1662-2400 cable, supplied, terminated in banana plugs or alligator clips for 4-terminal measurements. **1662-P1** Test Fixture available for rapid connection of axial-lead components. *Analog voltage output* proportional to meter deflection (±10-V full scale, 0.003% resolution) provided at two sockets on rear: one with an output impedance of <10 Ω to drive a 1782 Analog Limit Comparator, the other with an output impedance of ≈ 2 kΩ to drive a DVM or dc recorder, etc. *Limit voltage output,* transition from ≈ 13 V to ≈ 0.2 V behind 10 kΩ for high, go, or low indication to drive external circuits. *Limits programmable* by means of dc voltages, from 0 to ±10 V with source impedance <10 Ω, applied to rear connector.

Supplied: 1662-2400 cable for connection to unknown, 7- and 9-contact connectors for external connections, 5 alligator clips, and power cord.

Available: 1782 Analog Limit Comparator for comparison to additional limits, 1662-2400 cable for connection of external standard.

Environmental: *Operating temperature,* 10 to 40°C. *Zero drift,* <2 ppm/°C from 10 to 40°C.

Power: 100 to 125 or 200 to 250 V, 50-60 Hz, 17 W.

Mechanical: Rack-bench cabinet. *Dimensions* (w x h x d): Bench, 19.75 x 8.688 x 14.812 in. (502 x 221 x 376 mm); rack, 19 x 7 x 14.812 in. (483 x 178 x 376 mm). *Weight:* Bench, 28 lb (13 kg) net, 36 lb (16.5 kg) shipping; rack, 21½ lb (10 kg) net, 28 lb (13 kg) shipping.

Catalog Number	Description	Price in USA
	1662 Resistance Limit Bridge	
1662-9700	Bench Model	**$1200.00**
1662-9701	Rack Model	**1165.00**
1662-9601	**1662-P1 Test Fixture**	**110.00**

Type 1644-A MEGOHM BRIDGE

- 10^3 to 10^{15} ohms
- 1% accuracy to 10^{12} ohms
- ΔR measurements to $\pm 0.2\%$
- seven test voltages
- self-checking internal standards

The 1644-A will measure:

- **Insulation Resistance** of cables, transformers, chokes, components, connectors, wiring, terminals, resistors, capacitors, relays, printed circuits, rotating machines, switches, circuit breakers, meters, strain gages, thermocouples, delay lines, slip rings, commutators, heaters, filters, lightning arresters, and other devices.
- **Resistance** of high-valued resistors, rersistance films, diodes, transistors, and piezoelectric elements.
- **Voltage and Temperature Coefficients** of resistance.
- **Volume and Surface Resistivity** of solids, s uch as printed-board material, resins, plastics, potting and casting compounds, rubber, refractories, and semiconductors; of liquids, such as oils, plasticizers, and solvents; and of sheet materials, including plastics, recording tape, and varnished fabrics.

The circuit is a dc Wheatstone bridge with a high-impedance, high-sensitivity detector. Precision, wire-wound resistors are used for the fixed bridge arm and the lower-valued decade-step arms. Metal-film and carbon-film resistors are used for the higher decade steps, with trimmers for precise adjustment in terms of the wire-wound standards. The balancing arm is a wire-wound variable resistor.

The guard terminal eliminates the effects of stray resistances to ground. For capacitor leakage resistance measurement, charging time is a fraction of a second.

— See **GR Experimenter** for July 1964.

specifications

Resistance Range: 1 kΩ to 1000 TΩ (10^3 to 10^{15} Ω) in ten ranges.
Accuracy: 10^3 Ω to 10^{10} Ω, ±1%. After self-calibration: 10^{10} to 10^{12} Ω, ±1%*; 10^{13} Ω, ±2%; 10^{14} Ω, ±10%; 10^{15} Ω, ± one scale division.
ΔR% Dial: ±5% range; accurate to ±0.2% or, for small changes, to ±0.1%.
Test Voltage: Voltage accuracy is ±3% ±0.5 V.

Fixed Voltages**	10	20	50	100	200	500	1000	V
Minimum Unknown R	1	3	7	20	50	150	500	kΩ

Minimum Test Voltage for 1% Resolution: for approx 1-mm meter deflection	Multiplier Setting	Max R_x	Volts
	100 G or less	10^{11}	10
	100 G	10^{12}	100
	1 T	10^{13}	200

* At high voltages; 1% accuracy is obtainable at 10 V up to 10^{11} Ω; see above.
** Any voltage between 10 and 1000 V may be obtained using an external resistor.

Short-Circuit Current: <15 mA, 10-50 V; <10 mA, 100-1000 V.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 13 W.

Mounting: Flip-Tilt Case or rack mount.

Dimensions (width x height x depth): Portable model, 12¾ x 12½ x 7¾ in. (325 x 320 x 200 mm); rack model, 19 x 12¼ x 5 in. (485 x 315 x 130 mm).

Weight: Net, 19 lb (9 kg); shipping, 31 lb (14.5 kg).

Catalog Number	Description	Price in USA
	1644-A Megohm Bridge	
1644-9701	Portable Model	**$875.00**
1644-9820	Rack Model	**885.00**

PATENT NOTICE. See Notes 1, 15, and 22.

Type 1863 and Type 1864 MEGOHMMETERS

Type 1863
- 5 test voltages: 50 to 500 V
- 50 kΩ to 20 TΩ (2 x 10^{13}Ω)
- economical, simple operation
- direct reading, safe, stable

Type 1864
- 200 test voltages: 10 to 1090 V
- 50 kΩ to 200 TΩ (2 x 10^{14}Ω)
- direct reading, safe, stable
- simple operation

If one of these GR megohmmeters doesn't exactly suit your high-resistance-measurement needs, the other one should. Although similar in appearance and accuracy, their operating ranges differ to match differing needs in the laboratory and production area.

The Choice for Production and Inspection

The Type 1863 Megohmmeter will measure resistance at any of five common test voltages up to 500 V, has fewer controls, and is the lower priced model. It is, therefore, the best selection when several test stations are to be equipped, when the operators are inexperienced, or when specifications call for standard insulation-testing voltages.

The Choice for Laboratory Investigations

The 1864 is the more flexible of the two instruments. The test voltage can be set to any value from 10 to 109 volts in 1-volt steps and to 1090 volts in 10-volt steps. Thus, the 1864 can be set to any common, or uncommon, test voltage for ceramic, mica, or paper capacitors, or other devices. The reverse resistance of rectifiers can be readily measured; the low test voltages available are especially useful in measuring solid-state diodes. An additional range permits measurements up to 2 × 10^{14} ohms (200 TΩ).

Both instruments are easy to use with direct-reading meter indication and lighted range switch that shows the multiplier for each range and voltage. The maximum current possible at the terminals is limited to a safe 5 milliamperes and a panel light near the terminals warns when voltage is present. Stable power supplies and feedback voltmeter circuit minimize drift and time-wasting adjustments. Guard and ground terminals permit measurement of grounded or ungrounded two- or three-terminal resistors. The instruments are supplied for rack mounting or in a convenient, portable flip-tilt case that is a stand for the meter in use and protects it in transit and storage.

— See **GR Experimenter** for March-April 1969.

specifications

Voltage and Resistance Range:

Voltage	R_{min} Full Scale	R_{max} 10% of Scale	R_{max} 2½% of Scale	Useful Ranges
Type 1863				
50, 100 V	50 kΩ	500 GΩ	2 TΩ	7
200, 250, 500 V	500 kΩ	5 TΩ	20 TΩ	7
Type 1864				
10 to 50 V	50 kΩ	500 GΩ	2 TΩ*	7*
50 to 100 V	200 kΩ	5 TΩ	20 TΩ	8
100 to 500 V	500 kΩ	5 TΩ	20 TΩ*	7*
500 to 1090 V	5 MΩ	50 TΩ	200 TΩ	8

* Recommended limit.

Resistance Accuracy: ±2(meter reading + 1)% on lowest 5 ranges (min reading is 0.5). For higher ranges add:

	sixth	seventh	eighth
1863	2%	4%	—
1864	2%	3%	5%

Voltage Accuracy (across unknown): ±2%.
Short-Circuit Current: 5 mA approx.
Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 13 W.
Accessories Supplied: Mounting hardware with rack models.
Mounting: Flip-tilt case and rack mount.
Dimensions (width x height x depth): Portable, 9⅝ x 10 x 6¾ in. (245 x 255 x 175 mm); rack, 19 x 7 x 4⅝ in. (485 x 180 x 120 mm).
Net Weight: Portable, 9½ lb (4.4 kg); rack, 11 lb (5 kg).
Shipping Weight (est): 14 lb (6.5 kg).

Catalog Number	Description	Price in USA
	1863 Megohmmeter	
1863-9700	Portable Model	**$385.00**
1863-9701	Rack Model	**385.00**
	1864 Megohmmeter	
1864-9700	Portable Model	**485.00**
1864-9701	Rack Model	**485.00**

INDUCTANCE MEASURING

This section describes two completely self-contained inductance systems, their separate bridges, and a power supply that provides up to 400 V or 5 A dc bias. These instruments are but a part of our total inductance-measuring capability. Five other instruments are offered: These are impedance bridges capable of capacitance and resistance measurements as well as inductance measurements. They are shown in the tinted blocks below and are more fully described earlier in this catalog. Of particular interest to those of you to whom time is money is the 1683 Automatic RLC Bridge — completely automatic, systems oriented, and capable of up to 20 measurements per second.

0.1 nH	10 nH	50 nH	100 nH	200 nH	1 μH	20 μH	1000 H	1100 H	2000 H

1660: *±0.1% accuracy,* comparison precision within 10 ppm. Measurements can be made from 50 Hz to 10 kHz. Loss is expressed as conductance from 0.1 n℧ to 1111 ℧ accurate to ±1%. Measures series or parallel L and features 6-digit resolution by means of in-line readout dials with automatic decimal point.

1683: *±0.1% accuracy, automatic bridge.* Measurements can be made at 120 Hz or 1 kHz. Loss is expressed as series resistance from 1 mΩ to 1 MΩ with accuracies up to ±1%. Fully automatic bridge with 5-digit resolution and provisions for full systems use. 5-terminal connections to unknown.

1608: *±0.1% accuracy.* Measurements are made at 1 kHz with internal oscillator or from 20 Hz to 20 kHz with external oscillator. Loss is expressed as Q from 0.5 to 2000. Inductance readout is digital and inductors can be biased with currents up to 40 mA.

1656: *±0.1% accuracy.* Measurements are made at 1 kHz and loss is expressed as Q from 0.02 to ∞, accurate to ±5%. Inductance is balanced by 4 lever switches with in-line readout. Small biasing currents possible.

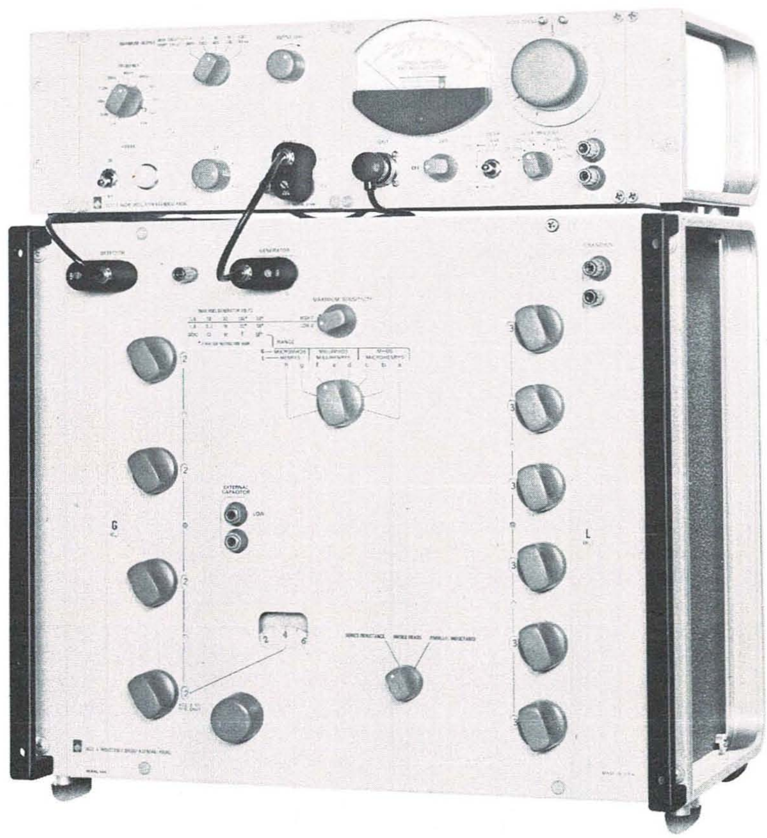
1630-AV: *±1% accuracy.* Measurements can be made from 50 Hz to 15 kHz. Loss is expressed as Q from 1 to ∞. Supplies up to 5 A dc bias current.

1650-B: *±1% accuracy.* Measurements are made at 1 kHz. Loss is expressed as Q from 0.02 to 1000. Excellent low-cost, general-purpose bridge for lab or production use.

1654: *±0.003% comparison accuracy.* Measures impedance-magnitude and phase-angle differences.

Type 1660-A PRECISION INDUCTANCE-MEASURING ASSEMBLY

- 0.1 nH to 1.1 kH, ±0.1% accuracy
- comparison to 6-figure resolution
- series or parallel L, no sliding balance
- in-line readout, automatic decimal point



1660-A Precision Inductance-Measuring Assembly including: 1632-A Inductance Bridge, 1311-A Oscillator, 1232-A Tuned Amplifier and Null Detector.

The 1660-A assembly contains the 1632-A Inductance Bridge with appropriate oscillator and null detector, assembled, interconnected, and measurement-ready. The inductance bridge can be supplied alone if a suitable oscillator and detector are otherwise available or if measurements are required at frequencies other than the 11 provided by the oscillator in the assembly.

The 1632 measures series or parallel components of two-terminal grounded inductors, at audio frequencies. Its high accuracy makes it suitable for the most demanding direct-reading measurements, while its six-place resolution makes possible high-precision intercomparisons of inductance standards by substitution methods.

The bridge circuit is shown schematically on the panel. The standard reactance is a capacitor, which, owing to its very low residual impedances, exhibits a negligible change in its effective capacitance over the audio range. The Owen circuit also makes possible the use of the high accuracy of decade resistors for the inductance balance.

Inductance is indicated by the setting of a six-decade control, conductance by the setting of four decades and a continuously variable control. The dials, which show only the pertinent digit of each decade, indicate inductance directly. Resistance, either series or parallel, is the reciprocal of the conductance setting. An eight-position multiplier automatically indicates both the decimal point and the units of measurement.

For maximum accuracy in the measurement of both large and small values of inductance, the residual impedances associated with the unknown terminals have been minimized.

specifications

RANGE AND ACCURACY

Inductance: Range, 0.1 nH to 1111 H. Accuracy, ±0.1%, direct reading, except at extremes of inductance, frequency, and Q ranges; ±1% on lowest range (0.1 nH to 111 μH). If Q is less than 1, accuracy is reduced to $(+0.05 \pm Q_B)\%/Q_X$. Values of Q_B at 1 kHz are:

Range	a, b, c	d- Low Z	d- High Z e- Low Z	e- High Z f- Low Z	f- High Z g	h
R_B	1 Ω	10 Ω	100 Ω	1 kΩ	10 kΩ	100 kΩ
Q_B at 1 kHz	±0.03%	±0.005%	±0.002%	±0.002%	±0.02%	±0.1 %

Above 1 kHz, multiply Q_B values by f_{kHz}. Additional error of 0.001 f^2_{kHz}% on lowest L range and of 0.04 f^2_{kHz}% on highest range. Two nearly equal inductors can be intercompared to a precision of 10 ppm or better. Bridge adds about 1 pF to capacitance across inductor.

Conductance: Range, 0.1 n℧ to 1111 ℧. Accuracy, ±1%, direct reading, reduced at extremes of inductance, conductance, frequency, and Q ranges. C_N capacitor decades are adjusted within ±1% + 5 pF.

If Q is greater than 10, the error in either series resistance or parallel conductance is increased to Q_X $(+0.05 \pm Q_B)\%$. (See above table for values of Q_B at 1 kHz, and, above 1 kHz, multiply Q_B values by f_{kHz}.) When bridge reads series conductance, there is an additional error in series resistance of 0.15 Q_X% at 1 kHz, when the L decades are set at 1/10 full scale (R_N = 10 kΩ); this error is proportional to frequency (with constant Q_X) and approximately proportional to resistance (R_N) of L decades.

Maximum Measurable Q: Series connection, proportional to frequency, 60 at 100 Hz; parallel connection, 80 at 100 Hz and R_N of 100 kΩ, inversely proportional to frequency and to R_N.

Frequency Range: Nominally 1 kHz and lower. Usable to 10 kHz with accuracy considerations discussed above. Oscillator in 1660 assembly generates 50, 60, 100, 120, 200, 400, and 500 Hz, 1, 2, 5, and 10 kHz only.

GENERAL

Generator: Type 1311-A Oscillator supplied in 1660 assembly. Type 1310-A or 1210-C is recommended for continuous frequency coverage. Max safe bridge voltage is 1 V on low-L ranges to 100 V on high ranges; values engraved on panel.

Detector: Type 1232-A Tuned Amplifier and Null Detector supplied in 1660 assembly and recommended for general use.

Accessories Supplied: 274-NL Shielded Patch Cord and 874-R34 Patch Cord for generator and detector connection; 1632-P1 Transformer to match low bridge input impedances to 600-Ω generator.

Power Required: For 1660, 105 to 125 or 210 to 250 V, 50 to 400 Hz, 22 W for 1311-A Oscillator. Null Detector operates from internal battery supply. Bridge requires no power.

Mounting: 1660 supplied assembled in cabinet. 1632 in Rack-Bench Cabinet.

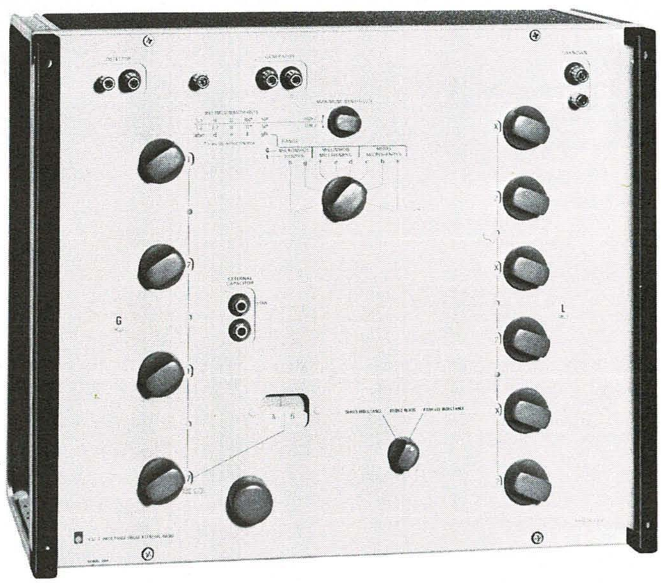
Dimensions (width x height x depth): 1660 assembly, 19 x 23 x 10½ in. (485 x 590 x 270 mm); 1632 bench model, 19 x 16 x 10½ in. (485 x 410 x 270 mm); 1632 rack model, 19 x 15¾ x 8½ in. (485 x 400 x 230 mm)

Net Weight: 1660 assembly, 62 lb (29 kg); 1632 bridge, 40 lb (18.5 kg).

Shipping Weight: 1660 assembly, 92 lb (42 kg); 1632 bridge, 53 lb (24.5 kg).

Catalog Number	Description	Price in USA
1660-9701	**1660-A Precision Inductance-Measuring Assembly**	**$2390.00**
8410-1372	**Replacement Battery,** 9 req'd	**1.95**

Type 1632-A INDUCTANCE BRIDGE



Although available in the Type 1660-A assembly with oscillator and null detector, the 1632-A Inductance Bridge is offered separately for those who have the necessary companion instruments or wish to use frequencies not provided.

The 1632 is ideally suited to the measurement of standard inductors, by direct measurement to ±0.1%, or by substitution measurement, in comparison to external standards to a resolution of up to 1 ppm. Specifications for the bridge alone are as given above for the assembly, except as noted.

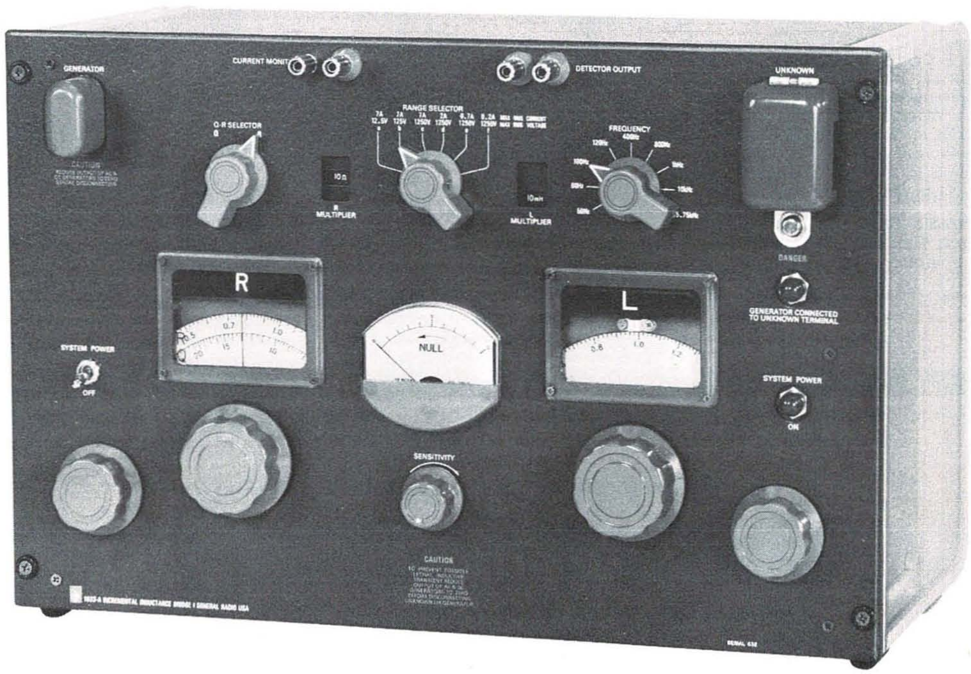
Oscillators page 220 ff

Catalog Number	Description	Price in USA
	1632-A Inductance Bridge	
1632-9801	Bench Mount	**$1600.00**
1632-9811	Rack Mount	**1600.00**

Detectors page 133

Type 1633-A INCREMENTAL-INDUCTANCE BRIDGE

- direct reading at 9 frequencies in series L and R or Q
- 0.2 μH to 1000 H
- 20 Hz to 20 kHz
- accuracy $\pm 1\%$
- apply up to 1250 V and 50 A, ac and dc
- numerous safety features



The 1633-A was designed primarily for measuring inductance and loss of transformers, chokes, and similar components at very high levels of ac and dc excitation and over a wide frequency range. Easy to operate and flexible in application, it can also measure other nonlinear elements such as Zener diodes, rectifiers, thermistors, and lamps. The bridge contains a highly selective nine-frequency detector for effective harmonic rejection and can be supplied complete with high-power ac and dc supplies as the Type 1630 Inductance-Measuring Assembly.

The incremental-inductance bridge uses a new circuit that incorporates active elements* in stable operational amplifiers. Although large signal and bias levels may be applied to the unknown, this circuit keeps signals in the bridge small, minimizes corrections, and eliminates sliding balance. Current and voltage in the unknown are nearly identical in magnitude and waveform to those applied at the GENERATOR terminals. In many instances measurements can be made while the unknown is actually operating in the circuit.

Up to 7 amperes, rms (combined ac and dc), at up to 1250 volts, can be impressed on the sample, and, with a 1633-P1 Range-Extension Unit, up to 50 amperes. Two power supplies are available, a dc supply and a variable-frequency oscillator, which are designed specifically for use with the bridge. Most conventional power supplies are not suitable.

The internal detector is highly selective at nine frequencies between 50 Hz and 15.75 kHz. Owing to high detector sensitivity and low noise, measurements can be made at excitation levels below one volt on the highest inductance ranges and 10 millivolts on the lowest range.

— See **GR Experimenter** for May 1962.

* H. P. Hall, R. G. Fulks, "The Use of Active Devices in Precision Bridges," Electrical Engineering, May 1962.

specifications

RANGES OF MEASUREMENT

Measurement	Frequency	Full-Scale Ranges a	b	c	d	e	f	Lowest Scale Division	ACCURACY
Inductance	50, 60, 100, 120 Hz	10 mH	100 mH	1 H	10 H	100 H	1000 H	20 μH	±(1% of reading or 0.1% of full scale) $\pm 2\pi/100 \times f_{kHz}/Q_x$)%*, ±2% above 10 kHz, ±3% above 15.75 kHz.
	400, 800, 1000 Hz	1 mH	10 mH	100 mH	1 H	10 H	100 H	2 μH	
	10, 15.75 kHz	100 μH	1 mH	10 mH	100 mH	1 H	10 H	0.2 μH	
Resistance	All	10 Ω	100 Ω	1 kΩ	10 kΩ	100 kΩ	1 MΩ	10 mΩ	±(2% of reading or 0.1% of full scale) $\pm \frac{Q_x/f_{kHz}}{2\pi}$%
Q		∞ to 1, direct reading at above frequencies						1000	1/Q accuracy = ± 2% ±0.001 ±0.0005f_{kHz}
Max rms volts		12.5	125	1250	1250	1250	1250		
Min rms volts for 1% accuracy (internal detector)	50, 60 Hz	0.025	0.25	2.5	2.5	2.5	2.5		
	1 kHz	0.006	0.06	0.6	0.6	0.6	0.6		
Max rms amperes**		7	7	7	2	0.7	0.2	Max rms current = $\sqrt{I^2_{dc} + I^2_{ac}}$	

* The frequency-error term is 5 times larger on highest L range.
** If application requires more than 7 A, 1633-P1 Range-Extension Unit, which contains a 0.1-Ω resistor, can be externally connected to shunt R_B on the 3 lowest bridge ranges; inductance and resistance values are then reduced by a factor of 10. With this resistor, measurements up to 50 A, ac or dc, are possible.

GENERAL

Generator: External only (not supplied). For optimum performance when dc bias is used, ac supply must be able to withstand large dc currents in output circuit, and dc supply large ac currents. For dc bias, use 1265-A Adjustable DC Power Supply, 200 W; over the audio-frequency range, use 1308-A Audio Oscillator and Power Amplifier, 200 VA.

Detector: Internal or external. Internal, selective at any one of above 9 frequencies; response varies <3 dB for frequencies within 1% of nominal; second-harmonic response about 50 dB below fundamental. External, for continuous coverage from 20 Hz to 20 kHz, use 1232-A Tuned Amplifier and Null Detector.

Power Required: 105 to 125 or 210 to 250 V, about 6 W, 50 to 60 Hz.

Accessories Supplied: Power cord.

Accessories Available: 1633-P1 Range-Extension Unit.

Mounting: Rack-Bench Cabinet.

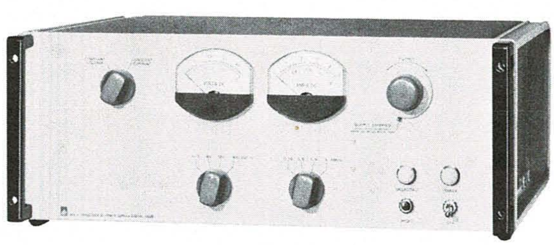
Dimensions (width x height x depth): Bench model, 19 x 12¾ x 10¼ in. (485 x 325 x 260 mm); rack model, 19 x 12¼ x 8¾ in. (485 x 315 x 225 mm).

Weight, Net, 31 lb (14.5 kg); shipping, 48 lb (21.8 kg).

Catalog Number	Description	Price in USA
	1633-A Incremental-Inductance Bridge	
1633-9801	Bench Model	**$1550.00**
1633-9811	Rack Model	**1550.00**

PATENT NOTICE. See Notes 1 and 15.

Type 1265-A ADJUSTABLE DC POWER SUPPLY



The 1265-A supplies dc bias for the 1633-A Incremental-Inductance Bridge. Its characteristics include wide ranges of current and voltage, a passive low-impedance output circuit that will pass high alternating currents, and a choice of voltage or current regulation.

The instrument has four voltage ranges and four current ranges and will deliver its maximum rated power of 200 watts to 8, 80, or 800 ohms. Ranges are interconnected to prevent overloading. Damage from overloads is prevented by an electronic overload circuit.

specifications

Full-Scale Output Ranges: 12.5, 40, 125, 400 V dc; 0.16, 0.5, 1.6, 5 A dc; in any combination up to 200 W.

Meters: Voltage and current; ranges switch with output ranges.

Overload Protection: Overload circuit trips at approx 1½ times full-scale current.

Regulation (Voltage or Current): 0.2% for 10% line-voltage change; 1% for 100% load change.

Speed of Response: Approx 0.1 second.

Hum Level (rms): For 60-Hz operation, approx 70 dB below full-scale dc output (55 dB on 5-A ranges); for 50-Hz operation, 6 dB higher.

Power Required: 105 to 125 or 210 to 250 V, 50 or 60 Hz, 380 W at rated load. (Specify if for 50 Hz.)

Accessories Supplied: Power cord.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench model, 19 x 7½ x 17¼ in. (485 x 190 x 440 mm); rack model, 19 x 7 x 15 in. (485 x 180 x 385 mm).

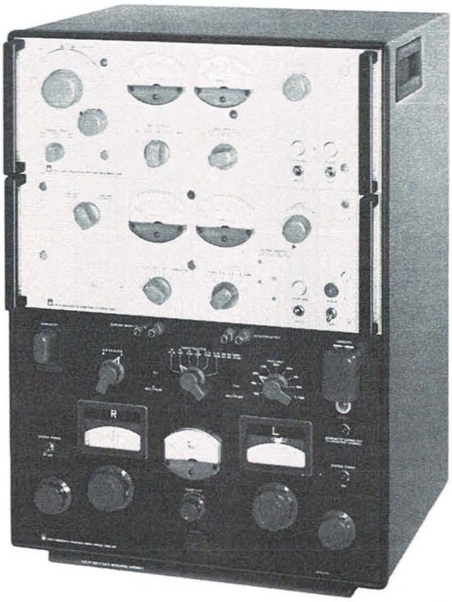
Weight: Net, 70 lb (32 kg); shipping, 124 lb (57 kg).

Catalog Number	Description	Price in USA
	1265-A Adjustable DC Power Supply	
1265-9801	Bench Model, 115 V, 60 Hz	**$1450.00**
1265-9803	Bench Model, 115 V, 50 Hz	**1450.00**
1265-9811	Rack Model, 115 V, 60 Hz	**1450.00**
1265-9813	Rack Model, 115 V, 50 Hz	**1450.00**

PATENT NOTICE. See Notes 1 and 15.

Type 1630-AV INDUCTANCE-MEASURING ASSEMBLY

- For measurements at 50, 60, 100, 120, 400, and 800 Hz, and 1, 10, and 15.75 kHz.



This assembly is a complete system for the measurement of inductance and loss of coils with ferromagnetic cores. It consists of a 1633 Incremental-Inductance Bridge, a 1265 Adjustable DC Power Supply, and a 1308 Audio Oscillator and Power Amplifier in a cabinet-type rack with all necessary interconnecting cables.

The supplies can produce 200-voltampere outputs into a wide range of load impedances and are designed to pass the large dc and ac currents required.

Space is provided at the top of the rack for the addition of an oscilloscope, which permits the current waveform or the hysteresis loop to be viewed during the measurements.

The 1308-A oscillator provides continuous coverage from 20 Hz to 20 kHz. When measurements are required at frequencies other than the nine internal-bridge-detector frequencies, the 1232-A Tuned Amplifier and Null Detector should be used. Order also 480-P308 Rack Adaptor Set, so that the detector can be installed in the rack.

Dimensions (width x height x depth): 22½ x 43 x 20 in. (580 x 1100 x 510 mm).
Weight, Net, 310 lb (145 kg); shipping, 460 lb (215 kg).

Catalog Number	Description	Price in USA
1630-9827	**1630-AV Inductance-Measuring Assembly**	**$4800.00**

PATENT NOTICE. See Notes 1 and 15.

Type 1633-P1 RANGE-EXTENSION UNIT

The 1633-P1 can be used with the 1633-A Incremental-Inductance Bridge to extend the current ratings to 50 amperes. It connects a 250-watt, 0.1-ohm resistor in parallel with one of the bridge arms.

specifications

Range: Upper limit is 100 mH up to 120 Hz and 10 mH up to 1 kHz. (Bridge readings must be multiplied by 0.1.) Only a, b, and c ranges can be used; bridge operation otherwise unchanged.
Accuracy: Additional ±1% up to 400 Hz. Correction can be made for errors at higher frequencies.
Temperature Coefficient (of power resistor): 20 ppm/°C.
Rating: 20 A continuous, or 50 A intermittent, ac or dc. Forced-air cooling required for continuous 50-A operation.
Terminals: High-current type for up to ¼-in.-dia leads to generator and unknown.
Accessories Supplied: Cable for connection to bridge.
Dimensions (width x height x depth): 10½ x 4¼ x 5 in. (270 x 110 x 130 mm).
Weight: Net, 5¼ lb (2.4 kg); shipping, 7 lb (3.2 kg).

Catalog Number	Description	Price in USA
1633-9601	**1633-P1 Range-Extension Unit**	**$195.00**

CAPACITANCE STANDARDS

CHOOSING A STANDARD CAPACITOR

A properly designed air capacitor approaches the ideal standard reactance in that it has very low loss and very small changes with time, frequency, and environment. Capacitance changes with changes in atmospheric pressure (about 18 ppm per inch Hg) and in relative humidity (about 2 ppm per % RH) can be eliminated by hermetic sealing of the capacitor. Changes with temperature can be reduced to a few ppm per °C by the use of low-temperature-coefficient materials in the capacitor. The maximum capacitance of an air-dielectric unit of practical size is of the order of 1000 pF.

For higher capacitance, solid dielectrics are used. The preferred dielectric for standard capacitors is high-quality mica, because of its dimensional stability, low loss, and high dielectric strength. The temperature coefficient of a mica capacitor is of the order of +35 ppm per °C. At dc or extremely low frequencies the mica dielectric has the disadvantage of relatively large change of capacitance with frequency.

Polystyrene has a dielectric constant and dissipation factor very nearly constant with frequency, so that the capacitance change from dc to 1 kHz is a small fraction of a percent. The temperature coefficient of a polystyrene capacitor is, however, of the order of −140 ppm per °C.

FREQUENCY CHARACTERISTICS

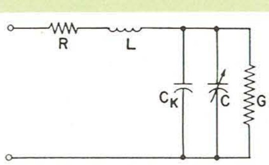
Although the characteristics of the high-quality capacitors used as standards closely approach those of the ideal capacitor, to obtain high accuracy the small deviations from ideal performance must be examined and evaluated. The residual parameters that cause such deviations are shown in the lumped-constant, two-terminal equivalent circuit of Figure 1. R represents the metallic resistance in the leads, supports, and plates; L, the series inductance of the leads and plates; C, the capacitance between the plates; C_k, the capacitance of the supporting structure. The conductance, G, represents the dielectric losses in the supporting insulators, the losses in the air or solid, dielectric between capacitor plates, and the dc leakage conductance.

The effective terminal capacitance C_e of the capacitor becomes greater than the electrostatic or zero-frequency capacitance C_o as the frequency increases because of the inductance L. When the frequency, f, is well below the resonance frequency f_r (defined by $\omega_r^2 LC_o = 1$), the fractional increase in capacitance is approximately

$$\frac{\Delta C}{C_o} \approx \omega^2 LC_o = \left(\frac{f}{f_r}\right)^2 \qquad (1)$$

This change in capacitance with frequency for the capacitors described on the following pages is given either as a plot on logarithmic co-ordinates of the percent increase, $\Delta C/C_o$, versus frequency or as a tabulation of the values of L or f_r. Since the inductance is largely concentrated in the leads and supports, it is nearly independent of the setting of a variable capacitor. With this information, the increase in capacitance at, for example, a frequency of 1 MHz can be computed from the calibrated value at 1 kHz with high accuracy. For small increases, the accuracy may be greater than that of a measurement at 1 MHz because of the difficulties in determining the measurement errors produced by residuals in the connecting leads outside the capacitor.

Figure 1.



The three-terminal capacitor has a similar increase in capacitance produced by inductance. The lowest resonance is determined not solely by the calibrated direct capacitance but also by the terminal capacitances, which may be much larger than the direct capacitances.

High-frequency capacitance standards, Types 1405 and 1406, use coaxial connectors with low-inductance design to reduce series inductance to a few nanohenries.

When the capacitor has a solid dielectric, such as mica, there is another source of capacitance change with frequency. The capacitance increases at low frequencies as the result of dielectric absorption caused by interfacial polarization in the dielectric. The change in capacitance with frequency of a 1000-pF capacitor with mica dielectric is shown in Figure 2. The dotted line slanting downward to the right represents the change in the dielectric constant of mica resulting from interfacial polarization; that slanting upward to the right shows the change in effective capacitance resulting from series inductance. The magnitude of the change at low frequencies depends upon the dielectric material and is, for example, much smaller for polystyrene than for mica.

DISSIPATION FACTOR

The dissipation factor of a capacitor is determined by the losses represented in Figure 1 by R and G. The resistance R is not usually significant until the frequency is high enough for the skin effect to be essentially complete. At such frequencies the resistance varies as the square root of frequency and may be expressed as $R_1\sqrt{f}$, where R_1 is the resistance at 1 MHz and f is the frequency in MHz. The total dissipation factor at high frequencies is then

$$D = \frac{G}{\omega C} + R_1\sqrt{f}\,\omega C \qquad (2)$$

At low frequencies only the dielectric losses represented by G are important. The leakage conductance component is negligible at frequencies above a few hertz and is important only when the capacitor is used at dc for charge storage. The dominant components at audio frequencies are the dielectric losses in the insulating structure and in the dielectric material between the plates.

In the air capacitor the losses in the air dielectric and on the plate surfaces are negligible under conditions of moderate humidity and temperature. The loss is, therefore, largely in the insulating supports. When good-quality, low-loss materials, such as quartz, ceramics, and polystyrene, are used for insulation, the conductance varies approximately linearly with frequency and the dissipation factor, D_k, of the supports is nearly constant with frequency. The total low-frequency dissipation factor of an air capacitor whose equivalent circuit is that of Figure 1 may be expressed as

$$D = \frac{G}{\omega(C + C_k)} = \frac{D_k C_k}{C + C_k} \qquad (3)$$

When the capacitance C is variable, this D is then inversely proportional to the total capacitance. Since the quantity $D_k C_k$ is nearly independent of both frequency and capacitance setting, it is a convenient figure of merit for a variable capacitor.

In a capacitor with a solid dielectric the dominant component of the conductance G is the loss in the dielectric, which varies with frequency. The resulting variation of D with frequency, shown for a mica capacitor in Figure 2, is the sum of three principal components: a constant dissipation factor caused by residual polarizations; a loss produced by interfacial polarizations, which decreases with frequency; and an ohmic loss in the leads and plates, which results in a D proportional to the 3/2 power of frequency. The total dissipation factor has a minimum value at a frequency that varies inversely with capacitance and which ranges from 1 kHz to 1 MHz for capacitance values from 1 μF to 100 pF.

The capacitors described in these pages include air-dielectric reference standards, both fixed and variable, both fixed and decade mica-dielectric, and other decades with polystyrene, mica, and paper dielectric.

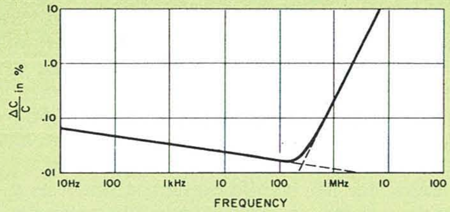
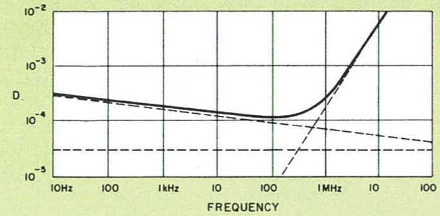
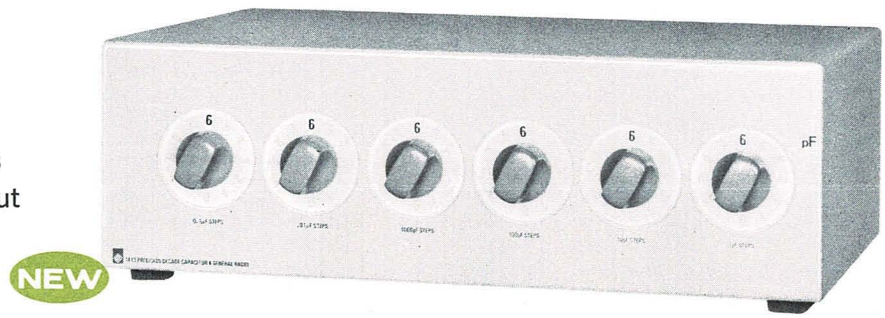


Figure 2. Variation with frequency of capacitance and dissipation factor for a 1000-pF mica capacitor, Type 1409.



Type 1413 PRECISION DECADE CAPACITOR

- 0 to 1.11111 μF
- 0.05% basic accuracy
- 6-digit resolution
- 3-terminal connections
- provision for BCD output



The 1413 is not only a precision standard, it is a systems component as well — connections are made at the rear and each decade provides contact closures for 1-2-4-8 BCD output. It is an excellent companion to the 1654 Impedance Comparator.

Six precision decades are employed to provide a range of 0 to 1.11111 μF in increments as small as 1 pF and with an accuracy of 0.05% + 0.5 pF. Air capacitors are used for the two lower decades and precision silvered-mica capacitors are used for the remainder. The lower four decades contain adjustments that are factory set but accessible for readjustment later if desired.

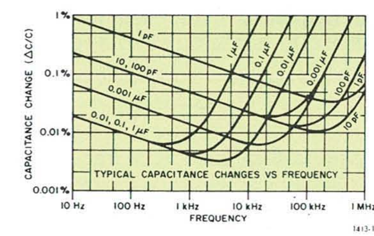
The shielding is divided into two parts, arranged to provide low terminal-to-guard capacitances and low detector input capacitance in order to reduce errors with the 1654. When the two shields are connected together, the 1413 becomes a well-shielded three-terminal capacitor with an extremely low zero capacitance suitable for a variety of applications.

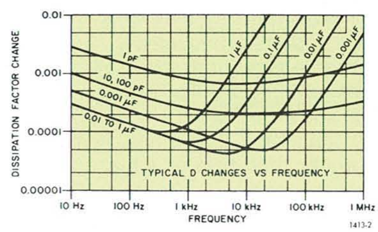
specifications

Range: 0 to 1.11111 μF, controlled by six in-line-readout dials.
Accuracy: $\pm$(0.05% + 0.5 pF) at 1 kHz.
Stability: $\pm$(0.01% + 0.1 pF) per year. *Temperature coefficient:* $\approx$20 ppm/°C from 10 to 50°C.
Zero Capacitance: $\leq$ 0.1 pF.
Voltage Rating: 500 V pk max up to 10 kHz.
Frequency: See curves.

	1 pF to 100 pF	101 pF to 1000 pF	1001 pF to 2000 pF	2001 pF to 0.1 μF	0.1 μF to 1.11111 μF
Dissipation Factor, max at 1 kHz	0.002	0.001	0.0005	0.0003	0.0004
Insulation Resistance, 3 term., after 2 m at 500 V dc	$\geq 5 \times 10^{-10}$ Ω				$\geq 5 \times 10^{9}$ Ω
Terminal Capacitance, max high to case	4 pF	8 pF	10 pF	30 pF	60 pF
high to ground	75 pF	105 pF	115 pF	165 pF	200 pF
low to ground	45 pF	70 pF	80 pF	110 pF	120 pF

Interface: *Connections,* 2 rear-mounted GR874® locking connectors. *Data output,* 36-pin Amphenol Type 57 connector provides connections to 1-2-4-8 weighted BCD contacts rated at 28 V, 1 A, on each decade switch.
Available: 0480-9703 Rack Adaptor Set to convert bench models to rack models, 874-Q2 Adaptor to convert GR874 connector to binding posts (2 req'd), 938-L Shorting Link to connect shields together when 874-Q2 Adaptors are used, 4220-3036 Connector to mate with Data Output Connector.
Mechanical: Convertible-bench cabinet. *Dimensions* (w x h x d): 17 x 5.59 x 11.96 in. (432 x 142 x 304 mm); rack 19 x 5.22 x 10.9 in. (483 x 133 x 505 mm). *Weight:* Bench 23 lb (10.5 kg) net, 29 lb (13.5 kg) shipping; rack 24 lb (11 kg) net, 30 lb (14 kg) shipping.





Catalog Number	Description	Price in USA
	1413 Precision Decade Capacitor	
1413-9700	Bench Model	**$930.00**
1413-9701	Rack Model	**950.00**
0480-9703	**Rack-Adaptor Set**	**20.00**

Type 1423-A PRECISION DECADE CAPACITOR

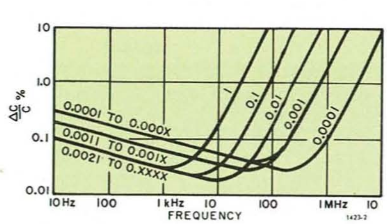
- 100 pF to 1.111 μF
- ±0.05 % accuracy
- two- or three-terminal connection

This capacitor is a versatile tool for calibration laboratories and production-line testing. With it a bridge can be standardized to an accuracy exceeded only by that of the highest quality, individually certified laboratory standards such as the GR 1404 Reference Standard Capacitors. Used with a limit bridge, such as the GR 1605-A Impedance Comparator, the 1423 facilitates fast and accurate production-line measurements of arbitrary capacitance values with minimum setup time.

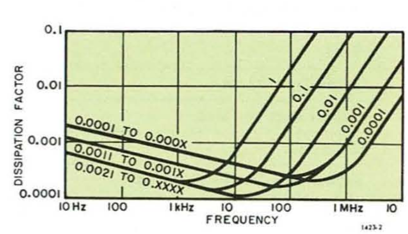
Any value of capacitance from 100 pF to 1.111 μF, in steps of 100 pF, can be set on the four decades and will be known to an accuracy of 0.05%. The terminal capacitance values are set precisely to the nominal value and can be readjusted later at calibration intervals, if necessary, without disturbance of the main capacitors.

The 1423 consists of four decades of high-quality silvered-mica capacitors similar to those used in the GR 1409 Standard Capacitors. The capacitors and associated switches are mounted in an insulated metal compartment, which in turn is mounted in a complete metal cabinet. This double-shielded construction ensures that capacitance at the terminals is the same for either the three-terminal or the two-terminal method of connection (except for a constant difference of about one picofarad). This external capacitance can be included in the two-terminal calibration by the adjustment of a single trimmer.

— See **GR Experimenter** for June 1961.



(Left) Change in capacitance as a function of frequency. These changes are referred to the values that the capacitors would have if there were neither interfacial polarization nor series inductance. The 1-kHz value on the plot should be used as a basis of reference in estimating frequency errors. (Right) Dissipation factor as a function of frequency.



specifications

Nominal Values: 100 pF to 1.111 μF in steps of 100 pF.

Accuracy: ±(0.05% + 0.05pF) at 1 kHz, calibrated in the three-terminal connection. Two-terminal connection (capacitor inserted into Type 777-Q3 Adaptor) adds about 1.3 pF reading.

Stability: ±(0.01% + 0.05pF) per year.

Certificate: A certificate is supplied certifying that each component capacitor was adjusted by comparison, to a precision better than ±0.01%, with working standards whose absolute values are known to an accuracy typically ±0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Frequency: See curves for typical variation of capacitance and dissipation factor with frequency.

Dissipation Factor: Not greater than 0.001, 0.0005, and 0.0003 for capacitances of 100 to 1000 pF, 1100 to 2000 pF, and 2100 pF to 1.1110 μF, respectively.

Temperature Coefficient of Capacitance: Approx +20 ppm per degree between 10° and 50°C.

Insulation Resistance: $>5 \times 10^{10}$ Ω to 0.1 μF and $>5 \times 10^{9}$ Ω from 0.1 μF to 1.111 μF.

Maximum Voltage: 500 V peak, up to 10 kHz.

Accessories Supplied: Two Type 777-Q3 Adaptors.

Mounting: Rack-Bench Cabinet.

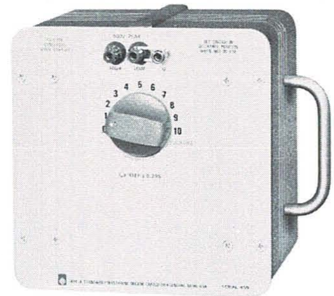
Dimensions (width x height x depth): Bench, 19 x 7¼ x 10½ in. (485 x 185 x 270 mm); rack, 19 x 7 x 8½ in. (485 x 180 x 220 mm).

Weight (both models): Net, 26 lb (12.0 kg); shipping, 39 lb (18 kg).

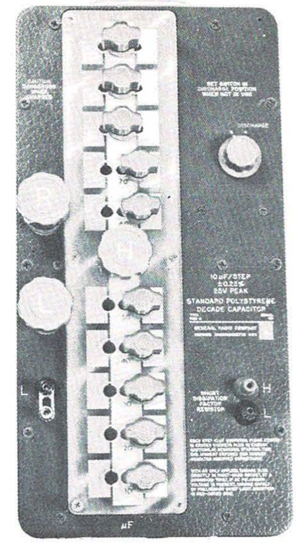
Catalog Number	Description	Price in USA
	Precision Decade Capacitor	
1423-9801	**1423-A,** Bench Model	**$895.00**
1423-9811	**1423-A,** Rack Model	**895.00**

DECADE CAPACITORS

- **10-μF Standard Decade — Polystyrene Dielectric — Type 1424-A**
- **100-μF Standard Decade — Polystyrene Dielectric — Type 1425-A**
- **10-μF Decade — Paper Dielectric — Type 1424-M**



Type 1424-A. Type 1424-M is similar in appearance.



Type 1425-A

TYPE 1424-A

Polystyrene capacitors, combined in 10 1-μF units, are housed in two hermetically sealed, non-ferrous metal cases with Teflon*-insulated high terminals, the cases being the common (LOW) terminal. The aluminum outer cabinet and panel are insulated from both capacitor terminals, so that either two- or three-terminal connections can be used.

Residual series inductance and resistance have been minimized by the use of current-sheet conductors, ribbon leads, and multiple switch contacts.

TYPE 1424-M

This capacitor is a 1-microfarad-per-step decade, which has less rigorous performance specifications than the 1424-A and a correspondingly lower price. Sealed foil-paper capacitors of noninductive extended-foil construction are used with a viscous impregnant to improve stability.

TYPE 1425-A

Polystyrene capacitors are connected in 10-μF steps. The configuration and dimensions of binding posts, bus, studs, and current-sheet connectors are arranged to minimize residuals. Switching resistance is kept low through the use of tapered plug connectors, rather than rotary switches. Binding posts have large contact areas and are easily tightened by hand to minimize contact resistance.

— See **GR Experimenter** for July 1965.

* Registered trademark of E. I. duPont de Nemours and Company.

specifications

Accuracy: The accuracy stated in the table below is guaranteed for two years under the terms of our standard warranty, if the capacitor has not been damaged by excessive current or voltage.

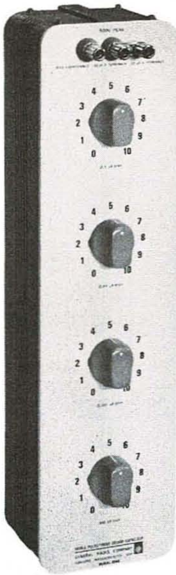
Certificate: 1424-A and 1425-A: A certificate is supplied giving measured values obtained by comparison, to a precision better than ±0.01%, with working standards whose absolute values are known to an accuracy better than ±0.05%, determined and maintained in terms of reference standards periodically measured by the National Bureau of Standards. 1424-M: A certificate is supplied, certifying the accuracy of adjustment in terms of reference standards, periodically measured by the National Bureau of Standards.

Frequency Characteristic: Calibration and adjustment are made at 1 kHz. Plots of typical change in capacitance and dissipation factor with frequency are given in the calibration certificate.

Type	1424-A	1425-A	1424-M
Total Capacitance	10 μF	100 μF	10 μF
Capacitance per Step	1 μF	10 μF	1 μF
Dielectric	Polystyrene	Polystyrene	Paper
Adjustment Accuracy at 1 kHz	±0.25%	±0.25%	±1%
Stability	±0.05%/year	±0.05%/year	±0.35%/year
Dissipation Factor at 1 kHz	<0.0003	<0.0004	<0.005
Insulation Resistance	$>10^6$ ΩF	$>10^6$ ΩF	$>10^4$ ΩF
Voltage Recovery *	<0.1%	<0.1%	<5%
Temp Coefficient of Capacitance (typical) ppm/°C	−140	−140	+180
Max Operating Temperature °C	65	65	90
Max Safe Voltage	500 V, peak, below 10 kHz	25 V, peak, below 10 kHz	500 V, peak, up to 2 kHz
Dimensions Width, height, depth; inches (mm)	9½, 7¾, 8 (245, 195, 205)	9⅜, 19⅛, 8⅛ (240, 485, 205)	9½, 6, 8 (245, 150, 205)
Net Weight lb (kg)	16½ (7.5)	46½ (21.5)	7¾ (3.6)
Shipping Weight lb (kg)	19 (9)	67 (31)	11 (5)
Catalog Number	1424-9701	1425-9701	1424-9713
Price in USA	**$475.00**	**$1950.00**	**$245.00**

* Dielectric absorption.

Type 1419 DECADE CAPACITORS



- 100 pF to 1.1 μF
- choice of models
- two- or three terminal connection

Type 1419 Decade Capacitors are offered in three models using two different dielectric materials to satisfy a variety of needs.

Types 1419-A and -B (Polystyrene)

Capacitance and dissipation factor constant with frequency, essentially noninductive, very low dielectric absorption. The dielectric is specially prepared of purified high-molecular-weight polystyrene, having very high resistance and freedom from interfacial polarization. Moisture sealing with Teflon* feed-through insulators assures high performance under adverse humidity conditions.

Type 1419-K (Silvered Mica)

Higher accuracy, low dissipation factor, and +35 ±10 ppm/°C temperature coefficient (10-50°C) for use in higher ambient temperatures.

* Registered trademark of E. I. duPont de Nemours and Company.

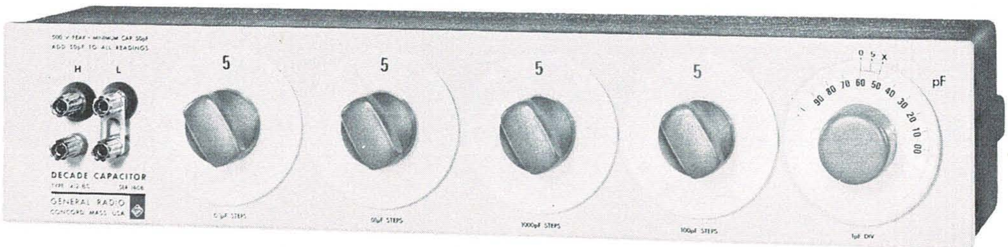
specifications

TYPE NUMBER	1419-A	1419-B	1419-K
Dielectric	Polystyrene	Polystyrene	Silvered Mica
Maximum Capacitance of Box (μF)	1.110	1.1110	1.110
In Steps of (μF)	0.001	0.0001	0.001
Dials	3	4	3
Zero Capacitance, typical			
2-terminal connection	37 pF	50 pF	41 pF
3-terminal connection	15 pF	20 pF	13 pF
Accuracy[1]			
2-terminal connection[2]	±1%	±(1% + 2 pF)	±0.5%
3-terminal connection	±1% except ±1.5% on smallest decade	+1% or −(2% + 4 pF)	±0.5% except ±1% on smallest decade
Dissipation Factor at 1 kHz	<0.0002		<0.0003
Insulation Resistance at 100 V, 25°C, 50% RH, (ohms), typical	$>10^{12}$		$>5 \times 10^{9}$
Max Voltage[3] (dc or peak)	500 V up to 35 kHz		500 V up to 10 kHz
Max Operating Temperature (C)	65		75
Voltage Recovery[4]	<0.1%		<3%
Resonant Frequencies (typical)	1 μF—400 kHz; 0.1 μF—1MHz; 0.01 μF—2.7 MHz; 0.001 μF—7.8 MHz; 0.0001 μF—23 MHz		
Dc Cap/1-kHz Cap	<1.001		Typically 1.03
Cabinet	Lab-bench		
Over-all Dimensions — in. (mm)	13 x 4⅜₆ x 5 (330 x 110 x 130)	16⅜₆ x 4⅜₆ x 5 (415 x 110 x 130)	14⅛ x 5½ x 6 (359 x 140 x 153)
Net Weight — lb (kg)	8⅜ (3.8)	10½ (4.8)	11¼ (5.5)
Shipping Weight — lb (kg)	10 (4.6)	11 (5)	18 (8.5)
Catalog Number	1419-9701	1419-9702	1419-9711
Price in USA	**$270.00**	**$350.00**	**$495.00**

1 Capacitance increments from zero position are within this percentage of the indicated value for any setting at 1 kHz.
2 Units are checked with switch mechanism high, electrically, and the common lead and case grounded.
3 At frequencies above the indicated max, the allowable voltage decreases and is (approx) inversely proportional to frequency. These limits correspond to a temperature of 40°C at max setting of each decade in box.
4 Final % of original charging voltage after a charging period of one hour and a 10-second discharge through a resistance equal to one ohm per volt of charging.

Type 1412-BC DECADE CAPACITOR

- 50 pF to 1.11115 μF
- better than 1-pF resolution
- accuracy ±(0.5% + 5 pF)
- low loss, leakage, dielectric absorption

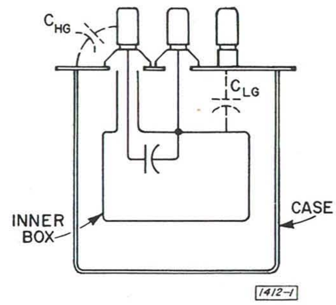


The wide capacitance range and high resolution of this decade capacitance box make it exceptionally useful in both laboratory and test shop. Owing to its fine adjustment of capacitance, it is a convenient variable capacitor to use with the 1654 Impedance Comparator. The polystyrene dielectric used in the decade steps is necessary for applications requiring low dielectric absorption and constancy of both capacitance and dissipation factor with frequency.

Four decades of polystyrene capacitors and a variable air capacitor are used, mounted in a double-shield box. The double shielding provides 2-terminal and 3-terminal capacitances that are the same except for the capacitance between the terminals. The variable air capacitor with a linear ΔC of 100 pF and a resolution of better than 1 pF provides continuous adjustment between the 100-pF steps of the smallest decade.

— See **GR Experimenter** for August 1966.

The double shielding used in the 1412-BC Decade Capacitor keeps C_{HG} very small. This capacitance is the difference between the 3-terminal and 2-terminal capacitance of the box; C_{LG} is approx 125 pF.



specifications

Capacitance: 50 pF to 1.11115 μF in steps of 100 pF with a 0- to 100-pF variable air capacitor providing continuous adjustment with divisions of 1 pF. Capacitances for 2- and 3-terminal connections differ by about 1 pF.

Min Capacitance: 50 pF with all controls set at zero.

Dielectric: Polystyrene for decade steps.

Accuracy: ±(0.5% + 5 pF) at 1 kHz for total capacitance including 50-pF minimum for the 3-terminal connection.

Temperature Coefficient: −140 ppm/°C (nominal).

Frequency Characteristics: Dc Cap/1-kHz Cap <1.001. At higher frequencies the increase is approx $\Delta C/C = (f/f_r)^2$. The resonant frequency, f_r, varies from over 400 kHz for a capacitance of 1 μF to about 27 MHz for a capacitance of 150 pF when connections are made to the front terminals. f_r is about 300 kHz and 70 MHz for rear connections and the same capacitances.

Max Operating Temperature: 65°C.

Dielectric Absorption (Voltage Recovery): 0.1% max.

Dissipation Factor: 150 to 1000 pF, 0.001, max, at 1 kHz; over 1000 pF, 0.0002, max, at 1 kHz.

Insulation Resistance: 10^{12} ohms, min.

Max Voltage: 500 V peak up to 35 kHz.

Terminals: Four 938 Binding Posts with grounding link are provided on the panel. Two of the binding posts are connected to the case and located for convenient use with patch cords in 3-terminal applications. Access is also provided to rear terminals for relay-rack applications.

Mounting: Lab-Bench Cabinet. Brackets are provided for rack mounting.

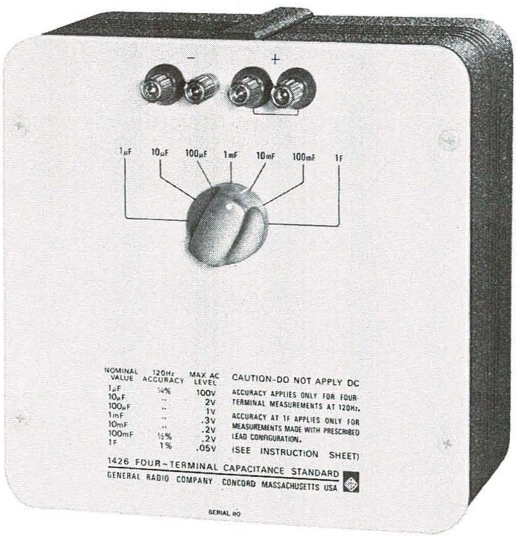
Dimensions (width x height x depth): 17¼ x 3½ x 6 in. (440 x 89 x 155 mm).

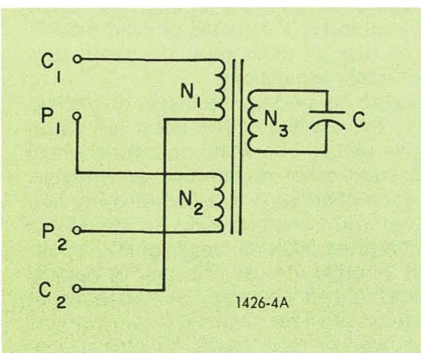
Weight: Net, 8½ lb (3.9 kg); shipping, 10 lb (4.6 kg).

Catalog Number	Description	Price in USA
1412-9410	**1412-BC Decade Capacitor**	**$280.00**

Type 1426 FOUR-TERMINAL CAPACITANCE STANDARD

- 1 μF to 1 farad in decade steps
- accuracy ¼%, 1% at 1 F





Elementary schematic diagram of the 1426.

The 1426 consists of a 1-μF polystyrene capacitor and a transformer that multiplies the effective capacitance to higher values. This arrangement gives stability unattainable with very-high-value true capacitors. Such construction prohibits general circuit applications and particularly uses with dc applied to the capacitor.

The 1426 capacitance standard is of great value in calibrating four-terminal, high-capacitance bridges like the GR 1617. With calibration, the 1426 can be used as a two-terminal standard at 120 Hz and at settings up to 1 mF.

specifications

Capacitance: 1 μF to 1 F in 7 switch-selected decade values.

Accuracy: ±¼%, except ±½% for 100 mF and ±1% for 1 F; measured at 120 Hz at 23°C at <Max Volts specified below. Measurements must use 4-terminal connections with all but the 1-μF value; at 1 F, lead arrangement must be as prescribed in operating instruction manual.

Dissipation Factor: <0.0003 for 1 μF at 120 Hz; <0.1 for larger values.

Capacitance	1 μF	10 μF	100 μF	1 mF	10 mF	100 mF	1 F
Max Ac Volts	100 V	2 V	1 V	0.3 V	0.2 V	0.2 V	0.05 V

Max Dc Voltage: No dc permissible as values above 1 μF are dc short circuits and could be changed in value by dc current; 100 V max for 1-μF standard only.

Temperature Coefficient: 140 ppm/°C typical.

Frequency Characteristic: 1-μF standard is true capacitor with 170-kHz resonance; other values very frequency dependent. Add ¼% to accuracy tolerance at 100 Hz, add 1% from 60 to 150 Hz.

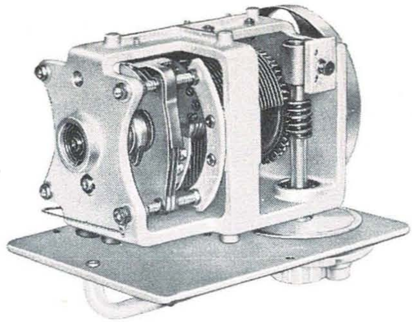
Dimensions (width x height x depth): 8 x 5⅞ x 8 in. (205 x 150 x 205 mm).

Weight: Net, 7½ lb (3.5 kg); shipping, 11 lb (5 kg).

Catalog Number	Description	Price in USA
1426-9700	**1426 Four-Terminal Capacitance Standard**	**$275.00**

Type 1422 PRECISION CAPACITOR

- variable air capacitor
- stability: better than 0.02% full scale per year
- settable to 40 ppm
- low temperature coefficient, low losses
- wide selection to suit needs



Panel and interior views of 1422-D Precision Capacitor.

The 1422 is a stable and precise variable air capacitor intended for use as a continuously adjustable standard of capacitance.

One of the most important applications is in ac bridge measurements, either as a built-in standard or as an external standard for substitution measurements. It is available in a variety of ranges, terminal configurations, and scale arrangements to permit selection of precisely the required characteristics.

TWO-TERMINAL

The 1422-D is a dual-range, two-terminal capacitor, direct reading in total capacitance at the terminals. For high-frequency use, the 1422-N, similar to the high-capacitance section of the 1422-D, is designed to have low residual inductance and resistance.

For convenience in making substitution measurements, two 1422's have scales reading in capacitance removed, i.e., the capacitance is maximum at the zero reading. These, the 1422-MD and 1422-ME, are also dual-range, two-terminal capacitors.

THREE-TERMINAL

The 1422-CB, -CC, -CL, -CD, and -CE are three-terminal capacitors with shielded coaxial terminals for use in three-terminal measurements. The calibrated direct capacitance is independent of terminal capacitances to ground, and losses are very low. The 1422-CL has approximately the same maximum capacitance as the -CC, but with more constant and much lower terminal capacitances, so that it can be used in measurement circuits where high capacitance to guard can not be tolerated.

CONSTRUCTION

The capacitor assembly is mounted in a cast frame for rigidity. This frame and other critical parts are made of aluminum alloys selected to give the strength of brass with the lightness of aluminum. The plates of most models are also aluminum, so that all parts have the same temperature coefficient of linear expansion.

A worm drive is used to obtain high precision of setting. To avoid eccentricity, the shaft and the worm are accurately machined as one piece. The worm and worm wheel are also lapped into each other to improve smoothness. The dial end of the worm shaft runs in a self-aligning ball bearing, while the other end is supported by an adjustable spring mounting, which gives positive longitudinal anchoring to the worm shaft through the use of a pair of sealed, self-lubricating, preloaded ball bearings. Similar pairs of preloaded ball bearings provide positive and invariant axial location for the main or rotor shaft. Electrical connection to the rotor is made by means of a silver-alloy brush bearing on a silver-overlay drum to assure a low-noise electrical contact.

Stator insulation in all models is a cross-linked thermosetting modified polystyrene having low dielectric losses and very high insulation resistance. Rotor insulation, where used (Types 1422-CB, -CL, and -N), is grade L-4 steatite, silicone treated.

specifications

Initial Accuracy: See table. The errors tabulated are possible errors, i.e., the sum of error contributions from setting, adjustment, calibration, interpolation, and standards. When the capacitor is in its normal position with the panel horizontal, the actual errors are almost always smaller. The accuracy is improved when the readings are corrected using the 12 calibrated values of capacitance given on the correction chart on the capacitor panel and interpolating linearly between calibrated points. Better accuracy can be obtained from a precision calibration of approximately 100 points on the capacitor dial, which permits correction for slight residual eccentricities of the worm drive and requires interpolation over only short intervals. This precision calibration is available for all models at an extra charge. Models so calibrated are listed with the additional suffix letter, P, in the type number. A plastic-enclosed certificate of calibration is supplied, giving corrections to one more figure than the tabulated accuracy.

Stability: The capacitance change with time is less than 1 scale division (0.02% of full scale) per year. The long-term accuracy can be estimated from the stability and the initial accuracy specifications.

Calibration: The measured values are obtained by comparison at 1 kHz, with working standards whose absolute values are known to an accuracy of ±(0.01% + 0.0001 pF). Each comparison is made to a precision better than ±0.01%. The values of the working standards are determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

The indicated value of total capacitance of a two-terminal capacitor is the capacitance added when the 1422 Capacitor is plugged into a 777-Q3 Adaptor. The uncertainty of this method of connection is approx ±0.03 pF.*

Resolution: Dial can be read and set to 1/5 of a small division. The backlash is less than 1/5 small division, corresponding to 0.004% of full-scale value. If the desired setting is always approached in the direction of increasing scale reading, no error from this cause will result.

Temperature Coefficient: Approx +20 ppm/°C, for small temperature changes.

Residual Parameters: See table. The series resistance varies as the square root of the frequency above 100 kHz. Its effect is negligible below this frequency.

Frequency Characteristic: See curves for two-terminal models. The resonance frequency for the -CB and -CC models is approximately 20 MHz; for the -CD model, 60 MHz for each section; -CL, 40 MHz.

Dissipation Factor: The losses in the two-terminal capacitors are primarily in the stator supports, which are of low-loss polystyrene (DC = 0.01×10^{-12}).

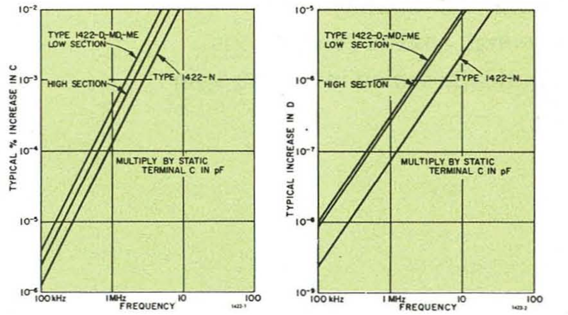
The very small dissipation factor of the direct capacitance of the three-terminal capacitors is difficult to measure and is estimated to be not greater than 20×10^{-6} for -CB and -CL, and 10×10^{-6} for -CC, -CD, and -CE.

Insulation Resistance: Under standard conditions (23°C, less than 50% RH), greater than 10^{12} ohms.

Max Voltage: All models, 1000 V, peak.

---

* John F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," General Radio Experimenter, July 1959.



Variation with frequency of effective capacitance and dissipation factor per pF of capacitance for two-terminal 1422 Precision Capacitors.

Terminals: Jack-top binding posts are provided on 2-terminal models; standard ¾-inch spacing is used. The rotor terminal is connected to the panel and shield. Locking GR874® coaxial connectors are used on three-terminal models.

Accessories Required: For connection to 3-terminal models, 2 GR874 Patch Cords or equivalent.

Accessories Available: 777-Q3 Adaptor (see Calibration above), for two-terminal units.

Mounting: Lab-Bench Cabinet.

Dimensions (width x height x depth): 9½ x 7 x 8½ in. (245 x 180 x 220 mm).

Weight: Net, 10½ to 12½ lb (4.8 to 5.7 kg), depending on model; shipping, all models, 15 lb (7 kg).

		Two-Terminal							Three-Terminal						
				RF	Reads Capacitance Removed										
TYPE 1422		**-D**		**-N**	**-MD**		**-ME**		**-CB**	**-CC**	**-CL**	**-CD**		**-CE**	
CAPACITANCE RANGE, pF	Min	100	35	100	0	0	0	0	50	5	10	0.5	0.05	0.05	0.005
	Max	1150	115	1150	1050	105	105	10.5	1100	110	110	11	1.1	1.1	0.11
SCALE, pF/Division:		0.2	0.02	0.2	0.2	0.02	0.02	0.002	0.2	0.02	0.02	0.002	0.0002	0.0002	0.00002
INITIAL ACCURACY: ± Picofarads Direct-Reading (Adjustment): Total Capacitance		0.6*	0.1*	0.6*	Differences from Zero				0.6	0.15	0.1	0.04	0.008	0.008	0.0016
Capacitance Difference		1.2	0.2	1.2	1	0.2	0.2	0.05	1.2	0.3	0.2	0.08	0.016	0.016	0.0032
With Corrections from Calibration Chart (supplied): Total Capacitance		0.3*	0.04*	0.3*					0.3	0.04	0.04	0.01	0.002	0.002	0.0004
Capacitance Difference†		0.6	0.08	0.6	0.6	0.08	0.08	0.02	0.6	0.08	0.08	0.02	0.004	0.004	0.0008
With Corrections from Precision Calibration (extra charge): Total Capacitance		0.1*	0.01*	0.1*					0.1	0.01	0.01	0.001	0.0002	0.0002	0.00004
Capacitance Difference†		0.2	0.02	0.2	0.2	0.02	0.02	0.004	0.2	0.02	0.02	0.002	0.0004	0.0004	0.00008
RESIDUALS (typical values): Series Inductance, μH		0.06	0.10	0.032	0.06	0.10	0.06	0.10	0.14	0.17	0.13	0.17	0.17	0.17	0.17
Series Resistance, ohms at 1 MHz		0.04	0.05	0.012	0.04	0.05	0.04	0.05	0.1		0.1				
Terminal Capacitance, pF, typical:		high terminal to case			min scale				36	850	34	98	25	37	28
					max scale				35	560	33	74	23	35	28
		low terminal to case			min scale				58	920	58	117	115	81	81
					max scale				53	600	55	92	93	67	67
Capacitance at Zero Scale Setting, pF, typical:					1140	135	145	35							

* Total capacitance is the capacitance added when the capacitor is plugged into a 777-Q3 Adaptor. † Divide error by 2 when one setting is made at a calibrated point.

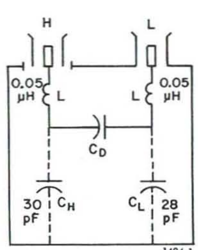
Catalog Number	Description	Price in USA
	Precision Capacitors	
	with precision calibration	
1422-9904	**1422-DP**	**$710.00**
1422-9913	**1422-MDP**	**720.00**
1422-9955	**1422-MEP**	**720.00**
1422-9880	**1422-NP**	**660.00**
1422-9902	**1422-CBP**	**660.00**
1422-9903	**1422-CCP**	**580.00**
1422-9508	**1422-CLP**	**600.00**
1422-9925	**1422-CDP**	**640.00**
1422-9580	**1422-CEP**	**690.00**

Catalog Number	Description	Price in USA
	with standard calibration	
1422-9704	**1422-D**	**$580.00**
1422-9854	**1422-MD**	**590.00**
1422-9855	**1422-ME**	**590.00**
1422-9714	**1422-N**	**570.00**
1422-9916	**1422-CB**	**570.00**
1422-9809	**1422-CC**	**490.00**
1422-9933	**1422-CL**	**510.00**
1422-9823	**1422-CD**	**510.00**
1422-9833	**1422-CE**	**570.00**
0777-9703	**777-Q3 Adaptor**	**7.95**

Type 1404 REFERENCE STANDARD CAPACITOR

- 10, 100, 1000 pF
- 20 ppm/year stability
- 3-terminal, coaxial connections
- hermetically sealed in dry nitrogen

These capacitors have been designed as primary reference standards of capacitance with which working standards can be compared. The 1615-A Capacitance Bridge is particularly well suited for this purpose and can be conveniently used to calibrate accurately a wide range of working standards in terms of a 1404 Reference Standard Capacitor. A single 1000- or 100-picofarad standard is also the only standard necessary to calibrate the bridge itself.



Equivalent circuit showing direct capacitance, C_D, and average values of residual inductance, L, and terminal capacitances, C_H and C_L. C_D = 1000 pF for 1404-A, 100 pF for 1404-B, and 10 pF for 1404-C.

In combination with an accurately known external resistor, this capacitor becomes a standard of dissipation factor.

All critical parts of the plate assembly are made of Invar for stability and low temperature coefficient. After heat cycling and adjustment, the assembly is mounted in a heavy brass container, which, after evacuation, is filled with dry nitrogen under pressure slightly above atmospheric and sealed. The container is mounted on an aluminum panel and protected by an outer aluminum case. Each capacitor is subjected to a series of temperature cycles to determine hysteresis and temperature coefficients and to stabilize the capacitance.

Two locking GR874® coaxial connectors are used as terminals. The outer shell of one is connected to the case, but the outer shell of the other is left unconnected to permit the capacitor to be used with an external resistor as a dissipation-factor standard.

—See **GR Experimenter** for Aug 1963 and Aug 1966.

specifications

Calibration: A certificate of calibration is supplied with each capacitor, giving the measured direct capacitance at 1 kHz and at 23° ±1°C. The measured value is obtained by a comparison to a precision better than ±1 ppm with working standards whose absolute values are known to an accuracy of ±5 ppm, determined and maintained in terms of reference standards periodically measured by the National Bureau of Standards.

Adjustment Accuracy: The capacitance is adjusted before calibration with an accuracy of ±5 ppm to a capacitance about 5 ppm above the nominal value relative to the capacitance unit maintained by the General Radio reference standards.

1615 Bridge page 89

Stability: Long-term drift is less than 20 parts per million per year. Maximum change with orientation is 10 ppm and is completely reversible.

Temperature Coefficient of Capacitance: 2 ±2 ppm/°C for 1404-A and -B, 5 ± 2 ppm/°C for 1404-C, from −20°C to +65°C. A measured value with an accuracy of ±1 ppm/°C is given on the certificate.

Temperature Cycling: For temperature cycling over range from −20° C to +65°C, hysteresis (retraceable) is less than 20 ppm at 23°C.

Dissipation Factor: Less than 10^{-5} at 1 kHz.

Residual Impedances: See equivalent circuit for typical values of internal series inductances and terminal capacitances.

Max Voltage: 750 V.

Terminals: Two locking GR874 coaxial connectors; easily convertible to other types of connectors by attachment of locking adaptors. Outer shell of one connector is ungrounded to permit capacitor to be used with external resistor as a dissipation-factor standard.

Accessories Required: For connection to 1615-A Capacitance Bridge, 2 Type 874-R20A or 874-R22LA Patch Cords.

Dimensions (width x height x depth): 6¾ x 6⅝ x 8 in. (175 x 170 x 205 mm).

Weight: Net, 8½ lb (3.9 kg); shipping, 14 lb (6.5 kg).

Catalog Number	Description	Price in USA
	Reference Standard Capacitor	
1404-9701	**1404-A,** 1000 pF	**$275.00**
1404-9702	**1404-B,** 100 pF	**275.00**
1404-9703	**1404-C,** 10 pF	**275.00**

Type 1409 STANDARD CAPACITOR

- 0.001 to 1 μF
- $\pm$0.01%/year stability
- calibration accuracy $\pm$0.02%
- two- and three-terminal calibration provided

Type 1409-T

Type 1409-X

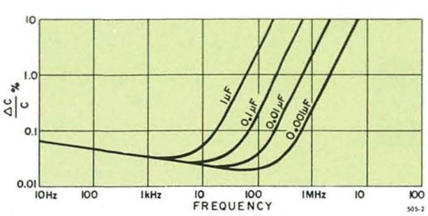
Type 1409-Y

The 1409 Standard Capacitors are fixed mica capacitors of very high stability for use as two- or three-terminal reference or working standards in the laboratory.

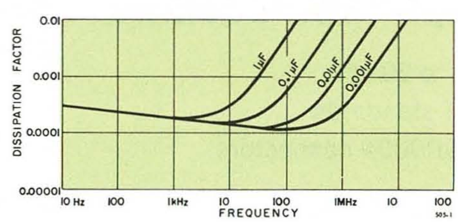
Typical capacitors, observed over more than 12 years, have shown random fluctuations of less than $\pm$0.01% in measured capacitance with no evidence of systematic drift.

These capacitor units consist of a silvered-mica and foil pile, spring-held in a heavy metal clamping structure for mechanical stability. The units are selected for low dissipation factor and are stabilized by heat cycling. They are housed, with silica gel to provide continuous desiccation, in cast aluminum cases, sealed with high-temperature potting wax. A well is provided in the wall of the case for the insertion of a dial-type thermometer. Three jack-top binding posts are provided on the top of the case and removable plugs on the bottom, for convenient parallel connection without error.

— See **GR Experimenter** for July 1957 and October 1960.



(Left) Change in capacitance as a function of frequency for typical Type 1409 Capacitors. The 1-kHz value on the plot should be used as a basis of reference in estimating frequency errors. (Right) Dissipation factor as a function of frequency.



specifications

Adjustment Accuracy: Within $\pm$0.05% of the nominal capacitance value (two-terminal) marked on the case. Accuracy is guaranteed for two years under the terms of our standard warranty if the capacitor has not been damaged by excessive current or voltage.

Calibration: A certificate of calibration is supplied with each unit, giving both two- and three-terminal measured capacitances at 1 kHz and at a specified temperature. The measured value is the capacitance added when the standard is plugged directly into General Radio binding posts. This value is obtained by comparison, to a precision better than $\pm$0.01%, with working standards whose absolute values are known to an accuracy typically $\pm$0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Stability: Capacitance change is less than 0.01% per year.

Temperature Coefficient of Capacitance: +35 $\pm$ 10 ppm per degree between 10° and 70°C.

Dissipation Factor: Less than 0.0003 at 1 kHz and 23°C (see curves). Measured dissipation factor at 1 kHz is stated in the certificate to an accuracy of $\pm$0.00005.

Series Inductance: Typically 0.050 μH for 1409-F through -M, 0.055 μH for -R through -Y.

Series Resistance at 1 MHz: 0.02 ohm, except for 1409-Y, which is 0.03 ohm.

Frequency Characteristics: See curves. Series resistance varies as the square root of the frequency for frequencies above 100 kHz.

Approx Terminal Capacitance: From H terminal to case (G), 12 to 50 pF. From L terminal (outside foils of capacitor) to case, 300 to 1300 pF.

Leakage Resistance: 5000 ohm-farads or 100 GΩ, whichever is the lesser.

Max Voltage: 500 V pk up to 10 kHz.

Dimensions (width x height x depth): 1409-Y, 3¼ x 5⅝ x 2 11/16 in. (85 x 145 x 70 mm); 1409-X, 3¼ x 4 x 2 11/16 in. (85 x 105 x 70 mm); others, 3¼ x 4 x 2 in. (85 x 105 x 50 mm).

Weight: Net, 1¼ lb (0.6 kg); shipping, 4 lb (1.9 kg). Add approx ½ lb (0.2 kg) for 1409-X, and approx 1 lb (2.2 kg) for 1409-Y.

Catalog Number	Type	Nominal Capacitance μF	Price in USA
1409-9706	**1409-F**	0.001	**$ 64.00**
1409-9707	**1409-G**	0.002	**64.00**
1409-9711	**1409-K**	0.005	**64.00**
1409-9712	**1409-L**	0.01	**66.00**
1409-9713	**1409-M**	0.02	**72.00**
1409-9718	**1409-R**	0.05	**77.00**
1409-9720	**1409-T**	0.1	**83.00**
1409-9721	**1409-U**	0.2	**94.00**
1409-9724	**1409-X**	0.5	**145.00**
1409-9725	**1409-Y**	1.0	**235.00**

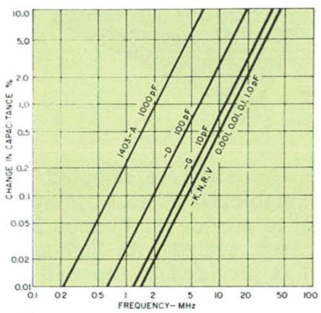
Type 1403 STANDARD AIR CAPACITOR

- 1000 pF to 0.001 pF
- calibration accuracy:
  ±0.02% ±0.01 fF

The 1403 Standard Air Capacitors are stable, three-terminal standards in decimal values from 0.001 to 1000 pF. Their terminals are arranged to plug directly into the UNKNOWN terminals of the 1615-A Capacitance Bridge.

specifications

Calibration: A certificate of calibration is supplied with each unit giving the measured capacitance at 1 kHz and at a specified temperature. The measured value is the direct capacitance between shielded terminals when the capacitor has at least one lead completely shielded and its case connected to a guard point. This value is obtained by comparison, to a precision better than ±(0.01% + 0.00001 pF), with working standards whose absolute values are known to an accuracy typically ±0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.



Typical increase (percent) in effective direct capacitance, with frequency produced by residual inductance.

Stability: Capacitance change is less than 0.05% per year.

Residual Impedances: See curve for effect of frequency. Capacitance from either terminal to case is ≈ 30 pF.

Dissipation Factor: $<20 \times 10^{-6}$ max at 1 kHz and 50% or less relative humidity.

Peak Voltage: 1500 V, except for 1403-A, which is 700 V.

Temperature Coefficient of Direct Capacitance: Typically 20 to 40 ppm per degree between 20° and 70°C. The larger coefficients apply to the smaller capacitance values.

Terminals: GR874® coaxial connectors, which provide complete shielding of the leads.

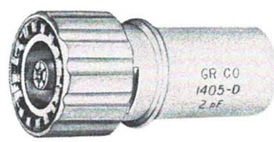
Dimensions: Diameter 3 1/16 in. (78 mm), height 5 1/4 in. (135 mm), over-all.

Weight: Net, 1 lb (0.5 kg); shipping, 4 lb (1.9 kg).

Catalog Number	Type	Nominal Capacitance - pF	Adjustment Accuracy - %	Price in USA
1403-9701	**1403-A**	1000	0.1	**$110.00**
1403-9704	**1403-D**	100	0.1	**95.00**
1403-9707	**1403-G**	10	0.1	**90.00**
1403-9711	**1403-K**	1.0	0.1	**80.00**
1403-9714	**1403-N**	0.1	0.1	**90.00**
1403-9718	**1403-R**	0.01	0.3	**100.00**
1403-9722	**1403-V**	0.001	1.0	**90.00**

Type 1405 COAXIAL CAPACITANCE STANDARDS

- 1 to 20 pF
- rf standards
- GR900® connectors



Extending the available values of rf capacitance downward, the 1405 standards permit impedance-measuring instruments to be calibrated at even higher frequencies accurately and with traceability to the National Bureau of Standards.

— See **GR Experimenter** for May 1968.

specifications

Calibration: A certificate of calibration is supplied with each unit, giving the measured capacitance at 1 kHz and at a specified temperature and relative humidity. The measured capacitance is the capacitance at the reference plane of the GR900 connector. This value is obtained by comparison, to a precision better than ±0.001 pF, with working standards whose absolute values are known to an accuracy typically ±0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Accessories Available: Adaptors 1615-P2 for calibrating with GR 1615 bridge and 900-Q9 for connecting standard to 1/4-inch x 28 threaded stud (GR 938 Binding Post) or tapped hole.

Terminal: GR900 precision coaxial connector.

Dimensions (diameter x height): 1 1/16 x 2 5/16 in. (27 x 59 mm).

Weight: Net, 4 oz (103 g); shipping, 5 oz (150 g).

		1405-A, 20 pF	1405-B, 10 pF	1405-C, 5 pF	1405-D, 2 pF	1405-E, 1 pF
Accuracy		±0.1% (0.02 pF)	±0.2% (0.02 pF)	±0.2% (0.01 pF)	±0.25% (0.005 pF)	±0.5% (0.005 pF)
Adjustment Accuracy		±0.02%	±0.04%	±0.04%	±0.1%	±0.2%
Stability	temperature	−0.002%/°C	−0.004%/°C	+0.002%/°C	−0.004%/°C	−0.01%/°C
	humidity	—	—	+0.001%/% RH	+0.0025%/% RH	+0.005%/% RH
	aging, C change/yr	<0.1%	<0.1%	<0.1%	<0.15%	<0.3%
Frequency	0.1% C increase	30 MHz	40 MHz	60 MHz	100 MHz	120 MHz
	10% C increase	0.3 GHz	0.4 GHz	0.75 GHz	1 GHz	1.7 GHz
Residuals	D at 1 kHz	$<150 \times 10^{-6}$		$<100 \times 10^{-6}$		
	insulation R	$>10^{12}$ Ω at 23°C and <50% RH				
	equivalent L	1.4 nH at <250 MHz	1.6 nH at <250 MHz	1.4 nF at <500 MHz	1.2 nH at <500 MHz	1.8 nH at <500 MHz
Peak Volts		1 kV	1 kV	1 kV	1 kV	3 kV
Catalog Number		1405-9704	1405-9703	1405-9702	1405-9701	1405-9700
Price in USA		**$85.00**	**$85.00**	**$65.00**	**$65.00**	**$65.00**

Type 1406 COAXIAL CAPACITANCE STANDARDS

- stable to 0.05% per year
- for rf impedance calibrations
- 50 pF through 1000 pF

The 1406 Coaxial Capacitance Standards are stable, low-loss air capacitors with small, stable and known series inductance. This permits the accurate, traceable calibration of high-frequency bridges and other impedance-measuring instruments.

INSTRUMENT CALIBRATION

The 1406 standards can be connected directly to instruments equipped with GR900 precision connectors and to others through appropriate adaptors. The Type 900-Q9 adaptor is offered to facilitate connection to ¼" x 28 threaded studs or tapped holes on ¾" to 1" centers. Series inductance and resistance have been kept low in the 900-Q9 and, when other adaptors are used, these quantities should be known to permit correcting for their effects at high frequencies.

These standards can be calibrated at audio frequencies with the GR 1615 Capacitance Bridge and the 1615-P2 Coaxial Adaptor, which has an adjustment for compensating for its capacitance and that of the binding posts and thus permits direct-reading measurements.

1615 Bridge page 89

REPEATABLE COAXIAL CONNECTION

GR900® precision coaxial connectors are used on the 1406's; their stability and repeatable performance have been proven in use at frequencies as high as 9 GHz. The use of coaxial connectors also meets the high-frequency calibration requirements of the National Bureau of Standards.

specifications

Calibration: A certificate of calibration is supplied with each unit, giving the measured capacitance at 1 kHz and at a specified temperature and relative humidity. The measured capacitance is the capacitance at the reference plane of the GR900 connector. This value is obtained by comparison, to a precision better than ±0.01%, with working standards whose absolute values are known to an accuracy typically ±0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Stability: The capacitance change is less than 0.05% per year.

Accuracy: Capacitance adjusted to within 0.1% of nominal value.

Residual Impedances: See table. Dissipation factor varies as the 3/2 power of frequency above about 100 kHz. Insulation resistance is greater than 10^{12} ohms at 23°C and less than 50% RH.

Temperature Coefficient of Capacitance: Typically 10 to 20 ppm/°C between 20°C and 70°C.

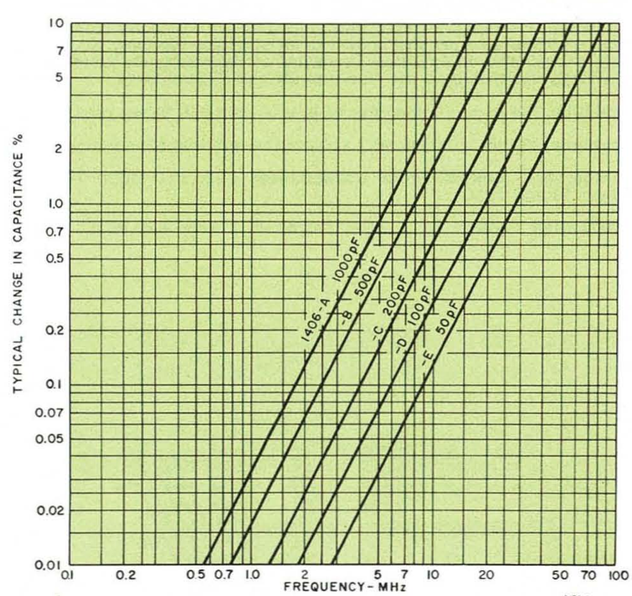
Accessories Available: Adaptors 1615-P2 for convenience in calibrating with 1615-A Capacitance Bridge and 900-Q9 for connecting 1406 to ¼-in. x 28 threaded stud (GR 938 Binding Post) or tapped hole.

Terminal: GR900 precision coaxial connector.

Mounting: Aluminum panel and cylindrical case.

Dimensions (diameter x height): 3¹⁄₁₆ x 5¼ in. (78 x 135 mm).

Weight: Net, 1½ lb (0.7 kg); shipping, 4 lb (1.9 kg).



Typical percent increase in capacitance with frequency of 1406 Coaxial Capacitance Standards.

Catalog Number	Type	Nominal Capacitance	Peak Volts	Typical Dissipation Factor 1 kHz (40% RH)	Typical Dissipation Factor 1 MHz	Typical Inductance	Price in USA
1406-9701	**1406-A**	1000 pF	700	3×10^{-6}	50×10^{-6}	8.6 nH	**$145.00**
1406-9702	**1406-B**	500 pF	900	5×10^{-6}	30×10^{-6}	8.4 nH	**135.00**
1406-9703	**1406-C**	200 pF	1200	20×10^{-6}	25×10^{-6}	8.1 nH	**130.00**
1406-9704	**1406-D**	100 pF	1500	30×10^{-6}	20×10^{-6}	7.6 nH	**130.00**
1406-9705	**1406-E**	50 pF	1500	50×10^{-6}	15×10^{-6}	6.7 nH	**130.00**
1615-9602	**1615-P2 Coaxial Adaptor,** GR900 to 1615 Bridge						**75.00**
0900-9874	**900-Q9 Adaptor,** GR900 to binding posts						**61.00**

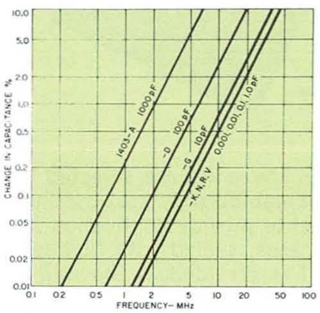
Type 1403 STANDARD AIR CAPACITOR

- 1000 pF to 0.001 pF
- calibration accuracy:
  ±0.02% ±0.01 fF

The 1403 Standard Air Capacitors are stable, three-terminal standards in decimal values from 0.001 to 1000 pF. Their terminals are arranged to plug directly into the UNKNOWN terminals of the 1615-A Capacitance Bridge.

specifications

Calibration: A certificate of calibration is supplied with each unit giving the measured capacitance at 1 kHz and at a specified temperature. The measured value is the direct capacitance between shielded terminals when the capacitor has at least one lead completely shielded and its case connected to a guard point. This value is obtained by comparison, to a precision better than ±(0.01% + 0.00001 pF), with working standards whose absolute values are known to an accuracy typically ±0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.



Typical increase (percent) in effective direct capacitance, with frequency produced by residual inductance.

Stability: Capacitance change is less than 0.05% per year.

Residual Impedances: See curve for effect of frequency. Capacitance from either terminal to case is ≈ 30 pF.

Dissipation Factor: $<20 \times 10^{-6}$ max at 1 kHz and 50% or less relative humidity.

Peak Voltage: 1500 V, except for 1403-A, which is 700 V.

Temperature Coefficient of Direct Capacitance: Typically 20 to 40 ppm per degree between 20° and 70°C. The larger coefficients apply to the smaller capacitance values.

Terminals: GR874® coaxial connectors, which provide complete shielding of the leads.

Dimensions: Diameter 3 1/16 in. (78 mm), height 5 1/4 in. (135 mm), over-all.

Weight: Net, 1 lb (0.5 kg); shipping, 4 lb (1.9 kg).

Catalog Number	Type	Nominal Capacitance - pF	Adjustment Accuracy - %	Price in USA
1403-9701	**1403-A**	1000	0.1	**$110.00**
1403-9704	**1403-D**	100	0.1	**95.00**
1403-9707	**1403-G**	10	0.1	**90.00**
1403-9711	**1403-K**	1.0	0.1	**80.00**
1403-9714	**1403-N**	0.1	0.1	**90.00**
1403-9718	**1403-R**	0.01	0.3	**100.00**
1403-9722	**1403-V**	0.001	1.0	**90.00**

Type 1405 COAXIAL CAPACITANCE STANDARDS

- 1 to 20 pF
- rf standards
- GR900® connectors

Extending the available values of rf capacitance downward, the 1405 standards permit impedance-measuring instruments to be calibrated at even higher frequencies accurately and with traceability to the National Bureau of Standards.

— See **GR Experimenter** for May 1968.

specifications

Calibration: A certificate of calibration is supplied with each unit, giving the measured capacitance at 1 kHz and at a specified temperature and relative humidity. The measured capacitance is the capacitance at the reference plane of the GR900 connector. This value is obtained by comparison, to a precision better than ±0.001 pF, with working standards whose absolute values are known to an accuracy typically ±0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Accessories Available: Adaptors 1615-P2 for calibrating with GR 1615 bridge and 900-Q9 for connecting standard to 1/4-inch x 28 threaded stud (GR 938 Binding Post) or tapped hole.

Terminal: GR900 precision coaxial connector.

Dimensions (diameter x height): 1 1/16 x 2 5/16 in. (27 x 59 mm).

Weight: Net, 4 oz (103 g); shipping, 5 oz (150 g).

		1405-A, 20 pF	1405-B, 10 pF	1405-C, 5 pF	1405-D, 2 pF	1405-E, 1 pF
Accuracy		±0.1% (0.02 pF)	±0.2% (0.02 pF)	±0.2% (0.01 pF)	±0.25% (0.005 pF)	±0.5% (0.005 pF)
Adjustment Accuracy		±0.02%	±0.04%	±0.04%	±0.1%	±0.2%
Stability	temperature	−0.002%/°C	−0.004%/°C	+0.002%/°C	−0.004%/°C	−0.01%/°C
	humidity	——	——	+0.001%/% RH	+0.0025%/% RH	+0.005%/% RH
	aging, C change/yr	<0.1%	<0.1%	<0.1%	<0.15%	<0.3%
Frequency	0.1% C increase	30 MHz	40 MHz	60 MHz	100 MHz	120 MHz
	10% C increase	0.3 GHz	0.4 GHz	0.75 GHz	1 GHz	1.7 GHz
Residuals	D at 1 kHz	$<150 \times 10^{-6}$		$<100 \times 10^{-6}$		
	insulation R	$>10^{12}$ Ω at 23°C and <50% RH				
	equivalent L	1.4 nH at <250 MHz	1.6 nH at <250 MHz	1.4 nF at <500 MHz	1.2 nH at <500 MHz	1.8 nH at <500 MHz
Peak Volts		1 kV	1 kV	1 kV	1 kV	3 kV
Catalog Number		1405-9704	1405-9703	1405-9702	1405-9701	1405-9700
Price in USA		**$85.00**	**$85.00**	**$65.00**	**$65.00**	**$65.00**

RESISTANCE STANDARDS

STANDARD RESISTORS

Because of its accuracy of adjustment, long-term stability, low and uniform temperature coefficient, and relative immunity to ambient humidity conditions, the wire-wound resistor is the most suitable type for use as a laboratory standard at audio and low radio frequencies, as well as at dc.

AC CONSIDERATIONS

Resistors designed for ac use differ from those intended for use only at dc in that low series reactance and constancy of resistance as frequency is varied are important design objectives. The residual capacitance and inductance become increasingly important as the frequency is raised, acting to change the terminal resistance from its low-frequency value.

For frequencies where the resistance and its associated residual reactances behave as lumped parameters, the equivalent circuit of a resistor can be represented as shown in Figure 1. L is the equivalent inductance in series with the resistance, and C is the equivalent capacitance across the terminals of the resistor.

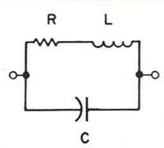


Figure 1.

It is necessary to differentiate clearly between the concepts of equivalent series and equivalent parallel circuits. The two-terminal circuit of Figure 1 can be described as an impedance $R_s + jX_s$ or as an admittance $G + jB = \frac{1}{R_p} + \frac{1}{jX_p}$, wherein the parameters are a function of frequency. This distinction between series and parallel components is more than a mathematical exercise — the use to which the resistor is to be put will frequently determine which component is of principal interest.

The expression for the effective series impedance is:

$$Z_s = R_s + jX_s = \frac{R + j\omega\left[L\left(1 - \frac{\omega^2}{\omega_r^2}\right) - R^2C\right]}{\left(1 - \frac{\omega^2}{\omega_r^2}\right)^2 + (\omega RC)^2}$$

where $\omega_r = \frac{1}{\sqrt{LC}}$ and $\frac{\omega^2}{\omega_r^2} = \omega^2 LC$.

The effective parallel admittance is given by:

$$Y = G + jB = \frac{1}{R_p} + \frac{1}{jX_p} \quad \frac{\frac{1}{R} + j\omega\left[C - \frac{L}{R^2}\left(1 - \frac{\omega^2}{\omega_r^2}\right)\right]}{1 + \left(\frac{\omega L}{R}\right)^2}$$

At low frequencies where terms in ω^2 are negligible, the resistor may be represented by a two-element network consisting of the dc resistance, R, in series with an inductance equal to $L - R^2C$ or in parallel with a capacitance equal to $C - L/R^2$. Because of the presence of the R^2 term in the equivalent reactive parameters, shunt capacitance is the dominating residual for high values of resistance, while for low values the series inductance invariably predominates. Generally, individual wire-wound resistors above a few kilohms are capacitive, while decades are capacitive at somewhat lower values.

In the simplified circuit of Figure 1, the effective parallel resistance of a high-valued resistor in which capacitance dominates would be independent of frequency. Actually, other effects may cause the parallel resistance to decrease with frequency. For example, dielectric losses in the shunt capacitance, C, are equivalent to a resistance

$$R_d = \frac{1}{D\omega C}$$

(where D is the dissipation factor of the distributed capacitance), which decreases with frequency and causes the effective parallel resistance to decrease rapidly beyond a certain frequency. In addition, distributed capacitance along the winding causes a similar rapid decrease in resistance even if its dielectric loss is negligible. The equations above indicate that the effective series resistance of low-valued resistors would be independent of frequency up to quite high frequencies. In practice, if the residual inductance and capacitance are kept small, skin effect becomes the main cause for departure from the low-frequency values of these resistors.

General Radio wire-wound resistance elements are designed to minimize inductance in low-resistance values and to minimize capacitance for high values of resistance. All units up through 200 ohms utilize an Ayrton-Perry winding. For very low-valued units, the residual inductance of such a winding is about 1% of that of a corresponding single winding.

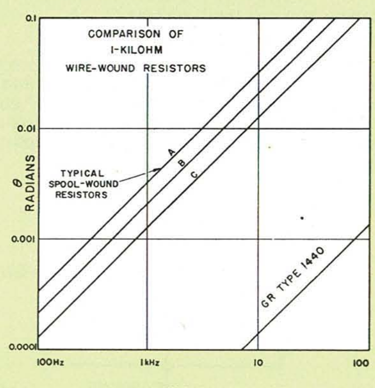
Elements of resistance from 500 ohms to 100 kilohms are unifilar wound on flat cards to provide low inductance and capacitance. Separate resistors of higher values are also wound on flat cards for optimum ac performance but spools are used in decade boxes (see Figure 2). This is because the effect of inductors is negligible at these high frequencies and the effect of capacitance between resistors, which is more important than capacitance across a single resistor, is minimized.

DECADE BOXES

In decade boxes, the residual impedances of the switches, wiring, and cabinet are added to those of the resistors themselves. For multiple-decade boxes, the series inductances are additive, but the capacitance is approximately that across the highest valued decade used (see specifications for each type).

The effect of the residual reactance depends greatly upon the way the resistor is connected in the circuit. For example, parallel capacitance can often be compensated for when the resistor is connected in parallel with a capacitor. For high-valued resistors, the upper frequency limit for a given error is some ten times higher in the effective parallel resistance than it is for the series connection.

Figure 2.



Type 1435 PROGRAMMABLE DECADE RESISTOR

- 1.11 MΩ
- 0.02% basic accuracy
- completely programmable

NEW

The 1435 is a completely-programmable five-decade resistor (expandable to six or seven decades on special order) particularly adaptable to automatic test equipment for the control of load, time constant, gain, etc.

Each decade is controlled by a 12-position front-panel control that displays 0 through X (10) and R (remote). This allows any decade or decades to be manually set while those remaining are remotely controlled. Another switch transfers total control of all the decades to the external control signal, regardless of the setting of the individual decade controls, and this transfer itself is externally programmable.

Four high-quality wire-wound resistors of low-temperature-coefficient Evanohm* wire are used in each decade. All are straight wound except the 10Ω/step decade which is Ayrton-Perry wound to reduce inductance. Due to discontinuities that may exist when the settings are changed (manually or remotely), two logic lines are provided to short or open the decade-output terminals during the switching interval.

* Registered trademark of the Wilbur B. Driver Co.

specifications

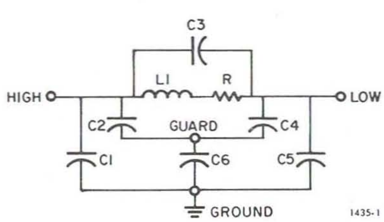
Range: 1,111,100 Ω total resistance; 10 Ω smallest step. Each decade can be individually controlled: manually by in-line-readout dials or remotely by external 1-2-4-8 BCD signals at standard DTL or TTL levels (logic 0 ≈ ground, logic 1 ≥ + 3.5 V) or closures to ground applied to rear-panel etched-board (36 pins.) *Switching speed,* <4 ms per change. *Switches* are mercury-wetted reed relays for low, stable, and repeatable zero resistance and are used for both manual and remote control.

Accuracy: The resistance difference between that at any setting and that at the zero setting is equal to the indicated value ±(0.02% + 0.9 mΩ) for all decades except 10Ω/step which is ±(0.05% + 0.9 mΩ); at low currents and at dc or low-frequency ac.

Zero Resistance: 700 mΩ total, typical.

Temperature Coefficient: +(10 ppm + 3 mΩ)/°C.

Frequency Characteristics: At high-resistance values, frequency characteristics depend mainly on capacitances and on the type of connections used (2- or 3-terminal, grounded or guarded). At low resistance values, they depend mainly on the inductance. Calculations based on values shown should give approximate series-resistance error.



Parameter	Decade Resistance R = 100 kΩ	R = 1 MΩ
C1	34 pF	40 pF
C2	193 pF	252 pF
C3	32 pF	24 pF
C4	101 pF	52 pF
C5	25 pF	18 pF
C6	1760 pF	1760 pF
L1	21 μH	21 μH

Maximum Power: 0.125 W per step (1.25 W max) without accuracy change; 0.25 W per step (2.5 W max) without damage.

Terminals: Five (HIGH, LOW, GROUND, 2 GUARDS) nickel-plated brass binding posts with standard ¾-in. spacing in parallel with 14-pin Amphenol Type 57 connector, all on rear panel.

Supplied: Power cord, Amphenol Type 225 connector to mate with programming input, Amphonel Type 57 connector to mate with resistance terminals.

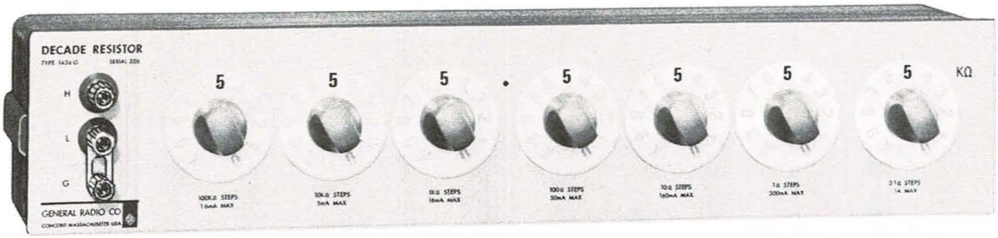
Power: 100 to 125 or 200 to 250 V, 50 to 60 Hz, 7 W.

Mechanical: Bench or rack mount. *Dimensions* (w x h x d): Bench, 19.75 x 4.22 x 12.88 in. (500 x 107 x 327 mm); rack, 19 x 3.47 x 10.8 in. (485 x 88 x 274 mm). *Weight:* Bench, 18 lb (8.5 kg) net, 23 lb (10.5 kg) shipping; rack, 13 lb (6 kg) net, 18 lb (8.5 kg) shipping.

Catalog Number	Description	Price in USA
	1435 Programmable Decade Resistor	
1435-9700	Bench Model	**$750.00**
1435-9701	Rack Model	**750.00**

Type 1434 DECADE RESISTOR

- ±0.05% accuracy
- 5-, 6-, or 7-dial settability
- excellent stability, low cost



These laboratory-quality, budget-priced decade boxes are designed for maximum usefulness and economy in laboratory measurement, testing, and development work. Their accuracy is adequate for all but the most exacting applications and their small size and clear readout should be particularly useful in experimental setups using small, modern components.

The 1434-M, -N, and -P contain five step decades of resistance in a small cabinet. The 1434-B and -X, 6-dial boxes, permit small as well as large values of resistance to be set with 3- or 4-place resolution and accuracy. The 1434-QC, a "best buy," has four step decades plus a rheostat to provide 1-ohm resolution in a 1-megohm box.

The larger, seven-decade, 1434-G box is easily converted into a 3½-inch relay-rack unit by the addition of angle brackets and dress strips, which are furnished. This box has lug terminals available at the rear, as well as at panel binding posts.

DESCRIPTION

High-quality, wire-wound resistors are used in these decades. The low price is made possible by the use of only six resistors per decade instead of ten. These are combined by switching in such a way that there are no discontinuities, that is, the resistance increases stepwise just as if ten resistors were used. The switches have solid-silver-alloy contacts for low resistance and long life.

Resistors are of low-temperature-coefficient Evanohm* wire, except the 1-ohm/step decade, which uses manganin wire, and the 0.1-ohm/step decade, which uses manganin ribbon. The resistors of the 100-ohm/step, 10-ohm/step, and 1-ohm/step decades are Ayrton-Perry wound to minimize inductance.

— See **GR Experimenter** for October 1965.

* Registered trademark of the Wilbur B. Driver Company.

specifications

Accuracy

Long-term: Two-year warranty applies to the tolerances given barring damage by excessive current. Tolerances apply at low currents and at dc or low-frequency ac.

Over-all: The resistance difference between that at any setting and at the zero setting is equal to the indicated value ±(0.05% + 5 mΩ).

Incremental: See table. This is the accuracy of the change in resistance between any two settings of the same dial.

Zero Resistance: Approx 3 mΩ per dial at low frequencies except for the 1434-QC for which it is approx 30 mΩ.

Max Current: See table; these values also appear on the panel of each decade box. When this max current is passed through a decade, the temporary change in value will be less than the accuracy specification. Currents appreciably higher than this will cause permanent damage.

Total Resistance of Decade	Resistance Per Step	Incremental Accuracy*	Max Current
1 Ω	0.1 Ω	±3.0%	1 A
10 Ω	1.0 Ω	±0.35%	0.3 A
100 Ω	10 Ω	±0.08%	160 mA
1 kΩ	100 Ω	±0.05%	50 mA
10 kΩ	1 kΩ	±0.05%	16 mA
100 kΩ	10 kΩ	±0.05%	5 mA
1 MΩ	100 kΩ	±0.05%	1.6 mA
100-Ω Rheostat**	1 Ω/div	±1 Ω	200 mA

* At low currents and low frequencies. ** Used in 1434-QC.

Temperature Coefficient: <±10 ppm/°C at room temperature, except for the low-valued units where the +0.4%/°C temperature coefficient of the zero resistance must be added.

Frequency Characteristics: Generally similar to those of the 1433 Decades.

Switches: Multiple, solid-silver-alloy switches are used to obtain low and stable zero resistance.

Terminals: Jack-top binding posts on standard ¾-in. spacing. A shield terminal is also provided. The 1434-G has lug connections accessible from the rear.

Mounting: All types except the 1434-G are in small cabinets for bench use. The 1434-G is also designed for bench use but, with the addition of mounting hardware, becomes 3½-in. high, 19-in. relay-rack unit.

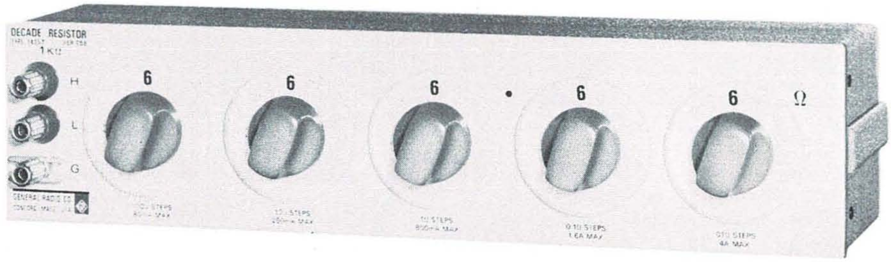
Mechanical Data:

Models	Width		Height		Depth		Net Weight		Shipping Weight	
	in.	mm	in.	mm	in.	mm	lb	kg	lb	kg
M, N, P, QC	11¾	300	2¾	70	4¼	110	3	1.4	4	1.9
B, X	13¾	350	2¾	70	4¼	110	3¼	1.5	4	1.9
G (bench)	17 5/16	442	3½	89	5	130	6	2.8	7	3.2
G (rack)	19	485	3½	89	3½	89	6	2.8	7	3.2

Catalog Number	Description	Total Resistance (Ω)	Resistance Per Step	Number of Decades	Price in USA
	Decade Resistor				
1434-9714	**1434-N**	11,111	0.1 Ω	5	**$145.00**
1434-9713	**1434-M**	111,110	1.0 Ω	5	**145.00**
1434-9716	**1434-P**	1,111,100	10 Ω	5	**160.00**
1434-9576	**1434-QC**	1,111,105	1 Ω/div	4 + rheostat	**150.00**
1434-9702	**1434-B**	1,111,100	1.0 Ω	6	**190.00**
1434-9724	**1434-X**	111,111	0.1 Ω	6	**170.00**
1434-9707	**1434-G**	1,111,111	0.1 Ω	7	**225.00**

Type 1433 DECADE RESISTOR

- ±0.02% accuracy
- good frequency characteristics
- low temperature coefficient
- excellent stability
- low zero resistance



The 1433 Decade Resistors are primarily intended for precision measurement applications where their excellent accuracy, stability, and low zero resistance are important. They are convenient resistance standards for checking the accuracy of resistance-measuring devices and are used as components in dc and audio-frequency impedance bridges. Many of the models can be used up into the radio-frequency range. While they are also useful as substitution boxes for optimizing electronic circuitry, the less expensive Type 1434 Decade Resistors are recommended for such less exacting applications.

The individual decades (510 Decade-Resistance Units) are available for applications requiring only one decade or as components to be built into experimental equipment, production test equipment, or commercial instruments.

DESCRIPTION

The 1433 Decade Resistor is an assembly of 510 Decade-Resistance Units in a single cabinet. Mechanical as well as electrical shielding of the units and switch contacts is provided by the attractive aluminum cabinet and panel. The resistance elements have no electrical connection to the cabinet and panel, for which a separate shield terminal is provided.

Each Type 510 Decade-Resistance Unit is enclosed in an aluminum shield, and a knob and etched-metal dial plate are supplied. Each decade has ten resistors in series; the contacts in the lower-valued decades have a silver overlay to ensure stability of resistance, and all the decades have a silver contact on the zero setting to give low and constant zero resistance. Winding methods are chosen to reduce the effects of residual reactances.

— See **GR Experimenter** for November-December 1968.

specifications

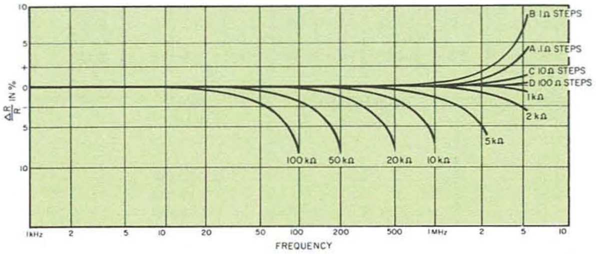
Long-Term Accuracy: Our two-year warranty applies to the tolerances given below unless the resistor is damaged by excessive current. These tolerances apply for low-current measurement at dc or low-frequency ac (see below).

Over-all Accuracy: The resistance difference between that at any setting and at the zero setting is equal to the indicated value ±(0.02% + 2 mΩ).

Incremental Accuracy: See table. This is the accuracy of the change in resistance between any two settings on the same dial.

Max Current: The max current for each decade is given in the table below and also appears on the panel of each decade box and on the dial plate of each decade resistance unit.

Frequency Characteristic: The accompanying plot shows the max percentage change in effective series resistance, as a function of frequency for the individual decade units. For low-resistance decades the error is due almost entirely to skin effect and is independent of switch setting, while for the high-resistance units the error is due almost entirely to the shunt capacitance and its losses and is approx proportional to the square of the resistance setting.



Max percentage change in series resistance as a function of frequency for Type 510 Decade-Resistance Units.

The high-resistance decades (510-E, -F, -G, and -H) are very commonly used as parallel resistance elements in resonant circuits, in which the shunt capacitance of the decades becomes part of the tuning capacitance. The parallel resistance changes by only a fraction (between a tenth and a hundredth) of the series-resistance change, depending on frequency and the insulating material in the switch.

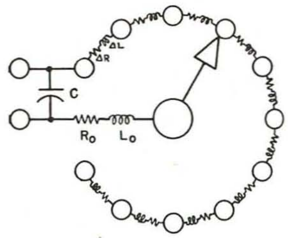
Characteristics of the 1433's are similar to those of the individual 510's modified by the increased series inductance, L_o, and shunt capacitance, C, due to the wiring and the presence of more than one decade in the assembly. At total resistance settings of approx 1000 ohms or less, the frequency characteristics of any of these decade resistors are substantially the same as those shown for the 510's. At higher settings, shunt capacitance becomes the controlling factor, and the effective value of this capacitance depends upon the settings of the individual decades.

Typical Values of R_o, L_o, and C for the Decade Resistors:

Zero Resistance (R_o): 0.001 Ω per dial at dc; 0.04 Ω per dial at 1 MHz; proportional to square root of frequency at all frequencies above 100 kHz.

Zero Inductance (L_o): 0.1 μH per dial + 0.2 μH.

Effective Shunt Capacitance (C): This value is determined largely by the highest decade in use. With the low terminal connected to the shield, a value of 15 to 10 pF per decade may be



Equivalent circuit of a resistance decade, showing location and nature of residual impedances.

assumed, counting decades down from the highest. Thus, if the third decade from the top is the highest resistance decade in circuit (i.e., not set at zero), the shunting terminal capacitance is 45 to 30 pF. If the highest decade in the assembly is in use, the effective capacitance is 15 to 10 pF, regardless of the settings of the lower-resistance decades.

Temperature Coefficient of Resistance: Less than ±10 ppm per degree C for values above 100 Ω and ±20 ppm per degree C for 100 Ω and below, at room temperatures. For the 1433's the box wiring will increase the over-all temperature coefficient of the 0.1- and 0.01-Ω decades.

Switches: Quadruple-leaf brushes bear on lubricated contact studs of ⅜-in. diameter in such a manner as to avoid cutting but yet give a good wiping action. A ball-on-cam detent is provided. There are eleven contact points (0 to 10 inclusive). The switch resistance is less than 0.0005 Ω. The effective capacitance is of the order of 5 pF, with a dissipation factor of 0.06 at 1 kHz for the standard cellulose-filled molded phenolic switch form and 0.01 on the mica-filled phenolic form used in the 510-G and 510-H units.

Max Voltage to Case: 2000 V pk.

Terminals: For 1433, low-thermal-emf jack-top binding posts on standard ¾-in. spacing; also provisions for rear-panel connections. Shield terminal is provided; 510's have soldering lugs.

Mounting: 1433's in lab-bench cabinet, rack models include mounting hardware; 510's complete with dial plate, knob, template, and mounting screws.

Dimensions and Weights: in. (mm), lb (kg):

	4-dial U, K, J, L, Q	5-dial T, N, M, P, Y	6-dial W, X, B, Z	7-dial F, G, H
Width*	12¼ (315)	14¾ (375)	17¼ (445)	
Height	3½ (89)			5¼ (135)
Depth	5 in. over-all, 4 in. behind panel			
Net Wt*	4¾ (2.2)	5¾ (2.7)	7 (3.2)	8¾ (4.0)
Ship. Wt*	5½ (2.5)	6½ (3.0)	8½ (3.9)	10¼ (4.7)

*Data given for bench models. All rack models same except 19 in. wide. Add approx 1 lb for rack-mount hardware.

Type 510's 31/16 in. (78 mm) diameter, 35/16 in. (85 mm) behind panel, 11 oz (0.4 kg) net weight.

Catalog Number							Price in USA	
Bench	Rack	Type	Total Ohms	Ohms per Step	No. of Dials	Type 510 Decades Used	Bench	Rack
1433-9700	1433-9701	**1433-U**	111.1	0.01	4	AA, A, B, C	$150.00	$160.00
1433-9702	1433-9703	**1433-K**	1111	0.1	4	A, B, C, D	155.00	165.00
1433-9704	1433-9705	**1433-J**	11,110	1	4	B, C, D, E	155.00	165.00
1433-9706	1433-9707	**1433-L**	111,100	10	4	C, D, E, F	150.00	160.00
1433-9708	1433-9709	**1433-Q**	1,111,000	100	4	D, E, F, G	170.00	180.00
1433-9710	1433-9711	**1433-T**	1111.1	0.01	5	AA, A, B, C, D	180.00	190.00
1433-9712	1433-9713	**1433-N**	11,111	0.1	5	A, B, C, D, E	180.00	190.00
1433-9714	1433-9715	**1433-M**	111,110	1	5	B, C, D, E, F	180.00	190.00
1433-9716	1433-9717	**1433-P**	1,111,100	10	5	C, D, E, F, G	200.00	210.00
1433-9718	1433-9719	**1433-Y**	11,111,000	100	5	D, E, F, G, H	280.00	290.00
1433-9720	1433-9721	**1433-W**	11,111.1	0.01	6	AA, A, B, C, D, E	205.00	215.00
1433-9722	1433-9723	**1433-X**	111,111	0.1	6	A, B, C, D, E, F	205.00	215.00
1433-9724	1433-9725	**1433-B**	1,111,110	1	6	B, C, D, E, F, G	235.00	245.00
1433-9726	1433-9728	**1433-Z**	11,111,100	10	6	C, D, E, F, G, H	310.00	320.00
1433-9729	1433-9730	**1433-F**	111,111.1	0.01	7	AA, A, B, C, D, E, F	235.00	245.00
1433-9731	1433-9732	**1433-G**	1,111,111	0.1	7	A, B, C, D, E, F, G	260.00	270.00
1433-9733	1433-9734	**1433-H**	11,111,110	1	7	B, C, D, E, F, G, H	345.00	355.00

Type 510 DECADE-RESISTANCE UNITS

Catalog Number	Type	Total Resistance Ohms	Resistance Per Step (ΔR) Ohms	Accuracy of Resistance Increments	Max Current 40° C Rise	Power Per Step Watts	ΔL µH	C** pF	Lo µH	Price in USA
0510-9806	**510-AA**	0.1	0.01	±2%	4 A	0.16	0.01	7.7–4.5	0.023	$26.00
0510-9701	**510-A**	1	0.1	±0.4%	1.6 A	0.25	0.014	7.7–4.5	0.023	27.00
0510-9702	**510-B**	10	1	±0.1%	800 mA	0.6	0.056	7.7–4.5	0.023	32.00
0510-9703	**510-C**	100	10	±0.04%	250 mA	0.6	0.11	7.7–4.5	0.023	32.00
0510-9704	**510-D**	1000	100	±0.02%	80 mA	0.6	0.29	7.7–4.5	0.023	32.00
0510-9705	**510-E**	10,000	1000	±0.02%	23 mA	0.5	13	7.7–4.5	0.023	27.00
0510-9706	**510-F**	100,000	10,000	±0.02%	7 mA	0.5	70	7.7–4.5	0.023	27.00
0510-9707	**510-G**	1,000,000	100,000	±0.02%	2.3 mA	0.5	—	7.7–4.5	0.023	53.00
0510-9708	**510-H**	10,000,000	1,000,000	±0.02%	0.7* mA	0.5	—	7.5–4.5	0.023	115.00
0510-9604	**510-P4**	Switch only	(Black Phenolic Frame)							14.00
0510-9511	**510-P4L**	Switch only	(Low-Loss Phenolic Frame)							15.00

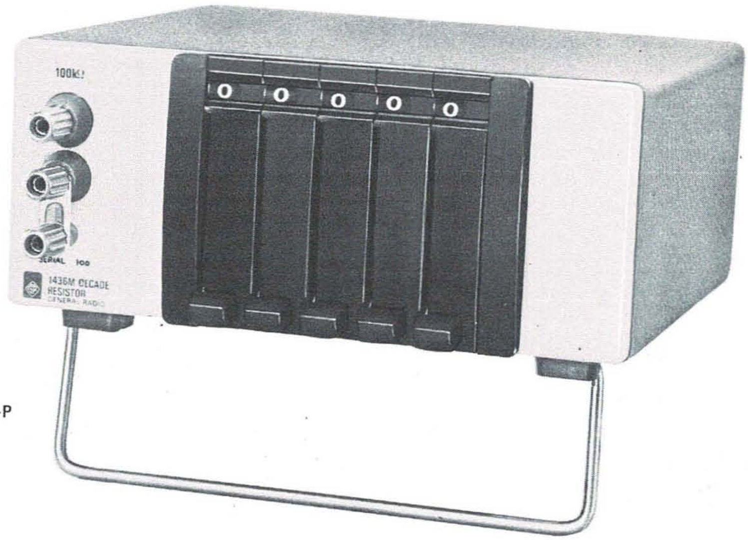
*Or a max of 4000 V, pk.

**The larger capacitance occurs at the highest setting of the decade. The values given are for units without the shield cans in place. With the shield cans in place, the shunt capacitance is from 0 to 20 pF greater than indicated here, depending on whether the shield is tied to the switch or to the zero end of the decade.

Type 1436 DECADE RESISTORS

- 111 kΩ or 1.11MΩ
- 0.02% basic accuracy
- simple lever adjustment
- clear, easy-to-read display
- exceptionally small size

NEW



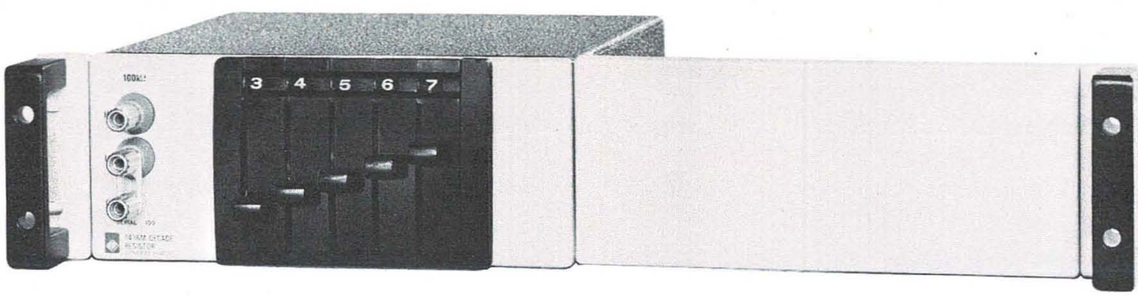
1436-M bench model. The 1436-M and 1436-P differ only in total resistance.

These decades feature small size, high accuracy, and convenient lever switches that provide digital readout and a means of easy and rapid adjustment.

Their accuracy at the higher values equals that of our most precise resistance decades. Solid silver-alloy is used for the contacts to ensure long life and repeatable, low resistance. All resistors are precision, wire-wound units that use low-temperature-coefficient Evanohm* wire for the higher values and Manganin** for the one-ohm steps. Resistors used for settings below one kilohm are Ayrton-Perry wound for low inductance. Six resistors are used per decade but they switch in such a manner that there are no discontinuities.

Both models of the 1436 are available without cabinets for custom installations; inquiries are invited.

*Registered trademark of the Wilbur B. Driver Co.
**Registered trademark of the Driver-Harris Co.



1436-M rack model. Two can be mounted side-by-side if desired.

specifications

Range:	Total Resistance	Smallest Step
1436-M	111,110 Ω	1 Ω
1436-P	1,111,100 Ω	10 Ω

Controlled by 5 lever switches with direct-reading digits. Solid silver-alloy contacts used for low, stable zero resistance.

Accuracy: The resistance difference between that at any setting and at the zero setting is equal to the indicated value ±(0.02% + 5 mΩ) at low currents and at dc or low-frequency ac.

Zero Resistance: ≈ 5 mΩ per decade, ≈ 25 mΩ total.

Temperature Coefficient: ±(10 ppm + 100 μΩ)/°C at room temperature.

Maximum Power: 0.1 W per step (1 W max total) without accuracy change, 0.25 W per step (2.5 W max total) without damage.

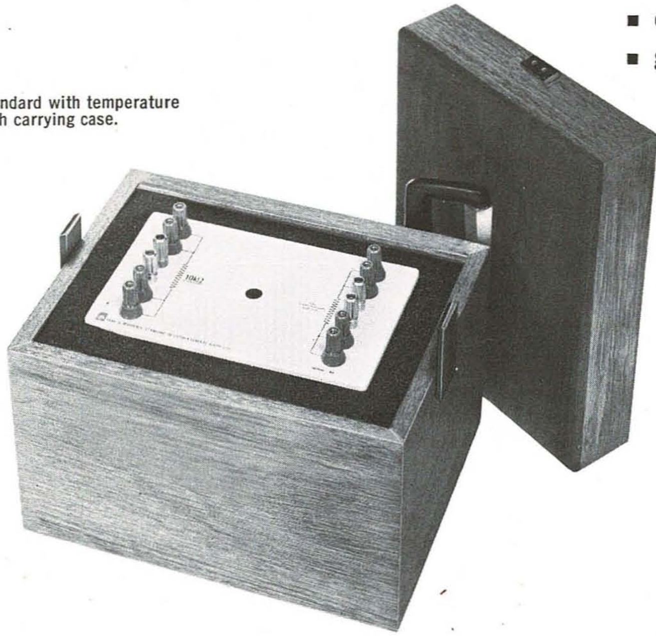
Terminals: Three (HIGH, LOW, GROUND) gold-plated-copper binding posts with standard ¾-in. spacing on front panel; lug connections on rear.

Mechanical: Convertible-Bench Cabinet. *Dimensions* (w x h x d): Bench, 8½ x 3⅞ x 8$\frac{5}{16}$ in. (220 x 99 x 213 mm); rack, 19 x 3½ x 7¼ in. (485 x 89 x 185 mm). *Weight:* Bench, 4¾ lb (2.2 kg) net, 6 lb (2.8 kg) shipping; rack 7¼ lb (3.3 kg) net, 9 lb (4.1 kg) shipping.

Catalog Number	Description	Price in USA
	1436-M Decade Resistor, 111,110Ω	
1436-9700	Bench Model	**$210.00**
1436-9701	Rack Model	**245.00**
	1436-P Decade Resistor, 1,111,100Ω	
1436-9702	Bench Model	**230.00**
1436-9703	Rack Model	**265.00**

Type 1444 REFERENCE RESISTANCE STANDARDS

- 10 kΩ
- 5 ppm accuracy
- 1 ppm per year stability
- extremely low temperature coefficient
- guarded 4-terminal connections



1444-A 10-kΩ standard with temperature sensor, shown with carrying case.

NEW

1444-B 10-kΩ standard, for use with oil bath, shown removed from carrying case.

The high stability and extremely low temperature coefficient of the 1444 Reference Resistance Standards well suit them for use in standards laboratories that lack a closely-controlled environment. And, because these standards are practically unaffected by atmospheric pressure and mechanical and thermal shock, they are also valuable as portable standards for intercomparison.

The resistor used as a standard consists of two large 5-kilohm resistor elements wound on metal substrates that have the same thermal expansion coefficient as the wire to avoid stresses caused by temperature changes. The Evan-Ohm* wire used is bare to eliminate any mechanical constraints caused by changes in the hardness of the normally used lacquer coating. After winding, the resistor elements are high-heat treated to ensure the utmost stability. The resistor is then placed in a heavy stainless-steel container, totally evacuated, back-filled with extra-dry nitrogen, and hermetically sealed. The nitrogen avoids possible oxidation effects that might otherwise be caused by the minute amounts of humidity present in even the best oil. All leads are brought out through glass-to-metal seals, a thermometer well is provided, and a temperature correction chart is supplied.

* Registered trademark of the Wilbur B. Driver Company.

1444-A The 1444-A contains an additional resistor, a 10-kΩ temperature sensor with a temperature coefficient of 1,000 ppm, which is mounted in close thermal contact with the standard resistor elements. The temperature of the standard can then be measured more easily and with a higher degree of accuracy by measurement of the resistance of the sensor. The container of the 1444-A is shock mounted in an outer container and then placed in a foam-rubber-lined carrying case.

1444-B The 1444-B is for laboratories that want to use the 10-kΩ standard in a temperature-controlled oil bath. It is basically the same as the 1444-A but contains no temperature sensor and no outer container and is terminated with heavy copper bars for use with mercury cups. It is supplied in the same foam-rubber-lined case as the 1444-A.

specifications

Nominal value: 10 kΩ.

Accuracy: ±5 ppm, compared with an uncertainty of 0.1 ppm to a standard measured by NBS with a stated uncertainty of 1 ppm.

Stability: 1 ppm/yr.

Environmental: *Temperature coefficient,* individual temperature-correction chart for 18 to 28°C supplied. At 23°C, alpha ⩽0.1 ppm/°C; beta ⩽−0.05 ppm/°C^2 between 18 and 28°C. Value changes <±0.1 ppm with normal *atmospheric and humidity* variations. *Thermal time constant,* 1 hour min.

Electrical: *Power,* 0.1 W max. *Voltage,* 500 V max to case. *Thermal emf,* <±0.1 μV under normal test conditions. *Current reversal,* value changes <±0.1 ppm. *Dielectric soaking effect,* value stabilizes within 5 s to ±0.1 ppm of final value. *Insulation resistance,* >10^{12} Ω from resistor terminals to ground.

Terminals: 1444-A: gold-plated copper binding posts, 4 each for standard, sensor, and ground. 1444-B: 4 nickel-plated binding posts on heavy copper bars for use with mercury cups, 1 ground terminal.

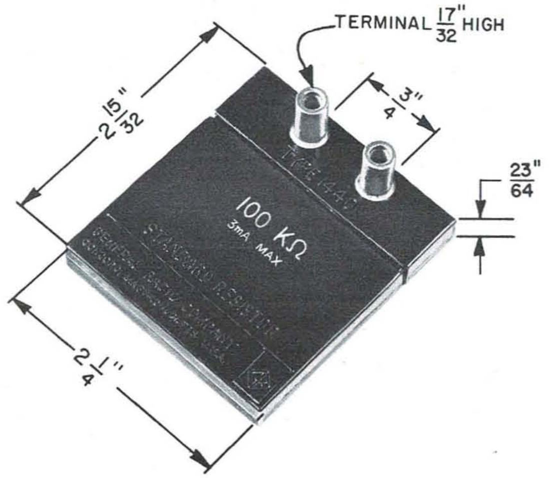
General: Thermometer well provided. Extra-dry-nitrogen filled, hermetically sealed in heavy stainless-steel case. Supplied with foam-rubber-lined carrying case. 1444-A also contains temperature sensor and outer container.

Mechanical: *Dimensions* (w x h x d), 1444-A (including storage case) 11.5 x 10.625 x 9.5 in. (292 x 270 x 241 mm); 1444-B (less storage case) 6.875 x 6.375 x 2.438 in. (175 x 162 x 62 mm). *Weight* (including storage case), 1444-A 11.5 lb (5.5 kg) net, 16.5 lb (7.5 kg) shipping; 1444-B 8.4 lb (3.9 kg) net, 14 lb (6.5 kg) shipping.

Catalog Number	Description	Price in USA
1444-9700	**1444-A Reference Resistance Standard,** 10 kΩ, with sensor	**$600.00**
1444-9701	**1444-B Reference Resistance Standard,** 10 kΩ, without sensor	**600.00**

Type 1440 STANDARD RESISTOR

- accuracy ±0.01%
- stability ±10 ppm per year
- low thermal emf to copper



These extremely stable resistors are intended for use as laboratory or production standards for calibrating resistance bridges and for substitution measurements.

They are card-type, wire-wound resistors, carefully wound and adjusted. Low-temperature-coefficient Evanohm* wire is used for values above 10 ohms, manganin for the lower-resistance units. All units are heat cycled to reduce strains and are repeatedly checked to eliminate any that show abnormal behavior. They are encased in sealed, oil-filled, diallylphthalate boxes to promote long-term stability and to provide mechanical protection.

The 1440 resistors have low-thermal-emf binding posts and removable banana plugs to provide the four terminals necessary for accurate measurements at low values of resistance. A label on the reverse side lists initial calibration and date, space for future calibration data, and serial number.

— See **GR Experimenter** for October 1965.

* Registered trademark of the Wilbur B. Driver Company.

specifications

Accuracy: ±0.01% for all units except those of 1 Ω, which are ±0.02%. This accuracy is guaranteed for our standard warranty period of two years, unless the resistor has been damaged by excessive current. Measurements on the low-value units should be made with a four-terminal connection. All measurements at 23°C.

Calibration Accuracy: Resistors are calibrated by comparison, to a precision of ±20 ppm, with working standards whose absolute values are known typically to ±10 ppm as determined and measured in terms of reference standards periodically measured by the National Bureau of Standards. The measured deviation in % from nominal value, at 23°C and 0.01 watt, is entered on the label on the reverse side of the resistor.

Stability: Typically ±10 ppm per year.

Temperature Coefficient (Max): ±10 ppm/°C for resistances above 10 Ω; ±20 ppm/°C for 10 Ω and below.

Power Rating: 1 W. The corresponding current is indicated on the resistor and in the table below. This dissipation will cause a temperature rise of approx 25°C and a resulting temporary resistance change due to the temperature coefficient. If this rating is exceeded, permanent changes may result.

Residual Impedances: Approx shunt capacitance (2-terminal measurement), 2.5 pF; less for 3-terminal measurement. Typical series inductance, see table.

Approx Frequency Characteristic: See table.

Terminals: Gold-plated jack-top copper binding posts (¾-in. spacing) with banana plugs that are removable and can be replaced by 6-32 screws for installation of soldering lugs.

Dimensions (less terminals): 2¼ x 2¹⁵⁄₃₂ x ¹¹⁄₃₂ in. (58 x 64 x 10 mm).

Net Weight (approx): 2 oz (60 g).

Catalog Number	Resistance	Max Current	Typical Inductance	Approx Frequency for 0.1% Resistance Change: Series R	Parallel R	Price in USA
1440-9601	1 Ω	1.0 A	0.12 µH	300 kHz	30 kHz	**$45.00**
1440-9611	10 Ω	310 mA	0.13 µH	1 MHz	300 kHz	**45.00**
1440-9621	100 Ω	100 mA	0.20 µH	3 MHz	1 MHz	**45.00**
1440-9631	1 kΩ	30 mA	2.5 µH	2 MHz	1 MHz	**45.00**
1440-9641	10 kΩ	10 mA		200 kHz	1 MHz	**45.00**
1440-9651	100 kΩ	3 mA		20 kHz	100 kHz	**45.00**
1440-9661	1 MΩ	1 mA		2 kHz	10 kHz	**45.00**

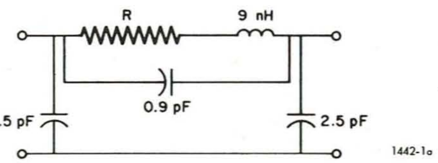
Units of 0.1 Ω and 0.01 Ω, as well as other special values, available on request.

Type 1442 COAXIAL RESISTANCE STANDARD

- ±0.05%-per-year stability
- one- or two-port

The General Radio 1442's are designed to serve as standards of resistance and, used with GR coaxial capacitance standards, as standards of dissipation factor. In either role, they can be used to calibrate impedance bridges at frequencies as high as 100 MHz.

— See **GR Experimenter** for March-April 1969.



Equivalent circuit of a 1442 resistor shown with approximate values of capacitance and inductance.

specifications

Initial DC Accuracy: ±(0.1% + 0.3 mΩ) except ±0.25% for 1442-C through -E.

Stability: ±0.05% per year.

Dissipation: 1 W max.

Capacitance (inner to outer conductor): 5 pF, typical.

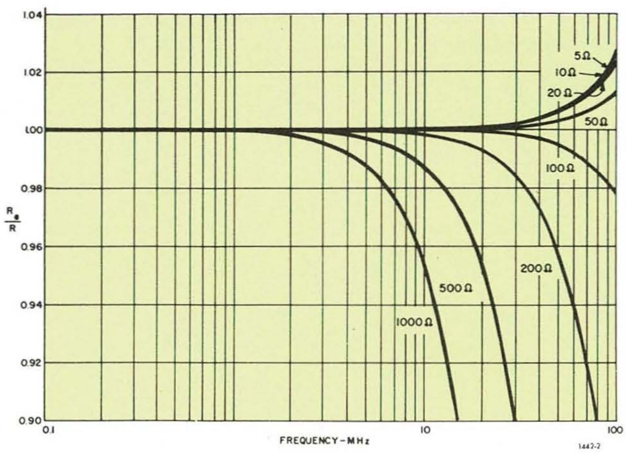
Inductance: 9 nH, typical.

Temperature Coefficient of Resistance: ±50 ppm/°C, except ±100 ppm/°C for 1442-C through -F.

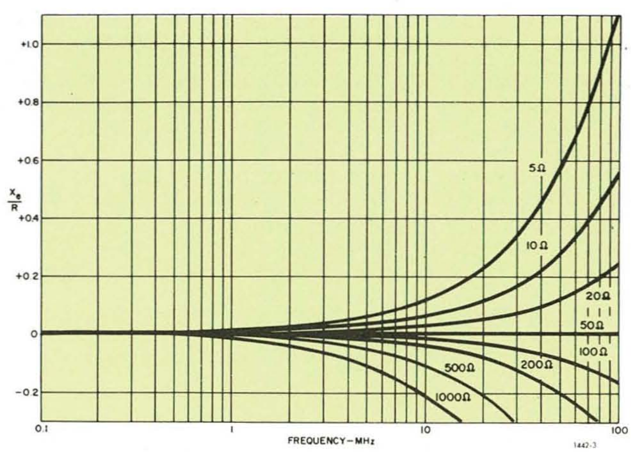
Accessories Available: 900-WN Short Circuit, 900-Q9 adaptor for connecting standard to ¼-inch x 28 threaded stud (GR 938 binding post) or tapped hole.

Dimensions (diameter x length): 1 3/16 x 2⅜ in. (31 x 61 mm).

Catalog Number	Description	Resistance	Price in USA
	Coaxial Resistance Standard		
1442-9702	1442-C	0.5Ω	**$80.00**
1442-9703	1442-D	1.0Ω	**80.00**
1442-9704	1442-E	2.0Ω	**80.00**
1442-9705	1442-F	5Ω	**70.00**
1442-9706	1442-G	10Ω	**70.00**
1442-9707	1442-H	20Ω	**70.00**
1442-9708	1442-J	50Ω	**70.00**
1442-9709	1442-K	100Ω	**70.00**
1442-9710	1442-L	200Ω	**70.00**
1442-9711	1442-M	500Ω	**70.00**
1442-9712	1442-N	1000Ω	**70.00**



Typical ratios of effective ac series resistance to dc resistance, using a GR 900-WN connected to one end of the 1442 resistor.



Typical ratios of effective ac series reactance to dc resistance, using a GR 900-WN connected to one end of the 1442 resistor.

INDUCTANCE STANDARDS

CONSTRUCTION

For minimum generation of, or pickup from, external magnetic fields, the toroidal inductor is preferable to the solenoid. The symmetry of the toroid contributes both to stability and to a constant temperature coefficient.

An air core in the inductor results in the highest stability and a negligible variation of inductance with current, but at the expense of a relatively low Q. Because stability is the prime requirement in a laboratory standard, the Type 1482 Standard Inductors have air cores.

For a given volume, a larger inductance and Q can be obtained from a core of the high-permeability ferromagnetic materials, often termed "iron," although they usually are special alloys. Since the permeability of the material can change with age and particularly with current, the iron-core inductor is inherently less stable than the air-core type. Good stability can still be realized in iron-core inductors by proper design and choice of core materials, as in the Type 940 Decade Inductors and 1491 decade boxes.

INDUCTANCE CHANGES

The inductance depends not only upon the geometry and the permeability of the core but upon the residual impedances, which are shown in the equivalent circuit of Figure 1. The largest changes of inductance with frequency are produced by the effective shunt capacitance, C_o, of the winding and the terminals. When the frequency, f, is well below the resonance frequency, f_r, the fractional increase in inductance is approximately

$$\frac{\Delta L}{L_o} \approx \omega^2 L_o C_o = \left(\frac{f}{f_r}\right)^2, \qquad (1)$$

where L_o is the zero-frequency inductance.

There is practically no change in inductance with current when the core is air, but ferromagnetic core materials have a permeability that changes with magnetizing force, and the change is usually appreciable. The curves shown on page 131 for the Type 940 Inductors are typical. The inductance increases linearly over a small region near zero current, then rises rapidly to a maximum followed by a sudden decrease as saturation is approached. To make these curves independent of the inductance magnitude, the current has been normalized to a value, I_1, which is that current which produces a specified fractional increase in inductance at a specified permeability.

Q CHANGES

The storage factor, $Q = \omega L/R$, of an inductor is simply proportional to frequency when L and R are constant. But, as noted above, L can vary with frequency, and the losses are also functions of frequency. The components of loss are best described in terms of dissipation factor, $D = 1/Q$, since the total D is the sum of the component D's and these can be plotted as straight lines in logarithmic coordinates, as shown in Figure 2.

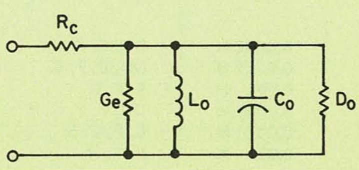


Figure 1. Equivalent circuit of an air-core inductor. R_c is the series resistance, G_e is the conductance due to eddy-current loss, and D_o is the dissipation factor of the distributed capacitance.

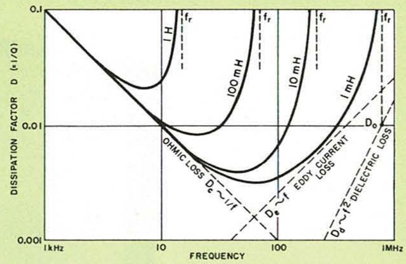


Figure 2. Dissipation-factor variation with frequency in typical air-core Type 1482 Standard Inductors.

$$D \simeq \underbrace{\frac{1}{1-\left(\frac{f}{f_r}\right)^2}}_{\text{Resonance Factor}} \left[\underbrace{\frac{R_c}{\omega L_o}}_{\text{Ohmic Loss, } D_c} + \underbrace{G_e \omega L_o}_{\text{Eddy-Current Loss, } D_e} + \underbrace{\left(\frac{f}{f_r}\right)^2 D_o}_{\text{Dielectric Loss, } D_d}\right] \qquad (2)$$

The higher permeability of an iron core makes possible lower values of D_c and D_e, while f_r is slightly reduced and D_o is not changed. The core adds three more components to the dissipation factor: one from eddy currents in the core, proportional to frequency, another from hysteresis loss in the core, independent of frequency, and a third from residual losses in the core, constant with frequency and relatively small. The effects of these losses are shown in the plots of Q versus frequency for Type 940 Decade Inductors.

CALIBRATION

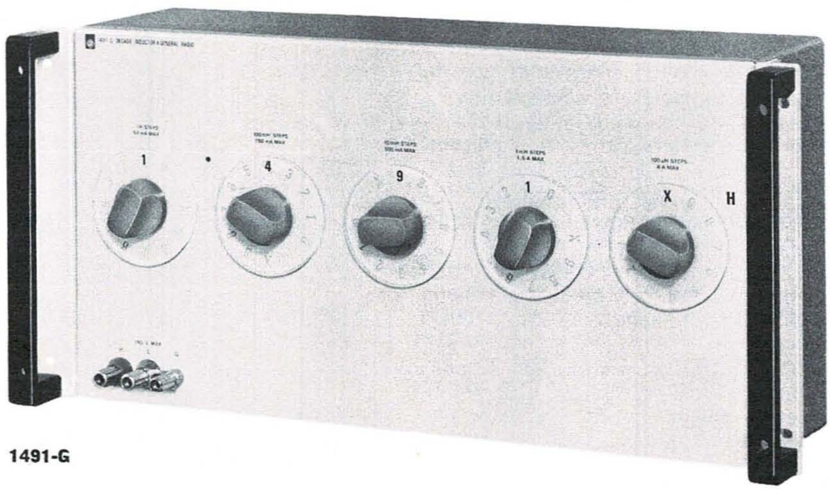
The calibrated inductance of a standard inductor is the change in the measured inductance of a circuit when a portion of that circuit is removed and replaced by the inductor. This measured inductance includes small and variable mutual inductances between the inductor and the rest of the circuit, which are negligible when the calibrated inductance is larger than, say, 100 microhenrys, but which can introduce accuracy-limiting uncertainties into the calibration of smaller inductances. These uncertainties can be reduced to less than one nanohenry to permit accurate calibrations down to one microhenry, if the mutual components are made a definite part of the calibrated inductance. One method of achieving this, used in the Type 1482 Standard Inductors of 200 microhenrys and less, is to provide, on the inductor, a switching link, which connects either the inductor coil or a short circuit through internal leads to the external connection terminals. The calibrated inductance, which is the measured difference of the connection terminals when the switch is moved from coil to short, is to a high degree independent of the external connections or environment.*

Since the inductance usually varies with frequency, an accurate calibration requires that the frequency be specified. When, as in inductors with iron cores, the inductance also varies with current, the calibration must also specify a corresponding current or voltage. Since the frequency or current at which the inductor will be used is not usually known, a convenient reference level is zero frequency and zero current (initial permeability). Measurements made at two currents within the linear range and at well below resonant frequency are extrapolated to obtain inductance at zero current and initial permeability of the core material.

*John F. Hersh, "Connection Errors in Inductance Measurement," General Radio Experimenter, 34, 10, October, 1960.

Type 1491 DECADE INDUCTOR

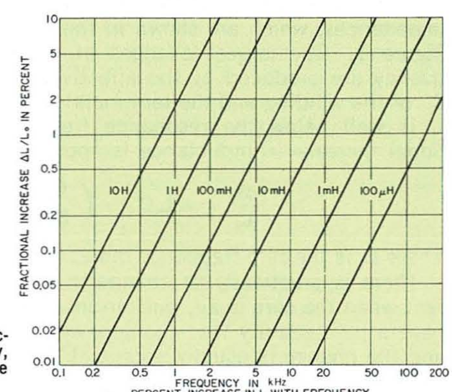
- high-Q, 200 and above
- shielded toroidal cores for
  small mutual inductance
  little effect from external fields
- sealed against moisture



1491-G

The 1491 Decade Inductor is an assembly of several 940 Decade-Inductor Units in a single metal cabinet. The units have no electrical connection to the panel, but a separate ground terminal is provided, which can be connected to the adjacent low terminal, leading to the smallest decade.

These inductance decades are convenient elements for use in wave filters, equalizers, and tuned circuits throughout the range of audio and low radio frequencies. As components in oscillators, analyzers, and similar equipment, they are especially useful during the preliminary design period, when the ability to vary circuit elements over relatively wide ranges is necessary to determine optimum operating values. As moderately precise standards of inductance they have values of low-frequency storage factor, Q, that are much larger than those of air-core coils.



Variation of inductance with frequency, for the 1491 Decade Inductors.

specifications

(see also specifications for 940 decade units)

Frequency Characteristics: Percentage increase in effective series inductance (above the zero-frequency value, L_o) may be obtained by interpolation in accompanying graph for any setting of the highest-value decade used, when LOW terminal is grounded to cabinet.

Zero Inductance: Approx 1 μH.

Max Voltage: 500 V rms. Switch will break circuit at 500 V if turned rapidly, but voltages above 150 V may cause destructive arcing with switch between detent positions.

Terminals: Binding posts on ¾-in. centers; separate ground terminal provided.

Mounting: Lab-Bench Cabinet.

Dimensions (width x height x depth):

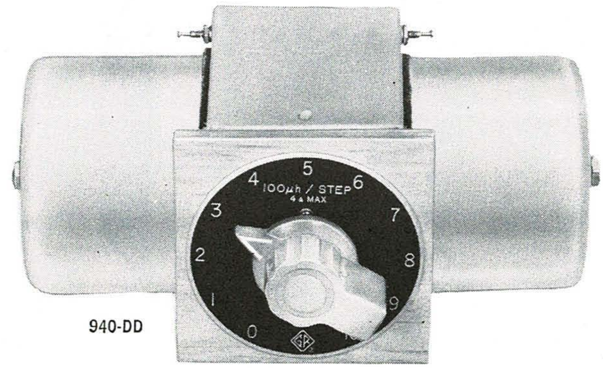
1491-A, -B, -C			
	Bench	12¾ x 8¾ x 6½ in.	325 x 225 x 170 mm
	Rack	19 x 8¾ x 4⅞ in.	485 x 225 x 125 mm
1491-D, -F, -G			
	Bench	17 x 8¾ x 6½ in.	435 x 225 x 170 mm
	Rack	19 x 8¾ x 4⅞ in.	485 x 225 x 125 mm

Weight (bench models; add 1¾ lb (0.8 kg) for rack models):

	Net	Shipping (est)
1491-A, -B, -C	18 lb (8.5 kg)	25 lb (11.7 kg)
1491-D, -F	23 lb (10.5 kg)	30 lb (13.7 kg)
1491-G	26½ lb (12.5 kg)	34 lb (15.5 kg)

Catalog Number Bench	Catalog Number Rack	Description	Inductance Total	Inductance Steps	940's Included	Price in USA Bench	Price in USA Rack
		Decade Inductor					
1491-9701	1491-9711	**1491-A**	0.111 H	0.0001 H	DD, E, F	**$650.00**	**$670.00**
1491-9706	1491-9716	**1491-F**	1.111 H	0.0001 H	DD, E, F, G	**840.00**	**860.00**
1491-9703	1491-9713	**1491-C**	1.11 H	0.001 H	E, F, G	**630.00**	**650.00**
1491-9707	1491-9717	**1491-G**	11.111 H	0.0001 H	DD, E, F, G, H	**1050.00**	**1070.00**
1491-9704	1491-9714	**1491-D**	11.11 H	0.001 H	E, F, G, H	**840.00**	**860.00**
1491-9702	1491-9712	**1491-B**	11.1 H	0.01 H	F, G, H	**650.00**	**670.00**

Type 940 DECADE- INDUCTOR UNIT



940-DD

Each 940 Decade-Inductor Unit is an assembly of four inductors (relative values, 1, 2, 2, 5) wound on molybdenum-permalloy dust cores, which are combined by switching to give the eleven successive values from 0 to 10. The decade switch has high-quality ceramic stator-and-rotor members and well-defined ball-and-socket detents. All contacts are made of a silver alloy and have a positive wiping action.

specifications

Accuracy: Each unit is adjusted so that its inductance at zero frequency and initial permeability will be the nominal value within the accuracy tolerance given in the following table:

Unit	940-DD	940-E	940-F	940-G	940-H
Inductance per step	100 µH	1 mH	10 mH	100 mH	1 H
Accuracy	±2%	±2%	±1%	±0.6%	±0.6%

Under our standard warranty, this accuracy is guaranteed for 2 years if the inductor has not been damaged.

Frequency Characteristics: For any specific operating frequency, Figure 2 shows the percentage increase in effective series inductance (above the value when $f = 0$), which is encountered with the extreme settings of each of the five decade-inductor units when the chassis is floating. Interpolation may be used for intermediate settings.

Change in Inductance with Current: Fractional change in initial inductance with ac current for each type of toroid is shown in the normal curves, Figure 1, in terms of the ratio of the operating current, I, to I_1, the current for 0.25% change, solid line (0.1%, broken line). For ratios below unity, inductance change is directly proportional to current. Values of I_1, listed below, are approximate and are based on the largest inductor in the circuit for each setting.

Incremental Inductance: Dc bias current I_b will reduce the initial inductance as shown in the incremental curves, Figure 1.

Switch Setting	RMS I_1 (mA) 0.1% Increase	0.25% Increase			
	940-DD	940-E	940-F	940-G	940-H
1	141	17	5.4	1.7	0.54
2, 3, 4	100	12	3.8	1.2	0.38
5, 6, 7, 8, 9, 10	63	8	2.4	0.8	0.24

Storage Factor Q: See Figure 3:

Dc Resistance: Approx 45 Ω per henry.

Temperature Coefficient: Approx —25 ppm per degree C between 16° and 32°C.

Max Safe Current: Approx 200 times the pertinent I_1 value (30 times for the 940-DD). Max current engraved on dial.

Terminals: Solder lugs. Circuit insulated from chassis.

Mounting: Hardware included, with dial plate and knob.

Dimensions (width x height x depth): 8 x 3½ x 4¼ in. (205 x 90 x 110 mm).

Weight: Net, 3½ lb (1.6 kg); shipping, 6 lb (2.8 kg).

Catalog Number	Description	Inductance Total	Inductance Steps	Price in USA
	Decade Inductor			
0940-9810	**940-DD**	1 mH	100 µH	**$220.00**
0940-9705	**940-E**	0.01 H	0.001 H	**195.00**
0940-9706	**940-F**	0.1 H	0.01 H	**145.00**
0940-9707	**940-G**	1 H	0.1 H	**195.00**
0940-9708	**940-H**	10 H	1 H	**220.00**

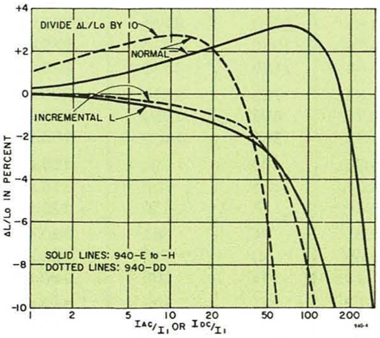


Figure 1. Percentage change in normal and incremental inductance with ac and bias current. Incremental curve is limited to an ac excitation less than I_1.

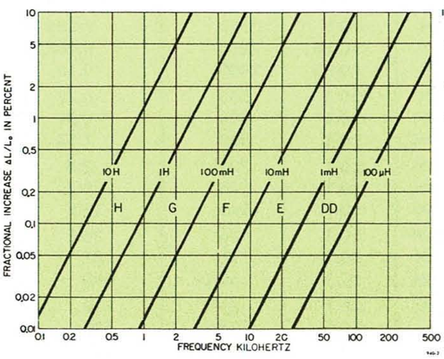


Figure 2. Change in effective inductance with frequency for the 940 Decade-Inductor Units.

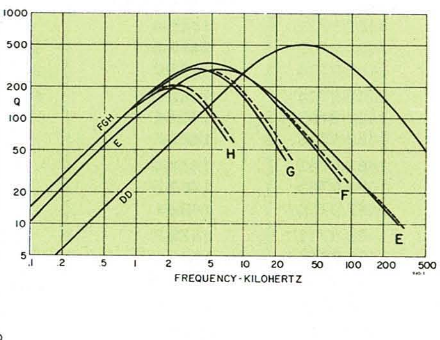
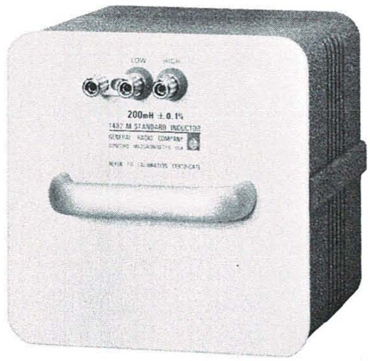


Figure 3. Variation of Q for the maximum inductance of each 940 Decade-Inductor Unit at low excitation levels. Dashed curves correspond to use with chassis floating.

Type 1482 STANDARD INDUCTOR

- stable within ±0.01% per year
- low, known temperature coefficient
- minimized connection errors
- toroidal — free from external fields



1482-M

The 1482 is an accurate, highly stable standard of self inductance for use as a low-frequency reference or working standard in the laboratory. Records extending over 13 years, including those of inductors that traveled to national laboratories in several countries for calibration, show long-term stabilities well within ±0.01%.

Each inductor is a uniformly wound toroid on a ceramic core. It has a negligible external magnetic field and hence essentially no pickup from external fields. The inductor is resiliently supported in a mixture of ground cork and silica gel, after which the whole assembly is cast with a potting compound into a cubical aluminum case.

1632 Bridge page 101

Sizes of 500 μH and above have three terminals, two for the inductor leads and the third connected to the case, to provide either a two- or three-terminal standard. The 50-, 100-, and 200-μH sizes have three additional terminals for the switching used to minimize connection errors, as described in the introduction to the inductance section.

For comparing other inductors with these standards, the 1632-A Inductance Bridge is recommended.

— See **GR Experimenter** for November 1960.

specifications

Inductance Range: See table.

Accuracy of Adjustment: See table.

Calibration: A certificate of calibration is provided with each unit, giving measured values of inductance at 100, 200, 400, and 1000 Hz, with temperature and method of measurement specified. These values are obtained by comparison, to a precision, typically, of better than ±0.005%, with working standards whose absolute values, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards, are known to an accuracy typically ±(0.02% + 0.1 μH) at 100 Hz.

Stability: Inductance change is less than ±0.01% per year.

Dc Resistance: See table for representative values. A measured value of resistance at a specified temperature is given on the certificate of calibration.

Low-Frequency Storage Factor Q: See table for representative values of Q at 100 Hz (essentially from dc resistance). An individual value of Q, calculated from the measured dc resistance, is given on each certificate of calibration.

Temperature Coefficient of Inductance: Approx 30 ppm per °C. Minute temperature corrections may be computed from dc resistance changes. A 1% increase in resistance, produced by a temperature increase of 2.54°C. corresponds to 0.0076% increase in inductance.

Resonant Frequency: See table for representative values. A measured value is given on the certificate of calibration.

Max Input Power: For a rise of 20°C, 3 W; for precise work, a rise of 1.5°C, 200 mW. See table for corresponding current limits.

Terminals: Jack-top binding posts on ¾-in. spacing with removable ground strap.

Mounting: Aluminum cabinet with handle and rubber feet.

Dimensions (width x height x depth): 6½ x 6½ x 8 in. (165 x 165 x 205 mm).

Weight: Net, 11½ lb (5.5 kg); shipping, 13 lb (6 kg).

Catalog Number	Description	Nominal Inductance	Adjustment Accuracy (Percent)	*Resonant Frequency (kHz)	*Dc Resistance (Ohms)	*Q at 100 Hz	Milliamperes, rms for, 200 mW	3 W	Price in USA
	Standard Inductor								
1482-9701	**1482-A**	50 μH	±0.5	3100	0.039	0.81	2260	8770	**$225.00**
1482-9702	**1482-B**	100 μH	±0.25	2250	0.083	0.76	1550	6010	**225.00**
1482-9703	**1482-C**	200 μH	±0.25	1400	0.15	0.84	1150	4470	**225.00**
1482-9704	**1482-D**	500 μH	±0.1	960	0.38	0.83	725	2810	**225.00**
1482-9705	**1482-E**	1 mH	±0.1	800	0.84	0.75	490	1890	**195.00**
1482-9706	**1482-F**	2 mH	±0.1	580	1.52	0.83	360	1400	**185.00**
1482-9707	**1482-G**	5 mH	±0.1	320	3.8	0.83	230	890	**180.00**
1482-9708	**1482-H**	10 mH	±0.1	220	8.2	0.77	156	600	**170.00**
1482-9710	**1482-J**	20 mH	±0.1	145	14.5	0.87	117	450	**170.00**
1482-9711	**1482-K**	50 mH	±0.1	84	36.8	0.85	74	280	**180.00**
1482-9712	**1482-L**	100 mH	±0.1	71	81	0.78	50	192	**180.00**
1482-9713	**1482-M**	200 mH	±0.1	39.0	109	1.15	43	166	**180.00**
1482-9714	**1482-N**	500 mH	±0.1	24.5	280	1.12	27	103	**190.00**
1482-9716	**1482-P**	1 H	±0.1	14.6	616	1.02	18	70	**225.00**
1482-9717	**1482-Q**	2 H	±0.1	10.6	1125	1.12	13.3	52	**250.00**
1482-9718	**1482-R**	5 H	±0.1	6.8	2920	1.08	8.3	32	**330.00**
1482-9720	**1482-T**	10 H	±0.1	4.9	6400	0.98	5.6	22	**450.00**

* Representative values. Actual values given on certificate.

DETECTORS

In most types of electrical measurements, a detector is used for aural or visual indication of the desired measurement condition. Such devices as null indicators, demodulators, and voltmeters are usually combined with filters and amplifiers to constitute detectors for specific purposes. Different types of measurement impose different requirements on the detector. Thus, bridge measurements require both selectivity and shielding to reduce extraneous signals and high sensitivity for maximum precision of measurement. For measurement of relative signal levels (gain or loss), a wide linear range is desirable, as well as an accurately calibrated level indication. In demodulators, distortion must be minimized to ensure faithful reproduction of the modulation envelope.

A simple rectifier followed by a meter or earphones can be used to convert an ac signal to dc or to demodulate an rf signal, but such a system has inherently low sensitivity. For higher sensitivity, some form of amplifier is necessary. At audio frequencies, the signal is usually amplified directly and then rectified to operate a meter, although with null detectors, earphones can be used at the user's option. At radio frequencies, a radio receiver, if well shielded, is a satisfactory detector, but a broadband heterodyne detector employing a wide-range local oscillator is usually more flexible in application. Here, the incoming signal is heterodyned with that of a local oscillator to produce the difference frequency, which is amplified in an intermediate-frequency amplifier.

General Radio offers detectors using all three types of amplifiers — untuned, tunable, and fixed-tuned intermediate frequency.

The 1232-A Tuned Amplifier and Null Detector is tunable over the audio-frequency range, with two additional fixed frequencies of 50 and 100 kHz. Its unusually high sensitivity, low noise level, excellent selectivity, and high gain make it suitable for the most exacting bridge-measurement requirements. With the 1232-P1 RF Mixer, it can be used as the i-f amplifier in a heterodyne-detector system at frequencies up to 10 MHz. An accessory pre-amplifier, the 1232-P2, will improve is effective sensitivity in low-frequency, high-impedance applications.

For audio-frequency bridge measurements, the 1240-A Bridge Oscillator-Detector provides both the bridge power source and the detector in a simple, compact structure.

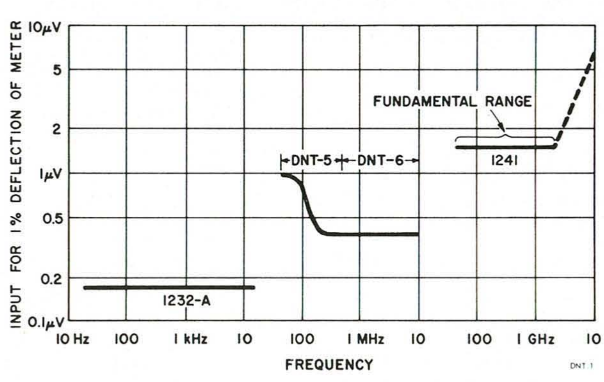
Complete heterodyne-detector systems, the DNT-5 and DNT-6, are available, which use the above amplifiers and mixers.

For VHF and UHF measurements, the Type 1241 Heterodyne Detectors are useful. With the 1236 I-F Amplifier as the amplifier/indicator, these three assemblies include the 874-MRAL Mixer and a local oscillator appropriate to the desired frequency range.

Simple rectifiers are often used at the high frequencies. The 874-VQ Voltmeter Detector and 874-VR Voltmeter Rectifier, used with an audio amplifier such as the 1234 Standing-Wave Meter or 1232 amplifier, are sensitive detectors of modulated signals over a wide range of frequencies.

OTHER DETECTORS

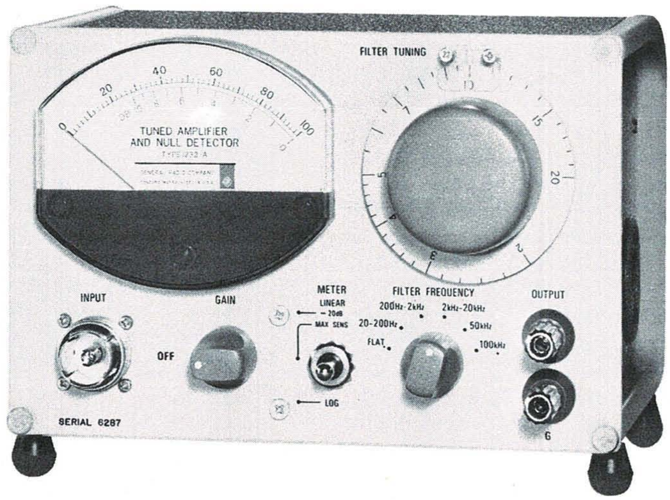
Elsewhere in this catalog are detectors in disguise. For example, the GR sound-level meters, 1551-C, 1561, and 1565, are excellent very high sensitivity, untuned audio-frequency detectors. Among the GR analyzers are several highly selective tuned amplifiers well suited to serve as detectors, the 1900-A and 1568-A Wave Analyzers, for example.



Sensitivity and frequency ranges of various detectors.

Type 1232-A TUNED AMPLIFIER AND NULL DETECTOR

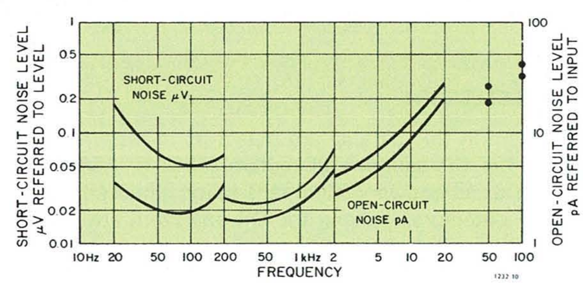
- 20 Hz to 20 kHz, 50 and 100 kHz
- 0.1-μV sensitivity
- bandwidth approx 5%
- 120-dB gain



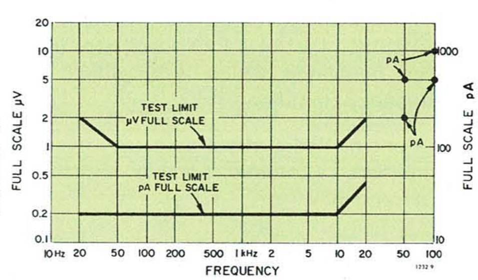
This battery-operated, solid-state amplifier will excel in common applications and fit many unusual requirements with its combined high sensitivity, low noise, choice of narrow or broad bandwidth, high gain, portability, and accessories for added versatility. Use it as a

- bridge detector at audio frequencies; with the 1232-P2 Preamplifier it is equally sensitive for extremely high-impedance, low-frequency balances. With the 1232-P1 RF Mixer it is a sensitive, heterodyne, rf detector to 10 MHz with excellent harmonic rejection.
- audio preamplifier and general-purpose, tunable or broadband audio amplifier
- a-m detector for 0.5- to 500-MHz carrier frequencies when used with an 874-VQ Voltmeter Detector;
- sensitive audio wave analyzer for approximate measurements.

— See **GR Experimenter** for July 1961.



(Left) Typical noise levels as a function of frequency. (Right) Minimum input for full-scale meter deflection as a function of frequency, when amplifier is tuned to peak response.



specifications

Frequency Response:
Tunable Filters — 20 Hz to 20 kHz in 3 ranges; between 2% and 6% bandwidth to 15 kHz; 2nd harmonic at least 34 dB down from peak, 3rd at least 40 dB down; rejection filter on two highest ranges reduces 60-Hz level to at least 60 dB below peak (50 dB at 50 Hz). Dial accuracy is ±3%.
50- and 100-kHz Filters — 2nd harmonic 44 and 53 dB down, respectively.
Flat Response — ±3 dB 20 Hz to 100 kHz.

Sensitivity: See plot. Typically better than 0.1 μV over most of the frequency range.

Noise Level Referred to Input: See plot. Noise figure at 1 kHz is less than 2 dB at an optimum source impedance of 27 kΩ.

Noise Level Referred to Output: Less than 5 mV on FLAT filter-frequency position, min gain setting, and —20-dB switch position; less than 50 mV in MAX SENS position.

Input Impedance: Approx 50 kΩ at max gain; varies inversely with gain to 1 MΩ at min gain.

Max Safe Input Voltage: 200 V ac or 400 V dc.

Voltage Gain: Approx 120 dB on the tunable ranges; 100 dB, flat range; 106 dB at 50 kHz; 100 dB at 100-kHz position.

Output: 1 V into 10,000 Ω. Internal impedance is 3000 Ω.

Meter Linearity: DB differences are accurate to ±5% ±0.1 division for input of less than 0.3 V.

Compression (on LOG position): Reduces full-scale sensitivity by 40 dB. Does not affect bottom 20% of scale.

20-dB Position: Reduces gain by 20 dB in linear mode.

Distortion (in FLAT position): Less than 5% (from meter rectifiers).

Power Supply: 12 V dc, from 9 mercury (M72) cells in series. Est battery life 1500 hours. Optionally, a rechargeable battery (non-mercury) can be supplied on special order.

Accessories Available: 1232-P1 RF Mixer for heterodyne operation to 10 MHz; 1232-P2 Preamplifier to maintain sensitivity of 1232-A at low frequencies when operating from a source impedance above 100 kΩ; rack-adaptor sets (see below) convert 1232 and companion instruments to 19-in. rack-mount width.

Terminals: Input, GR874 coaxial connector; output, binding posts.

Mounting: Convertible-Bench Cabinet.

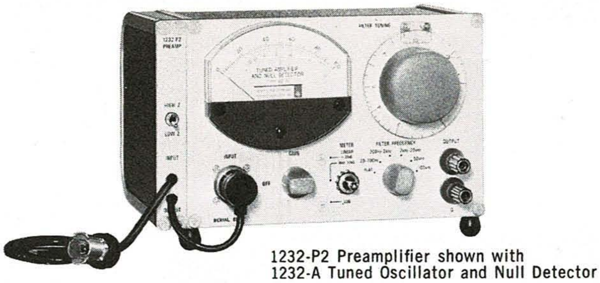
Dimensions (width x height x depth): 8 x 6 x 7½ in. (205 x 155 x 190 mm).

Weight: Net, 5¾ lb (2.7 kg); shipping, 8 lb (3.7 kg).

Catalog Number	Description	Price in USA
1232-9701	**1232-A Tuned Amplifier and Null Detector**	**$455.00**
1232-9829	**1232-AP Tuned Amplifier and Null Detector,** with preamplifier	**555.00**
	Rack-Adaptor Sets	
0480-9838	**480-P308,** for 1232-A alone	**11.00**
0480-9836	**480-P316,** for 1232-A with 1310 or 1311 oscillator or similar 8-in. wide instrument with convertible-bench cabinet	**6.75**
0480-9837	**480-P317,** for 1232-AP (with preamp) and companion 8-in. instrument	**6.75**
8410-1372	**Replacement Battery,** 9 req'd	**1.95**

PATENT NOTICE. See Note 15.

Type 1232-P2 PREAMPLIFIER



1232-P2 Preamplifier shown with 1232-A Tuned Oscillator and Null Detector

The 1232-P2 has particular application to measurements with the 1615-A Capacitance Bridge. It increases sensitivity for measurements made at frequencies well below 1000 Hz if the bridge is set to both its lowest C and D (not G) ranges simultaneously. Low-frequency measurement of small samples of dielectric materials can be made more accurately with the addition of this preamplifier.

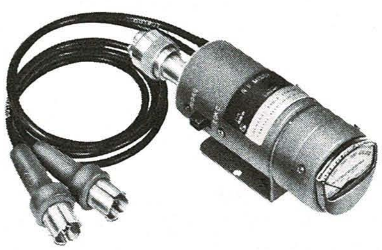
— See **GR Experimenter** for February 1967.

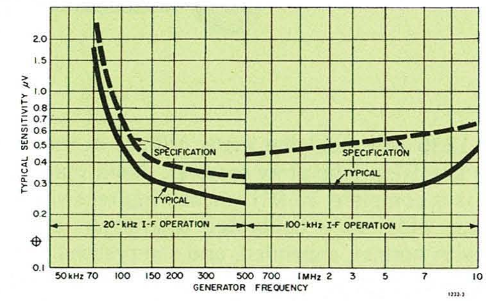
specifications

Input Impedance: Greater than 100 MΩ in parallel with 70 pF.
Output Impedance: 10 kΩ.
Voltage Gain: Approx 0.7.
Noise (referred to input): Open-circuit equivalent, 0.1 pA; short-circuit equivalent, 0.3 µV (when used with Type 1232-A tuned to 100 Hz).
Optimum Source Impedance: 3 MΩ.
Connectors: GR874 on cables, input and output.
Power Required: 12 V, 200 µA, supplied by 1232-A.
Dimensions (width x height x depth): 3/4 x 6 x 7 1/2 in. (20 x 150 x 190 mm).
Weight: Net, 15 oz (425 g); shipping, (est) 3 lb (1.4 kg).

Catalog Number	Description	Price in USA
1232-9602	**1232-P2 Preamplifier**	**$95.00**

Type 1232-P1 RF MIXER





Sensitivity (open-circuit voltage from 50-ohm source, equivalent to noise level).

With the 1232-A, this mixer can be used from 70 kHz to 10 MHz as a heterodyne detector with high harmonic rejection, a level indicator in attenuation measurements, or, with a swept local oscillator and oscilloscope, for approximate spectrum analysis.

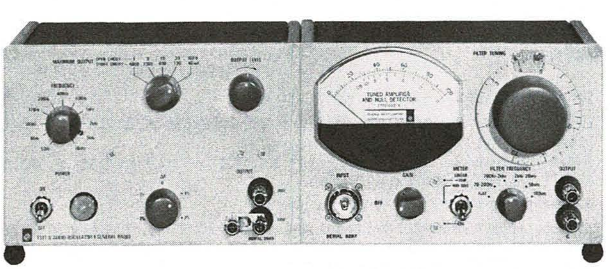
— See **GR Experimenter** for December 1963.

specifications

Frequency Range: 70 kHz to 10 MHz. (Can be used up to 60 MHz, with care in the selection and identification of local-oscillator frequencies.) Recommended local oscillators for the 70-kHz to 0.5-MHz and the 0.5- to 10-MHz ranges are 1210-C and 1211-C, respectively.
I-F Output Frequencies: Switch-selected, 20 kHz or 100 kHz.
Bandwidth: 0.8 kHz in 20-kHz position, 10 kHz in 100-kHz position with a 20-kΩ output load (1232-P1 RF Mixer alone).
Sensitivity: See plot.
Input Impedance: Approx 200 Ω.
Output Impedance: Approx 20,000 Ω.
Dimensions: 2 1/4 in. (58 mm) dia., 6 3/4 in. (175 mm) long.
Weight: Net, 1 lb (0.5 kg); shipping, 3 lb (1.4 kg).

Catalog Number	Description	Price in USA
1232-9601	**1232-P1 RF Mixer**	**$140.00**

Type 1240 BRIDGE OSCILLATOR - DETECTOR



The 1232-A Tuned Amplifier and Null Detector and the 1311-A Audio Oscillator have been combined for use with audio-frequency bridges and other null-balance devices. This assembly occupies a minimum of bench space and is supplied with removable panel extensions, which adapt it for rack mounting.

The oscillator supplies 11 fixed frequencies from 50 Hz to 10 kHz. The detector is tunable continuously from 20 Hz to 20 kHz, with additional spot frequencies of 50 kHz to 100 kHz. The assembly is also available with the 1232-P2 Preamplifier included.

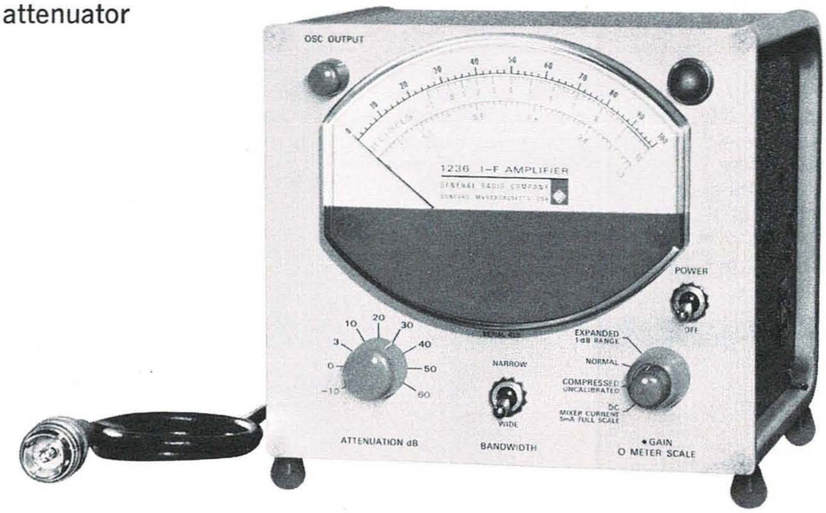
specifications

Power Required: Null detector, internal battery; oscillator, 105 to 125 or 210 to 250 V, 50 to 400 Hz, 22 W max.
Dimensions (width x height x depth): 19 x 6 x 7 3/4 in. (485 x 155 x 200 mm), with panel extensions.
Weight: Net, 13 1/2 lb (6.5 kg); shipping, 28 lb (13 kg).

Catalog Number	Description	Price in USA
1240-9701	**1240-A Bridge Oscillator-Detector**	**765.00**
1240-9829	**1240-AP Bridge Oscillator-Detector,** with preamp	**860.00**
8410-1372	**Replacement Battery,** 9 req'd	**1.95**

Type 1236 I-F AMPLIFIER

- 30-MHz precision lab receiver
- bandwidths: 0.5 and 4 MHz
- 2-dB noise figure, 3.5-μV sensitivity
- preamplifier and 70-dB attenuator
- expanded scale



The 1236 will meet the many critical demands placed upon a precision laboratory receiver. More than an amplifier, it is a complete 30-MHz measuring receiver with preamplifier, wide-range calibrated attenuator, and a large meter with normal, expanded, and compressed scales. The high sensitivity, or low noise figure, with narrow bandwidth will provide good small-signal performance and noise rejection for improved measurement accuracy. The availability of a wider bandwidth also greatly simplifies use at higher frequencies where sources are generally less stable.

Gain stability during a measurement is ensured by a fully regulated power supply; 10% line-voltage variations change gain less than 0.05 dB. Frequency stability of the local oscillator can be achieved by use of the 30-MHz i-f output of the amplifier to drive an external afc loop.

PRECISION ATTENUATION MEASUREMENT

Large values of attenuation can be measured with particular ease with the 1236 owing to the wide dynamic range of its preamplifier and attenuator. A 1-dB full-scale, expanded meter scale is provided, which facilitates measurement of small values of, or changes in, attenuation. A continuous gain control permits setting initial readings for easy subtraction in substitution measurements.

SWR MEASUREMENT

The 1236 is recommended for the most precise SWR measurements, of both high and low values. The expanded SWR scale in dB is equivalent to 1.12:1 full scale. The high sensitivity of the 1236 permits the SWR of solid-state devices to be measured at signal levels low enough to avoid the effects of device nonlinearity.

As a null detector, the 1236 offers the advantages of its compressed (agc) meter scale for convenience in rapid null balancing and its added sensitivity for sharp nulls and more precise data. It will also find application in noise-figure measurements.

PRECISION HETERODYNE RECEIVERS

Local Oscillators page 235 ff

The 1236 I-F Amplifier is available in combination with an appropriate local oscillator (power supply for which is built into the 1236), mixer, low-pass filter, preamplifier and connecting coaxial components to make up complete precision test receivers. These Type 1241 Heterodyne Detectors are available for use in any one of three frequency ranges from 40 to 2030 MHz.

1241 Detectors page 137

— See **GR Experimenter** for July-Aug 1967.

specifications

Center Frequency: 30 MHz.

Bandwidth: Wide band approx 4 MHz, narrow band approx 0.5 MHz, selectable by panel switch.

Noise Figure: Typically 2 dB.

Sensitivity: <9 μV (wide band), <3.5 μV (narrow band) open-circuit voltage behind 400-Ω source for a 3-dB increase of meter deflection.

Meter Characteristics

Normal Scale: -2 to 10 dB. **Linearity:** ±0.2 dB over 0 to 10-dB range.

Expanded Scale: 1-dB full scale, 1.12:1 SWR. **Linearity:** ±0.03 dB.

Compressed Scale: 40-dB min range.

Attenuator

Range: 70 dB in 10-dB steps.

Accuracy: $\pm$(0.1 dB + 0.1 dB/10 dB) at 30 MHz.

Continuous Gain Control: 10 dB min range.

Video Output (Modulation): 1.5 V max behind 600 Ω; bandwidth, 1 MHz.

I-F Output: 0.5 V max into 50 Ω.

Power-Supply Output: 150 to 300 V dc adjustable, at 30 mA, regulated; 6.3 V ac at 1 A.

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 60 Hz, 22 W (without oscillator).

Accessories Supplied: Power cord.

Accessories Available: As local oscillator, GR 1362, 1363, and 1218; 874-MRAL Mixer; GR874 low-pass filters, attenuators, and adaptors, and 1237 VHF/UHF Preamplifier.

GR874 page 141

Mounting: Convertible-Bench Cabinet.

Dimensions (width x height x depth): 8 x 7⅜ x 8 in. (205 x 190 x 205 mm).

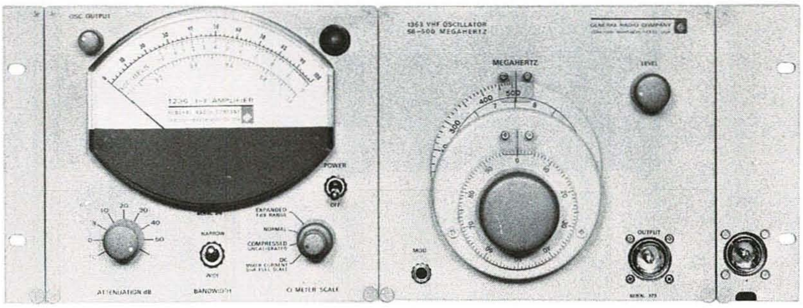
Weight: Net, 12½ lb (6 kg); shipping, 14¾ lb (7 kg).

Catalog Number	Description	Price in USA
1236-9701	**1236 I-F Amplifier**	**$835.00**

Type 1241 HETERODYNE DETECTOR

40 to 2030 MHz

- high sensitivity
- choice of bandwidth
- AGC for null detection
- 70-dB calibrated attenuator
- expanded scale



1241-9701 Heterodyne Detector.

This general-purpose instrument is a highly sensitive high-frequency detector for relative signal-level measurements and for use as a null detector.

Its excellent shielding makes it suitable for low-level measurements in the presence of high-level external fields.

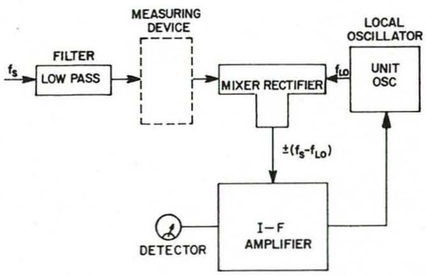
GAIN, LOSS, SIGNAL LEVEL

It can be used: to measure insertion loss and attenuation, crosstalk in multiterminal devices such as switches, and antenna gain and radiation patterns; as a field-strength indicator; and as a laboratory high-frequency receiver.

Signal levels can be measured over an 80-dB range, more with the use of external attenuators.

RF VOLTMETER

When calibrated at one signal level and frequency with the aid of a standard-signal generator, the 1241 Detector can be used at that frequency as a selective voltmeter in a 50-ohm system.



Block diagram of the heterodyne detector.

DETECTOR

It is the recommended null detector for the 1602-B UHF Admittance Meter, 1609 Precision UHF Bridge, and the 1607-A Transfer-Function and Immittance Bridge.

As a standing-wave indicator with the 874-LBB and 900-LB Slotted Lines, it is particularly useful for measurements on nonlinear elements, where a high degree of harmonic rejection and small applied signal level are required.

The expanded 1-dB-full-scale range (equivalent to 1.12 SWR) makes accurate low-SWR measurements possible at low signal levels.

DESCRIPTION

Each assembly comprises one 874-MRAL Mixer, one 1236 I-F Amplifier, one 874-G10L 10-dB Pad, one 874-EL-L 90° Ell, plus one oscillator and one filter, both depending on the frequency range desired (see price table). For maximum shielding, components are equipped with locking GR874® coaxial connectors, which can be used interchangeably with the nonlocking type.

The frequency range can be extended through the use of oscillator harmonics, but with reduced sensitivity and dynamic range.

To cover wide frequency ranges, however, it is recommended that one complete detector be ordered, plus the necessary oscillators and filters for the additional frequency ranges desired. For instance, for the range from 40 to 950 MHz, one would order a 1241-9700 detector, plus one 1362 UHF Oscillator and one 874-F1000L Filter.

GR874 Filters page 159

HF Oscillators page 235 ff

specifications

Frequency Range: See DNT sensitivity curves and price table below.

Sensitivity: Typically 4 μV behind 50 Ω (—100 dBm) for 3-dB meter deflection over residual noise reading (narrow bandwidth).

Mixer: Type 874-MRAL Mixer.

Input Terminal: Mixer input terminal is a locking GR874 coaxial connector. For connection to other coaxial types, see GR874 coaxial adaptors.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz, 40 W.

Accessories Available: The 1237-A VHF/UHF Preamplifier is recommended to provide local-oscillator isolation and improved sensitivity.

Mounting: Rack models, i-f amplifier, oscillator mixer and filter mounted on 19-in. panel; bench models, constituents supplied individually.

Dimensions (width x height x depth): Rack, 19 x 7 x 8¼ in. (485 x 180 x 210 mm), except 1241-9705 is 14-in. high; bench, see specifications for individual components.

Weights (est): Net, 1241-9700, 20 lb (9.5 kg); 1241-9702, 23½ lb (11 kg); 1241-9704, 28½ lb (13 kg). Add approx 6 lb (2.8 kg) for shipping weight, approx 2 lb (1.0 kg) for rack models.

Catalog Number		Frequency Range — MHz				Local Oscillator Supplied	Filter Supplied	Price in USA	
Bench	Rack	Fundamental	2nd Harmonic*	3rd Harmonic*	4th Harmonic*			Bench	Rack
1241-9700	1241-9701	40†-530	82-1030	138-1530	194-2030	**1363**	**874-F500L**	**$1500.00**	**$1535.00**
1241-9702	1241-9703	190-950	410-1870	630-2790	850-3710	**1362**	**874-F1000L**	**1500.00**	**1530.00**
1241-9704	1241-9705	870-2030	1770-4030	2670-6030	3570-8030	**1218**	**874-F2000L**	**1845.00**	**1900.00**

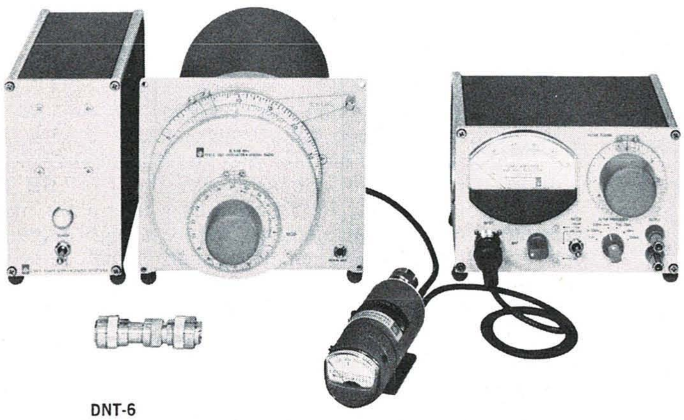
* For harmonic operation, the appropriate low-pass filter must be used.

† 40 MHz is the practical low-frequency limit.

Types DNT-5 and 6 HETERODYNE DETECTOR

70 kHz to 10 MHz

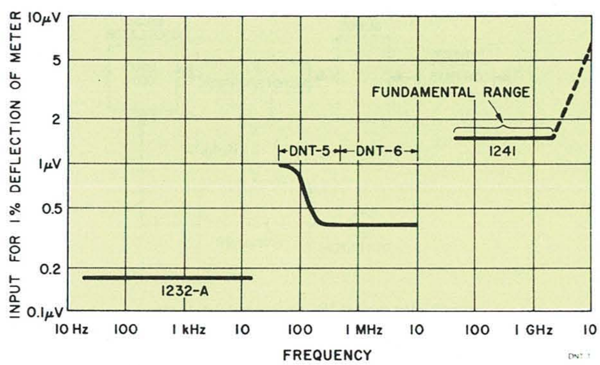
DNT-5



DNT-6

The DNT-5 and -6 Heterodyne Detectors use the Type 1232-A Tuned Amplifier and Null Detector as the i-f amplifier — DNT-5 at 20 kHz and DNT-6 at 100 kHz. Both are very sensitive and well shielded from external fields and are ideal for low-level measurements.

They are excellent detectors for the 1606-B RF Bridge. With the addition of an external calibrated attenuator, such as the Type 874-GAL, a substitution method can be used in the several voltage-level measurements listed on the preceding page. For detailed specifications, see the listing of the various components, as indicated.



specifications

1232 Det page 134

1210 Osc page 228

1211 Osc page 236 ff

Frequency Range	70 to 500 kHz	0.5 to 10 MHz
Type	DNT-5	DNT-6
Null Detector	**1232-A**	**1232-A**
Oscillator	**1210-C**	**1211-C**
Rf Mixer	**1232-P1**	**1232-P1**
Fixed Attenuator	**874-G10L**	**874-G10L**
Power Supplies	**1203**	**1269-A**
Net Wt, lb (kg)	17½ (8)	24½ (11.5)
Ship. Wt, lb (kg)	24 (11)	33 (15)

Catalog Number	Description	Price in USA
	Heterodyne Detector	
1235-9605	**DNT-5,** for 105 to 125 V	**$ 980.00**
1235-9795	for 195 to 250 V	**980.00**
1235-9606	**DNT-6,** for 105 to 125 or 195 to 235 or 210 to 250 V	**1240.00**

PATENT NOTICE. See Note 15.

Type 1234 STANDING-WAVE METER

- 1.05 full-scale SWR
- large meter, light-keyed scales
- precision attenuators
- high sensitivity

The 1234 Standing-Wave Meter incorporates many features to simplify its primary use in measuring SWR with a slotted line, such as the GR 874-LBB or the 900-LB Precision Slotted Line. Accurate measurements of low voltage SWR are possible with the expanded 1.05 scale on the oversize meter face. Reading the wrong meter scale is virtually impossible, as the correct scale is identified by a small meter light.

Panel controls give the operator quick control over (1) the exact frequency of the 1-kHz amplifier, to permit matching exactly the frequency of the modulating oscillator, (2) bandwidth, for optimizing signal-to-noise ratio, without affecting amplifier gain, and (3) meter damping, for reduced meter fluctuations due to noise. These, with the other more usual controls, give the user control over instrument characteristics adequate for a wide variety of measurement conditions.

In attenuation measurements, the 1234 also offers many advantages. Three precision attenuators have a total range of 70 dB in 1-, 5-, and 10-dB steps. Meter scales and attenuators are calibrated for use with a square-law detector. Readings can be interpolated with extremely high resolution on the 1.6- and 0.45-dB full-scale meter ranges. The wide-range, 5-dB/step attenuator control has a "memory" dial that permits rapid substitution measurements without subtraction and thus reduces the possibility of error.

— See **GR Experimenter** for February 1968.

specifications

Meter Scales: SWR, 1 to 4, 3.2 to 10, 1 to 1.2 and 1 to 1.05; dB, 0 to 10, 0 to 1.6, and 0 to 0.45; bolometer current, 0 to 10 mA.
Meter Accuracy: 0 to 10-dB scale, ±(0.01 dB + 2% of reading); 0 to 1.6-dB scale, ±0.02 dB; 0 to 0.45-dB scale, ±0.007 dB.

Attenuator: Three separate attenuators: 20 dB in 10-dB steps, accuracy ±0.1 dB/10 dB; 45 dB in 5-dB steps, accuracy* ±0.05 dB/5 dB, cumulative error 0.1 dB max; 5 dB in 1-dB steps, accuracy ±0.01 dB/1 dB, cumulative error 0.03 dB max.

* Accuracy for source R < 1.5 times optimum listed in table.

INPUT	Crystal				Bolometer
Optimum Source R	35 kΩ	20 kΩ	2 kΩ	200 Ω	200 Ω
Input Impedance	1 MΩ	350 kΩ// 80 H	35 kΩ// 8 H	3.5 kΩ// 0.8 H	3.5 kΩ// 0.8 H
Sensitivity (fs)	1.2 μV	1 μV	0.32 μV	0.1 μV	0.1 μV
Noise**	0.12 μV	0.12 μV	0.036 μV	0.012 μV	0.012 μV

** Equivalent input noise level with source resistance equal to optimum and with minimum bandwidth.

Bandwidth: 10 to 100 Hz, adjustable with constant gain.
Frequency: 1 kHz, adjustable ±30 Hz.

Gain Control: Coarse and fine, 6-dB range.

Bolometer Bias Current: 4.3 and 8.7 mA, adjustable ±10%. Voltage limited for bolometer protection.

Meter Speed: Slow and fast, switch selected.

Outputs: Dc, 1.5 V max behind 1500 Ω. Ac, 0.1 V rms (1 to 4 SWR range), 0.3 V rms (1 to 1.2 range), and 1 V rms (1 to 1.05 range); 500-Ω source impedance. Load resistance >6000 Ω.

GENERAL

Power Required: 100 to 125 or 200 to 250 V, 50 to 60 Hz, 4 W. Or 22 to 35 V dc, 90 mA from ext battery, 1538-P3 Battery and Charger suitable.

Accessories Supplied: Battery connector.

Accessories Available: 1538-P3 Battery and Charger.

1538-P3 page 268

Mounting: Flip-Tilt case.

Dimensions (width x height x depth): 8⅜ x 8¾ x 11¼ in. (215 x 225 x 290 mm).

Weight: Net, 9 lb (4.1 kg); shipping, 12½ lb (6.0 kg).

Catalog Number	Description	Price in USA
1234-9701	**1234 Standing-Wave Meter**	**$625.00**

COAXIAL ELEMENTS

GR874®

GR900®

GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO

MICROWAVE COAXIAL EQUIPMENT — DC TO MICROWAVE

14 mm - 50 ohms

GR874®

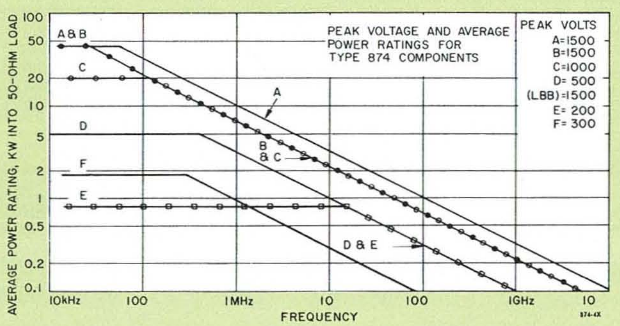
GR900®

Described on the following pages is one of the most comprehensive lines of coaxial equipment available anywhere. There are two basic classifications: the GR874® series, whose common element is the general-purpose GR874 coaxial connector, and the GR900® series, based on the GR900 precision coaxial connector. Each series includes connectors, adaptors, and circuit elements, as well as a slotted line, so that measurement setups can be conveniently assembled.

GR900 page 170 ff

GR874

General Radio entered the coaxial-component field over 22 years ago, with the introduction of the GR874 connector, which offered not only excellent electrical performance but a major convenience feature: any two, although identical, could be mated. The hermaphrodite, quick-connect GR874 was soon joined by a family of circuit elements and adaptors using the new connector. GR874-equipped instruments — notably the slotted line and the admittance meter — were added to solve the special measurement problems of vhf and uhf. The availability of precise measuring instruments in turn made possible a continuous refinement of the basic connector. An important development was the locking version of the GR874 connector, particularly useful in microwave applications where the needs for mechanical stability and repeatability are demanding. Locking and nonlocking versions of the GR874 connector are fully compatible.



GR900

True precision came to coaxial measurements in 1963, in the form of the GR900 precision coaxial connector and associated equipment. Until that breakthrough, the development of more accurate instruments for coaxial measurements had been retarded for want of a precise connector. The GR900 connector opened the door to the development of a new, precision slotted line, new measuring techniques, and new applications for coaxial lines where only waveguide had gone before. Today, the GR900 line includes adaptors, standards, terminations, air-line sections, and other components.

HIGH PRECISION, REPEATABILITY

Another significant figure has been added to coaxial measurement: Where one formerly spoke of a SWR of 1.03, one now speaks of a SWR of, say, 1.034, with confidence in the last figure. In terms of accuracy, resolution and repeatability attained, the GR900 development must rank as one of the most significant of the past decade.

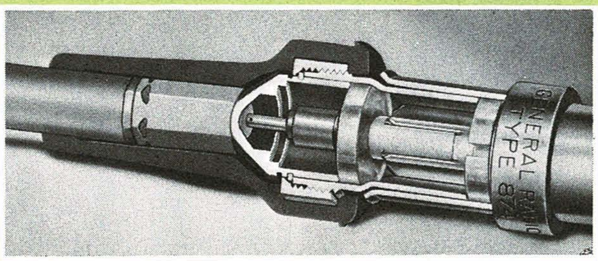
ORIGINAL EQUIPMENT USERS

Both the GR874 and the GR900 connectors have gained wide popularity, not only as circuit elements but also among instrument manufacturers, who have put the electrical and physical advantages of these connectors to good use on their products.

Category	Applicable Type 874 Items	See Curve	Peak Volts
Adaptors	-QHJA, -QHPA, -QLJA, -Q900L	A	1500
	-QCP, -QCJA, -QCJL, -QNP, -QNPL, -QNJA, -QNJL, -QSCP, -QSCJ, -QSCJL, -QAP7L	C	1000
	-QBJA, -QBJL, -QBPA, -QTNJ, -QTNJL, -QTNP, -QUJ, -QUJL, -QUP	D	500
	-QMDJ, -QMDJL, -QMDP, -QMMJ, -QMMJL, -QMMP, -QMMPL	F	300
Air Lines			
Adjustable	-LAL, -LK10L, -LK20L	B	1500
Fixed	-L10, -L10L, -L20, -L20L, -L30, -L30L	A	1500
Connectors	-B, -BBL, -PLT, -PRLT, -PFL	A	1500
	-CA, -CLA, -C8A, -CL8A, -PBA, -PB8A, -PLA, -PL8A, -PRLA, -PRL8A -PBRLA, -PBRL8A	C	1000
	-C58A, -CL58A, -C62A, -CL62A, -PB58A, -PB62A, -PL58A, -PL62A, -PRL58A, -PRL62A, -PBRL58A, -PBRL62A	D	500
	-C174A, -CL174A, -PB174A, -PL174A, -PRL174A, -PBRL174A	F	300
Elements	-EL, -EL-L, -T, -TL	A	1500
	-K, -KL	D	500
Filters	-F185L, -F500L, -F1000L, -F2000L, -F4000L	E	200
Patch Cords	-R20A, -R20LA	C	1000
	-R22A, -R22LA	D	500
Slotted Line	-LBB	D	1500

GR874® SERIES

14 mm - 50 ohms



Cutaway view of GR874 basic connector mated with GR874 cable connector.

Based on the GR874® connector is a complete line of coaxial components and instruments, including a Slotted Line, Admittance Meter, Transfer-Function and Immittance Bridge, adaptors, stubs, attenuators, filters, and many other devices. The user of the GR874-equipped laboratory need seldom turn to other connector types for a needed element. If he does, he will be able to select a GR874 adaptor to connect to almost any other common type of connector.

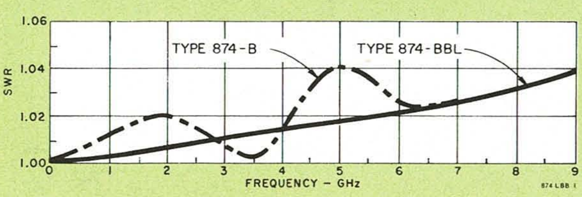
New members of the GR874 line are constantly being developed, so that equipping a laboratory with the GR874 line today will seem an even wiser choice tomorrow.

LOCKING CONNECTORS

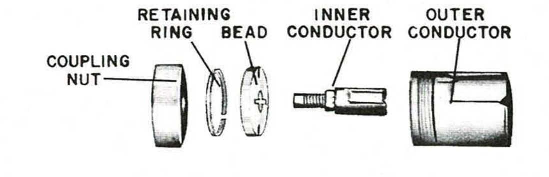
The GR874 connector is also available in a locking version similar to, and compatible with, the nonlocking, quick-disconnect version. The locking version, however, has a threaded coupling nut that permits the two connectors to be mechanically locked together in a stable, semipermanent connection for better electrical repeatability, low leakage, and less chance of accidental disconnection, while retaining the other performance advantages of the nonlocking GR874 connector. The quick connect/disconnect feature is retained if the coupling nut is not engaged. Many GR874 components are now available equipped with locking or nonlocking connectors; a final L in the type number designates a locking version. Most GR874-equipped instruments use the locking connector by which the adaptors to other connector types can be semipermanently attached to the instrument.

ELECTRICAL CHARACTERISTICS

The GR874 connector has the lowest reflection characteristics of any standard, general-purpose, 50-ohm coaxial connector in the dc-to-9-GHz frequency range. Its small reflections at high frequencies makes the GR874 of particular value in pulse applications and in time-domain reflectometry. Its SWR performance is typically superior to that of the type N connector. GR874 cable connectors, in fact, offer SWR performance superior to that of any cable with which they can be used, and therefore add no significant reflections when used in measurement setups.



Typical SWR of pairs of Type 874-B and -BBL Connectors



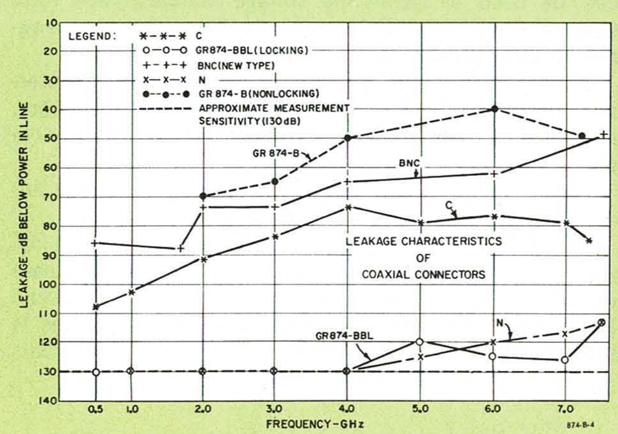
Exploded view of Type 874-B Basic Connector.

MECHANICAL CHARACTERISTICS

The elements of a GR874 connector, as shown in the exploded view, are an inner conductor, an outer conductor, a supporting polystyrene bead, a phosphor-bronze retaining ring, and a threaded coupling nut. All metal parts are machined and formed to very close tolerances, and all are made of hard-drawn brass, except for the center conductor, which is heat-treated beryllium copper to ensure good gripping capability and long wear. A bright-alloy finish on all surfaces produces high conductivity for low loss and gives long-lasting protection against tarnish.

Inner and outer conductors are similar in principle; each is a tube with four longitudinal slots in one end, with two opposite quadrants displaced inward. When two connectors are joined, the undisplaced quadrants of one overlap the displaced quadrants of the other (see cutaway view).

PATENT NOTICE. See Note 4.



Typical leakage characteristics of GR874 connectors compared with other types.

Type 1602-B UHF ADMITTANCE METER

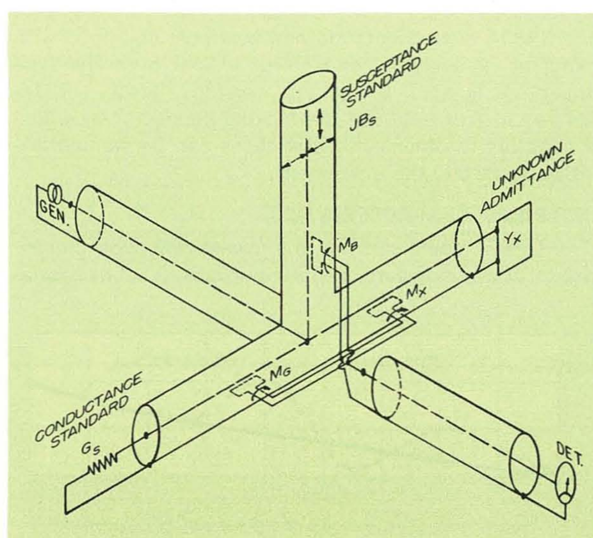
- 20 to 1500 MHz
- direct reading — conductance and susceptance
- measures SWR directly

This null-type instrument measures complex impedance and admittance in coaxial systems and, as a reflectometer, can be used to determine voltage standing-wave ratio (request Reprint E-112 for more details), impedance magnitude, and reflection coefficient magnitude.

It can be used for adjusting a network to a predetermined admittance, for matching one network to another, and for matching antennas and other networks to 50-ohm circuits.

A full line of accessories is available to adapt the Admittance Meter to specific types of measurements:

The 874-LK20L Constant-Impedance Adjustable Line, which can be set to one-half wavelength to eliminate corrections for the length of transmission line between the unknown and the measuring point. When the line is set to one-quarter wavelength, the Admittance Meter dials



Schematic diagram of admittance-meter circuit, with standards, generator, and null detector connected for admittance measurements.

read in impedance parameters, i.e., the series resistance and reactance of the unknown.

The 874-UBL Balun, for use with balanced impedances.

The 874-ML Component Mount, for the connection of lumped elements (resistors, capacitors, or inductors).

Low-SWR adaptors (which can be locked in place) for conversion to types N, BNC, TNC, etc. With these adaptors and the adjustable line mentioned above, the over-all accuracy of measurement is more than adequate for measurements in the design, test, and installation of antennas.

For measurements demanding higher accuracy and repeatability, consider the Type 1609 Precision UHF Bridge. Operating on the same principle as the 1602-B and over the same frequency range, the 1609 is equipped with GR900® precision coaxial connectors and vernier controls for minimized uncertainty and high balance precision. The 1609 is described in full in the section on GR900 coaxial instruments.

The 1602-B UHF Admittance Meter comprises three identical loops, in parallel, driving a null detector and magnetically coupled to three coaxial lines. All these lines are fed from the same voltage, so the current in each line,

The Admittance Meter assembled for component measurements, with unit oscillator and 1241 Detector. A line stretcher (Type 874-LKL) connects the component mount to the unknown terminal of the Admittance Meter.

hence the magnetic field, is proportional to the terminating impedance. One of these lines is terminated with a standard resistance, one with a reactance standard, and one with the unknown admittance. The coupling of each loop is adjusted until a null is obtained on the detector. Each loop has a calibrated scale and the settings at null condition indicate the value of the unknown.

GR 1609
page 176

— See **GR Experimenter** for May 1960.

specifications

RANGES OF MEASUREMENT

Conductance: 0.01 to 4000 millimhos.

Susceptance: −4000 to +4000 millimhos.

Standing-wave ratios of less than 1.2 can be measured by a direct-reading method; SWR as high as 10 can be readily measured by a voltage-ratio method.

Frequency: 40 to 1500 MHz, direct reading. Range is extended downward to 20 MHz, with a frequency correction applied to the susceptance reading.

Accuracy (for both conductance and susceptance):

Up to 1000 MHz,

from 0 to 20 millimhos, $\pm(3\% + 0.2$ millimho)

from 20 to ∞ millimhos, $\pm(3\sqrt{M}\% + 0.2$ millimho) where M is the scale-multiplying factor.

Above 1000 MHz, errors increase slightly, and, at 1500 MHz, the basic figure of 3% in the expression above becomes 5%. For matching impedances to 50 ohms, the accuracy is 3% up to 1500 MHz.

GENERAL

Accessories Supplied: Two 1602-P4 50-Ω Terminations, for use as conductance standards; one 1602-P1 Adjustable Stub and one 1602-P3 Variable Air Capacitor, for susceptance standards; two 874-R22LA Patch Cords for connections to generator and detector; 1602-P10 and -P11 Multiplier Plates. A wooden storage case is furnished.

Detectors
page 133

Generator: External only (not supplied). Generator must supply 1 to 10 V.

Detector: External only (not supplied). Sensitivity must be 10 μV or better. Type 1241 Detector is recommended.

Generators
page 235

Accessories Available: 874-FBL Bias Insertion Unit, coaxial adaptors, line-stretcher, balun, component mount, Smith charts.

Terminals: GR874® coaxial connectors, all locking-type except for detector terminal. Can be easily converted to type N or other common connector with GR874 adaptors.

Dimensions (width x height x depth): 5½ x 7½ x 5½ in. (140 x 190 x 140 mm).

Weight: Net, 8¼ lb (3.8 kg); shipping, 18 lb (8.5 kg).

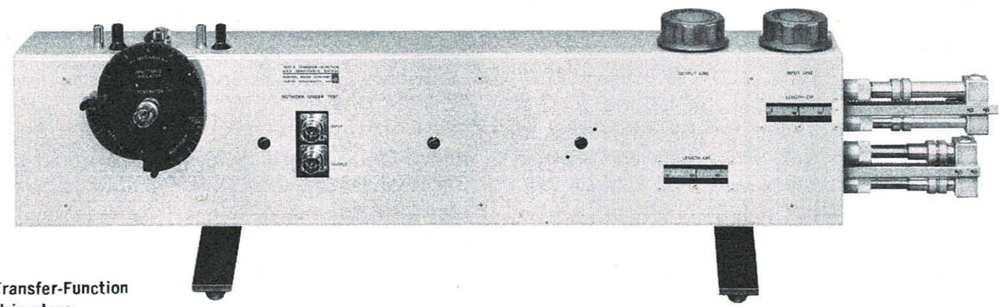
Catalog Number	Description	Price in USA
1602-9702	**1602-B UHF Admittance Meter**	**$550.00**

PATENT NOTICE. See Note 4.

Accessories supplied with the GR 1602-B Admittance Meter

Type 1607-A TRANSFER-FUNCTION AND IMMITTANCE BRIDGE

- 25 to 1500 MHz
- measure transistors, IC's, diodes, networks:
  - 2-terminal admittance and impedance (Y and Z)
  - 4-terminal transfer functions (Y and Z)
  - transistor S-, y-, and h-parameters
  - active or passive devices



Instrument with Transfer-Function Indicator mounted in place.

The Transfer-Function and Immittance* Bridge is a null-type instrument for vhf and uhf measurements of the forward and reverse complex transfer functions and the input and output impedances and admittances of four-terminal electrical networks, either active or passive. Thus, transistor parameters for the preparation of Linvill charts can be easily measured. Two-terminal circuits or components can also be measured.

Among these measurements are:

Transistors** — h_f(α or β), and $|\beta|$, h_r, h_i, h_o, y_c, y_o, y_f, y_r.

Tunnel Diodes — Equivalent circuit parameters.

General two-terminal or four-terminal networks —
Z_{11}, Z_{22}, Z_{21}, Z_{12} and Y_{11}, Y_{22}, Y_{21}, Y_{12}.
I_2/I_1, I_1/I_2 and E_2/E_1, E_1/E_2.

Ungrounded components —
Inductors — inductance and self-resonance.
Capacitors — capacitance and resonances.
Resistors — resistance and shunt capacitance.

*Immittance = impedance and/or admittance.
**S-parameters to 300 MHz.

Components, Coaxial Lines, and Other Grounded Elements — Z, Y, $|\Gamma|$, SWR.

The 1607-A Transfer-Function and Immittance Bridge comprises three identical loops, fed from a common source and magnetically coupled to three coaxial lines. One of these lines is terminated with a resistance standard, one with a reactance standard, and one with the network to be tested. The coupling of each loop is adjusted until a null is obtained on an external detector in which the three lines are terminated.

Two interchangeable loop-and-scale assemblies (Transfer-Function Indicator and Immittance Indicator, respectively) allow either four-terminal or two-terminal networks to be measured with equal ease.

Two built-in constant-impedance, adjustable-length lines eliminate line-length corrections.

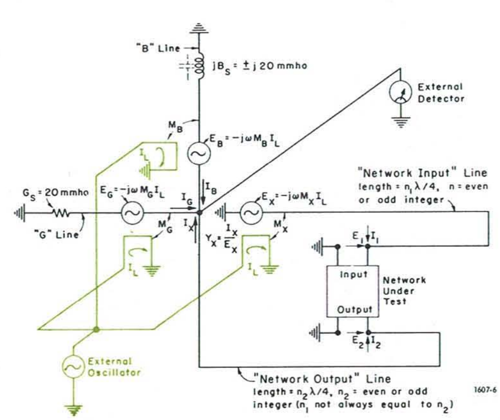
— See **GR Experimenter** for May 1959, July 1960, and February 1965.

specifications

Frequency Range: 25 to 1500 MHz, with reduced accuracy above 1000 MHz, or when flexible cable is used in the lines. The use of cable is generally required below 150 MHz and is optional at other frequencies.

Measurement Range:	Accuracy (25 to 1000 MHz):*
Voltage and Current Ratios (R) 0-30, 0-300†	$2.5\,(1+\sqrt{R})\,\% + 0.025$**
Transimpedance (Z_{21}) 0-1500 Ω, 0-15,000 Ω†	$\pm\ 2.5\left(1+\sqrt{\frac{Z_{21}}{50}}\right)\% + 1.25\ \Omega$**
Transadmittance (Y_{21}) 0-600 m℧, 0-6000 m℧†	$\pm\ 2.5\left(1+\sqrt{\frac{Y_{21}}{20}}\right)\% + 0.5\ \text{m℧}$**
Impedance (Z_{11}) 0-1000 Ω, 0-10,000 Ω†	$\pm\ 2.0\left(1+\sqrt{\frac{Z_{11}}{50}}\right)\% + 1.0\ \Omega$**
Admittance (Y_{11}) 0-400 m℧, 0-4000 m℧†	$\pm\ 2.0\left(1+\sqrt{\frac{Y_{11}}{20}}\right)\% + 0.4\ \text{m℧}$**

*These specifications apply individually to the real and imaginary components.
**When a 1607-P10 or -P11 Multiplier Plate is used, the fixed errors (shown after the % sign) are significantly reduced.
†With multiplier plate.



Schematic diagram of rf circuits of the Transfer-Function and Immittance Bridge.

Dc Bias: Bias terminals are provided. Maximum current, 2.5 A, continuous; higher currents are permissible for short periods; maximum voltage, 400 V.

Generator and Detector: External only, not included; GR Unit Oscillators and DNT Detectors are recommended.

Accessories Supplied: Range-Extension Unit; Transfer-Function Indicator; Immittance Indicator; 6 terminations (open, short, matched, etc.); standards; 10-dB attenuator; 8 air lines (21.5 and 43 cm); 3 U-line sections; constant-impedance adjustable line; a special tee; two 0.1 multiplier plates; 10 patch cords; storage case for instrument and accessories.

Accessories Required: Mount for unknown device. See below for mounts available. Note that termination kit is required for some transistor mounts.

Accessories Available: Smith Charts, 1237 VHF/UHF Preamplifier recommended for maximum accuracy and convenience and to eliminate local oscillator trap.

Dimensions (width x height x depth): 40 x 11½ x 14½ in. (1020 x 295 x 370 mm).

Weight: Net, 63 lb (29 kg); shipping, 132 lb (61 kg).

—For a more detailed description, request **GR Reprints E107** and **E109.**

Detectors page 133

Catalog Number	Description	Price in USA
1607-9701	**1607-A Transfer-Function and Immittance Bridge**	**$2350.00**

Oscillators page 235 ff

PATENT NOTICE. See Note 4.

Type 1607 Transistor and Component Mounts

The mounts listed below permit the three-terminal measurement of a variety of devices with the 1607-A Transfer-Function and Immittance Bridge. When the recommended short- and open-circuit terminations are used, the reference plane for the measurements is precisely established at the transistor socket or other appropriate surface. By this means the effects of coaxial line lengths and of the mount itself between unknown and instrument are eliminated.

In the transistor mounts, the leads are inserted into hollow contact tubes that are the center conductors of small coaxial lines. Thus, all but about 1/32 inch of the leads at the header are completely shielded, bends or irregularities of the leads have no effect, and the discontinuity at the transistor-to-mount connection is minimized. Additional advantages: complete accessibility to the socket, provisions for bolting a heat sink to the mount, and a fourth lead in the mount socket, which is dc ground.

specifications

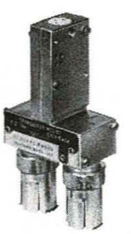
Mount Type	Transistor, diode, and tube packages accepted
1607-P41 and -P42	TO-5, 9, 11, 12, 16, 26, 31, 33, 37, 38, 39, 43; MD-14; MM-4, 8; MT-13, 20, 28, 37; RO-2, 3, 4, 5, 10, 24, 30, 33, 34, 46, 49, 50, 61, 62, 79, etc.
1607-P43 and -P44	TO-18, 28, 52, 54; MT-30, -38; RO-44, 48, 51, 64, 65, 66, 70, 73, 78; U-3; X-8; etc.

Accessories Supplied: Two damper resistors (10 and 50 Ω) with each transistor mount, to control oscillations in measurement of wide-band, high-gain transistors.

Accessories Required: Terminations and U-Block (see below).

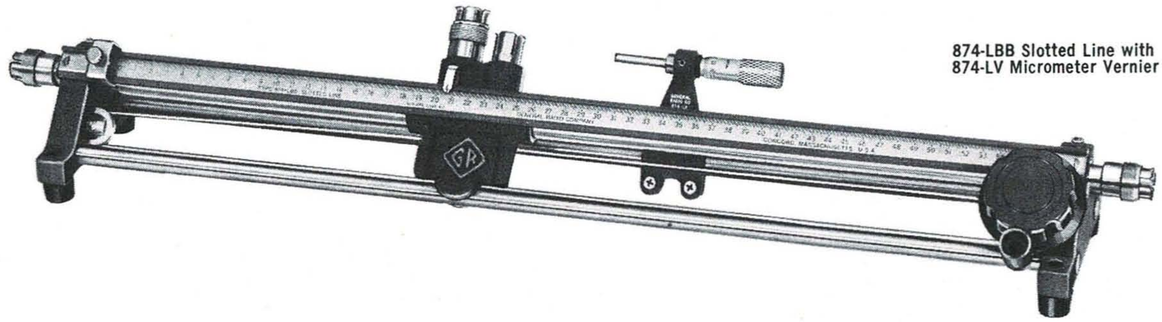
Net Weight: Mount, approx 12 oz (0.4 kg); Termination Kit, approx 1 lb (0.5 kg).

Shipping Weight: One mount, 2 lb (1 kg); Termination Kit, 2½ lb (1.2 kg).

	Grounded Connection	Pin Circle Dia (in.)	Leads	Terminations Required	Type	Catalog Number	Price in USA
Transistor Mounts (2-inch max lead length) 	base	0.2	4	1607-P40 Termination Kit (see below)	**1607-P41 Transistor Mount**	1607-9641	**$200.00**
	emitter or collector	0.2			**1607-P42 Transistor Mount**	1607-9642	200.00
	base	0.1			**1607-P43 Transistor Mount**	1607-9643	200.00
	emitter or collector	0.1			**1607-P44 Transistor Mount**	1607-9644	200.00
Termination Kit 	Terminations: **874-U10 U-Line Section, 874-WN10 Short-Circuit, and 874-WO10 Open-Circuit.**				**1607-P40 Termination Kit**	1607-9640	55.00

Type 874-LBB SLOTTED LINE

- 300 MHz to 9 GHz
- residual SWR: <1.02 to 1 GHz
  <1.035 to 4 GHz
  <1.10 to 8.5 GHz
- rugged construction
- many lines in one with GR874® adaptors



874-LBB Slotted Line with 874-LV Micrometer Vernier

900-LB page 175

One of the most important basic measuring instruments used at uhf and higher frequencies is the slotted line. General Radio makes two slotted lines, one based on the GR874® connector, the other on the GR900® precision connector. The GR874 line, while not so accurate as the 900-LB precision type, is satisfactory for most everyday measurements, and thousands are in use throughout the world. It is particularly weil suited to the student laboratory. It can be converted in seconds to use any of the popular UG connectors through GR874 low-SWR adaptors, available for BNC, C, HN, LC, Microdot, N, SMA , SC, TNC, GR900 and Amphenol APC-7 connectors. A complete set of adaptors will convert the 874-LBB into the equivalent of 23 low-SWR slotted lines. See curves in **GR Experimenter** for August 1966.

The slotted line is used to determine the standing-wave pattern of the electric field in a coaxial transmission line. From a knowledge of the standing-wave pattern, one can determine several characteristics of the circuit connected to the load end of the slotted line. For instance, the degree of mismatch (usually expressed as SWR) between the load and the transmission line can be calculated from the ratio of the maximum amplitude of the wave to the minimum. The load impedance can be calculated from the standing-wave ratio and the position of a minimum point on the line with respect to the load. The electrical length or time delay can also be measured accurately. These capabilities make the slotted line a valuable instrument for measurements on antennas, components, coaxial elements, networks, transistors, and diodes.

The 874-LBB Slotted Line is a 50-ohm, air-dielectric, coaxial line whose electric field is sampled by a probe, which projects through a longitudinal slot in the outer conductor. The probe rides on a carriage, which is driven by a pulley-and-cord linkage conveniently operated from one end of the line. Both the position of the probe and the degree of coupling can be precisely set. A diode rectifier, built into the carriage, can be tuned to the operating frequency by means of a 900-DP Probe Tuner or adjustable stub.

A source of about one milliwatt rf power is adequate for most measurements. A convenient source is one of the GR oscillators, available in several models and offering a wide choice of frequency range. The detector can be a standing-wave indicator, the GR 1234, for instance, or one of the 1241 Heterodyne Detectors.

—See **GR Experimenter** for August 1966 and Reprint A120.

specifications

Characteristic Impedance: 50 Ω ± 0.5%.

Probe Travel: 50 cm. Scale in cm; 1 mm per division.

Detectors page 133 ff

Scale Accuracy: ± (0.1 mm + 0.05%).

Frequency Range: 300 MHz to 8.5 GHz (usable to 9 GHz). Operation below 300 MHz (where probe travel equals one-half wavelength) is possible by use of lengths of GR874 air line.

Constancy of Probe Pickup: ±1.25%.

Oscillators page 235 ff

Residual SWR: <1.01 + 0.0016 f^2_{GHz} to 7.5 GHz; 1.10 from 7.5 to 8.5 GHz.

Accessories Supplied: Storage box, rf probe, 2 microwave diodes, and Smith Charts.

Accessories Required: 900-DP Probe Tuner (recommended) or 874-D20L Adustable Stub for tuning diode when audio-frequency detector such as the GR 1234 is used; suitable generator and detector; one each 874-R22LA and 874-R22A Patch Cords (supplied with DNT Detectors and GR Oscillators).

Accessories Available: The 874-LBB with accessories required for impedance and SWR measurements is available as the 874-EKA Basic Slotted-Line Kit. For measurement of SWR >10 the 874-LV Micrometer Vernier is recommended. Also available are Smith Charts and adaptors to other popular connectors.

Dimensions (width x height x depth): 26 x 4½ x 3½ in. (660 x 115 x 89 mm).

Weight: Net, 8½ lb (3.9 kg); shipping, 23 lb (10.5 kg).

Catalog Number	Description	Price in USA
0874-9651	**874-LBB Slotted Line**	$475.00

SLOTTED-LINE ACCESSORIES

GENERATORS

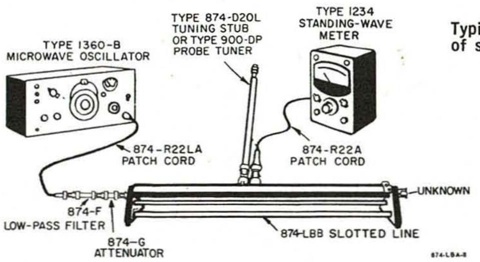
Oscillators suitable for use with the 874-LBB are described in the Generator section of this catalog. The GR RF Oscillators can be square-wave modulated with the 1264-B Modulating Power Supply. The 1360-B Microwave Oscillator for use at higher frequencies has internal 1-kHz square-wave modulation.

DETECTORS

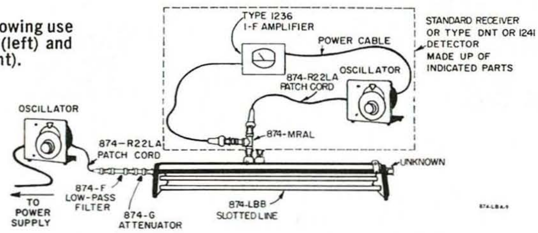
The GR 1234 Standing-Wave Meter is recommended as a fine general-purpose detector capable of measuring a wide range of SWR values with ease. A probe tuner such as the 900-DP is required.

The heterodyne detector is a general-purpose laboratory detector. It is excellent for measurements of nonlinear circuits and of high values of SWR, where a high degree of harmonic rejection is necessary, and for precise electrical-length measurements. The GR DNT and 1241 Detectors cover the frequency range from 40 to 2030 MHz (up to 5 GHz by the use of harmonics).

A low-pass coaxial filter should be used to eliminate harmonics of the signal source, and a 874-G10L Fixed Attenuator to isolate the oscillator from the effects of load changes.



Typical measurement setups showing use of slotted line, SWR indicator (left) and heterodyne detector (right).



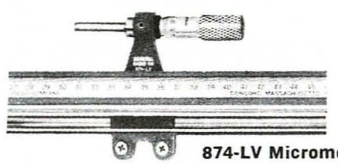
Oscillators page 235 ff

Detectors page 133

	Catalog Number	Price in USA
MICROMETER VERNIER — 874-LV		
PROBE TUNER — 900-DP		
BASIC SLOTTED-LINE KIT — 874-EKA		

MICROMETER VERNIER — 874-LV

For precise measurements of high SWR by the width-of-minimum method, and for precise phase measurements. Consists of a micrometer head calibrated in centimeters (calibrated to 0.001 cm), mounted on an arm that can be attached to the rear base rod of the slotted line. One turn of the micrometer barrel advances the head by 0.5 mm. Maximum range is 2.5 cm. Can be read to ±0.002 mm.



874-LV Micrometer Vernier — Catalog Number 0874-9652 — **$48.00**

PROBE TUNER — 900-DP

An accessory for the 874-LBB, this Probe Tuner can be used in place of an rf probe and adjustable stub. It has convenient, calibrated probe-depth adjustment and vernier tuning for resonance at any frequency from 300 MHz to 9 GHz. Installation tools are included.

Frequency Range: 0.3 to 9 GHz. **Tuning:** Shunt.

Probe Depth Scale: Calibrated in inches (0.001/div).

Stub Tuner: Calibrated in cm.

Dimensions: Length 11 in. (280 mm), dia ⅞ in. (23 mm), closed.

Net Weight: 8½ oz (245 g).

900-DP Probe Tuner — Catalog Number 0900-9654 — 195.00

BASIC SLOTTED-LINE KIT — 874-EKA

For impedance and SWR measurements with the slotted line. The coaxial elements listed below are available as the 874-EKA. The 874-LBB Slotted Line is included in the kit, but the generator and detector are not.

Shipping Weight: 38 lb (17.5 kg).

Type	Description	Type	Description	Type	Description
874-A2	**Coaxial Cable** (25 ft)	874-D50L	**Adjustable Stub**	874-QNPL	**Adaptor,** Connects to type N Jack
874-A3	**Coaxial Cable** (25 ft)	874-LAL	**Adjustable Line**	874-R22A	**Patch Cord**
874-BBL	**Basic Connector,** Locking (2)	874-LBB	**Slotted Line**	874-R22LA	**Patch Cord,** Locking
874-B	**Basic Connector** (2)	874-PL58A	**Panel Connector,** Locking	874-R34	**Patch Cord**
874-CA	**Cable Connector** (2)	874-PRL58A	**Panel Connector,** Locking, Recessed	874-TL	**Tee,** Locking
874-C8A	**Cable Connector** (2)			874-W50BL	**50-ohm Termination**
874-CLA	**Cable Connector,** Locking (2)	874-QBJL	**Adaptor,** Locking, Connects to type BNC Plug	874-WN	**Short-Circuit Termination**
874-C58A	**Cable Connector** (2)			874-WO	**Open-Circuit Termination**
874-CL58A	**Cable Connector,** Locking (2)	874-QNJL	**Adaptor,** Locking, Connects to type N Plug	874-TOK	**Tool Kit**
874-D20L	**Adjustable Stub**			874-Z	**Stand**

874-EKA Basic Slotted-Line Kit — Catalog Number 0874-9521 — 875.00

CABLE MEASUREMENTS

Various combinations of GR874® coaxial elements can be used very effectively with GR oscillators and associated equipment to measure attenuation, characteristic impedance, velocity of propagation, and capacitance of both coaxial and twin-conductor cables.

For convenience in ordering, the necessary equipment is offered in assemblies for specific types of measurement. These kits and their use are described in General Radio Reprint E-104, "The Measurement of Cable Characteristics," available on request.

GR874® ADAPTORS

14 mm — 50 ohms

Thirty-six different low-SWR adaptors provide easy conversion from the GR874® connector to most popular military and commercial coaxial connectors. Many of the adaptors are available with locking-type GR874 connectors to allow semipermanent attachment of the adaptor while ensuring stable electrical performance.

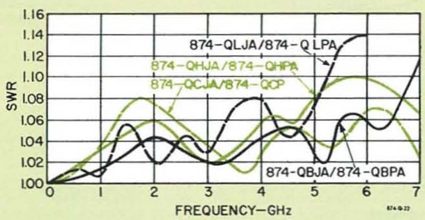
GR874 adaptors extend the usefulness of GR874 connectors without sacrificing electrical performance. The SWR of the combination of GR874 connector and GR874 adaptor is actually comparable to that of the "other series" connector alone.

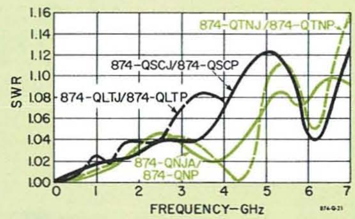
ORIGINAL EQUIPMENT USES

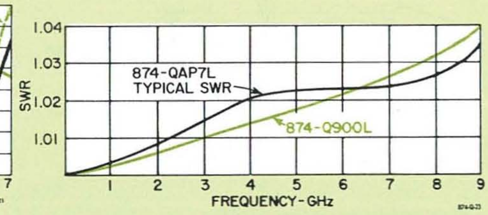
Original-equipment manufacturers will recognize the possibilities of these adaptors in combination with the GR874 locking recessed panel connector. An instrument originally equipped with these connectors can, by means of appropriate GR874 adaptors, be quickly converted to almost any coaxial connector series, with the resulting panel connector rigidly attached and protruding less than an inch beyond the panel surface.

REPLACES COUNTLESS ADAPTORS

Because any two GR874 adaptors mate, a few of them can perform a cross-connection task that would otherwise involve a costly collection of direct adaptors. For instance, interconnection of all possible combinations of types N, C, BNC, TNC, UHF, and Microdot plugs and jacks would require 72 direct adaptors, whereas only 12 GR874 adaptors are needed to do the same job.







Typical SWR introduced in line by pairs of GR874® adaptors plugged together.

GR874® ADAPTORS

In ordering adaptors by type number, note that the P or J suffix letter identifies the connector on **the adaptor,** not the connector that the adaptor fits. (For instance, the Type 874-QNJ Adaptor **contains** a type N **jack,** and therefore fits a type N plug.) A final L in the type designation indicates a locking adaptor.

ADAPTORS TO:		Contains GR874 and . . .	Type Nonlocking	Type Locking	Catalog Number	Price in USA
BNC	 QBJA  QBJL  QBPA	BNC Jack	**874-QBJA**		0874-9700	$6.25
		BNC Jack		**874-QBJL**	0874-9701	7.75
		BNC Plug	**874-QBPA**		0874-9800	8.50
		BNC Plug		**874-QBPAL**	0874-9801	10.00
C	 QCJA  QCJL  QCP	C Jack	**874-QCJA**		0874-9702	9.00
		C Jack		**874-QCJL**	0874-9703	11.00
		C Plug	**874-QCP**		0874-9802	8.50
HN	 QHJA  QHPA	HN Jack	**874-QHJA**		0874-9704	9.00
		HN Plug	**874-QHPA**		0874-9804	11.00

GR874® ADAPTORS

Weights are 1 to 8 oz, depending on adaptor.
See page 142 for power and voltage ratings.

ADAPTORS TO:		Contains GR874 and . . .	Type Nonlocking	Type Locking	Catalog Number	Price in USA
LC	 QLJA	LC Jack	874-QLJA		0874-9706	$15.00
Microdot	 QMDJ QMDJL QMDP	Microdot Jack Microdot Jack Microdot Plug	874-QMDJ 874-QMDP	 874-QMDJL	0874-9720 0874-9721 0874-9820	11.00 13.00 13.00
N	 QNJL QNPL	N Jack N Jack N Plug N Plug	874-QNJA 874-QNP	 874-QNJL 874-QNPL	0874-9710 0874-9711 0874-9810 0874-9811	6.00 7.50 6.50 8.00
SMA	 QMMJ QMMP	* SMA Jack SMA Jack SMA Plug SMA Plug	874-QMMJ 874-QMMP	 874-QMMJL 874-QMMPL	0874-9722 0874-9723 0874-9822 0874-9823	17.00 19.00 24.00 25.00
SC	 QSCJ QSCJL QSCP	SC Jack SC Jack SC Plug	874-QSCJ 874-QSCP	 874-QSCJL	0874-9712 0874-9713 0874-9812	17.00 19.00 19.00
TNC	 QTNJ QTNJL QTNP	TNC Jack TNC Jack TNC Plug	874-QTNJ 874-QTNP	 874-QTNJL	0874-9716 0874-9717 0874-9816	9.50 12.00 13.00
UHF	 QUJ QUJL QUP	UHF Jack UHF Jack UHF Plug	874-QUJ 874-QUP	 874-QUJL	0874-9718 0874-9719 0874-9818	7.00 8.50 6.50
GR 274 and 938	 Q2 777-Q3 874-Q10	274 Jack 938 Plug, shielded 938 Plug, unshielded	874-Q2 777-Q3 874-Q10		0874-9864** 0777-9712** 0874-9877**	53.00 66.00 53.00
Amphenol APC-7 Connector		7-mm precision connector		874-QAP7L	0874-9791	69.00
GR900® Connector		GR 900-AB		874-Q900L	0874-9709	19.00

* Also mates with NPM, STM, and others. ** Sold only in packs of 10 each. Catalog number and price are for pack.

GR874® STANDARD TERMINATIONS

These terminations are used to establish known impedance at a specific location on coaxial lines.

Resistive terminations are useful in slotted-line measurements and for checking accuracy of directional couplers, bridges, and admittance meters. The known location of a purely resistive termination permits the production of many known complex impedances through the addition of sections of 874-L Air Line, fixed or adjustable.

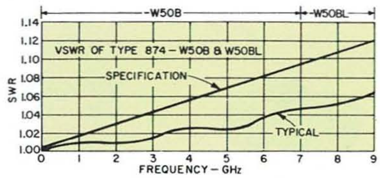
Open- and short-circuit terminations are useful in establishing initial coaxial line-length conditions for impedance measurements.

RESISTIVE TERMINATIONS

50-OHM

Available with either locking or nonlocking connectors, these terminations consist of a 50-ohm cylindrical resistor mounted in a specially tapered coaxial holder. They are useful up to 9 GHz for impedance matching, establishment of reference conditions, and as terminations.

SWR: <1.005 + 0.013f_{GHz}.
DC Resistance: 50 Ω ±0.5%.
Max Power: 2 W continuous.



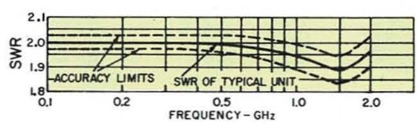

874-W50B


874-W50BL

	Catalog Number	Price in USA
874-W50B 50-ohm Termination	0874-9954	**$30.00**
874-W50BL 50-ohm Termination, locking	0874-9955	**31.00**

100-OHM

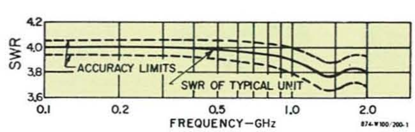
DC Resistance: 100 Ω ±1%.
Max Power: ⅓ W continuous.



	Catalog Number	Price in USA
874-W100 100-ohm Coaxial Standard	0874-9956	**48.00**

200-OHM

DC Resistance: 200 Ω ±1%.
Max Power: ¼ W continuous.



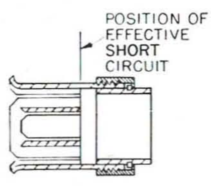
	Catalog Number	Price in USA
874-W200 200-ohm Coaxial Standard	0874-9958	**53.00**

SHORT-CIRCUIT TERMINATIONS

Type 874-WN

A fixed short circuit mounted in a GR874 connector for establishing reference conditions on coaxial lines.

Position of Short-Circuit Plane: 0 to 0.07 cm toward load, dc to 7 GHz.



874-WN

	Catalog Number	Price in USA
874-WN Short-Circuit Termination	0874-9970	**8.00**

GR874® STANDARD TERMINATIONS

(continued)

Type 874-WNL

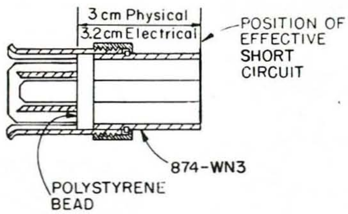
Similar to 874-WN but with locking GR874® connector.

Position of Short-Circuit Plane: 0 to 0.07 cm toward load, dc to 9 GHz.

	Catalog Number	Price in USA
874-WNL Short-Circuit Termination, locking	0874-9971	$9.50

Type 874-WN3

Same as 874-WN except that short circuit is 3.2 cm (electrical distance) beyond face of bead in GR874 connector. This distance corresponds to the bead-to-reference-plane distance in 874-ML Component Mount and 874-UBL Balun.



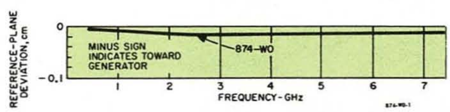
	Catalog Number	Price in USA
874-WN3 Short-Circuit Termination	0874-9972	8.00

OPEN-CIRCUIT TERMINATIONS

Type 874-WO

Produces an open circuit at the same point that the 874-WN produces a short. Acts as a shielding cap for open-circuited lines.

Position of Open-Circuit Plane: 0 to 0.05 cm toward load, dc to 7 GHz.



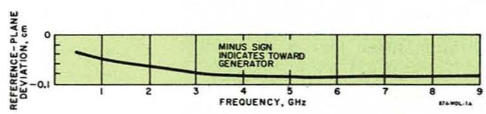
	Catalog Number	Price in USA
874-WO Open-Circuit Termination	0874-9980	7.00

Type 874-WOL

Produces an open circuit at the same point the 874-WNL produces a short.

Position of Open-Circuit Plane: 0 to 0.10 cm toward load, dc to 9 GHz.

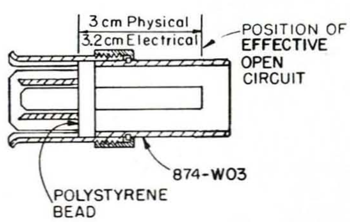
Typical Reference-Plane Deviation (toward generator):



	Catalog Number	Price in USA
874-WOL Open-Circuit Termination, locking	0874-9981	8.50

Type 874-WO3

Same as 874-WO except that open circuit is at a position corresponding to that of short circuit in 874-WN3 and to the bead-to-reference-plane distance in the 874-ML Component Mount and 874-UBL Balun.



	Catalog Number	Price in USA
874-WO3 Open-Circuit Termination	0874-9982	7.00

GR874® ATTENUATORS — 50 ohms

	Catalog Number	Price in USA

FIXED ATTENUATORS

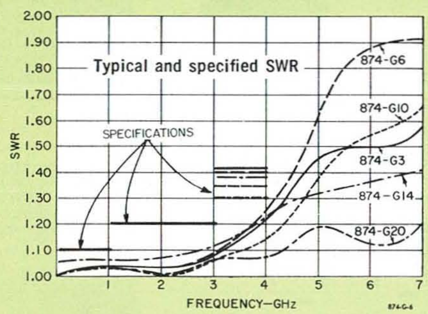
Single-section, T-type resistance pads, for insertion of fixed attenuation in 50-ohm systems and for isolation and matching to 50 ohms over a broad frequency range. Each attenuator consists of one disk and two cylindrical resistors, as shunt and series elements, respectively. The 6-, 14-, and 20-dB attenuators are particularly convenient in pulse applications as X2, X5, and X10 voltage dividers, respectively.

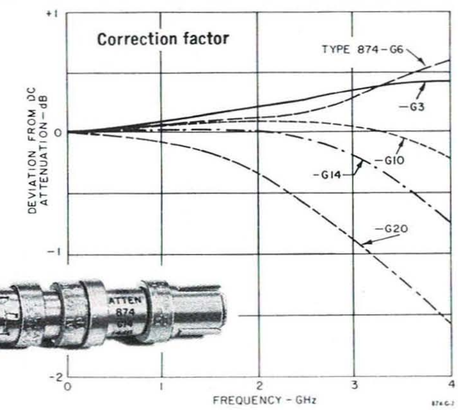
DC Resistance: 50 Ω ±1% when terminated in 50 Ω.

Attenuation Accuracy (relative to correction curves shown): ±0.2 dB to 1 GHz, ±0.4 dB to 2 GHz, ±0.6 dB to 4 GHz.

Temperature Coefficient: <0.0003 dB/°C/dB.

Max Power: CW, 1 W; pulse, 2000 W peak, 1 W average.
Length: 3½ in. (89 mm).





Attenuation at dc (dB)	Type		Catalog Number	Price in USA
	Fixed Attenuator			
3±0.045	**874-G3**		0874-9564	**$37.00**
	874-G3L*		0874-9565	**40.00**
6 ±0.09	**874-G6**	(×2)	0874-9568	**37.00**
	874-G6L*		0874-9569	**40.00**
10 ±0.15	**874-G10**		0874-9570	**37.00**
	874-G10L*		0874-9571	**40.00**
14 ±0.21	**874-G14**	(×5)	0874-9560	**37.00**
	874-G14L*		0874-9561	**40.00**
20 ±0.30	**874-G20**	(×10)	0874-9572	**37.00**
	874-G20L*		0874-9573	**40.00**

*Locking Connectors

ADJUSTABLE ATTENUATOR

A waveguide-below-cutoff type, useful as a calibrated attenuator or as a sampling device. Calibrated in decibels, on a micrometer-type scale. Absolute attenuation is the sum of insertion loss and scale reading. Phase shift is essentially constant as attenuation is varied. The main line is a short coaxial section with locking GR874 connectors, one end for source, the other for load. It introduces minimum discontinuity when inserted in a 50-ohm line. The loop output is brought out through three feet of 50-ohm cable with locking GB874 connector. When fed at the output connector, signals with relative phases of 0° and 180° are produced at the main line connectors.

Calibrated Range: 120 dB (relative attenuation) with input line terminated in 50 Ω; 129 dB with input line terminated in adjustable stub to minimize the electric field at the coupling point (scale reads −9 to 120 dB).

Insertion Loss (from input connector to end of output cable at 1 GHz, when signal source impedance is 50 Ω):
With input line terminated in 50 Ω, and scale set at 0 dB, 30.4 dB ±2 dB; **set at −9 dB,** 17 ±2 dB (settings below 0 are not accurate).
With input line terminated in adjustable stub (which extends the range over which the calibration is accurate to the −9 dB scale setting), 19 ±2 dB minimum.
(Insertion loss is approximately inversely proportional to frequency up to 1 GHz.)

Insertion Loss Directly Through Tee: Negligible.

Accuracy of Attenuation:
Stub-terminated input, ±(0.01 times difference in attenuation reading +0.2) dB, direct-reading.
50-Ω terminated input, ±(0.015 times difference in attenuation reading +0.2) dB, when corrected. Correction chart supplied.

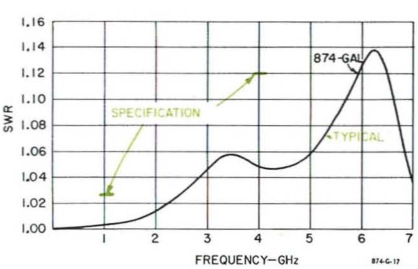
SWR Introduced into Line: <1.03 at 1 GHz; <1.12 from 1 to 4 GHz.

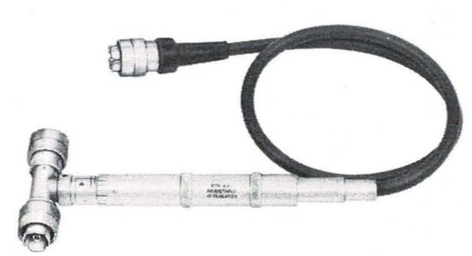
SWR of Output: <4 at 1 GHz; <5 from 1 to 4 GHz.

Max Power: Input power limit inversely proportional to square root of frequency. Power should not exceed 300 W at 1 GHz. Output power should not exceed ½ W.

Frequency Range: 100 MHz to 4 GHz.
Net Weight: 1¼ lb (0.6 kg).

SWR introduced into line:





	Catalog Number	Price in USA
874-GAL Adjustable Attenuator	0874-9577	**130.00**

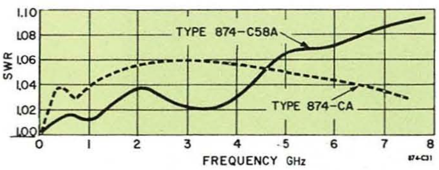
GR874® CONNECTORS

14 mm — 50 ohms

CABLE CONNECTORS

The GR874® cable connector is available in 10 types to accommodate five basic cable sizes in both locking and non-locking versions. These connectors fit more than 40 different RG types of coaxial cable, as well as General Radio Types 874-A2 and -A3 cable. Each cable connector consists of a basic connector plus inner and outer transition pieces, a soft-copper ferrule, a heat disk, and a flexible cable guard. The transition pieces maintain the 50-ohm characteristic impedance of the connector throughout the reduction to the cable diameter. The cable inner conductor is soldered to the inner transition piece, and the cable braid and jacket are crimped to the outer transition by the ferrule. Braid and jacket are thus kept from working loose to cause reflections and leakage.

A Neoprene cable guard serves as a protective handle. Sized to grip the cable securely without compressing it, the cable guard adds to the quick-connect-disconnect convenience of the connector.



Average SWR of single connector on infinite length of 50-ohm cable.

PANEL CONNECTORS

Panel connectors are available to fit the five popular cable sizes (as are cable connectors), to accept wire leads, and in four configurations: nonlocking, locking, recessed, and nonrotational. They are mounted to a panel by means of a flange and four screws; the nonlocking connector can be mounted either front or back. The recessed connectors reduce the front protrusion to ⅛ inch to save space and present a neat appearance. The keyed, locking panel connector, which adds a nonrotation feature to the locking connector, is for use where accidental loosening or turning of the connector might damage an attached component.

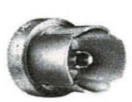
The GR874 line of coaxial connectors includes 34 different types, as listed in the following chart.

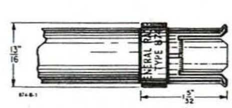
GR874® RIGID OR AIR-LINE CONNECTORS

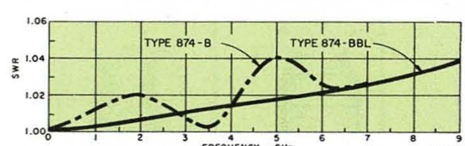
14 mm — 50 ohms

For custom building coaxial components or sections of rigid 14-mm, 50-ohm air line using inner-conductor rod, 0874-9508, and outer-conductor tube, 0874-9509, listed elsewhere in this section.

BASIC CONNECTOR — NONLOCKING

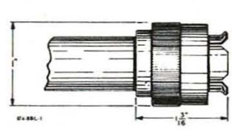






Typical SWR of pairs of 874-B and -BBL Connectors.

BASIC CONNECTOR — LOCKING

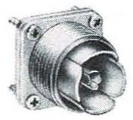
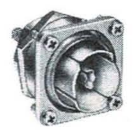
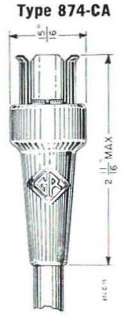
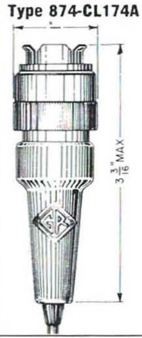
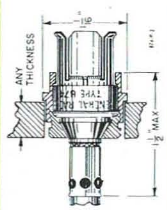
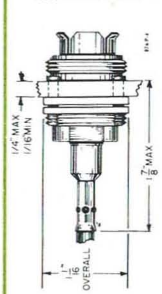
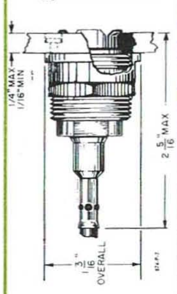
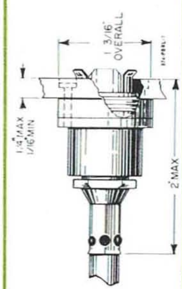


	Catalog Number per pack of 10	Price in USA
874-B	0874-9865	$25.00
874-BBL	0874-9866	39.00

See page 142 for power and voltage ratings.
Weights: 1-4 oz.

GR874® CABLE CONNECTORS

GR874 CABLE CONNECTORS (for flexible cables)

	Cable-Mounted		Panel-Mounted				
Cable Types	Nonlocking 	Locking 	Nonlocking 	Locking 	Locking, Recessed 	Keyed, Locking (Recessed) 	
874-A2	874-CA 0874-9867 $39.00	874-CLA 0874-9830 $54.00	874-PBA 0874-9839 $54.00	874-PLA 0874-9840 $48.00	874-PRLA 0874-9851 $52.00	874-PBRLA 0874-9857 $72.00	Type *Catalog Number *Price in USA
50-OHM: RG-8A/U, RG-9B/U, RG-10A/U, RG-87A/U, RG-116/U, RG-156/U, RG-165/U, RG-166/U, RG-213/U, RG-214/U, RG-215/U, RG-225/U, RG-227/U NON 50-OHM: RG-11A/U, RG-12A/U, RG-13A/U, RG-63B/U, RG-79B/U, RG-89/U, RG-144/U, RG-146/U, RG-149/U, RG-216/U	874-C8A 0874-9831 $41.00	874-CL8A 0874-9832 $53.00	874-PB8A 0874-9841 $55.00	874-PL8A 0874-9842 $48.00	874-PRL8A 0874-9852 $51.00	874-PBRL8A 0874-9858 $82.00	Type *Catalog Number *Price in USA
50-OHM: 874-A3, RG-29/U, RG-55/U (Series), RG-58A/U (Series), RG-141A/U, RG-142A/U, RG-159/U, RG-223/U	874-C58A 0874-9833 $36.00	874-CL58A 0874-9834 $51.00	874-PB58A 0874-9843 $54.00	874-PL58A 0874-9844 $45.00	874-PRL58A 0874-9853 $50.00	874-PBRL58A 0874-9859 $79.00	Type *Catalog Number *Price in USA
NON 50-OHM: RG-59/U, RG-62/U (Series), RG-71B/U, RG-140/U, RG-210/U	874-C62A 0874-9835 $36.00	874-CL62A 0874-9836 $50.00	874-PB62A 0874-9845 $54.00	874-PL62A 0874-9846 $47.00	874-PRL62A 0874-9854 $50.00	874-PBRL62A 0874-9860 $78.00	Type *Catalog Number *Price in USA
50-OHM: RG-174/U, RG-188/U, RG-316/U NON 50-OHM: RG-161/U, RG-187/U, RG-179/U	874-C174A 0874-9837 $65.00	874-CL174A 0874-9838 $77.00	874-PB174A 0874-9847 $68.00	874-PL174A 0874-9848 $60.00	874-PRL174A 0874-9855 $65.00	874-PBRL174A 0874-9861 $93.00	Type *Catalog Number *Price in USA
Wire Leads	—	—	—	874-PLT 0874-9850 $52.00	874-PRLT 0874-9856 $58.00	—	Type *Catalog Number *Price in USA
	Type 874-CA 	Type 874-CL174A 	Type 874-PBA 	Type 874-PL58A 	Type 874-PRL58A 	Type 874-PBRLA 	

See page 142 for power and voltage ratings.
Weights: 1-4 oz.

* Sold only in packs of 10 each. Catalog number and price are for pack.

GR874® AIR LINES

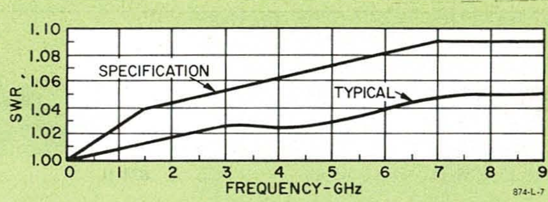
14 mm — 50 ohms

	Catalog Number	Price in USA

RIGID AIR LINES

For spacing stubs or other elements of a coaxial system; also useful as time-delay elements and as absolute impedance in time-domain reflectometers. Each air line (10, 20, or 30 cm) consists of a length of 50-ohm, air-dielectric coaxial line with a GR874 coaxial connector, either regular or locking, at each end. Locking versions use 874-BBL Basic Connectors and are thus usable up to 9 GHz.

Characteristic Impedance: 50 Ω ±0.4%.



Electrical Length	Time Delay	Air Line Type	Catalog Number	Price in USA
10.086 ± 0.06 cm	0.3362 ± 0.0018 ns	**874-L10** **874-L10L**, locking	0874-9604 0874-9605	$13.00 16.00
20.096 ± 0.06 cm	0.6698 ± 0.0018 ns	**874-L20** **874-L20L**, locking	0874-9608 0874-9609	16.00 19.00
30.111 ±0.06 cm	1.0036 ± 0.0018 ns	**874-L30** **874-L30L**, locking	0874-9612 0874-9613	18.00 21.00

ADJUSTABLE LINES

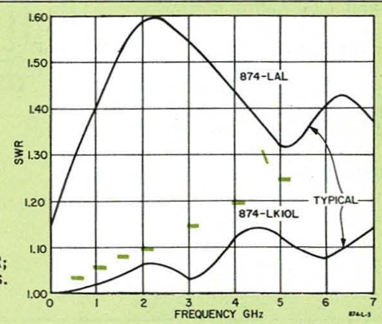
Type 874-LAL

An air-dielectric coaxial line that can be telescoped to change its length. Used in matching networks, as a phase shifter, and as a variable time-delay element. Contacts are made by multiple-spring fingers. Connectors are locking GR874.

Characteristic Impedance: Not constant — approx 50 Ω when fully collapsed, approx 57 Ω when fully extended.

Adjustment Range: 25 cm.

Physical Length: 33 cm (min) to 58 cm (max).



Curves shown are typical SWR; dashed points are specifications.

	Catalog Number	Price in USA
874-LAL Adjustable Line	0874-9621	42.00

CONSTANT-IMPEDANCE — 874-LK

A line stretcher with a very low VSWR and a uniform characteristic impedance of 50 ohms. Especially useful for eliminating the usual Smith-chart corrections for length of line between unknown and impedance-measuring device. These lines are useful as impedance-matching transformers and phase-adjustment elements in coaxial systems. Locking GR874 connectors.

Characteristic Impedance: 50 Ω.
Adjustment Range: 874-LK10L, 10 cm (half wavelength at 1.5 GHz); 874-LK20L, 22 cm (half wavelength at 680 MHz).
Physical Length: 874-LK10L, 35 to 45 cm; 874-LK20L, 58 to 80 cm.
SWR: 874-LK20L, <1.03 at 500 MHz, <1.06 at 1 GHz, <1.08 at 1.5 GHz, <1.10 at 2 GHz. Type 874-LK10L, same as 874-LK20L to 2 GHz, <1.15 at 3 GHz, <1.2 at 4 GHz, <1.25 at 5 GHz. See typical curve above.

	Catalog Number	Price in USA
Constant-Impedance Adjustable Line **874-LK10L**, 10 cm **874-LK20L**, 20 cm	 0874-9627 0874-9631	 65.00 74.00

TROMBONE CONSTANT-IMPEDANCE — 874-LTL

With this line stretcher, built like a trombone slide, the user can vary the length of a 50-ohm transmission line between two fixed terminals without moving the terminals or using flexible cables. Consists of two 874-LK20L Adjustable Lines joined at one end by a U-shaped section to form a rigid assembly. Can be plugged into two adjacent GR874 coaxial connectors or inserted in a line by means of two ells (not included) when installed vertically to save bench space. Low SWR. An excellent phase shifter, and variable time delay.

Characteristic Impedance: 50 Ω.

Frequency Range: Dc to 2 GHz (874-LK10L is recommended above 2 GHz).

Adjustment Range: 44 cm (half wave at 340 MHz).

Physical Length: 61 to 83 cm.

Spacing: 1 3/16 inches between centers.

SWR: <1.10 to 1 GHz, and <1.25 to 2 GHz.

Net Weight: 2 1/4 lb (1.1 kg).

	Catalog Number	Price in USA
874-LTL Trombone Constant-Impedance Adjustable Line	0874-9645	165.00

GR874® COUPLING ELEMENTS — 3-PORT

TEE — 874-T

For connecting stubs and other elements in shunt with a coaxial line. Available with regular or locking connectors.

Dimensions: 3⅜ x 2¼ in. (86 x 58 mm).

Net Weight: 874-T, 4 oz (115 g); 874-TL, 5 oz (145 g).

874-TL

	Catalog Number	Price in USA
874-T Tee	0874-9910	$18.00
874-TL Tee, locking	0874-9911	23.00

MIXER — 874-MRAL

A broadband mixer of improved design for use in general applications and, with the GR 1236 I-F Amplifier, as a heterodyne detector. It offers a wider frequency range, increased sensitivity, lower SWR, low-leakage locking connectors, and reduced local-oscillator power required.

Frequency Range: 10 MHz to 9 GHz.

Max I-F: 60 MHz.

Local Oscillator Power: Typically less than 6 mW required for 0.2-mA rectified current (signal and L.O. source impedances = 50 Ω).

Output Impedance: 400 Ω average, paralleled by 7 pF.

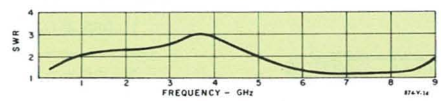
Diode: 1N23C.

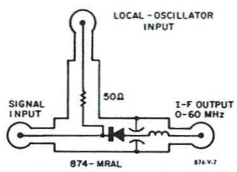
Sensitivity: Typically < 6-μV input behind 50 Ω will increase output of i-f amplifier (30-MHz i-f, 0.5-MHz bandwidth, 2-dB noise figure) by 3 dB, for mixer current of 0.5 mA.

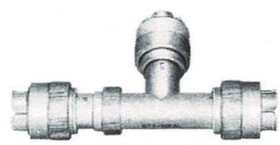
Dimensions: 4⅝ x 2½ in. (120 x 64 mm).

Net Weight: 8 oz (230 g).

Typical SWR: (mixer current = 0.5 mA).







	Catalog Number	Price in USA
874-MRAL Mixer	0874-9947	79.00

MIXER RECTIFIER — 874-MR

A broadband rf mixer for use with the 1216-A Unit I-F Amplifier as a heterodyne detector.

Frequency Range: 40 MHz to 5 GHz; at lower and higher frequencies with less sensitivity.

Max I-F: 30 MHz.

Max Input from Local Oscillator: 2 V.

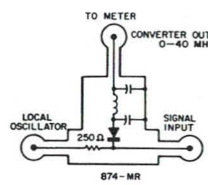
Sensitivity: Typically <5 μV for discernible deflection on meter of 1216-A Unit I-F Amplifier. (Equivalent to about 10 μV behind 50 Ω to increase 1216-A output by 3 dB).

Output Impedance: Approx 400 Ω.

Diode: 1N21B.

Dimensions: 3¾ x 3½ in. (96 x 89 mm).

Net Weight: 874-MR, 7 oz (200 g); 874-MRL, 8 oz. (230 g).



874-MRL

	Catalog Number	Price in USA
874-MR Mixer Rectifier	0874-9944	48.00
874-MRL Mixer Rectifier, locking	0874-9945	51.00

VOLTMETER RECTIFIER — 874-VR

The 874-VR is used to monitor the voltage in a coaxial system. Similar to the 874-VQ, the 874-VR has a 50-ohm resistor in series with the output-port center conductor. In combination with a signal source and properly calibrated indicator it can simulate a 50-ohm generator with known open-circuit voltage. It is used in this manner with the GR 1263-C in an oscillator amplitude-regulating system.

Frequency Range (as Calibrated Voltmeter): 15 MHz to 2.5 GHz.

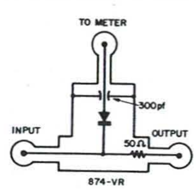
Max Voltage: 2 V.

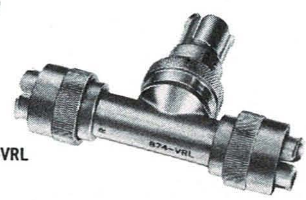
Bypass Capacitance: Approx 300 pF.

Diode: 1N23B.

Dimensions: 3¾ x 2½ in. (96 x 64 mm).

Net Weight: 874-VR, 5 oz (145 g); 874-VRL, 6 oz (170 g).





Type 874-VRL

	Catalog Number	Price in USA
874-VR Voltmeter Rectifier	0874-9942	42.00
874-VRL Voltmeter Rectifier, locking	0874-9943	46.00

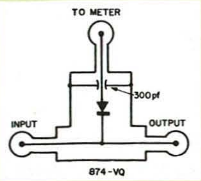
GR874® COUPLING ELEMENTS — 3-PORT

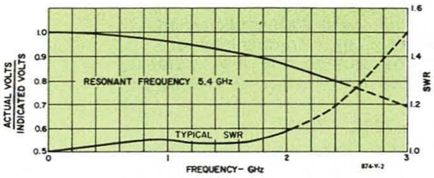
(cont'd)

VOLTMETER DETECTOR — 874-VQ

For use as a general purpose detector of rf level using a dc indicator or of modulated signals using a sensitive amplifier. It can be inserted into a 50-ohm line, introducing no appreciable discontinuity, or, with a GR874 50-ohm termination, used as a matched detector to terminate a line.

Frequency Range (as Matched Detector): 0.5 MHz to 2 GHz. Usable from 60 Hz to 7 GHz.
Max Voltage: 2 V.
SWR: <1.1 at 1 GHz; <1.2 at 2 GHz.
Bypass Capacitance: Approx 300 pF.
Diode: 1N23B.
Dimensions: 3¾ x 2½ in. (96 x 64 mm).
Net Weight: 874-VQ, 5 oz (145 g); 874-VQL, 6 oz (170 g).





Typical SWR and correction factor for 874-VQ.

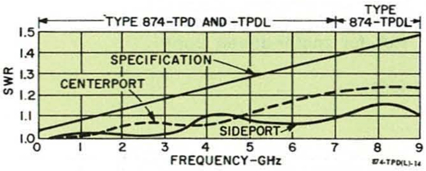
874-VQL

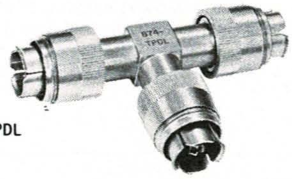
	Catalog Number	Price in USA
874-VQ Voltmeter Detector	0874-9940	$37.00
874-VQL Voltmeter Detector, locking	0874-9941	40.00

POWER DIVIDER — 874-TPD

A coaxial tee with a 16.67-ohm resistor in each leg, connected so that the tee is matched at any port when the other two ports are terminated in 50-ohm loads. The match holds throughout the wide frequency range. The use of stable deposited-carbon-film resistors and the linear SWR-frequency relationship makes the power divider particularly valuable for pulse work.

Frequency Range: 874-TPD, dc to 7 GHz; 874-TPDL, dc to 9 GHz.
SWR: $<1.03 + 0.05\, f_{GHz}$ (see curve).
Insertion Loss: Input to each output, 6 dB (+2, −0.5 dB).
Equality of Power Division: 0.3 dB (symmetrically fed).
Phase Difference Between Outputs: 0°.
Max Input Power: 2 W continuous.
Dimensions: 4 x 2⅜ in. (105 x 61 mm).
Net Weight: 6 oz (170 g).





874-TPDL

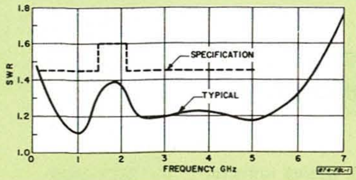
	Catalog Number	Price in USA
874-TPD Power Divider	0874-9912	84.00
874-TPDL Power Divider, locking	0874-9913	89.00

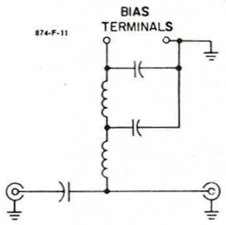
BIAS INSERTION UNIT — 874-FBL

Used with slotted lines, the GR 1602-B Admittance Meter, and 1609 UHF Admittance Bridge for immittance and similar measurements where bias is to be applied to diodes, transistors, and other solid-state devices. It comprises a blocking capacitor in series with the line, an isolating choke, and a low-pass filter.

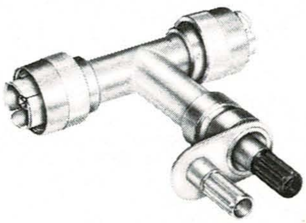
In slotted-line measurements, it is inserted at the source end of the line and therefore introduces no reflections at the measurement terminals.

Dc Current: 2.5 A, max.
Dc Voltage: 400 V, max.
SWR: See curves.
Insertion Loss: Typically, <1.7 dB from 300 MHz to 3 GHz, <0.8 dB from 3 GHz to 5 GHz.
Dimensions: 4⅜ x 3⅞ in. (115 x 99 mm).
Net Weight: 6½ oz (185 g).





Schematic Diagram of 874-FBL



	Catalog Number	Price in USA
874-FBL Bias Insertion Unit	0874-9759	89.00

GR874® COAXIAL ELEMENTS — 2-PORT

COUPLING CAPACITOR (Dc block) — 874-K

A short length of coaxial line having a disk capacitor in series with the inner conductor. High frequencies are transmitted with small reflections, but dc and low audio frequencies are blocked. Available with regular or locking connectors.

Coupling Capacitance: 4700 pF, −20%, +50%.

SWR: <1.06 at 1 GHz; <1.15 at 2 GHz; <1.3 from 2 to 4 GHz.

Voltage Rating: 500 V.

Length: 3 in. (77 mm).

	Catalog Number	Price in USA
874-K Coupling Capacitor	0874-9596	$14.00
874-KL Coupling Capacitor, locking	0874-9597	17.00

90° ELL — 874-EL

Convenient right-angle line section with GR874 coaxial connector at each end. Available with regular or locking connectors.

Characteristic Impedance: 50 Ω.

Electrical Length: Approx 7 cm.

SWR: <1.06 at 2 GHz; <1.15 at 4 GHz.

Dimensions: 2¼ in. (57 mm) on a side.

	Catalog Number	Price in USA
874-EL 90° Ell	0874-9526	15.00
874-EL-L 90° Ell, locking	0874-9527	18.00

ROTARY JOINT — 874-JR

Used when one part of a coaxial system must be rotated with respect to another part. Not for motor-driven applications.

SWR: <1.06 at 1 GHz; <1.3 at 4 GHz.

Length: 2½ in. (64 mm).

	Catalog Number	Price in USA
874-JR Rotary Joint	0874-9590	21.00

RADIATING LINE — 874-LR

Leakage coupler for fields within a coaxial system. Short coaxial line with opening in outer conductor that can be partly or completely covered by a rotatable sleeve.

SWR: Closed, <1.10 at 1 GHz, <1.4 at 3 GHz, and <1.35 at 4 GHz.

Length: 4⅜ in. (112 mm).

	Catalog Number	Price in USA
874-LR Radiating Line	0874-9660	18.00

COUPLING PROBE — 874-MB

Electrostatic probe consisting of a binding post mounted on a GR874 coaxial connector.

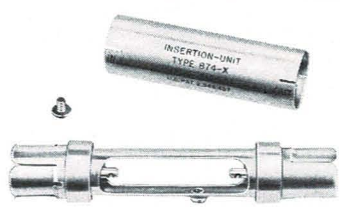
Length: 3 in. (77 mm).

	Catalog Number	Price in USA
874-MB Coupling Probe	0874-9666	7.50

INSERTION UNIT — 874-X

Small components, pads, vhf transformers, filters, or other networks mounted within the 2-inch long, 9/16-inch diameter space in the 874-X can be conveniently inserted into a 50-ohm coaxial system with minimum leakage and discontinuity.

Length: 4⅜ in. (115 mm).



	Catalog Number	Price in USA
874-X Insertion Unit	0874-9990	18.00

SERIES INDUCTOR — 874-XL

Used as a general-purpose tuning element in resonant-line circuits, matching transformers, and baluns at low frequencies.

Series Inductance: 0.226 μH ±5% at 1 kHz.

Net Weight: 3½ oz (98 g).

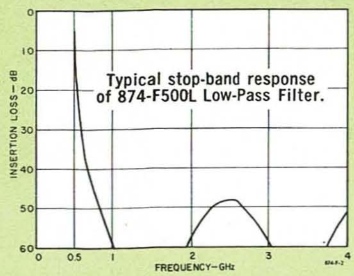
	Catalog Number	Price in USA
874-XL Series Inductor	0874-9998	27.00

GR874® COUPLING ELEMENTS – 2-PORT

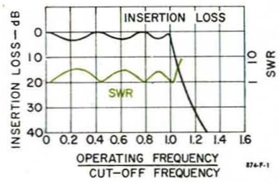
(cont'd)

LOW-PASS FILTERS — 874-F

Recommended for use in immittance- or voltage-measuring systems to reduce harmonics, and especially in systems containing nonlinear elements or sections that might resonate at a harmonic. Also useful in slotted-line measurements. Filters are Chebyshev type, which produce a very steep cutoff characteristic at the expense of passband flatness. Spurious responses in the stopband are very small. All filters are equipped with locking GR874® connectors.



Typical insertion loss and SWR, Type 874-F Filters.



874-F2000L

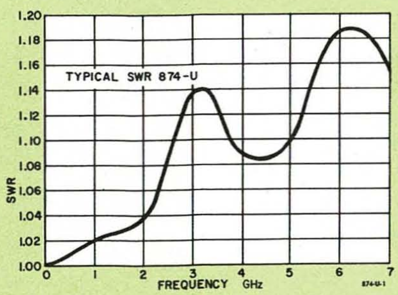
	Length	Catalog Number	Price in USA
874-F185L 185-MHz Low-Pass Filter	17⅝ in.	0874-9533	**$53.00**
874-F500L 500-MHz Low-Pass Filter	10$\frac{3}{16}$ in.	0874-9537	**32.00**
874-F1000L 1-GHz Low-Pass Filter	7⅛ in.	0874-9541	**30.00**
874-F2000L 2-GHz Low-Pass Filter	4⅜ in.	0874-9545	**30.00**
874-F4000L 4-GHz Low-Pass Filter	2⅞ in.	0874-9549	**30.00**

U-LINE SECTION — 874-U

A coaxial line section in the shape of a U, with GR874 connectors. Supplied as an accessory with the 1607-A Transfer-Function and Immittance Bridge, but useful in many other coaxial setups as well.

Dimensions: 2¼ x 2 x ⅞ in. (58 x 51 x 23 mm).

Weight: 7½ oz (215 g).



	Catalog Number	Price in USA
874-U U-Line Section	0874-9528	**30.00**

COMPONENT MOUNT — 874-ML

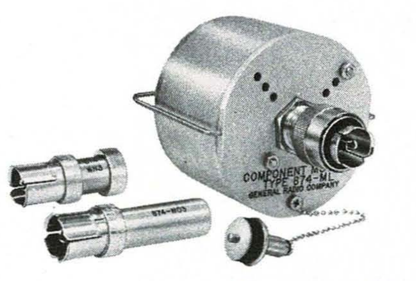
A shielded enclosure for convenient mounting of small components being measured. Use of mount minimizes stray capacitance in impedance measurements of circuit elements and networks from dc to 5 GHz. Locking GR874 coaxial connector.

Accessories Supplied: One 874-WN3 Short-Circuit Termination, one 874-WO3 Open-Circuit Termination.

Accessory Recommended: One 874-LK20L Constant-Impedance Adjustable Line for use with 1602-B UHF Admittance Meter.

Dimensions: Diameter 3 in. (77 mm); height of shield can 2⅝ in. (67 mm).

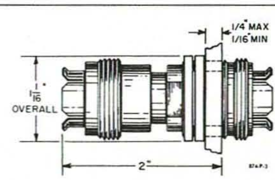
Net Weight: 10½ oz (295 g).



	Catalog Number	Price in USA
874-ML Component Mount	0874-9663	**53.00**

PANEL CONNECTOR — LOCKING FEEDTHROUGH

Mates any pair of GR874 connectors directly through a panel or wall. Can be mounted as recessed or nonrecessed panel locking connector. Can be mounted through bulkheads 2 in. or more thick.



	Catalog Number	Price in USA
874-PFL Panel Feedthrough Connector, locking	0874-9849*	**115.00**

* Sold only in packs of 10 each. Catalog number and price are for pack.

GR874® COAXIAL CABLE AND PATCH CORDS

(See also page 292)

COAXIAL CABLE — 874-A2

This is a flexible, double-shielded, low-loss coaxial cable, consisting of No. 14 stranded inner conductor separated from the two tinned-copper braids by 0.244-inch-OD polyethylene dielectric and a 0.375-inch-OD, gray, noncontaminating polyvinyl-chloride jacket.

Characteristic Impedance: 50 Ω ±5%.

Capacitance: 30.8 pF/ft, nominal.

Attenuation: Approx 2.6 dB/100 ft at 100 MHz; 10.5 dB/100 ft at 1 GHz.

Propagation Velocity Factor: 66%.

Net Weight: 2¾ lb (1.3 kg) per 25 ft.

Use GR874® connectors: Types 874-CA, -CLA, -PBA, -PLA, -PRLA, and -PBRLA.

	Catalog Number	Price in USA
874-A2 Coaxial Cable, 100 ft	0874-9862*	$48.00

COAXIAL CABLE — 874-A3

This cable is more flexible than the 874-A2 but with somewhat higher losses; the same as RG-58A/U but with double-braid shielding. The inner conductor is 19 strands of 0.0071-inch tinned soft-copper wire, separated from the double braid by 0.116-inch-OD polyethylene dielectric. The jacket is 0.206-inch-OD, black, noncontaminating polyvinyl chloride. This cable is recommended for most general-purpose applications.

Use GR874 connectors: Types 874-C58A, -CL58A, -PB58A, -PL58A, -PRL58A, and -PBRL58A.

Characteristic Impedance: 50 Ω ±5%.

Nominal Capacitance: 29 pF/ft.

Attenuation: Approx 5.3 dB/100 ft at 100 MHz; 22 dB/100 ft at 1 GHz.; 45 dB/100 ft at 3 GHz.

Propagation Velocity Factor: 66%.

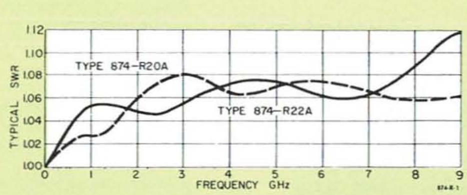
Net Weight: 1 lb (0.5 kg) per 25 ft.

	Catalog Number	Price in USA
874-A3 Coaxial Cable, 100 ft	0874-9863*	24.00

PATCH CORDS

These three-foot coaxial patch cords meet the need for flexible connections in the measurements laboratory. The 874-R20A and -R22A Patch Cords have very low SWR characteristics (see curves) and are available with either locking or nonlocking GR874® connectors. Frequency range to 9 GHz.


874-R33




874-R20A

The 874-R33 Patch Cord terminates in a pair of banana plugs, one connected to the center conductor and the other to the braid through a 5-inch pigtail. These plugs mate directly with GR 274 and 938 Jacks and 938 Binding Posts. The 874-R34 Patch Cord terminates in a 274-NK Shielded Double Plug.


874-R34


874-R22LA

Other patch cords and cables on pages 290 through 292.

Patch Cord Type	Cable Type	Catalog Number	Price in USA
874-R20A	874-A2	0874-9680	16.00
874-R20LA locking	874-A2	0874-9681	19.00
874-R22A	874-A3	0874-9682	15.00
874-R22LA locking	874-A3	0874-9683	18.00
874-R33	low C, 72 Ω coaxial	0874-9690	9.00
874-R34	RG-58C/U	0874-9692	9.50

* Sold only in packs of 100 ft lengths; catalog number and price are for pack.

GR874® TUNING ELEMENTS

VARIABLE CAPACITOR — 874-VCL

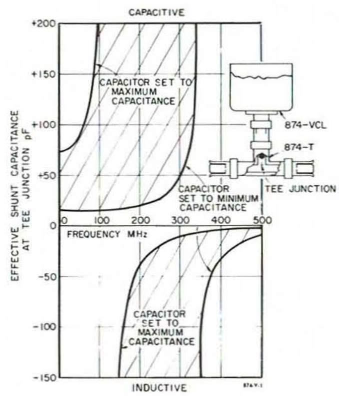
Tuning element for resonant-line circuits, matching transformers, and baluns at low frequencies where line-type elements are awkward to use. Well shielded, Rexolite insulation, precision ball bearings, locking connector.

Scale: 0 to 100.

Capacitance Range: Low frequencies, 14 to 70 pF at connector, 16.5 to 72.5 at junction of 874-T Tee. Linear capacitance variation.

Dimensions: 2½ in. dia, 5¼ in. height, (64 x 135 mm).

Net Weight: 12½ oz (350 g).



	Catalog Number	Price in USA
874-VCL Variable Capacitor	0874-9931	$105.00

ADJUSTABLE STUBS — 874-D20L and -D50L

For matching or tuning, for use as adjustable short-circuit terminations, and as reactive elements. With an external indicator, the stub can function as a reaction-type wavemeter. Consists of a coaxial line with a sliding short circuit of the multiple-spring-finger type. The 20-centimeter stub is calibrated in electrical distance from junction in 874-T Tee. The 50-centimeter stub is not calibrated but has an adjustable reference marker. Each is equipped with a locking connector.

Characteristic Impedance: 50 Ω.

Max Travel: 874-D20L, 20 cm; 874-D50L, 50 cm.

Physical Length: 874-D20L, 28 to 48 cm; 874-D50L, 58 to 109 cm.

Net Weight: 874-D20L, 7 oz (196 g); 874-D50L, 13 oz (364 g).

Adjustable Stub	Catalog Number	Price in USA
874-D20L, 20-cm	0874-9511	30.00
874-D50L, 50-cm	0874-9513	37.00

GR874® MISCELLANEOUS

Type 874-Z STAND

A solid, stable support for components of coaxial systems. Consists of a heavy cast-iron base with rubber feet, 22-inch and 8-inch stainless-steel rods, and three universal clamps. The vertical rod can be used to hold long tuning stubs. The horizontal rod can be moved longitudinally or can be interchanged with the vertical rod. One 22-inch rod can be clamped to two bases to support a long horizontal run of coaxial parts. Clamps fit a range of diameters. Base can be bolted to bench top.

Dimensions: Base, 3½ x 4$\frac{7}{16}$ in. (89 x 115 mm); rod lengths, 22 and 8 in. (560 and 205 mm).

Net Weight: 5½ lb (2.5 kg).

	Catalog Number	Price in USA
874-Z Stand	0874-9996	32.00
874-ZC Extra Clamp	0874-9997	2.75

GR874® MISCELLANEOUS (continued)

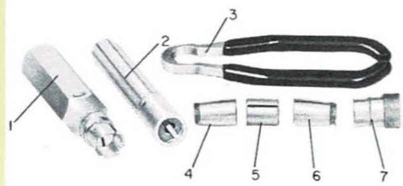
		Catalog Number	Price in USA

TOOLS

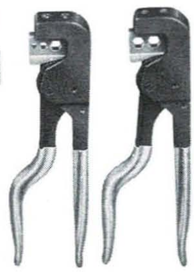
Several special tools are available to facilitate assembly of GR874 connectors — these tools ensure quick assembly, neat, uniform appearance, and best electrical and mechanical performance.

The 874-TOK Tool Kit consists of an inner-conductor wrench to install both the insulating bead and the inner conductor and an outer-conductor wrench to install the outer conductor and to tighten the coupling nut. The other pieces aid in installation of the retaining ring.

When a GR874 connector is installed on cable, the ferrule must be crimped to secure the cable to the connector. Pliers can be used to crimp the ferrule, but, for the neatest crimp in the shortest time, use of a 874-TO58 or -TO8 Crimping Tool is recommended.



874-TOK
1. Outer-conductor wrench
2. Inner-conductor wrench
3. Coupling-nut wrench
4. Front-ring expander (red)
5. Keeper for ring expanders
6. Back-ring expander (green)
7. Ring pusher



874-TO58 874-TO8

	Use on following GR874 cable connectors	Catalog Number	Price in USA
874-TOK Tool Kit	all	0874-9902	$ 32.00
874-TO8 Crimping Tool	874-( )8A family	0874-9900	120.00
874-TO58 Crimping Tool	all others	0874-9901	120.00

Type 874-VI VOLTMETER INDICATOR

Measures dc output of either 874-VQ or 874-VR at any level between 0.1 and 2 volts. A built-in 60-Hz calibration system eliminates errors arising from differences in crystal rectification efficiencies.

Input Resistance: 600 Ω min, 10,000 Ω max.

Range and Accuracy of Calibrating Voltage: 0.1 to 2 V, ±0.05 V.

Crystal Current for Full-Scale Indication: 200 μA.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz.

874-VI Voltmeter Indicator	0874-9936	130.00

GR874 INNER-CONDUCTOR ROD*

For use in constructing 14-mm, 50-ohm rigid coaxial air lines and elements to meet special needs. Ends are machined to accept GR874 connectors.

Material: High-conductivity silver-plated brass.

Length: 15⅞ in. **Diameter:** 0.24425 ±0.00025 in.
Both ends have tapped hole to accept 874-BBL or 874-B connector.

Inner-Conductor Rod	0874-9508	5.25

GR874 OUTER-CONDUCTOR TUBE*

For use in constructing 14-mm, 50-ohm rigid coaxial air lines and elements to meet special needs. Ends are machined to accept GR874 connectors.

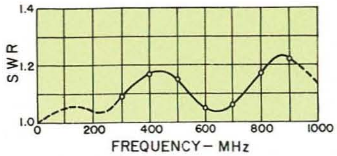
Material: Brass, bright-alloy plated.

Length: 15⅞ in. **Diameter:** O.D., 0.624 +0.000, −0.002 in.; I.D., 0.5625 ±0.0010 in.
Both ends grooved and slotted to accept 874-BBL or 874-B connector.

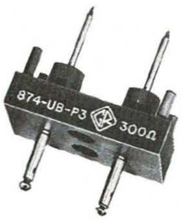
* Characteristic impedance of GR874 Tube and Rod is 50 Ω ±0.375% (±0.1875 Ω).

Outer-Conductor Tube	0874-9509	5.25

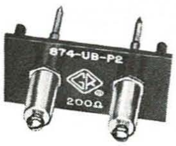
Type 874-UBL BALUN



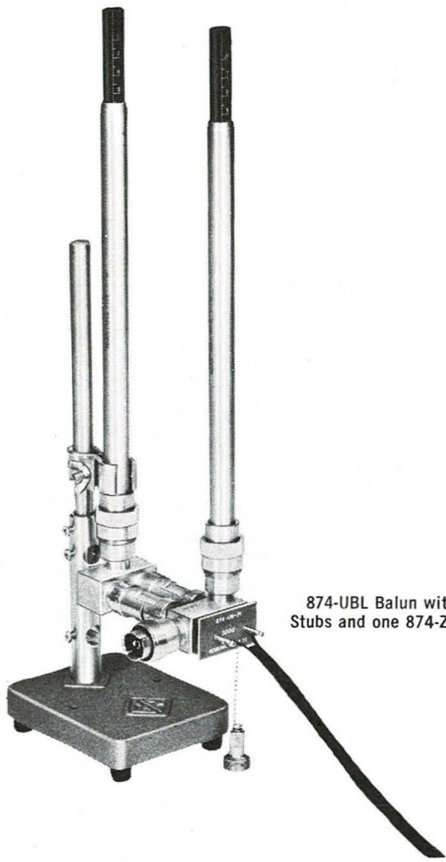
Typical SWR of 874-UB-P2.



874-UB-P3



874-UB-P2



874-UBL Balun with two Stubs and one 874-Z Stand.

The 874-UBL Balun is a tuned coaxial 4:1 transformer that matches 50-ohm coaxial line to 200-ohm balanced line and thus extends the usefulness of generally available coaxial instruments to balanced devices. Used with the slotted line, admittance meter, or transfer-function and immittance bridge, the balun permits measurements on balanced components over a frequency range from 54 MHz to 1 GHz without appreciable insertion loss or transformation error.

Tuning elements required for various frequency ranges are listed below. These elements are not supplied with the balun but must be purchased separately.

specifications

Frequency Range: 54 MHz to 1 GHz with accessory tuning elements as listed below.

Frequency Range MHz	Tuning Elements Required
54-88	2 Type 874-VCL and 2 Type 874-XL
88-140	2 Type 874-VCL and 2 Type 874-L30
140-174	2 Type 874-VCL and 2 Type 874-L20
174-216	2 Type 874-VCL and 2 Type 874-L10
170-280	2 Type 874-D50L and 2 Type 874-L30
225-280	2 Type 874-D20L and 2 Type 874-L30
275-380	2 Type 874-D20L and 2 Type 874-L20
350-525	2 Type 874-D20L and 2 Type 874-L10
470-1000	2 Type 874-D20L

Accessories Supplied: One 874-UB-P1 300-ohm Terminal, one 874-WN3 Short-Circuit Termination, and one 874-WO3 Open-Circuit Termination.

Accessories Recommended: 874-LK20L Adjustable Line (for use with 1602-B UHF Admittance Meter) one 874-Z Stand, and tuning elements listed below.

Dimensions: 3⅛ x 3⅜ x 2⅜ in. (79 x 81 x 60 mm).

Net Weight: 1¼ lb (0.6 kg).

Catalog Number	Description	Price in USA
0874-9921	**874-UBL Balun**	**$175.00**

BALUN ACCESSORIES

874-UB-P2 200-OHM TERMINAL UNIT

Connects the balun directly to 200-ohm transmission line or to balanced components via screw terminals.

Characteristic Impedance: 200 Ω.

Frequency Range: Dc to 1 GHz.

Recommended Transmission Line: RG-86/U.

SWR: 1.2 to 300 MHz, 1.3 to 1 GHz.

Dimensions: 1 x 1¾ x 1⅞ in. (25 x 44 x 48 mm).

Net Weight: 1 oz (28 g).

874-UB-P3 300-OHM TERMINAL PAD

Converts the 200-ohm balanced output impedance produced by the balun to 300 ohms. Facilitates power and voltage measurements on balanced 300-ohm systems with signal generators and detectors designed for use with 50-ohm coaxial circuits.

Catalog Number	Description	Price in USA
0874-9923	**874-UB-P2 200-ohm Terminal Unit**	**$16.00**
0874-9924	**874-UB-P3 300-ohm Terminal Pad**	**37.00**

Type 1237 VHF/UHF PREAMPLIFIER

- 150 kHz to 1 GHz
- 10- to 30-dB gain
- >35-dB isolation

The 1237 is a low-noise, low-level transistor amplifier for use as a general-purpose amplifier, preamplifier and isolator from 150 kHz to 1 GHz. In many measurement applications, the preamplifier will improve sensitivity for a sharper null, greater measurement accuracy, and better bridge performance. As an accessory for the GR 1607 Transfer-Function and Immittance Bridge and in other small-signal measurements, the 1237 replaces a local-oscillator trap to isolate the local-oscillator signal from the bridge.

It is particularly useful as part of a heterodyne detector system used with a bridge for small-signal measurements. In bridge measurements of active devices, the local-oscillator signal must be isolated from the bridge; the reverse attenuation of the 1237 provides such isolation between the bridge and mixer. A 30-MHz notch filter blocks preamplifier noise at that frequency which would otherwise reduce the sensitivity of a tuned 30-MHz i-f amplifier such as the GR 1236.

The signal detection system that employs a modulated signal, envelope detector, and tuned audio amplifier is usually not as sensitive as a heterodyne detector. However, with the broadband gain of one or two 1237's added ahead of the envelope detector, the sensitivity of this method approaches that of a heterodyne detector and gives the benefits of wide-band operation without need for a local oscillator.

The 1237 VHF/UHF Preamplifier consists of a three-stage solid-state amplifier, a 30-MHz stop-band filter, and an ac power supply. It will operate from a 9-V external battery for field use or for isolation from line frequencies.

Power output of the 1237 preamplifier operating at 1-dB gain compression typically increases from −15 to 0 dBm from 50 to 400 MHz and remains about 0 dBm above 400 MHz.

— See **GR Experimenter** for March/April 1969.

specifications

Frequency Range: 150 kHz to 1 GHz.

Gain: >10 dB.(see typical curve)

Reverse Attenuation: >33 dB; below 700 MHz, >43 dB.

Noise Figure: See typical curve.

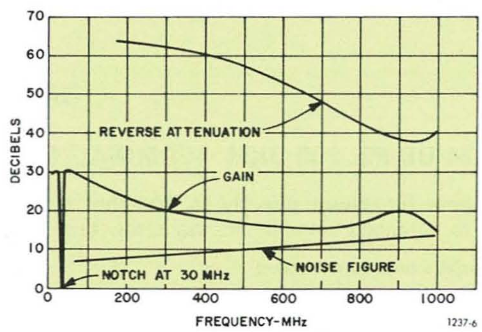
Terminals: Input and output, GR874® locking coaxial connectors.

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 1.5 W; or 9 V dc, 18 mA.

Dimensions (width x height x depth): 6¼ x 3$^{11}/_{16}$ x 2½ in. (160 x 94 x 64 mm).

Weight: Net, 1½ lb (0.7 kg); shipping, 3 lb (1.4 kg).

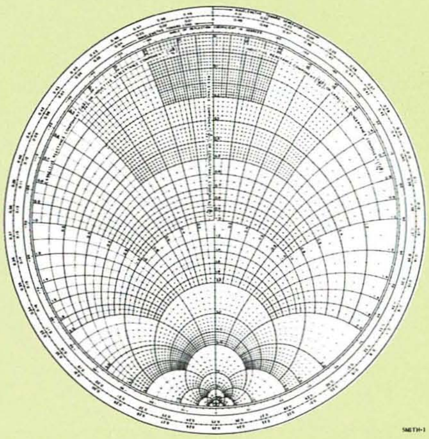
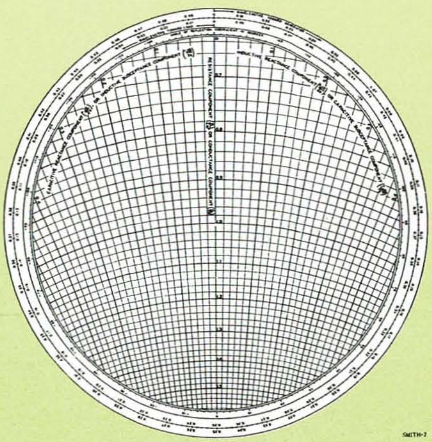
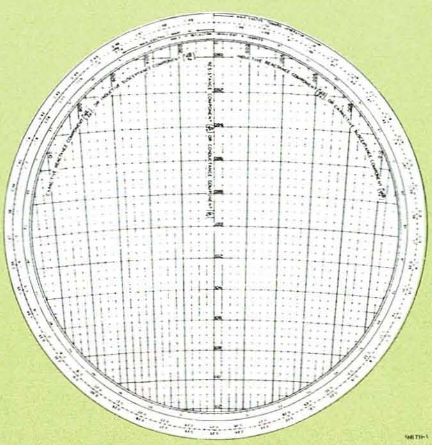
Catalog Number	Description	Price in USA
1237-9700	**1237 VHF/UHF Preamplifier**	**$195.00**



Typical noise figure, gain, and reverse attenuation characteristics of the VHF/UHF preamplifier.

SMITH CHARTS

The Smith Chart facilitates measurements made with slotted lines. It can be used to determine the impedance corresponding to any SWR and to convert from impedance to admittance, and vice versa. Six forms of Smith Chart are available. Those with normalized coordinates are for use with lines of any impedance. The 50-ohm characteristic impedance (20-millimho characteristic admittance) is common to all General Radio coaxial equipment. Type NX charts are 22½ x 35 in; all others are 8½ x 11 in.

	Description	Catalog Number	Price in USA
	Type NX Smith Chart (wall size), normalized coordinates (about 75 charts per pad)	5301-7563	per pad of 75 charts **$12.00**
	Type N Smith Chart normalized coordinates	5301-7560	supplied in units of 50 charts per unit **$2.50**
	Type Y Smith Chart 20-millimho admittance coordinates	5301-7568	
	Type Z Smith Chart 50-ohm impedance coordinates	5301-7569	
	Type NE Smith Chart normalized, expanded coordinates (for use when SWR ≤1.58)	5301-7561	
	Type HE Smith Chart normalized, highly expanded coordinates (for use when SWR ≤1.12)	5301-7562	

GR900®

INSTRUMENTS AND ELEMENTS

GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO

GR900® PRECISION COAXIAL COMPONENTS AND STANDARDS

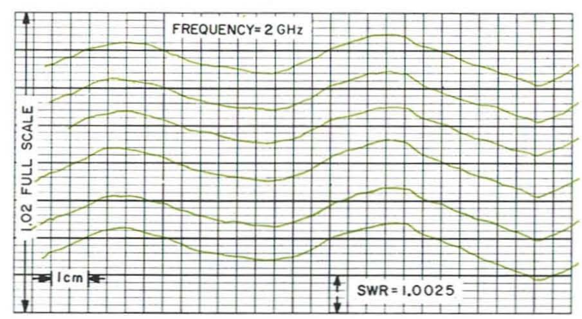
14 mm — 50 ohms

GR900®

For many years the coaxial connector had been the limiting factor in the design of highly accurate measuring equipment. Not only was it impossible to design such equipment without a precision connector, it was not even worth trying, since any improvements would be obscured by the connector deficiencies. It was obvious that the first step in the development of a line of ultra-precise coaxial instruments had to be the development of a precision connector. General Radio, using its long experience in coaxial-connector development, thus designed the first commercial coaxial connector that could honestly be called "precision" — the GR900® connector.

The design objective was a connector far better electrically than any existing type and one that could be sold at a reasonable price. The design tolerance on characteristic impedance was set at ±0.1%. Extensive production engineering was required to find economical methods of manufacturing to such a close tolerance.

The successful completion of the GR900 connector development signaled the initiation of an entire line of precision coaxial components and instruments. The GR900 line, which includes a precision slotted line and recording system, uhf immittance bridge, air-line sections, adaptors, standard terminations, and tuners, is well on its way to becoming the standard of precision in the microwave industry.



Repeatability run showing typical consistency of performance as Type 900-BT Precision Coaxial Connector is rotated to six different orientations. Multiple plot was produced at 2 GHz by a Type 900-LB Precision Slotted Line and a Type 1521 Graphic Level Recorder.

Electrical Characteristics

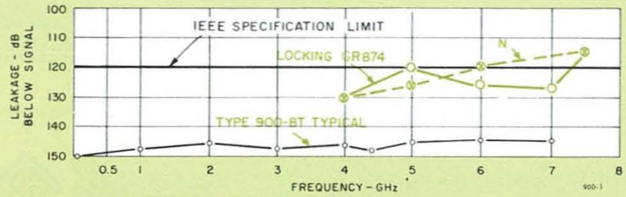
SWR

Probably the most important single characteristic of a precision connector is its SWR, that is, the extent to which it introduces reflections into an otherwise matched transmission line. The SWR test specification of $1.001 + 0.001f_{GHz}$ applies both to single 900-BT Connectors and to those supplied in pairs with a calibration certificate.

Repeatability

Of vital importance to many precision measurements is the consistency of performance of the connector as the connection is broken and remade. The SWR repeatability of a pair of GR900 connectors is typically within 0.03%. In an attenuation measurement, for example, this would result in an insertion-loss repeatability of ±0.002 dB, typically.

Further, extremely close tolerances on repeatability of phase (within 0.008° at 1 GHz) gives added assurance of small connector error in precision coaxial measurements.



Typical leakage curve of mated pair of Type 900-BT Precision Coaxial Connectors compared with other popular types.

Leakage

Leakage of the GR900 connector (see graph) is better than 130 dB below signal level — lower than that of any other commonly used coaxial connector. This is due to the triple shielding action of the butt contact of the outer conductors, the interlocking and overlapping of the centering gear rings and the outer locking nut, and the precise machining of the mating surfaces.

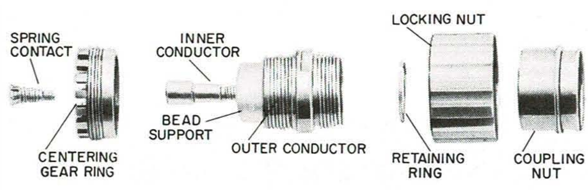
Insertion Loss

The insertion loss, or attenuation, of the GR900 connector is extremely small. It has been minimized by the use of Teflon* for the bead, by the use of solid silver alloys for both inner and outer conductors, and, in particular, by the unique design of the contact.

Electrical Length

The electrical length of a pair of Type 900-BT Connectors is 3.50 cm and is virtually independent of frequency. The dc resistance of a mated pair is typically 0.4 milliohm

* Registered trademark of the E. I. du Pont de Nemours and Company.



Exploded view of Type 900-BT Precision Coaxial Connector.

for the inner conductors, 0.04 milliohm for the outer conductors.

The standard GR900 connector (Type 900-BT) meets all the specifications contained in Part III, Section 1 of the IEEE Standard for Precision Coaxial Connectors, No. 287. The Type 900-BT Connector is also available in pairs with calibration certificate, which verifies that combined SWR of the **two** connectors is within the limits specified in the IEEE document.

Other Members of the GR900® Family

One of the most important advantages of the GR900 connector over other precision types is the broad and rapidly expanding line of instruments and components equipped with it. Moreover, the availability of GR900 cable connectors and of kits for fabricating GR900 panel and component connectors and air-line sections brings GR900 precision to every corner of the laboratory.

Mechanical Features

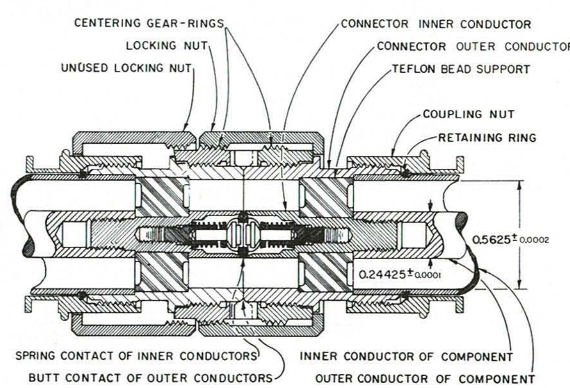
The basic GR900 connector (Type 900-BT) is designed for use on rigid, air-dielectric, 50-ohm, 14-mm (9/16-inch) coaxial transmission line (principal dimensions: 0.5625 inch and 0.24425 inch). The eight parts of the connector are shown in the accompanying exploded view. The spring contact and inner conductor are of gold-plated solid silver alloy, the bead support Teflon, the centering gear ring stainless steel, the outer conductor gold-plated coin silver, the retaining ring phospor-bronze, and the coupling and locking nuts chrome-plated brass.

When the parts are assembled onto an air line, the coupling nut and retaining ring attach the outer conductor of the connector to the outer conductor of the line (see cross-section drawing). The inner conductor is threaded into the center conductor of the air line and is supported by the Teflon bead.

When two GR900 connectors are mated, the centering gear rings interlock and overlap to center the connectors with respect to each other. This also prevents the connectors from rotating against each other with possible impairment of repeatability and reliability. The front surfaces of the outer conductors butt firmly together under the pressure of the locking nut. Only one of the locking nuts is used in a connection; the other is backed off to a storage position.

The front surfaces of the inner conductors are recessed 0.001 inch with respect to the surfaces of the outer conductors to ensure outer-conductor contact. Inner-conductor contact is made by a spring-contact assembly, which projects slightly beyond the surface of the outer conductors until the connector is mated. The spring-contact assembly consists of six independently sprung segments, which are forced back and spread upon mating, thereby making a wiping contact both with the other spring contact and with the inside of the inner conductor. This method avoids the reflections caused by slots in the inner and outer conductors and eliminates changes in the electrical diameter due to wear. Only one spring contact is necessary for a good electrical connection; the spring contact will mate with any flat surface.

When two connectors are mated, the outer conductors meet in the midpoint of the connection, and this point becomes the electrical reference plane. The over-all diameter of the mated pair is 1-1/16 inches.



Cross-section view of mated Type 900-BT Precision Coaxial Connectors.

Index to GR900® Coaxial Elements

Type 1641 SWEEP-FREQUENCY REFLECTOMETER

- 20 MHz to 7 GHz in two ranges
- residual SWR typically <1.02
- direct reading in SWR and loss
- all coaxial hardware internal
- precalibrated, simplified operation
- complete — add only source and scope

The GR 1641 Sweep-Frequency Reflectometer measures standing-wave ratio (direct reading) and return and insertion loss in dB with precision from 20 to 1500 MHz and 0.5 to 7 GHz in single or sweep frequency operation. Not just an indicator of return and transmitted signals, the 1641 contains all the required coaxial hardware: directional couplers, detectors, and terminations; only the device under test is connected externally. Once calibrated, the 1641 does not require recalibration when measurement ranges are changed. Measuring ranges as well as frequency range are broad: SWR can be determined from 1.005 to infinity, insertion loss from 0 to 50 dB.

The GR 1641 is intended to meet the many requirements for an economical, yet accurate, reflectometer that is simple in operation. In most production and quality-control testing, and frequently in design and development testing, SWR and loss, without phase information, are adequate. The 1641 is faster, easier, and less apt to add errors (residual or operational) than more complex systems. With the GR 1641 you spend your time making measurements, not connections.

COMPLETE ASSEMBLY

With the addition of appropriate rf sources (the ones you're presently using are probably fine) and a storage oscilloscope for sweep measurements, the 1641 is ready for use, precalibrated and completely interconnected.

A panel meter on the Reflectometer reads directly in SWR and in dB for return and insertion loss and provides the most accurate readout. Sweep measurements with an oscilloscope readout are fast and simple to make and, in addition, permit simultaneous display of both SWR and loss characteristics without connection changes.

The frequency range of the Reflectometer is covered by two rf units that can be accommodated by the main chassis at the same time; the instrument can be ordered with either rf unit initially, the other to be added later.

The GR900® line of precision coaxial components makes available adaptors to all popular connector types, tuners and air-line standards for highest accuracy at fixed frequencies, terminations as matched or calibrated-mismatch standards, and low-SWR precision attenuators.

PRECISION INSTRUMENT

High accuracy is one of the key goals attained in the design of the 1641, symbolized by the use of GR900® precision coaxial connectors throughout and carried through the entire design. All measurement results are obtainable to an accuracy of a few percent depending upon the mode and frequency range of operation. The use of GR900® connectors eliminates another potential source of error; precision adaptors from common connector types to GR900® are available that have little effect on measurement accuracy. Thus, the GR 1641 can be converted to a type N or TNC precision reflectometer; typical residual SWR for such conversions is shown below.

Connector Type	Typical Residual SWR at 300 MHz	3 GHz
GR900	1.007	1.015
APC7	1.01	1.02
N	1.01	1.02
TNC	1.01	1.03
SMA	1.02	1.04

APPLICATIONS

The GR 1641 Sweep-Frequency Reflectometer will measure to suit the majority of needs for determining standing-wave ratio and insertion loss as specified commonly in industrial and military testing specifications applied to production alignment and testing and to quality-control procedures. At single or swept frequencies it can be used to aid in the adjustment of device parameters, in data collection, and in the GO-NO GO testing of devices against established limits.

The sweep mode of the Reflectometer lends itself particularly to the search for, and identification of resonances as it is fast, broadband, and will display SWR and loss simultaneously. Thus, cables and other transmission networks can be quickly analyzed, and filters, cavities, and couplers adjusted for desired performance.

Devices of many types are suitable for measurement with the 1641. The unknown can be one-, two-, or multi-port, passive or active, bi- or unidirectional. The instrument measures directly the vital characteristics of attenuators, isolators, power dividers, terminations and loads, switches, couplers, amplifiers, and many other common devices. Antenna SWR is an obvious application. By measuring insertion loss through a transmission path between two antennas, their characteristics and those of the intervening dielectric material can also be analyzed. Resolution of the 1641 is adequate for measuring connectors and other low-SWR devices.

All the above uses are enhanced by the ability of the 1641 Reflectometer to be remotely programmed. In conjunction with programmable sources and suitable data conversion, processing, and recording instruments, the 1641 can conduct computer-controlled tests for sorting or qualifying devices and for automatic data acquisition.

AUXILIARY INSTRUMENTS

For the display of sweep-frequency measurements, the Tektronix Type 564 Storage Oscilloscope with two 2A63 Plug-ins is suitable; an accessory calibrated graticule is supplied for use with this instrument. Other oscilloscopes with a vertical sensitivity of at least 0.1 V per cm and horizontal sensitivity to suit the selected sweep generator will serve the purpose. A storage oscilloscope is recommended for use at the slow sweep rates required for low-level (low SWR and high attenuation) measurements. For permanent records, an X-Y recorder or linear strip-chart recorder can be driven from the Reflectometer output if it has at least 1-volt full-scale sensitivity and at least 1-kilohm input impedance.

Although the GR 1641 depends on an external source of test signals, its requirements are not stringent. For single or sweep-frequency operation, the source must provide at least 0 mW of leveled output into 50 ohms; additional output up to 100 mW makes possible greater resolution. The source should be capable of being 10-kHz modulated and its output leveled by signals supplied by the Reflectometer. A source with 1-kHz internal modulation can be used.

High-frequency sweep sources are available from other manufacturers and have output, leveling, and modulation capabilities compatible with the needs of the Reflectometer. For single-frequency measurements and sufficient output power for maximum resolution, select from the many General Radio high-frequency oscillators.

— See **GR Experimenter** for March-April 1969.

specifications

Frequency Range: 20 MHz to 7.0 GHz in two bands, 20 to 1500 MHz and 0.5 to 7.0 GHz.

Characteristic Impedance: 50 ohms, nominal.

SWR ranges: 1.02 to ∞ and 1.005 to 2.0. Meter ranges, 1.005 to 1.03, 1.02 to 1.10, 1.05 to 1.35, 1.2 to 2.0, and 2.0 to ∞.

Insertion- and Return-Loss Ranges: 0 to 40 dB and 10 to 50 dB. Meter ranges, 0 to 13, 10 to 23, 17 to 30, 27 to 40, and 37 to 50 dB.

ACCURACY

SWR and Return-Loss Measurement Accuracy:

	Directivity	(Equivalent Residual SWR)	% of Reflection Coefficient of Unknown Fixed Freq	Sweep Freq
20 to 1500 MHz	>43 dB to 1 GHz >40 dB to 1.5 GHz	(<1.015) (<1.02)	3%	4%
0.5 to 7 GHz	>40 dB to 4 GHz >37 dB to 7 GHz	(<1.02) (<1.03)	6%	11%

Insertion Loss (in terms of insertion loss (τ) in dB of unknown):

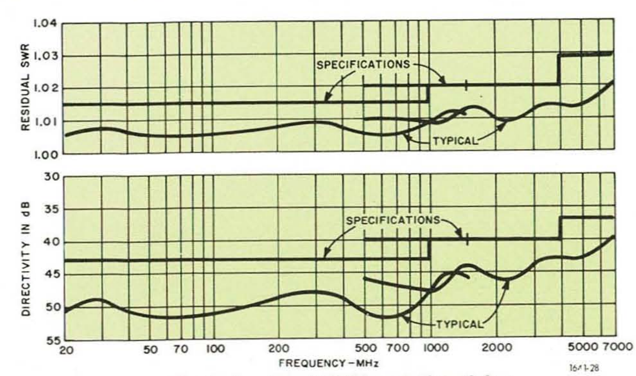
	Fixed Frequency	Swept Frequency
20 to 1500 MHz	$\pm(0.1 + 0.015\ \tau)$dB	$\pm(0.3 + 0.015\ \tau)$dB
0.5 to 7.0 GHz	$\pm(0.1 + 0.015\ \tau)$dB	$\pm(0.6 + 0.015\ \tau)$dB

Residual Detector Match to Unknown: SWR $<1.01 + 0.007f_{GHz}$.

Equivalent Residual Source Match to Unknown: SWR <1.03, 20 to 1500 MHz; $<1.01 + 0.007f_{GHz}$, 0.5 to 7 GHz.

GENERAL

Source Power Required: Typically 10 mW for 1.02 to ∞ SWR range and 0 to 40-dB loss ranges. Typically 100 mW for 1.005 to 2.0 SWR and 10 to 50-dB loss range.



Typical residual SWR and directivity.

RF-Source Power: 1 W max.

RF Signal to Unknown: 100 μW typical.

Modulation Output: 10kHz, -15 to +15 V max, on-off. 400-Ω source impedance, 1-kΩ min load impedance. Internal detector tunable to 1-kHz for use with external modulation source.

DC-Signal Output: 1 V max across a load of ≧ 1 kΩ for full-scale indication.

Remotely Programmable Functions: Display function (SWR or loss) and range (SWR and loss). Require contact closures to ground.

Power Required (1641): 100 to 125 or 200 to 250 V, 50 to 60 Hz, 5 W.

Accessories Supplied: 900-W100 Standard 100-Ω Termination, 900-WNC Standard Short-Circuit Termination, 1641-P2 Transfer Detector, calibrated graticule for Tektronix R564 Oscilloscope, Patch Cords GR874-to-GR874®, Patch Cords GR874-to-BNC, power cord.

Accessories Available: Kit 1641-9605 includes in a carrying case GR900® adaptors to N, and SMA, GR874® adaptors to TNC, N, and BNC, and a 900-W50 50-ohm Standard Termination. Tektronix Type R564B Storage Oscilloscope and Type 2A63 Differential Amplifier Plug-in Unit (included with 1641-Z models).

These and other accessories available separately, including attenuators, tuners, and reference air lines.

Accessories Required: Rf source, fixed frequency or swept, with 10 to 100 mW output available, leveled; oscilloscope, preferably storage, or dc recorder, to display sweep-frequency data. Fixed-frequency measurement data displayed on front-panel meter.

Mounting: Rack model or bench model in metal cabinet.

Dimensions (w x h x d) (1641): Bench, 19½ x 12 x 23 in. (495 x 305 x 590 mm); rack, 19 x 10½ x 20½ in. (485 x 270 x 520 mm).

Net Weight: Bench, 70 lb (32 kg); rack, 60 lb (28 kg).

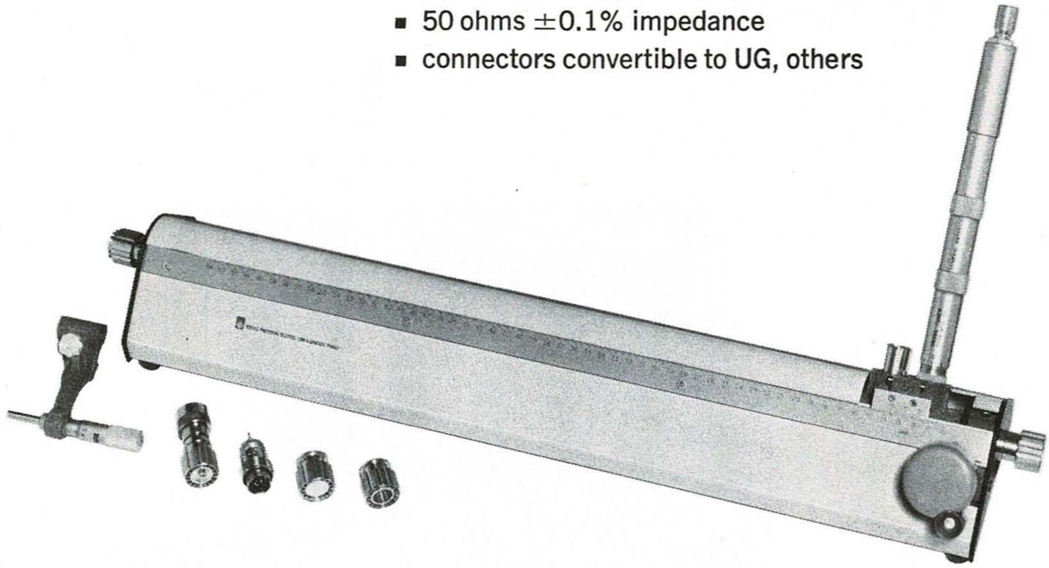
Shipping Weight: Bench, 150 lb (70 kg); rack, 150 lb (70 kg).

Catalog Number	Description	Price in USA
	1641 Sweep-Frequency Reflectometer,	
1641-9701	20 MHz to 7 GHz, Bench Model	**$5650.00**
1641-9711	Rack Model	**5600.00**
1641-9702	20 MHz to 1500 MHz, Bench Model	**4200.00**
1641-9712	Rack Model	**4150.00**
1641-9703	0.5 GHz to 7 GHz, Bench Model	**3175.00**
1641-9713	Rack Model	**3125.00**
	1641-Z Sweep-Frequency Reflectometer, with display oscilloscope	
1641-9901	20 MHz to 7 GHz, Bench Model	**7565.00**
1641-9911	Rack Model	**7515.00**
1641-9902	20 MHz to 1500 MHz, Bench Model	**6115.00**
1641-9912	Rack Model	**6065.00**
1641-9903	0.5 GHz to 7 GHz, Bench Model	**5090.00**
1641-9913	Rack Model	**5040.00**
1641-9601	**RF Unit** (20 MHz to 1500 MHz)	**2475.00**
1641-9602	**RF Unit** (0.5 GHz to 7 GHz)	**1450.00**
1641-9605	**Accessory Kit**	**495.00**

Type 900-LB PRECISION SLOTTED LINE

14 mm — 50 ohms

- 300 MHz to 8.5 GHz
- SWR: <1.002 at 1 GHz, <1.01 at 8.5 GHz
- 50 ohms ±0.1% impedance
- connectors convertible to UG, others



The most precise coaxial connector, the GR900, and a nearly perfect section of coaxial transmission line combine to give the 900-LB Precision Slotted Line unparalleled performance specifications. The residual SWR of the instrument is that of its GR900® connector: 1.001 + 0.001 f_{GHz}. For those whose applications demand the ultimate in accuracy, the 900-LB can be calibrated against a 900-LZ Reference Air Line, an impedance standard with a SWR under 1.0025 at 9 GHz.

In the field of microwave impedance measurement, the slotted line is **the** fundamental instrument, because of its inherent accuracy, broadband characteristics, and phase-measuring capabilities. Among the many transmission-line parameters that can be determined with the slotted line are SWR, reflection-coefficient magnitude and phase, attenuation or insertion loss, and wavelength. The admittance or impedance of source or termination can be measured and so also can transistor and diode characteristics and dielectric constant. It gives the design engineer all the information he needs to evaluate the over-all performance of devices and networks over a wide band.

The outstandingly low SWR of the 900-LB should save users the many hours required to calibrate less accurate instruments.

Equipped with the appropriate GR900 low-SWR adaptor, the 900-LB becomes a type N, BNC, TNC, etc slotted line whose specifications still exceed those of slotted lines originally equipped with the other series (see curve below).

Included with the slotted line is a full set of accessories; no additional parts are needed for common measurements, except the generator and detector, which should be selected according to frequency range of interest.

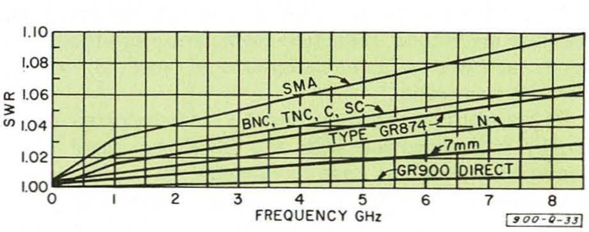
— See **GR Experimenter** for November 1963.

specifications

Characteristic Impedance: 50.0 Ω ±0.1%.

Probe Travel: 50 cm. Scale calibrated in centimeters from reference plane. Attached vernier can be read to 0.1 mm, micrometer carriage drive (supplied) to 0.002 mm.

Scale Accuracy: ±(0.1 mm + 0.05%).



Specified residual SWR of the 900-LB Precision Slotted Line in combination with various GR900® precision adaptors.

Frequency Range: 0.3 to 8.5 GHz. At 300 MHz, covers a half wavelength. Operates below 300 MHz with Type 900-L or -LZ Air Line.

Constancy of Probe Pickup (Flatness): ±0.5%.

Residual SWR: Less than 1.001 + 0.001 f_{GHz} (unknown connector side). SWR calibration data is supplied.

Repeatability: Within 0.05% (0.0005 in SWR).

Connector Contact Resistance (900-BT Connector): <0.57 mΩ.

Generators page 236 ff

Accessories Supplied: Adjustable probe-tuner assembly; rf probe; micrometer carriage drive (accurate to 0.01 mm); 900-WN Precision Short-Circuit Termination; 900-WO Precision Open-Circuit Termination; 874-R22A Patch Cord; adaptor 874-Q900L; 1N21C and 1N23C detector diodes; Smith charts; storage case.

Detectors page 133 ff

Accessories Required: Generator and detector.

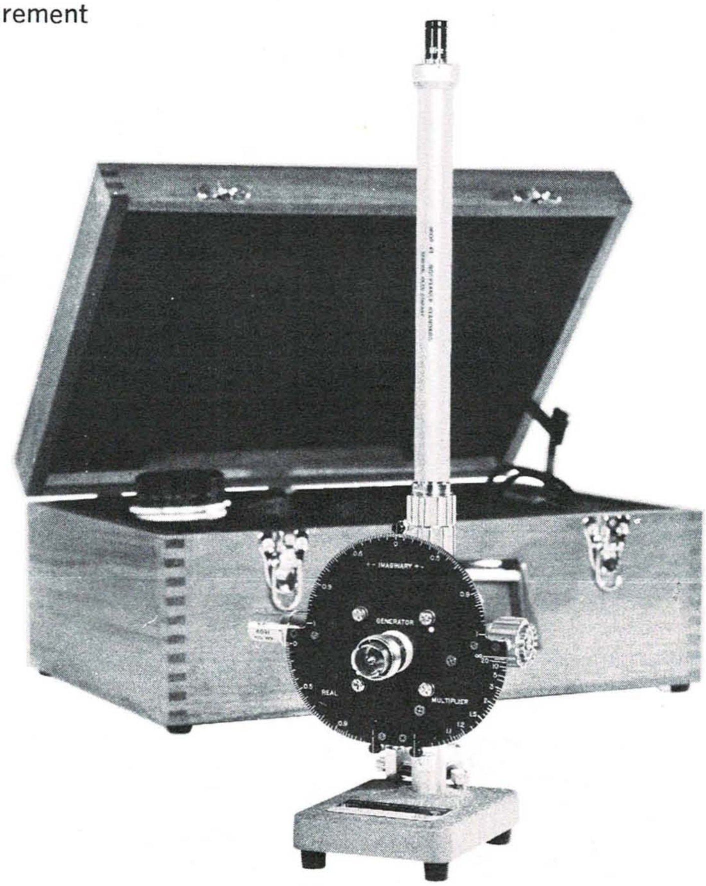
Dimensions (width x height x depth): 27½ x 10 x 4¾ in. (700 x 255 x 125 mm).

Weight: Net, 10¾ lb (4.9 kg); shipping, 34 lb (15.5 kg).

Catalog Number	Description	Price in USA
0900-9651	**900-LB Precision Slotted Line**	**$1300.00**

Type 1609 PRECISION UHF BRIDGE

- 20 to 1500 MHz
- direct reading
- GR900® precision coaxial connectors
- reflectometer for fast SWR measurement



The 1609 Precision UHF Bridge adds precision and stability to the long list of advantages that have made its forebear, the 1602 Admittance Meter, a favorite: ease and speed of use, the inherent accuracy of null techniques, convenient size.

The use of GR900® precision coaxial connectors puts the 1609 in a class with the 900-LB Slotted Line, extending precision coaxial measurements to much lower frequencies. The low reflection coefficient and high repeatability of the GR900 connectors make the 1609 particularly good for the measurement of near-50-ohm impedances and for substitution measurements; accuracies of 0.2% can be realized when the 1609 is used as a transfer bridge with GR 900-LZ Reference Air Lines as 50-ohm standards. GR900 precision terminations, standard mismatches, and other GR900-equipped impedance standards can also be used to calibrate the 1609. With GR900 low-SWR adaptors, the 1609 can be converted to a type N precision UHF bridge (or TNC, BNC, etc).

The 1609 includes many mechanical improvements, not the least of which is an over-all ruggedization for better stability and instrument repeatability. The use of more stable standards with locking mechanisms and a detented multiplier arm further contribute to more repeatable measurements. Vernier drives can be used on both balance arms, permitting finer balance, greater precision; a locking mechanism is incorporated.

APPLICATIONS

The Precision UHF Bridge will measure admittance (and impedance) over a wide range of values and frequencies, indicating both real and imaginary terms. It is ideal for measuring antennas, transmission lines, and circuits at frequencies where neither lumped-parameter bridges nor slotted-line techniques are adequate.

It can be used for setting a network to a predetermined admittance, for matching one network or termination to another, and for matching antennas and other devices to 50-ohm circuits.

As a comparator, the 1609 is used to determine impedance magnitude, reflection-coefficient magnitude, and, by a fast and simple meter-readout method, voltage standing-wave ratio.

Rf standard impedances can be intercompared to unusually high precision with the GR900-equipped 1609. In addition, it can be used to evaluate the high-frequency performance of impedance standards calibrated at low frequencies. Thus the useful frequency range of high-quality standards with small or well controlled residuals can be extended into the microwave region.

— See **GR Experimenter** for November 1967.

specifications

Frequency Range: 40 to 1500 MHz, direct reading; down to 20 MHz with correction factor applied to imaginary term.

Measurement Range: 0 to 400 m℧ or 0 to 1000 Ω, direct reading; can be extended to 4000 m℧ or 10,000 Ω with multiplier plates (supplied). Instrument measures admittance 4.9 cm on bridge side of mating plane of GR900® connector; readings normalized with respect to 20 m℧ (50 Ω). The addition of air line of appropriate length makes instrument direct-reading in Y or Z at any desired reference plane.

Accuracy: Applies to each term of normalized admittance reading separately.

Frequency	Larger term <1	Larger term 1 to 20
20 - 500 MHz	$\pm(0.02\lvert Y_N\rvert + 0.01)$	$\pm(0.02\sqrt{M}\lvert Y_N\rvert + 0.01M)$
500 - 1000 MHz	$\pm(0.03\lvert Y_N\rvert + 0.01)$	$\pm(0.03\sqrt{M}\lvert Y_N\rvert + 0.01M)$
1000 - 1500 MHz	$\pm(0.05\lvert Y_N\rvert + 0.01)$	$\pm(0.05\sqrt{M}\lvert Y_N\rvert + 0.02M)$

$|Y_N| =$ magnitude of bridge reading (normalized units)
$= \sqrt{(\text{real term})^2 + (\text{imag term})^2}$

$M =$ setting of multiplier arm; values of >1 to 20 required if normalized real or imaginary term is >1.

Impedance accuracy same as above substituting $|Z_N|$ for $|Y_N|$. SWR accuracy ±2% from 20 to 1000 MHz, ±4% from 1000 to 1500 MHz, for measurements near unity (matching to 50-Ω system).

Accessories Supplied: 20-m℧ (50-Ω) conductance standard, adjustable stub and variable air capacitor for susceptance standards, two multiplier plates, 874-R22LA Patch Cord, mahogany storage case.

Accessories Required: Generator with 20-mW to 2-W output, detector with better than 10-μV sensitivity. Recommended, GR oscillators, GR Type 1241 Detector or 1236 I-F Amplifier, 874-MRAL Mixer, and appropriate oscillator; 900-WN Short-Circuit Termination, 900-WO Precision Open-Circuit Termination, 900-W50 50-Ohm Standard Termination.

Oscillators page 235 ff

Detectors page 133 ff

Accessories Available: 900-LZ Reference Air Lines as impedance standards, GR900 standard terminations and standard mismatches for calibration, GR900 adaptors to other connector types.

Dimensions (width x height x depth): 5 x 7¼ x 5½ in. (130 x 185 x 140 mm).

Weight: Net, 16 lb (7.5 kg); shipping, 20 lb (9.5 kg).

Catalog Number	Description	Price in USA
1609-9701	**1609 Precision UHF Bridge**	**$950.00**

GR900 ® ADAPTORS
50-ohm

The availability of precision adaptors from the GR900® connectors to other popular coaxial connectors means that the user of GR900-equipped instruments can convert to other series and still retain precision performance. For example, a 900-LB Precision Slotted Line equipped with a 900-QNJ or -QNP Adaptor becomes a type N slotted line with an over-all residual SWR (line plus adaptor) of only 1.02 at 3 GHz. Conversely, users of instruments equipped with SMA, TNC, N, C, and GR874® connectors can, by means of adaptors, take advantage of the precision offered by GR900 tuners, air-line standards, terminations, and other elements.

Each GR900 adaptor includes a 900-BT Precision Coaxial Connector and an optimally designed connector of the other series. When ordering, note that the suffix letter "J" or "P" denotes the type of other-series connector (jack or plug) **included** in the adaptor. To obtain an adaptor to mate with a BNC plug, therefore, one would order a 900-QBJ Adaptor.

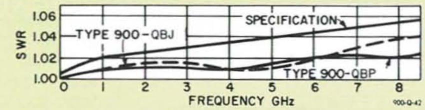
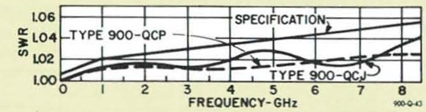
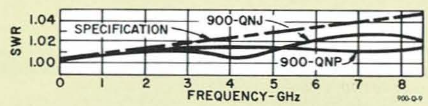
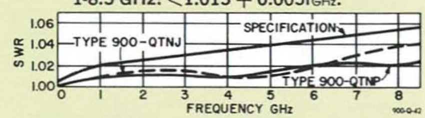
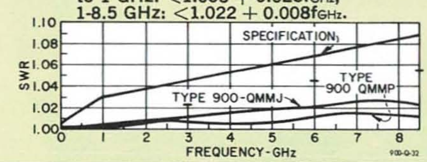
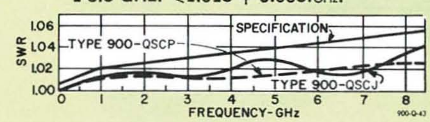
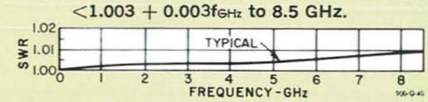
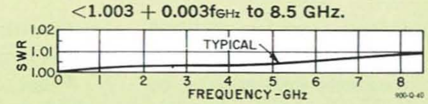
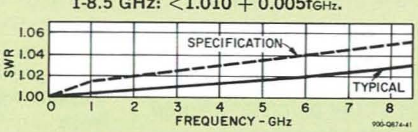
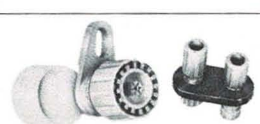
A set of the most commonly used GR900 precision adaptors is available, supplied in an attractive mahogany storage case. The set consists of one each of the plug and jack versions of the GR900 adaptors to types BNC, C, N, SC, SMA, and TNC, as well as the GR900 adaptors to Amphenol APC-7, Americon Precifix AA, R&S Precifix 7-mm, and GR874 connectors. The storage case with recessed foam inserts can be supplied separately for use with an individually selected assortment of adaptors. Shipping weight of set is 12 lb (5.5 kg), of case alone is 8 lb (3.7 kg).

Individual Adaptors, next page

Catalog Number	Description	Price in USA
0900-9451	**GR900 precision-adaptor set**	**$1475.00**
0900-9450	**GR900 storage case, only**	**44.00**

GR900® ADAPTORS

Net Weights: 4 oz (115 g) or less.
Lengths: 2⅝ in. (65 mm) or less.

Adaptor to Type	Type		Contains GR900® adaptor and	SWR for single adaptor (50-Ω characteristic impedance)	Max Voltage, Max Power[1] (to 1 MHz)	Catalog Number	Price in USA
BNC	900-QBJ		BNC Jack	to 1 GHz: $<1.005 + 0.015f_{GHz}$, 1-8.5 GHz: $<1.015 + 0.005f_{GHz}$. 	500 V, 3 kW.	0900-9701	$88.00
	900-QBP		BNC Plug			0900-9801	94.00
C	900-QCJ		C Jack	to 1 GHz: $<1.005 + 0.015f_{GHz}$, 1-8.5 GHz: $<1.015 + 0.005f_{GHz}$. 	1000 V, 7 kW.	0900-9703	94.00
	900-QCP		C Plug			0900-9803	94.00
N	900-QNJ		N Jack	$<1.004 + 0.004f_{GHz}$ to 8.5 GHz. 	1000 V, 7 kW.	0900-9711	83.00
	900-QNP		N Plug			0900-9811	77.00
TNC	900-QTNJ		TNC Jack	to 1 GHz: $<1.005 + 0.015f_{GHz}$, 1-8.5 GHz: $<1.015 + 0.005f_{GHz}$. 	500 V, 3 kW.	0900-9717	94.00
	900-QTNP		TNC Plug			0900-9817	94.00
SMA	900-QMMJ		SMA Jack	to 1 GHz: $<1.005 + 0.025f_{GHz}$, 1-8.5 GHz: $<1.022 + 0.008f_{GHz}$. 		0900-9723	94.00
	900-QMMP		SMA Plug			0900-9823	94.00
SC	900-QSCJ		SC Jack	to 1 GHz: $<1.005 + 0.015f_{GHz}$, 1-8.5 GHz: $<1.015 + 0.005f_{GHz}$. 	1000 V, 7 kW.	0900-9713	94.00
	900-QSCP		SC Plug			0900-9813	94.00
Amphenol APC-7 Americon Precifix AA	900-QAP7		7-mm Precision Connector	$<1.003 + 0.003f_{GHz}$ to 8.5 GHz.  Electrical length: 5.30 ± 0.02 cm.	1000 V, 6 kW.	0900-9791	125.00
Rohde and Schwarz Precifix & Dezifix A	900-QPF7		7-mm Precision Connector	$<1.003 + 0.003f_{GHz}$ to 8.5 GHz.  Electrical length: 5.30 ± 0.02 cm.	1000 V, 6 kW.	0900-9793	135.00
GR874	900-Q874		GR 874-BBL	to 1 GHz: $<1.000 + 0.015f_{GHz}$, 1-8.5 GHz: $<1.010 + 0.005f_{GHz}$. 	1500 V, 10 kW.	0900-9883	72.00
Binding Posts (¾- to 1-in. spacing)	900-Q9			Includes adaptor and hardware to adapt GR900® connector to ¼-in. x 28 tapped hole or threaded stud, such as exposed top of GR 938 Binding Post.		0900-9874	61.00

[1] At frequencies above 1 MHz, max power varies inversely with the square root of frequency.
Flange adaptor to flat surfaces on page 185.

GR900® TERMINATIONS

RESISTIVE TERMINATIONS

50-OHM STANDARD TERMINATION

Type 900-W50

A precision, low-SWR, 50-ohm standard for calibration of bridges, slotted lines, admittance bridges, and reflectometers. Can also be used as a precision dummy load or as a termination in measurements of networks with more than one port. This termination, together with the 900-WNC Short Circuit and 900-LZ Air Lines, can form a calibration set for computer correction of measuring instruments. With appropriate GR900 precision adaptor, can be used as a low-SWR, precision type N, BNC, C, etc., termination. A SWR calibration chart is supplied with each unit.

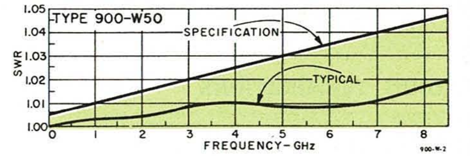
SWR: 1.005 + 0.005 f_{GHz} to 8.5 GHz.

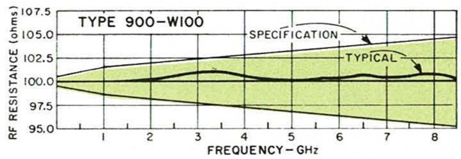
Dc Resistance: 50 Ω ±0.3%.

Max Power: 1 W with negligible change; 5 W without damage.

Temperature Coefficient: Less than 150 ppm/°C.

Over-all Length: 2 in. (51 mm). **Net Weight:** 3½ oz (100 g).





STANDARD TERMINATIONS

Type 900-W100 (100-OHM) **AND Type 900-W200** (200-OHM)

These known resistive terminations are especially useful in the calibration of bridges, reflectometers, etc. Position of pure resistance nominally 4 cm from the 900-BT reference plane. Short- and open-circuit terminations with a corresponding 4-cm offset are available (900-WN4 and -WO4; see below). A calibration chart is supplied with each unit.

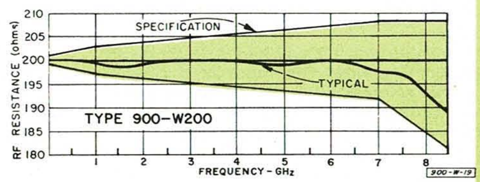
Magnitude of Mismatch: See curves.

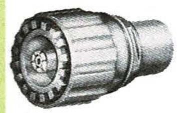
Dc Resistance: 900-W100, 100 Ω ±0.5%.
900-W200, 200 Ω ±0.5%.

Max Power: 1 W with negligible change; 5 W without damage.

Temperature Coefficient: Less than 150 ppm/°C.

Over-all Length: 2 in. (51 mm). **Net Weight:** 3½ oz (100 g).





	Catalog Number	Price in USA
900-W50 50-Ohm Standard Termination	0900-9953	**$72.00**
900-W100 100-Ohm Standard Termination	0900-9957	**88.00**
900-W200 200-Ohm Standard Termination	0900-9959	**88.00**

STANDARD MISMATCHES

Types 900-WR110, -WR120, -WR150

Introduce reflections of known SWR value (1.1, 1.2, and 1.5) into a 50-ohm transmission line. Useful in calibration of reflectometers and other SWR-measuring instruments. Mismatch calibration data (in SWR) are provided with each unit.

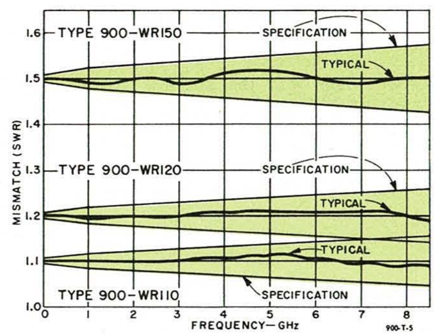
Magnitude of Mismatch: See curves.

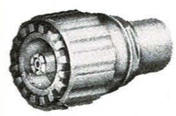
Dc Resistance: 900-WR110, 45.45 Ω ±0.5%.
900-WR120, 41.67 Ω ±0.5%.
900-WR150, 33.33 Ω ±0.5%.

Max Power: 1 W with negligible change; 5 W without damage.

Temperature Coefficient: Less than 150 ppm/°C.

Over-all Length: 2 in. (51 mm). **Net Weight:** 3½ oz (100 g).





	Catalog Number	Price in USA
900-WR110 Standard Mismatch	0900-9961	**72.00**
900-WR120 Standard Mismatch	0900-9963	**72.00**
900-WR150 Standard Mismatch	0900-9965	**72.00**

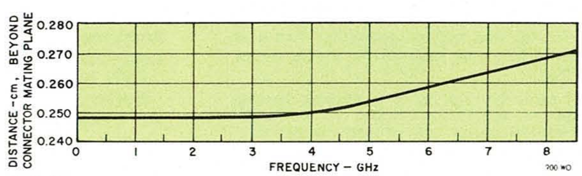
PRECISION OPEN-CIRCUIT TERMINATIONS

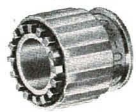
Type 900-WO

Establishes a well-shielded open circuit typically 0.26 cm from the mating plane of the GR900® connector, but this distance varies with frequency as shown in the graph.

Accuracy: Within ±0.012 cm of value shown on graph.

Low-Frequency Capacitance: 0.172 ± 0.008 pF.





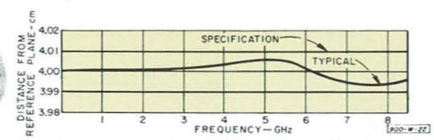
	Catalog Number	Price in USA
900-WO Precision Open-Circuit Termination	0900-9981	**17.00**

GR900® TERMINATIONS (cont'd)

PRECISION OPEN-CIRCUIT TERMINATIONS (cont'd)

Type 900-W04

This termination is similar to the 900-WO, except that the open is displaced 4 cm (±0.01 cm) to correspond to the 4-cm offset of the 900-W100 and -W200 Standard Terminations. It is also useful as a capacitance standard (2.670 pF ±0.25% below 70 MHz).



	Catalog Number	Price in USA
900-W04 Precision Open-Circuit Termination	0900-9985	**$88.00**

PRECISION SHORT-CIRCUIT TERMINATIONS

Type 900-WN

A precision-machined, silver-plated disk, mounted in a centering gear ring and locking-nut assembly, which short-circuits the face of a 900-BT connector. For establishing reference planes and for use in loss measurements. Reflection coefficient >0.999 to 8.5 GHz.

	Catalog Number	Price in USA
900-WN Precision Short-Circuit Termination	0900-9971	**17.00**

Type 900-WNC

Similar to 900-WN Termination, except that it includes a center contact to support the inner conductor of a 900-LZ Reference Air Line. The reference plane of the termination is exactly at the mating plane of the GR900 connector. Reflection coefficient is greater than 0.999 to 8.5 GHz.

	Catalog Number	Price in USA
900-WNC Precision Short-Circuit Termination	0900-9977	**28.00**

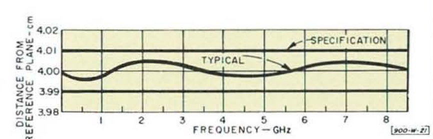
Type 900-WNE

Short circuit is displaced 0.26 ±0.005 cm to correspond to nominal position of open in 900-WO. Center contact will support center conductor of 900-LZ Reference Air Line. Reflection coefficient is >0.998 at 8.5 GHz.

	Catalog Number	Price in USA
900-WNE Precision Short-Circuit Termination	0900-9979	**28.00**

Type 900-WN4

Similar to the 900-WNC except that the short is 4.00 ±0.01 cm from the connector mating plane. Reflection coefficient is >0.996 at 8.5 GHz.



	Catalog Number	Price in USA
900-WN4 Precision Short-Circuit Termination	0900-9975	**77.00**

ADJUSTABLE SHORT-CIRCUIT

Type 900-D20

The 900-D20 is a coaxial sliding short circuit equipped with a GR900® connector. It can be used for tuning and matching or as a reactance standard.

With the GR 900-LB Precision Slotted Line, the 900-D20 permits the measurement of the source impedance of signal sources by a method described in the 900-LB operating-instruction manual and in Reprint A126, available on request. It is also useful for the measurement of two-port components and the calibration of measuring instruments by the Deschamps method.[1]

The adjustable short circuit consists of a sliding spring-finger contact of hardened beryllium copper in a length of air line with silver-plated inner and outer conductors. The operating handle is calibrated in centimeters and can be locked in position.

[1] Deschamps, G. A., "A Simple Graphical Analysis of a Two-Port Waveguide Junction" Proc IRE, No. 42, p. 859. May 1954.

Frequency Range: 0 to 8.5 GHz.
Reflection Coefficient (at 0.5, 4.5, and 8.5 GHz): Closed, >0.99; fully extended, >0.98, except >0.99 at 0.5 GHz.
Adjustment Range: 20 cm (physical and electrical).
Min Electrical Length: 2.5 cm at 0.5 GHz, 2.9 cm at 8.5 GHz.
Characteristic Impedance: 50 Ω ±0.1%.
Scale Accuracy: ±0.02 cm.
Dimensions: Length, 11 in. (280 mm) closed, 18¾ in. (480 mm) extended; diameter, 1¹⁄₁₆ in. (27 mm).
Weight: 15 oz (455 g).

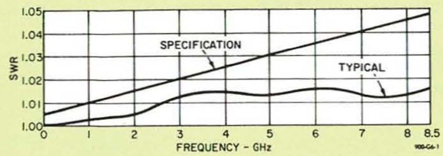
	Catalog Number	Price in USA
900-D20 Adjustable Short Circuit	0900-9430	**180.00**

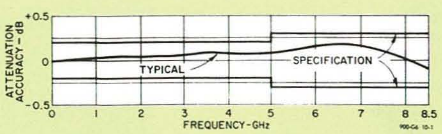
GR900® ATTENUATORS

FIXED ATTENUATORS — Type GR900

These 6-dB and 10-dB coaxial attenuators, available with GR900® precision connectors, have an SWR much lower than previously available and uniform attenuation over a wide frequency range. Their use will, therefore, permit greatly improved accuracy in measuring insertion loss, impedance, power, or phase, which requires precise impedance matching of the source and detector. In particular, these attenuators are ideal for swept measurement of the above quantities. Also, in point-by-point measurements, they reduce the need to tune out residual reflections from source or detector.

In particular, they display a high degree of repeatability in SWR, contact resistance, and insertion loss, which contributes to the value of these attenuators in substitution measurements. For example, repeatability of insertion loss is typically ±0.002 dB. The high repeatability and low SWR also permit attenuators to be accurately calibrated for use as attenuation standards.





SWR and attenuation accuracy curves for GR900's.

Frequency Range: dc to 8.5 GHz.
Attenuation Accuracy: ±0.2 dB, 0 to 5 GHz; ±0.3 dB, 5 to 8.5 GHz; ±0.04 dB at dc.
SWR: $<1.005 + 0.005\, f_{GHz}$.
Characteristic Impedance: 50.0 Ω.
DC Resistance: 50.0 Ω ± 0.03% when terminated in 50.0 Ω.
Max Power: 1.0 W continuous; peak, 500 W with 1-W avg.
Temperature Coefficient: <0.0001 dB/°C/dB.
Dimensions: 3¾ in. length (95 mm).
Net Weight: 11 oz (310 g).

	Catalog Number	Price in USA
Precision Fixed Attenuators		
900-G6 (6 dB)	0900-9850	**$205.00**
900-G10 (10 dB)	0900-9851	**205.00**

CONNECTORS

PRECISION COAXIAL CONNECTOR — Type 890-BT

The Type 890-BT is a low-cost version of the GR900® precision coaxial connector. It is intended for use when the lowest SWR is not important. Below 500 MHz, the difference in SWR, compared with the GR900, is insignificant; above 500 MHz, the SWR is worse. For example, at 8 GHz the SWR is 1.019, compared with 1.009 for the GR900. The GR 890 is generally used at lower frequencies on capacitance, inductance, or resistance standards, and at higher (microwave) frequencies where the SWR of the device is much greater than that of the connector. The other useful properties of the GR900 series, such as repeatability, well-defined reference plane, and low contact resistance, are retained.

The grooves in the Type 890-BT locking nut distinguish it from the Type 900-BT Connector but it mates with the GR900 series without restriction.

Impedance: 50 Ω ± 0.3% at frequencies where skin depth is insignificant.
Frequency: Dc to 8.5 GHz.
SWR: $<1.003 + 0.002\, f_{GHz}$ per connector; repeatabiity $\leq \pm 0.0005$ or ±0.05%.
Insertion Loss: $<0.004\sqrt{f_{GHz}}$ dB per pair; repeatability, ±0.001 dB to 30 MHz, ±0.002 dB to 1 GHz, ±0.0025 dB to 8.5 GHz.

Leakage: Better than 130 dB below signal.
Phase Repeatability: ≤0.008° at 1 GHz, 0.015° at 2 GHz, 0.05° at 6 GHz.
General: *Voltage,* 3000 V peak. *Power,* 20 kW to 1 MHz; 20 $kW\sqrt{f_{GHz}}$ above 1 MHz. *Electrical length,* 3.500, +0.005, −0.10 cm per pair; 1.750, +0.0025, −0.005 cm per single. *DC contact resistance,* <0.5 mΩ for inner conductor, <0.07 mΩ for outer conductor. *Air-line size,* Principal dimensions of coaxial air line on which connector mounts are: inner conductor, 0.24425 in. OD; outer conductor, 0.5625 in. ID.
Mechanical: *Dimensions:* Length, 1³⁄₁₆ in. (31 mm); maximum diameter, 1¹⁄₁₆ in. (27 mm). *Weight,* 2 oz (60 g).

	Catalog Number	Price in USA
890-BT Precision Coaxial Connector	0890-9405	**25.00**

GR900® CONNECTORS

The GR900® precision coaxial connector is available in 6 models: the 900-BT for use with the 14-mm rigid air line, the 900-C9 and 900-C58 for use with coaxial cable, and three connector kits to permit custom fabrication of GR900 air lines, terminations, and panel connectors. All GR900 connectors have the same basic mechanical features and mate with one another.

Type 900-BT PRECISION COAXIAL CONNECTOR

This is the basic GR900 connector, for use on rigid air-dielectric 50-ohm coaxial lines (principal dimensions: 0.5625 inch and 0.24425 inch). The 900-TOK Tool Kit is recommended for proper assembly.

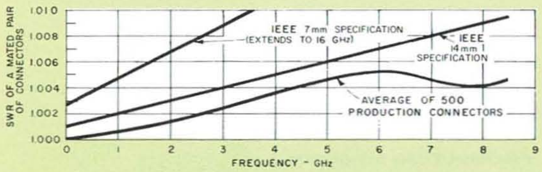
The 900-BT Connectors are available as single connectors or as a pair of connectors with calibration certificate. The same SWR specification ($<1.001 + 0.001\ f_{GHz}$) applies to either. These limits are those approved in the IEEE Recommended Practice for Precision Coaxial Connectors in the 14-mm general precision connector class.

900-BT Connectors are 100% tested at six frequencies.

Frequency Range: Dc to 8.5 GHz.

Characteristic Impedance: 50 Ω ±0.1% at frequencies where skin depth is negligible.

SWR: $1.001 + 0.001\ f_{GHz}$; applies to single connectors and 0900-9407 pairs.



Typical and specified SWR of single and certified pairs of 900-BT Precision Coaxial Connectors. Specified SWR is identical to that given as IEEE Recommended Practice.

Repeatability of SWR: Within 0.05%.

Repeatability of Phase: Within 0.008° at 1 GHz, 0.015° at 2 GHz, 0.05° at 6 GHz.

Leakage: Better than 130 dB below signal.

Insertion Loss: Less than $0.003\sqrt{f_{GHz}}$ dB per pair.

Insertion-Loss Repeatability: ±0.001 dB to 30 MHz, ±0.002 dB to 1 GHz, ±0.0025 dB to 8.5 GHz.

Max Voltage: 3000 V peak.

Max Power: 20 kW up to 1 MHz; 20 kW/$\sqrt{f_{MHz}}$ above 1 MHz.

Electrical Length: 3.500 ±0.005 cm per pair; 1.750 ±0.0025 cm for single connector.

Dc Contact Resistance: Inner conductor, less than 0.5 mΩ; outer conductor, less than 0.07 mΩ.

Dimensions: Length of one connector, 1³⁄₁₆ in. (31 mm); max diameter, 1¹⁄₁₆ in. (27 mm).

Net Weight: 2 oz (60 g).

	Catalog Number	Price in USA
900-BT Precision Coaxial Connector	0900-9405	$40.00
900-BT Precision Coaxial Connectors, (pair) with Calibration Certificate	0900-9407	90.00

GR900® Laboratory Precision Connector Kits

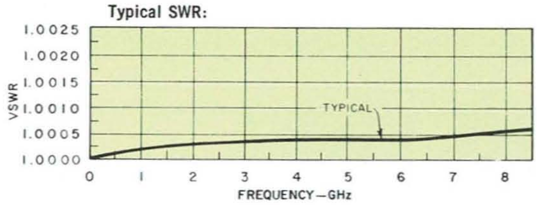
Three kits are available for custom fabrication of air lines and terminations compatible with the GR900® connector. Rigid air-lines can be made from GR900 Precision Rod (0900-9507) and Tube (0900-9509) to serve as precision capacitance or time-delay standards, as well defined reactance standards, and as dielectric sample holders for dielectric-constant and loss measurements with the slotted line.

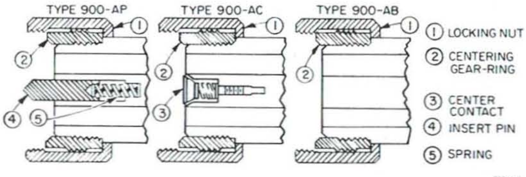
Type 900-AP is for use on elements having unsupported inner conductors. A reference air line can be assembled from a pair of these kits and appropriate lengths of precision rod and tube. The kit consists of coupling nut, centering gear ring, and a spring-loaded centering pin, which allows the inner conductor of a beadless air line to derive its support from the mating 900-BT Connector. Air lines can be machined from the GR precision rod and tube described elsewhere.

Type 900-AC contains the locking nut, centering gear ring, and center contact of a standard GR900® connector. It can be used in place of the 900-BT on any component whose inner conductor is supported within the component itself. Since it includes only those parts necessary in such applications, this kit offers the user superior electrical performance at a considerable saving in cost.

Type 900-AB is like the 900-AC Kit in appearance and function, except that it does not contain the center contact. Thus it can be used to fabricate an air line to be mated with a 900-BT Connector, but it cannot mate with a 900-LZ Reference Air Line or with another 900-AB or 900-AP Connector.

Typical SWR:





	Catalog Number	Price in USA
900-AP Laboratory Precision Connector Kit **Repeatability:** Within ($0.010 + 0.003\ f_{GHz}$)%.	0900-9406	$ 8.00
900-AC Laboratory Precision Connector Kit **Repeatability:** Within 0.05% (0.0005 in VSWR).	0900-9404	10.00
900-AB Laboratory Precision Connector Kit **Repeatability:** Within ($0.010 + 0.003\ f_{GHz}$)%.	0900-9402	6.75

GR900® CONNECTORS

(cont'd)

Catalog Number | Price in USA

Precision Coaxial Cable Connectors —

900-C9, 900-C58

Cable-connector counterparts of the 900-BT. The SWR of these connectors is much lower than that of even the best-made cables.

The braid-retention system does not compress the cable, yet has good pull and torque resistance. The usual distortion and flow of cable dielectric during inner-conductor soldering have been virtually eliminated by means of a Teflon spacer and a special, low-temperature solder supplied with every connector. All inner-conductor parts are captive.

The **900-C9**, although designed for RG-9B/U and RG-214/U, can be used with the following cables with some sacrifice in performance or mechanical reliability: RG-8/U, -8A/U, -10A/U, -87A/U, -116/U, -156/U, -165/U, -166/U, -213/U, -215/U, -225/U, and -222/U.

The **900-C58** connector, primarily for use with GR 874-A3 and RG-58/U series cables, will also find limited application with RG-29/U, -55/U series, -141A/U, -142A/U, -159/U, and -223/U.

The 900-TOK Tool Kit is recommended for assembling these connectors.

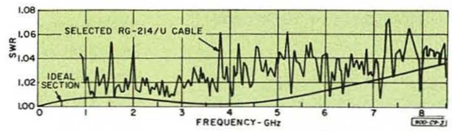
Frequency Range: Dc to 8.5 GHz.

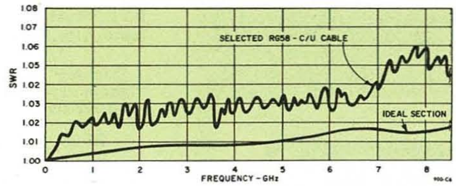
Characteristic Impedance: 50 Ω.

Insertion Loss (approx): $<0.006\sqrt{f_{GHz}}$ dB per pair for 900-C9; $<0.010\sqrt{f_{GHz}}$ dB per pair for 900-C58.

Max Voltage: 1500 V pk (-C9), 500 V pk (-C58).

Typical SWR performance of a single Type 900-C9 Connector on an "infinite" length of RG-214/U cable and on an "ideal" section with the same diameters.





Similar data for 900-C58 Connector.

	Catalog Number	Price in USA
900-C9 Precision Coaxial Cable Connector	0900-9421	**$61.00**
900-C58 Precision Coaxial Cable Connector	0900-9431	**72.00**

GR900® AIR LINES

PRECISION ADJUSTABLE LINE — Type 900-LK10

The 900-LK10 is a line stretcher with very low SWR and uniform characteristic impedance and insertion loss. It is especially useful in eliminating corrections for line length between an unknown and an impedance-measuring device. It can also serve as an impedance-matching transformer and phase-adjustment element in coaxial systems. GR900® precision connectors ensure repeatable connections with low loss and reflections.

Frequency Range: DC to 7 GHz.

Characteristic Impedance: 50.0 Ω ± 0.2% at frequencies where skin-depth is negligible.

SWR: $<1.005 + 0.005\ f_{GHz}$.

Electrical Length: 40 ± 0.1 cm, closed; >50 cm, extended; >10 cm travel.

Calibration: Scale direct reading in centimeters. Accuracy, ±0.2 mm.

Insertion Loss: $<0.05\sqrt{f_{GHz}}$ dB, closed; $<0.06\sqrt{f_{GHz}}$ dB, extended; $<0.001\sqrt{f_{GHz}}$ dB per cm of extension.

Voltage: 2500 V max.

Power: 15 kW max up to 1 MHz; $\frac{15\text{ kW}}{\sqrt{f_{MHz}}}$ max above 1 MHz.

Dimensions (dia x length): 1$\frac{1}{16}$ x 15½ in. (27 x 395 mm); 19¾ in. extended (500 mm).

Net Weight: 24 oz (680 g).

	Catalog Number	Price in USA
900-LK10	0900-9570	**270.00**

PRECISION AIR LINES — 900-L

Short sections of precision 50-ohm air line with a 900-BT Connector on each end. Useful as low-SWR line extenders, as aids in checking the SWR of precision connectors, and as 50-ohm impedance standards at frequencies at which the electrical length is an odd multiple of a quarter wavelength. Also useful as absolute impedance standards in time-domain-reflectometer systems and as capacitance and time-delay standards.

SWR: $<1.0013 + 0.0013\ f_{GHz}$ up to 8.5 GHz.

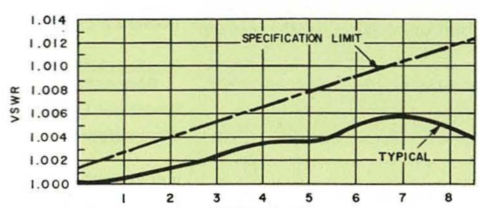
Characteristic Impedance (in air-line section): 50 Ω ± 0.065%. Additional skin-effect error is calculable.[1]

Accuracy of Electrical Length: Within ±0.02 cm.

Max Voltage: 3000 V pk.

Max Power: 20 kW up to 1 MHz, 20 kW/$\sqrt{f_{MHz}}$ above 1 MHz.

Dc Contact Resistance (each end): Inner conductor, <0.5 mΩ; outer conductor, <0.07 mΩ.



Electrical Length	C (pF)	Time Delay-ps (±1 ps)	Insertion Loss (dB)	Type	Catalog Number	Price in USA
3 cm	2.0000	100	$<0.005\sqrt{f_{GHz}}$	**900-L3**	0900-9608	**110.00**
10 cm	6.6667	333	$<0.012\sqrt{f_{GHz}}$	**900-L10**	0900-9605	**130.00**
15 cm	10.000	500	$<0.016\sqrt{f_{GHz}}$	**900-L15**	0900-9607	**135.00**
30 cm	20.000	1000	$<0.028\sqrt{f_{GHz}}$	**900-L30**	0900-9613	**150.00**

GR900® AIR LINES (continued)

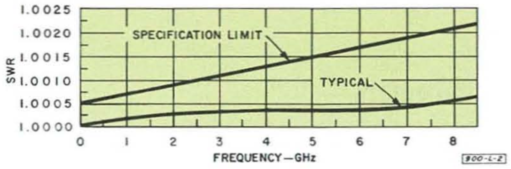
REFERENCE AIR LINES — 900-LZ

Beadless, virtually reflectionless coaxial air lines, with spring-loaded supporting tips on the ends of the inner conductor to mate with GR900 connectors; microfinished outer-conductor ends butt-contact the mating connectors. SWR is held to 1.0005 + 0.0002 f_{GHz}. Such near-perfect specifications make these air lines most useful in calibration applications, and especially in substitution measurements. The lines can also be used as precision capacitance or time-delay standards, as well defined reactance standards, and as dielectric sample holders for dielectric-constant and loss measurements with the slotted line. Also useful as absolute impedance references in time-domain reflectometry.

Frequency Range: Dc to 8.5 GHz.

Characteristic Impedance: 50 Ω ± 0.05% at 23°C and where skin depth is negligible. Additional skin-effect error is calculable.[1]

[1] J. Zorzy, "Skin-Effect Corrections in Standards," IEEE Transactions on Instrumentation and Measurement, Vol IM-15 No. 4, December 1966, p 358 (GR Reprint A-134).



SWR: <1.0005 + 0.0002 f_{GHz}; calibration data supplied.

SWR Repeatability: Within (0.010 + 0.003 f_{GHz})%.

Leakage: Better than 130 dB below signal.

Insertion Loss: Less than $0.0008\sqrt{f_{GHz}}$ dB/cm.

Max Voltage: 3000 V peak.

Max Power: 20 kW up to 1 MHz, 20 kW/$\sqrt{f_{MHz}}$ above 1 MHz.

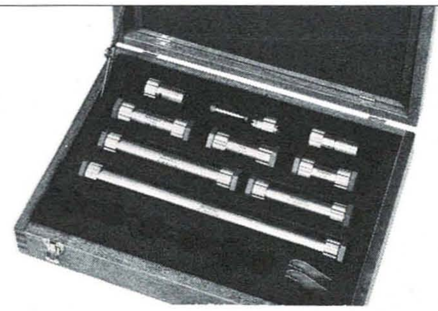
Dc Contact Resistance (each end, mated with GR900): Inner conductor, <0.5 mΩ; outer conductor, <0.07 mΩ.

Electrical Length - cm (±0.002 cm)	Capacitance - pF (±0.07%)	Time Delay - ps (±0.1 ps)	Odd λ/4 Frequencies * - GHz	Type	Catalog Number	Price in USA
2.998	2.0000	100.0	(2n+1)2.50	**900-LZ3**	0900-9603	$ 95.00
4.997	3.3333	166.7	(2n+1)1.50	**900-LZ5**	0900-9600	99.00
5.996	4.0000	200.0	(2n+1)1.25	**900-LZ6**	0900-9601	105.00
7.495	5.0000	250.0	(2n+1)1.00	**900-LZ7H**	0900-9602	105.00
9.993	6.6667	333.3	(2n+1)0.75	**900-LZ10**	0900-9604	110.00
14.990	10.000	500.0	(2n+1)0.50	**900-LZ15**	0900-9606	125.00
29.979	20.000	1000.0	(2n+1)0.25	**900-LZ30**	0900-9612	155.00

* Frequencies at which air-line section is an odd multiple of a quarter wavelength, where n is zero or any integer.

REFERENCE-AIR-LINE SET

A set consisting of one each of the seven lengths of 900-LZ Reference Air Lines supplied in an attractive mahogany storage case. Also included are two terminations ordinarily used with the Reference Air Lines, a 900-WN4 short circuit and a 900-WO4 open circuit. The storage case with recessed foam inserts can be supplied separately for use with an individually selected assortment of air lines and/or terminations. Shipping weight of set is 12½ lb (6 kg), of case alone is 8 lb (3.7 kg).



	Catalog Number	Price in USA
GR900 reference-air-line set	0900-9452	915.00
GR900 storage case, only	0900-9450	44.00

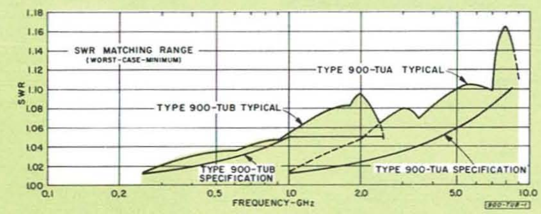
GR900® TUNERS

Types 900-TUA and 900-TUB TUNERS

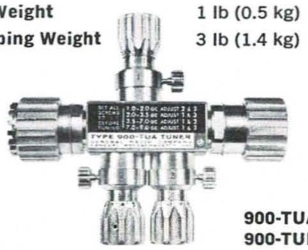
The 900-TUA and -TUB Tuners are compact, broadband tuners useful in matching out small residual reflections in low-SWR measuring instruments and devices.

Each tuner has three smoothly adjustable tuning screws, used in pairs to tune out reflections of any phase throughout the tuner's frequency range. Each screw has a "neutral" setting, independent of frequency, at which it is effectively out of circuit. Screws can be locked at any setting, permitting excellent SWR resettability, protection against accidental disturbance, and friction driving (with screws partially locked) if desired.

— See **GR Experimenter** for August 1964, January 1965, and August 1966.



	900-TUA	900-TUB
Frequency Range	1 to 8.5 GHz	0.25 to 2.5 GHz
Characteristic Impedance	50 Ω	50 Ω
SWR Matching Range (worst-case minimum)	1.00 + 0.012 f_{GHz}	1.00 + 0.05 f_{GHz} to 1 GHz; 1.05 from 1 to 2.5 GHz
SWR Resettability	<1.0005 + 0.0003 f_{GHz}	<1.0005 + 0.0003 f_{GHz}
Insertion Loss	<0.1 dB to 4 GHz; <0.3 dB to 8.5 GHz	<0.1 dB
Repeatability of Connection	0.05%	0.05%
Electrical Length	12.0 cm	18.5 cm
Dimensions	4½ × 3½ × 1 in. (115 × 88 × 25 mm)	6½ × 4¾ × 1 in. (165 × 120 × 25 mm)
Net Weight	1 lb (0.5 kg)	1¼ lb (0.6 kg)
Shipping Weight	3 lb (1.4 kg)	4 lb (1.9 kg)



	Catalog Number	Price in USA
900-TUA Tuner (1.0 to 8.5 GHz)	0900-9635	295.00
900-TUB Tuner (0.25 to 2.5 GHz)	0900-9637	345.00

GR900® PRECISION COAXIAL ELEMENTS — 14 mm

	Catalog Number	Price in USA

PRECISION 90° ELL — 900-EL

A coaxial right-angle bend with small reflections, the 900-EL permits coaxial devices, such as vertical liquid-dielectric sample holders, to be physically oriented as required without the use of flexible cable with poor electrical performance.

Frequency Range: Dc to 8.5 GHz.

Characteristic Impedance: 50 Ω ±0.4% at frequencies where skin depth is small.

SWR: $<1.004 + 0.004\ f_{GHz}$.

Electrical Length: $(10.00 + 0.0014\ f^2_{GHz} \pm 0.02)$ cm.

Insertion Loss: $<0.017\sqrt{f_{GHz}}$ dB.

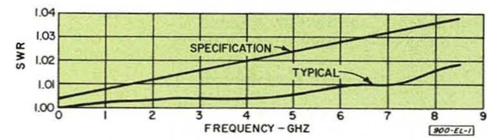
Max Voltage: 1500 V peak.

Max Power: 10 kW to 1 MHz; 10 kW/$\sqrt{f_{MHz}}$ over 1 MHz.

Mating Dimensions: 2.066 in. (5.246 cm) from center line of one connector to reference plane of second connector.

Over-all Dimensions: 2¹¹⁄₁₆ x 2¹¹⁄₁₆ x ⅞ in. (68 x 68 x 22 mm).

Net Weight: 10 oz (280 g).



Gear rings rotatable for proper mating in any orientation.

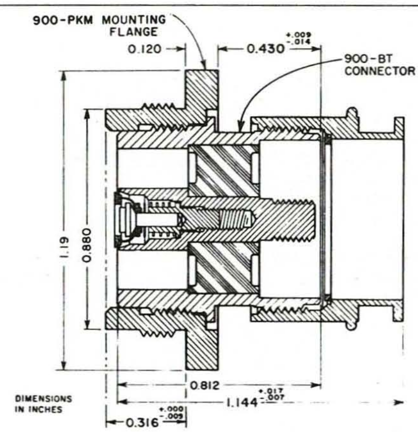
	Catalog Number	Price in USA
900-EL Precision 90° Ell	0900-9527	$220.00

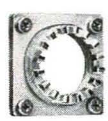
ADAPTOR FLANGE

Threads onto a 900-BT Connector in place of the centering gear ring and locking nut to connect GR900® components to bridges and other instruments that terminate in a flat-plane surface or to other flange-type connectors.

	Catalog Number	Price in USA
Adaptor Flange	0900-9782	14.00

PANEL MOUNTING KIT 900-PKM is used to equip standard 900-BT and 900-C9 Connectors for panel mounting. The kit includes a threaded flange, which accepts the outer conductor and mounting hardware. The 900-PKMR has a rotatable gear ring that permits proper mating to another GR900® connector in any orientation.





	Catalog Number	Price in USA
900-PKM Panel Mounting Kit	0900-9498	14.00
900-PKMR Panel Mounting Kit, Rotatable	0900-9500	28.00

PRECISION ROD AND TUBE

Used in fabrication of custom-length air lines and components, in conjunction with GR900® connectors and connector kits. Diameters are specified at 23°C. Both rod and tube have been stress-relieved to minimize dimensional changes during machining.

PRECISION INNER-CONDUCTOR ROD (supplied in pairs). Centerless-ground, silver-layered brass rod stock with a nominal 0.24425-in. diameter.

Length: 13 ± 1⁄32 in. (330 mm). **Straightness:** 0.0015 in./ft.

Diameter Accuracy: ±65 microinches. **Uniformity:** ±25 microinches.

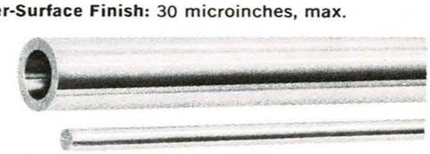
Surface Finish: 20 microinches, max.

PRECISION OUTER-CONDUCTOR TUBE. Precision-forged, silver-lined brass tubing with a nominal OD of 0.830 in. and a nominal ID of 0.5625 (9⁄16) in. Nominal wall thickness is 0.134 in.

Length: 27 in. (690 mm). **Straightness of ID:** 0.005 in./ft.

Inner-Diameter Accuracy: ±140 microinches.

Inner-Surface Finish: 30 microinches, max.



	Catalog Number	Price in USA
Precision Inner-Conductor Rod	0900-9507	22.00
Precision Outer-Conductor Tube	0900-9509	43.00

ROTATABLE CENTERING RING

A direct replacement for the centering gear ring on the GR 900-BT Precision Coaxial Connector, the rotatable centering gear ring will thread onto the connector wherever it is used, to permit proper mating with other GR900® connectors in any orientation.

	Catalog Number	Price in USA
Centering Ring, Rotatable	0900-9499	26.00

GR900® PRECISION COAXIAL ELEMENTS – 14 mm (continued)

COMPONENT MOUNT — 900-M

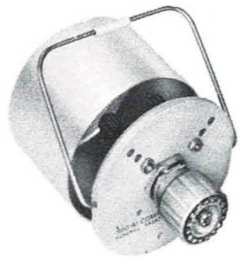
A shielded enclosure for mounting small components, the 900-M permits more accurate measurement of resistors, capacitors, etc, by minimizing connection capacitance and inductance. Contains GR900® connector and low-SWR coaxial-line section.

Electrical Length: 4.0 cm ±0.04 cm to ideal short-circuit at terminals.

Residual Impedance (at low frequencies): 2.93 pF, typical, with screw.

Accessories Required: 900-WN4 Precision Short Circuit, 900-WO4 Precision Open Circuit for establishing reference plane.

Weight: Net, 8 oz (230 g); shipping, 11 oz (315 g).



	Catalog Number	Price in USA
900-M Component Mount	0900-9540	**$88.00**

CLEANING KIT — 900-TOC

Use for cleaning GR900® connectors. Solvent supplied in 16-oz aerosol can will not affect Teflon* insulator nor any metal surfaces in these connectors. Also includes two brushes and 24 wiping pads.

*Trademark of E. I. du Pont de Nemours Co., Inc.

	Catalog Number	Price in USA
900-TOC Cleaning Kit	0900-9610	**8.25**

TOOL KIT — 900-TOK

Nine-piece tool kit in fitted case for convenient installation of Types 890-BT, 900-BT, 900-C58, and 900-C9 Precision Coaxial Connectors on suitable air line or component. Complete instructions for use of tools are supplied with each connector to simplify assembly and to ensure precision results.

Shipping Weight: 7 lb (3.2 kg).

	Catalog Number	Price in USA
900-TOK Tool Kit	0900-9902	**130.00**

STORAGE CASE

An attractive mahogany case with firm, foamed-plastic inserts having molded recesses designed to hold various types of GR900® precision coaxial components. The ideal way to keep together a set of adaptors, air lines, terminations or the like and to carry and to store them with minimum exposure to dirt or damage to precision machined surfaces.

Shipping Weight: 8 lb (3.7 kg).

	Catalog Number	Price in USA
GR900 storage case	0900-9450	**44.00**

FREQUENCY

FREQUENCY STANDARDS
COUNTERS

ENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO

FREQUENCY STANDARDS

Time is one of the three fundamental physical dimensions. Since frequency is specified in terms of events per unit time (cycles per second, or hertz), the production of an accurate frequency is directly related to the establishment of an exact time interval.[1] Although formerly determined by astronomical observations, exact time intervals are now derived from the atomic frequency standard. International agreement has defined the second as 9,192,631,770 cycles of the resonance-frequency transition of the cesium atom under zero-field conditions. This uniform time scale is called Atomic Time (A-1). The ephemeris second is the fraction 1/31,556,925.975 of the tropical year 1900. Measurements using the atomic scale indicate agreement with this constant astronomical time scale, Ephemeris Time, which is based on the orbital period of the earth about the sun (the time between vernal equinoxes). For everyday living, Mean Solar Time, also known as Universal Time (UT) or Greenwich Mean Time, which is based on the mean rotational period of the earth, must be used. For example, for navigation and the tracking of artificial satellites with the earth used as a platform, a precise knowledge of the earth's rotational period is required. Mean Solar Time is now defined in terms of atomic time, the predicted average rate being for this century 150×10^{-10} lower than A-1 time with some variations occurring that may modify this estimate.

Standard frequencies and time intervals for measurement purposes are usually derived from a secondary frequency standard, such as a quartz-crystal oscillator, which is periodically calibrated in terms of a primary standard by means of standard-frequency or standard-time radio transmissions. Depending upon the accuracy required, local frequency can be established by either frequency or time measurement. In order to eliminate confusion with respect to the time scale in use (atomic or UT, for example), it is important to obtain information directly from the government agency concerned about the transmitting stations, frequencies and time scales in use.

Atomic clocks establish a perfectly uniform time. By international agreement, the time intervals broadcast are related to this uniform atomic time with step corrections not exceeding 100 milliseconds to agree with astronomical observations of the earth's rotation. Astronomical time observations are carried out by national observatories throughout the world. Their measurements are made available to users by radio time-signal transmissions and by telegraph in their respective countries. Many nations have adopted a "coordinated Universal Time" scale (designated UTC), which is supervised by the Bureau International de l'Heure, Observatoire de Paris, Paris, France. Adoption of this scale has facilitated measurements of time and frequency on an international basis. The UTC offset from atomic time has been designated as -300×10^{-10} for 1968.

The user of a frequency standard equipped with means for measurement of the time of arrival of a radio time signal can then calibrate the standard directly in terms of time. For a precise calibration, the errors of the transmitted time signal must be taken into account. Correction data for time-signal transmissions should be obtained from the agency responsible for their emission.

In the United States, standard frequency and time broadcasts are made by the standard-frequency transmitters operated by the National Bureau of Standards, Radio Standards Laboratory, Boulder, Colorado, and by the U. S. Naval Radio Service monitored by the U. S. Naval Observatory, Washington, D. C. In Canada, standard time signals are broadcast by station CHU, a service of the Dominion Observatory at Ottawa.

Calibration accuracy using a standard-time transmission depends upon the characteristics of the transmitted signal and of the propagation path. The variations in the time of reception of high-frequency sky-wave time signals are seldom less than 100 microseconds, due to propagation-path variations. A low-frequency signal, known to be propagated via a ground-wave, should have variations of less than 2 microseconds over a 1500-mile path.[2]

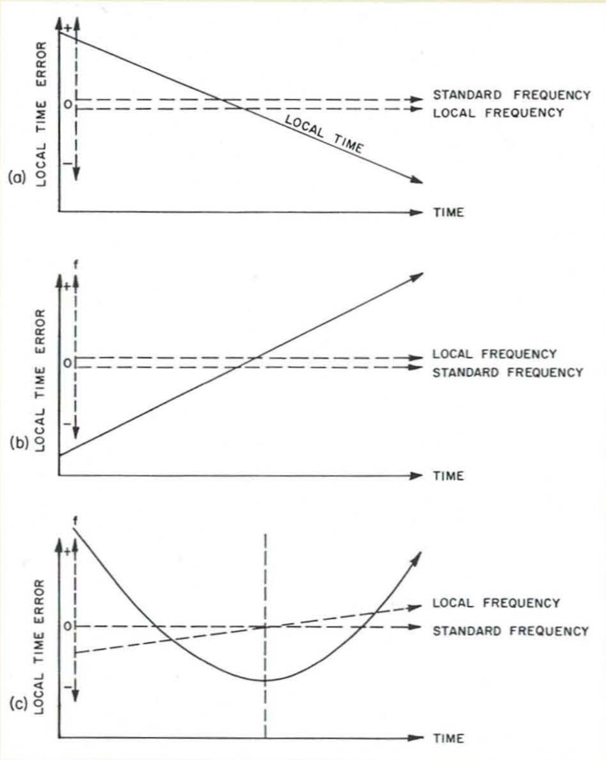


Figure 1.

CALIBRATION METHODS

The basic methods of intercomparing the frequencies of two sources are the same whether the primary standard is local or remote. The techniques employed will differ because of the propagation characteristics of radio transmissions and noise on the radio signal, which do not exist with local calibration. The principal techniques are: zero-beat — direct phase comparison; direct time comparison; frequency difference measurement — usually digital.

A. ZERO-BEAT TECHNIQUES

The basic method for frequency intercomparison is a direct comparison of the phase difference of two signals nearly equal in frequency. If not nearly equal, they must be nearly harmonically related. A change in relative phase between two signals may be determined by measurement of their beat frequency, by observation of a Lissajous figure on an oscilloscope, by measurement with a voltmeter of their common amplitude, by use of a phase-difference detector circuit, or by phase-recording systems.

The precision of the zero-beat method is limited by the ability to detect the zero-beat condition. Suppose, for example, one has a "zero-beat" detector capable of 1-hertz resolution and it is desired to set two standard frequencies equal to one another as closely as possible. If the two frequencies are 1 MHz, then the error will be 1 ppm. Greater resolution can only be attained by multiplication of the two frequencies or by increased resolution of the zero-beat detector. As a practical example of the zero-beat technique, consider the comparison of the 5-MHz carrier of WWV against a local 5-MHz signal. By use of either the receiver S meter or the beat-frequency oscillator, about 1-hertz resolution is available, and the local standard can be set to about 1 part in 10^7.

VLF phase-tracking receivers take advantage of the more stable propagation characteristics of VLF transmissions.[3] Because the frequency is low, a very high degree of phase resolution is required. VLF trackers are capable of resolving approximately ± 1 microsecond of phase delay; this provides a calibration precision of about $\pm 1 \times 10^{-10}$ in three hours, under undisturbed conditions. If a very narrow bandwidth is used, a phase tracker can extract the desired data under very adverse signal-to-noise ratio conditions.

B. DIRECT TIME INTERCOMPARISON.

Frequency may be established to a high degree of precision by direct comparison of time intervals derived from the frequency

[1] F. D. Lewis, "Frequency and Time Standards," Proceedings of the IRE, September 1955, pp 1046-1069.

[2] Doherty, R. N. et al, "Timing Potentials of Loran-C," Proceedings of the IRE, November 1961, p 1659.

[3] Pierce, J. A. "The Diurnal Carrier Phase Variation of a 16-kilocycle Transatlantic Signal," Proceedings of the IRE, May 1955, p 584.

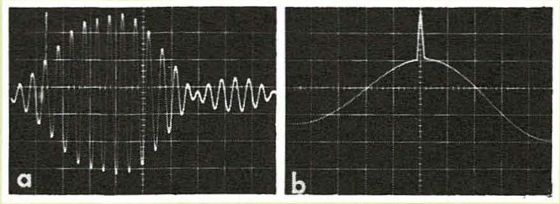


Figure 2. Time comparison of marker pulse and Loran-C 100-kHz pulses.
a. Sweep rate 20 μs/cm. (Note marker pulse on third cycle.)
b. Sweep rate 1 μs/cm, pulse centered.

to be calibrated and from the standard. The time interval compared is usually one second, derived from the standard to be calibrated by a precision electronic clock such as the GR Type 1123 Digital Syncronometer® time comparator. An example of this method is the comparison of locally produced one-second pulses with the one-second timing pulses transmitted by Radio Station WWV. There are two distinct advantages of this method of comparison over others: (1) Individual measurements do not have to have great accuracy since the accuracy is increased by taking longer and longer time intervals between measurements. (2) The measurement results in an accurately set local clock. Local time is known to the extent that the propagation time of the radio signal is known.

The basic principle of the measurement lies in the integrating character of the clock. If the frequency driving the clock is low, the time between successive zero crossings of the driving frequency is a little longer than standard, and at each cycle the clock will lose a fixed increment of time. Obviously, the longer the measurement interval, the larger the time error (Figure 1a). The case of a clock driven by too high a frequency is shown in Figure 1b; the clock steadily gains time with respect to standard time.

The assumption of an absolutely constant frequency with a fixed error with respect to the primary standard leading to a linear change in local time is not the situation usually encountered in practice. The local standard will generally have some drift, which will cause the time error to depart from linear as shown in Figure 1. If the drift in frequency is constant with time, for example $f = (f_o + kt)$, and the initial frequency setting, f_o, is low, it is obvious that at some future instant of time f will become equal to the standard frequency, and the time intervals will be precisely correct. The curves of time error are now parabolic. Figure 1c shows the shape of time error when the local frequency has a positive drift.

As an example of the use of this method of frequency calibration, assume that in your locality WWV can be received with a reproducibility of one millisecond. (This figure must be established by experiment.) Then, in a one day interval, a change in the local frequency of $10^{-3}/86{,}400$ or approximately $1{:}10^8$ can be established.

This method of calibration is limited in accuracy only by one's ability to establish time simultaneity in the measurement. If the local time is, for example, marked by a brief pulse like that produced by a Type 1123 Digital Syncronometer and a cycle of a burst from a Loran C transmitter can be observed, then time can be compared to a fraction of a microsecond,[4] and the local frequency can be established to within a few parts in 10^{10} in a time interval of only a few minutes (Figure 2).

[4] D. O. Fisher and R. W. Frank, "A New Approach to Precision Time Measurements," General Radio Experimenter, February-March 1965.

C. DIGITAL FREQUENCY MEASUREMENT

The introduction to the section on frequency meters describes the application of digital frequency meters to frequency measurement problems in general. Counters can obviously be used for precision frequency intercomparison. The accuracy is limited only by the maximum counting time from one source and the maximum counting rate of the counter. Thus, a 20-MHz counter such as the General Radio Type 1191 with its ten-second time base controlled by the standard can be used to calibrate another frequency source at 10 MHz to an accuracy of $1{:}10^8$. The counter is particularly convenient when the oscillator to be calibrated is not harmonically related to the standard frequency.

THE STANDARD-FREQUENCY LABORATORY

Figure 3 shows equipment that might be encountered in a typical Frequency Standard Laboratory. The requirements of any specific application will dictate how elaborate the system must be. If time information is not required, a master oscillator combined with a VLF Phase Tracker to monitor its performance may suffice as reference frequency source. Alternatively, one can use time signals to monitor the oscillator performance. A cesium beam (primary) standard can be used to check the frequency of a master oscillator but does not provide time calibration, and reference to time signals is still required. In the system shown in Figure 3, the master oscillator is monitored against WWVB (60 kHz, A-1 scale) by a phase tracker and provides exact reference frequencies while the two other (working standard) oscillators are offset by the proper ratio to provide time signals on the UTC scale. A frequency-intercomparison system permits the working standards to be compared with the reference and plots continuous records of their stability.

Multipliers, dividers, and synthesizers make other frequencies available for distribution for calibration and test purposes. These frequencies can be derived either from the master oscillator on the exact frequencies or from the working standards with UTC offset. Distribution amplifiers provide isolation between the various users.

The frequency comparison system can consist of a 20-MHz counter using the master oscillator as time base. If the other oscillators are measured at 5 MHz, a 1000-second gate time in the counter will provide $\pm 2 \times 10^{-10}$ resolution. Higher resolution requires the use of multipliers or error-multipliers. Multiplication to 100 MHz and the use of a 100-MHz counter provides a resolution of $\pm 1 \times 10^{-11}$ for a 1000-second count. Error-multipliers can increase the basic resolution up to 1000 times and do not require a 100-MHz counter. In either case, the digital data from the counter can be printed in numerical form or a digital-analog converter can be used for continuous strip-chart recording. The same frequency intercomparison system can also be used to measure the frequencies of oscillators in other locations if the signals are fed through the distribution lines to the frequency standard equipment.

FREQUENCY SYNTHESIZERS

The frequency synthesizer is both a frequency standard and a variable-frequency signal source. All output frequencies are synthesized coherently from a single-frequency source, usually a quartz crystal oscillator. In General Radio synthesizers, the output frequency is adjustable in decade steps, plus a continuous control. Modular construction permits synthesizers to be assembled with any desired resolution from 3 to 9 significant figures.

GR synthesizers use a room-temperature quartz-crystal oscillator as the standard source, which can be locked to an external standard, such as the Type 1115 Standard-Frequency Oscillator, when extreme stability is required.

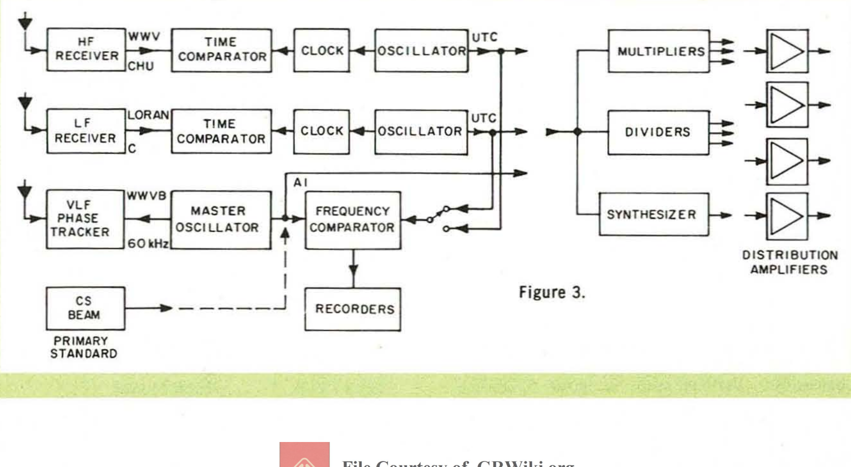


Figure 3.

Type 1115-C STANDARD-FREQUENCY OSCILLATOR

- fast-stabilizing crystal
- <5 x 10^{-10} per day after 3 days
- very high spectral purity
- 24 -hour internal battery
- meets MIL E16400D (vibration), MIL-I-26600 (RFI)

This highly stable piezoelectric oscillator is suitable for exacting scientific and military uses — in both laboratories and manufacturing plants and on shipboard — wherever a rugged, high stability standard of frequency is required.

Exceptional spectral purity of the 5-MHz output permits multiplication to microwave frequencies for such applications as microwave spectroscopy and phase-coherent radar. Typical noise pedestal at X band is -80 dB per $\sqrt{Hz}$.

When combined with the 1123-A Digital Syncronometer® time comparator this oscillator becomes a highly accurate time standard, which can be precisely compared with, and transferred to, other clocks, either remote or local.

The quartz crystal is a 5-MHz, 5th-overtone unit. It is mounted in a single stage, proportional-control oven, which also contains the oscillator and agc circuits.

The frequency of the oscillator is adjusted by a panel control, direct reading in parts in 10^{10}, to allow correction of crystal aging.

A nickel-cadmium battery is floated across the dc supply. In the event of power-line failure, operation for about 24 hours is ensured at room temperature.

— See **GR Experimenter** for June 1964.

specifications

Output: 5 and 1 MHz, 100 kHz; 1 V rms +50 −10% into 50 Ω at each frequency.

Frequency Adjustment: 2700 × 10^{-10} (1 × 10^{-10} per dial division).

External Frequency Control: Dc voltage from +0.5 to +12 V can be applied. Range is at least 5 × 10^{-7}, total.

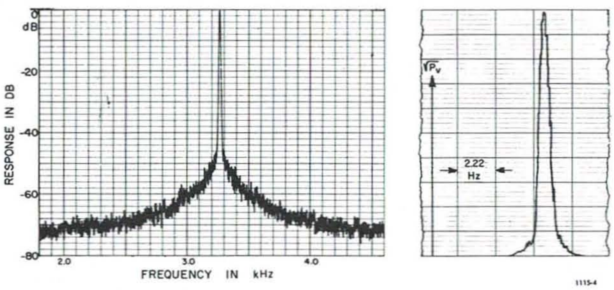
Frequency Stability

Temperature Effects: <±1 × 10^{-11} per degree C between 0°C and 50°C.

Loading of Output: <±2 × 10^{-11} open circuit to short circuit.

Supply Voltage: <±1 × 10^{-11} for ±10% ac line-voltage changes.
<±2 × 10^{-11} for 22 to 35 V, external dc.

Aging: <5 × 10^{-10} per day after 3 days of operation.
<1 × 10^{-10} per day is typical after 6 months.



(Left) X-band power spectrum of two 1115-C Standard-Frequency Oscillators. Analyzer bandwidth is 10 Hz. (Right) Center portion of spectrum measured with 0.54-hertz bandwidth. Vertical scale is linear ($\sqrt{power}$).

Short-Term Stability (5 MHz): Standard Deviation (sigma) is less than stated below (95% confidence):

Averaging Time	Frequency Deviation (Sigma)	Phase Deviation (Radians)
300 μs	100 × 10^{-11}	1 × 10^{-5}
1 ms	50 × 10^{-11}	1.5 × 10^{-5}
10 ms	10 × 10^{-11}	3 × 10^{-5}
100 ms	1.5 × 10^{-11}	4.5 × 10^{-5}
1 s	1 × 10^{-11}	3 × 10^{-4}
10 s	1 × 10^{-11}	3 × 10^{-3}

Spectral Purity: Line width of 5-MHz output multiplied by 2000 times (10 GHz or X band) is less than 0.25 Hz.

Noise Pedestal: Less than −145 dB per $\sqrt{Hz}$ at 5 MHz.

Power Required (ac or dc)
Ac: 90 to 130 or 180 to 260 V, 40 to 2000 Hz, 8 W at 115 V.
Dc: 22 to 35 V, 4 W at 24 V.

Emergency Power: Internal battery provides 24- to 35-hour operation depending on ambient temperature.

Terminals: Locking GR874, 5 MHz, 1 MHz, 100 kHz; type BNC, 1 MHz and 100 kHz for connection to 1123-A Digital Syncronometer.

Accessories Supplied: Power cord.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench model, 19 x 5⅝ x 14½ in. (485 x 145 x 370 mm); rack model, 19 x 5¼ x 14½ in. (485 x 135 x 370 mm).

Weight: Net, 37½ lb (17.5 kg); shipping, 52 lb (24 kg).

Catalog Number	Description	Price in USA
	1115-C Standard-Frequency Oscillator	
1115-9803	Bench Model	**$2150.00**
1115-9813	Rack Model	**2150.00**

Type 1123 DIGITAL SYNCRONOMETER

- bright readout, hours/minutes/seconds
- BCD time output — 10-μs resolution
- time comparisons to 20 ns
- 24-hour internal battery
- timing pulses at 100, 10, 1 kHz, 100, 10, 1, and 0.1 Hz

The 1123 Digital Syncronometer® time comparator is a solid-state digital clock. It provides precise time-of-day information, visually, and in BCD-output form for logging time-of-event and time-interval data to 10-microsecond resolution. By making accurate comparisons between its own time and transmitted standard time (WWV, Loran C, etc), the 1123 can be used to rate local standard-frequency oscillators.

Portable Standard Time

Any number of remote clocks can be started from and synchronized to a master clock without interruption of the master. Precise time can be transported; one sets the clock at a master station and actually carries the standard time to remote locations.

DESCRIPTION: (see diagram)

Functions of the Syncronometer may be divided into four general parts: starting, timekeeping, synchronizing, and readout.

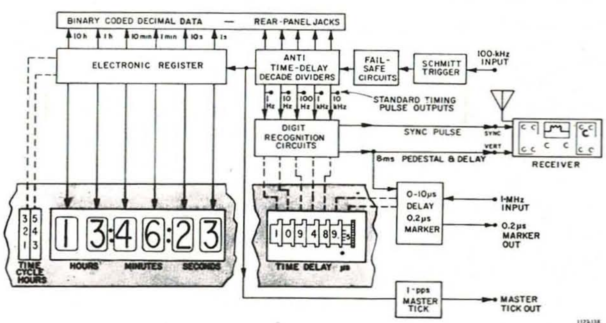
Starting is accomplished either by a front-panel push-button or by a pulse (from an external source or another Syncronometer). With either method any number of clocks can be started simultaneously and in synchronism with an operating master clock.

Timekeeping. A pulse train derived from the 100-kHz input is fed through fail-safe circuits, which stop the clock if input fails for even one cycle. The pulse train is then divided down to produce a 1-pulse-per-second master tick.

Time Comparison and Synchronization. The decade dividers of the timekeeping circuits provide, at output jacks, low-jitter, timing pulses at 100 kHz, 10 kHz, 1 kHz, 100 Hz, 10 Hz, 1 Hz, and 0.1 Hz. These signals also operate a five-digit recognition circuit to produce an 8-millisecond pedestal, occurring at 1 pps. This pedestal can be delayed a precise amount of time with respect to the master tick (delay time of 0.00000 through 0.99999 second is selected by front-panel thumbwheels). Pedestal and a sync pulse are provided for comparisons of the master tick with WWV-type transmissions on a CRO screen.

For intercomparisons where greater time resolution is possible (e.g., Loran C), a 1-MHz input is used to drive a delay circuit (0 to 9 microseconds in 1-microsecond steps, 0 to 1 microsecond continuously), which produces a 0.2-microsecond marker controlled by the last two front-panel thumbwheels.

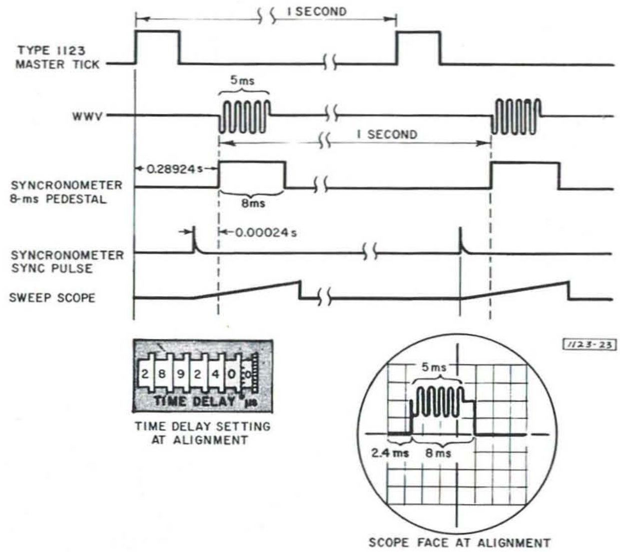
The thumbwheels used in measuring the time interval between the master tick of the Syncronometer and the standard transmissions serve in **synchronizing** the master tick as well.



Timekeeping, readout, and comparison circuits of the 1123 Digital Syncronometer.

To determine the precise time relationship of the Digital Syncronometer's master tick to WWV standard timing bursts, both the time transmission and the clock's 8-millisecond pedestal are displayed on a CRO screen. By means of front-panel thumbwheels, successive amounts of delay are introduced until the pedestal is exactly aligned with the WWV bursts. When the delay is determined, the 1123 need only be switched to self-sync operation, and the master tick will be shifted to synchronism with the transmission. The sync pulse retains oscilloscope synchronism and keeps the pedestal in view throughout the operation.

Where the characteristics of the standard-time transmission permit greater resolution than that provided by the 8-ms pedestal, the 0.2-μs marker can be used. With this marker, time comparisons with a precision of better than ±20 ns are possible.



Readout is both visual and electrical. The clock's 1-pps master ticks are accumulated and displayed in a six-digit bank of illuminated indicators, which can be preset to re-cycle at any number of hours from 1 to 99. The indication of each digit may be changed without carrying to the next digit or interrupting the master tick. Output BCD data from each digit of the visual bank and from each of the five decade dividers (0.1 second through 10 microseconds) are in parallel form, an invaluable aid in providing real-time information for time-dependent measurements.

— See **GR Experimenter** for February-March 1965.

specifications

Input: BNC connectors. 0.5 V at 100 kHz (sinusoid or square wave). 0.5 V at 1 MHz (sinusoid or square wave). Normally provided from 1115-C Standard-Frequency Oscillator (1 V into 50 Ω).

Outputs

Time of Day: From all decades, parallel 1-2-4-2 or 1-2-4-8 BCD, depending on model.

	1-2-4-2 Models	1-2-4-8 Models
Logical 0	Approx +0.5 V behind 100 kΩ	Approx +0.5 V behind 1 kΩ, (buffered)
Logical 1	Approx +15 V behind 100 kΩ	Approx +15 V behind 11 kΩ, (buffered)

Timing Pulses: 10 and 1 kHz, 100, 10, 1, and 0.1 Hz are available at output fittings on rear. These outputs are +15-V pulses with approx 100-Ω source impedance and a duty ratio of 0.2. In addition, a 100-kHz pulse signal is available.

Oscilloscope Sync Pulse: Settable in 1-ms steps 0.000 to 0.999 s.
Positive pulse, 13 V, Z approx 2.2 kΩ.
Duration, approx 7 μs.

Time-Comparison Pedestal: Follows oscilloscope sync by 000 to 990 μs (100- and 10-μs steps).
Positive pulse, 10 V from emitter follower.
Duration, approx 8 ms.
T_r <0.5 μs, T_f <0.5 μs.

0.2-μs Marker: 10-V positive pulse, 0.2-μs duration, with approx 20-ns rise and fall times, and 100-Ω source impedance. This marker is variable in 1-μs steps and a continuous 0- to 1-μs range from 0 to 10 μs after the 8-ms pedestal.

1-s Master Tick Output: Positive pulse from emitter follower.
Amplitude: 10 V. Duration, approx 5 ms. T_r <2 μs, T_f <2 μs.

Input Start Pulse: Logical 0 (0 V) to 1 (+15 V) holding for >10 μs. May come from second clock or external system.

Output Start Pulse: 11 μs, 0 to +15 V, from emitter follower.

Inhibit Pulse Output: Logical 1 (+15 V) to 0 (0 V); lasting approx 9 to 11 time units at lower frequencies, established by setting internal links for desired inhibit rate (no print on carry).

Visual Indication: 6 dimmable digital indicators for h, m, s.

Delay Setting for Time Measurement: 6 digital thumbwheel switches and 1 continuous (0-1 μs) control calibrated in 20-ns increments.

Visual Register Setting: Direct access to all six visual decades, carries inhibited.

Clock Functions: All control and setting functions are operated by a single pushbutton and are normally locked out and covered.

1. **Operate:** All program controls locked out.
2. **Start:** Clock will be started by 11-μs start pulse from pushbutton or from external source (BNC connector on rear). Start pulse produced and fed from instrument.
3. **Stop:** Clock will be stopped and all counting decades from 100 kHz to 1 Hz will be set to zero by pushbutton. Zero will hold until start command is received.
4. **Set:** Permits setting visual register. All visual-register carries interrupted; 100-kHz to 1-Hz dividers not affected. Selected decade is advanced by 1 count for each push of the initiate pushbutton.
5. **Self Sync:** Permits synchronizing master tick to within 10 μs of a measured time in another time system, as WWV on UT-2.
6. **Start-Slave:** Permits setting a second clock from the first. After the initiate button is pushed, a start pulse will be produced when the count reaches the setting of the time-delay switches of the first clock.

Measurement Rate: Switch permits oscilloscope sync at 10-Hz rate rather than the standard 1-Hz rate.

Power Required: 90 to 130 or 180 to 260 V, 50 to 60 Hz, 32 W approx or 24 to 32 V dc, 1 A approx. Self-contained nickel-cadmium battery for about 24-hour operation is supplied.

Accessories Supplied: Digital-output plug assembly, connector for external batteries, power cord, two 2-foot BNC cables, 3 board extenders.

Accessories Available: 1115-C Standard-Frequency Oscillator as source of 100-kHz and 1-MHz standard frequencies.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench model, 19 x 5⅝ x 14½ in. (485 x 145 x 370 mm); rack model, 19 x 5¼ x 12 in. (485 x 135 x 305 mm).

Weight: Net, 40 lb (18.5 kg); shipping, 54 lb (24.5 kg).

Catalog Number	Description	Price in USA
	1123 Digital Syncronometer	
	BCD Output Code 1-2-4-8	
1123-9760	115 V, Bench Model	**$3850.00**
1123-9763	115 V, Rack Model	**3850.00**
1123-9762	230 V, Bench Model	**3850.00**
1123-9765	230 V, Rack Model	**3850.00**
	BCD Output Code 1-2-4-2	
1123-9801	115 V, Bench Model	**3650.00**
1123-9811	115 V, Rack Model	**3650.00**
1123-9881	230 V, Bench Model	**3650.00**
1123-9891	230 V, Rack Model	**3650.00**

FREQUENCY-MEASURING INSTRUMENTS

An unknown frequency is measured by comparison with a standard frequency. The comparison may be direct, as with a digital frequency meter that includes a quartz-crystal-oscillator time base, or indirect, as with a calibrated, analog-type frequency meter.

The digital frequency meter, or counter, measures frequencies up to about 100 MHz directly and economically. The scaler is an economical means of extending the range, by direct-counting techniques, upward by a factor of 10 or 100 up to 500 MHz. The block diagram of Figure 1 illustrates the several possible frequency-measuring combinations.

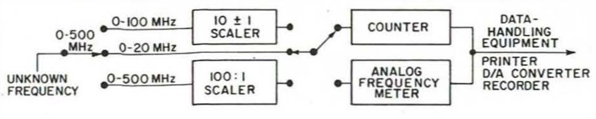


Figure 1. Frequency measurement techniques. Frequencies shown are approximate upper limits for the various systems.

Frequency can also be measured in terms of period or period multiples. A computing counter such as the GR 1159 measures all frequencies in its range in terms of their periods, computing and displaying the result in frequency terms. It is programmed to change ranges automatically to fill the readout registers with significant digits providing 6-place readout at all frequencies. It offers the advantages of fast, automatic, high-resolution measurement over its entire frequency range.

DIGITAL FREQUENCY METERS

The elements of a digital frequency meter (commonly called a counter) are shown in Figure 2. The reference standard, usually called the time base, is a quartz-crystal oscillator. For period measurement, the counter totals the number of standard pulses from the time base for one or more periods of the unknown frequency. For direct frequency measurement, it counts the number of cycles of the unknown in a standard time interval, usually one second. In either type of measurement, the result is displayed as a series of illuminated digits.

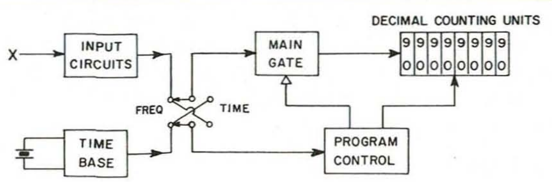


Figure 2. Elementary block diagram of a digital counter.

In addition to its basic function of measuring frequency (or period), the counter can also count events (pulses), whether uniform in rate or random, and display the total. It can also be made to measure the ratio of two input frequencies.

The GR 1191 and 1192 Counters employ integrated circuits and are designed for maximum performance at low cost. All models include a precise quartz oscillator as the measurement reference. Input controls are provided to permit reliable counting, regardless of input waveform. Counting-time controls vary the resolution of the readout so that any digits of interest are displayed — coarse digits for coarse measurements, fine digits for fine measurements.

RANGE EXTENSION — to 500 MHz

Higher frequencies are measured by a combination of an 1191 or 1192 Counter and the Type 1157-B Scaler (up to 500 MHz). This scaler has been designed as an independent, self-contained instrument based on the "add-a-unit" philosophy pioneered by General Radio. It can be used with other counters or other types of instruments for a variety of measurements.

PRESET OPERATION

The GR 1191 Counter can be operated in either of two preset modes by the addition of the GR 1399 Digital Divider/Period and Delay Generator, which can produce a time base for the counter of arbitrary frequency for normalized-unit readout or can count events and gate the counter to read time interval for a predetermined number of events.

1399 Divider/ Generator page 201

DIVIDER/PERIOD AND DELAY GENERATOR

The dual role of frequency divider and delay generator is performed digitally by the GR 1399. Its 8 thumb wheels permit precise divider ratios to be set up to divide either an external signal or, for the precision-delay function, the 10-MHz output from the internal time-base crystal oscillator. For use in automatic systems, the 1399 is fully programmable.

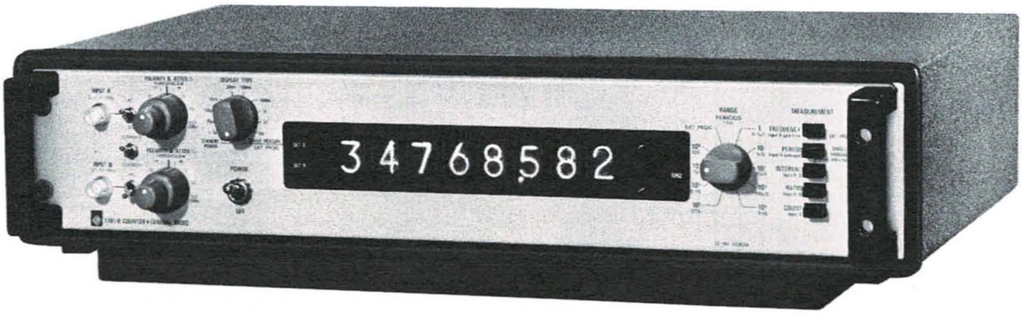
ACCESSORY EQUIPMENT

Data-handling equipment — D/A converter, data printer, and graphic recorder — is available for use with GR digital frequency meters and is described elsewhere in this catalog. Combinations of frequency meter and auxiliary equipment can be assembled to meet the user's requirements.

We shall be glad to quote on combinations to meet your needs.

Type 1191-B COUNTERS

- 35 MHz, to 500 MHz with scaler
- general-purpose counter-timer
- economical IC design
- programmable, all functions dc controlled
- 10-mV sensitivity



The 1191-B Counter represents several significant improvements over its predecessor. The upper-frequency limit is extended to 35 MHz, for more rapid data acquisition the minimum display time is reduced to less than 1 microsecond, and a standby-power mode of operation now lets the crystal oven remain on for maximum stability.

The 1191 is a general-purpose counter-timer for measuring frequency, period, period average, frequency ratio, and time interval. Extensive use of integrated circuits in the 1191 has resulted in an economical counter with full features and top performance.

OPERATION TO 500MHz

Scaler page 200

The 1191-B counter is available as the 1191-Z in combination with a scaler that extends the frequency-measuring range to 100 or 500 MHz by dividing the input frequency by a factor of 10 or100.

In combination, the 1191 Counter and a scaler are economical and provide all the features of the counter alone, full counter-timer functions, programmability, high-speed data access, with the extra benefits of high-frequency operation. 1191-Z models include all counter options: high-precision time base and data output.

The counter and scaler are offered in rack-mount or bench versions, the latter supplied with the two instruments mounted in a single cabinet.

Type 1191-Z 500 MHz Counter.

AUTOMATIC OPERATION

Remote programmability of measurement functions, ranges, and most of the secondary controls, such as display time, makes the 1191 unexcelled as a component in automatic measuring systems. The counter functions are dc controlled, most by simple contact closures to ground. Models are available with high-speed, buffered BCD outputs from internal storage to drive auxiliary data-handling equipment.

OPERATOR CONVENIENCE

The readout of the 1191 is 8 digits of high-intensity neon indicators, with automatic display of decimal point and measurement dimensions. The internal storage gives continuous, flicker-free display of rapidly corrected data. The operator has control of all input trigger circuit characteristics.

INPUT CIRCUITS

The counter has two high-sensitivity input channels, each consisting of a high-impedance, low-noise FET circuit preceded by a 3-position step attenuator and including controls for trigger level, slope and polarity. The 1-megohm input impedance is independent of control settings to permit use of general-purpose low-capacitance oscilloscope probes. One such probe is offered as an accessory to the 1191.

TIME BASE

Model options allow a choice of time base to match needs and budgets. An inexpensive room-temperature-crystal oscillator affords adequate stability for many applications. Or, the counter can be ordered with a more stable crytsal-oscillator time base with proportional temperature control. For the greatest possible stability, either oscillator can be phase locked to an external standard frequency of 10 MHz or any submultiple down to 100 kHz. A front-panel monitor is included for this purpose. Oscillator frequency can be set with an easily accessible, rear-panel dc-voltage adjustment.

specifications

MEASUREMENT RANGES AND ACCURACY

Frequency: Dc to 35 MHz; 1-μs to 10-s counting gate times. Accuracy, $\pm$ 1 count $\pm$ time-base accuracy.

Strobed Period: Period to 10^9 s less display time (<1 μs to 10 s), measured by counting 0.1-μs to 10-s intervals derived from internal 10-MHz clock. Accuracy, see note.

Single and Multiple Period: 1 to 10^8 periods measured by counting internal 10-MHz clock. Accuracy, see note.

Time Interval: 0.1 μs to 10^9 s measured by counting 0.1-μs to 10-s intervals derived from internal 10-MHz clock. Accuracy, see note.

Frequency Ratio: 1 to 10^8. Frequency "A", dc to 35 MHz, is measured over 1 to 10^8 periods of frequency "B", dc to 10 MHz. Accuracy, $\pm$ 1 count of "A" $\pm$ trigger error of "B" (see note).

Count: Register capacity, 10^8. Events at rates up to 35 MHz are accumulated between "start" and "stop" commands from manual panel buttons or, externally from contact closures or solid-state switches. In "count", storage is automatically disabled.

INPUT

Frequency: Channel "A", dc to 35 MHz (3 Hz to 35 MHz ac-coupled); channel "B", dc to 10 MHz (3 Hz to 10 MHz ac-coupled).

Sensitivity: 10 mV rms sine wave, 30 mV pk-pk pulse decreasing above 20 MHz to approx 100 mV rms at 35 MHz. Trigger level variable $\pm$100 mV.

Attenuator: x1, x10, x100 (0, 20, 40 dB); low-capacitance 10:1 probe available.

Voltage Rating: Input voltage should not exceed 150 V on x1 or 300 V on x10 or x100.

Impedance (all attenuator settings): Approx 1 MΩ shunted by 35 pF. At rear connectors (supplied mounted, unwired), shunt C increases to approx 70 pF.

Signal Polarity: Front-panel control permits selection of positive- or negative-going signal sense for triggering.

10-MHz TIME-BASE

Room-Temperature Oscillator (standard)

Stability: $<2 \times 10^{-7}/°C$ from 0° to 50°C. Drift less than $\pm 2 \times 10^{-6}$ per month. With $\pm$10% line-voltage variation, $<2 \times 10^{-8}$.

Manual Adjustment Range: $\pm 1 \times 10^{-5}$ at rear-panel control.

High-Precision Oscillator (in proportional-control oven) (optional)

Stability: $<2 \times 10^{-10}/°C$ from 0° to 50°C when operatod continuously. Drift $\pm 1 \times 10^{-8}$ per week, approx 1×10^{-9} per day after 1 month of continuous operation. With $\pm$10% line-voltage variation, $<2 \times 10^{-10}$.

Manual Adjustment Range: $\pm 1 \times 10^{-6}$ at rear-panel control.

Time-Base Output: 10-MHz square wave, 2 V pk-pk behind 50 Ω at rear-panel BNC connector.

External Phase-Lock: Both time-base oscillators can be locked to external standard frequency at 0.1, 1, 2.5, 5, or 10 MHz, of at least 1 V rms into 1kΩ. A front-panel phase-lock indicator lamp is provided.

Note — Error in time measurements: $\pm$0.3% of one period $\div$ number of periods averaged, for a 40-dB input signal-to-noise ratio. This assumes no noise internal to the counter. For input signals of extremely high signal-to-noise ratio, the trigger error in μs will be $<0.0005 \pm$ the signal slope in V/μs. In addition, all time measurements are subject to the $\pm$ 1-count gating error and to time-base accuracy.

DATA PRESENTATION

Display: 8-digit display with automatically positioned decimal point and measurement dimensions. High-intensity neon readout tubes.

Storage: Display can be either stored or not; variable from <1 μs to 10 s or infinity for display time (normal mode) and for data holdoff time (in storage mode).

Data Output (in some models): Fully buffered 1-2-4-8 BCD output at standard DTL levels; data zero is 0.5 V max and data 1 approx 5 V behind 6 kΩ.

PROGRAMMING

Input: All instrument functions controllable by closure to ground within capabilities of DTL micrologic (2- to 6-mA sink current required), except:

Functions controlled by other than contact closure:
Input Threshold: Requires dc voltage of $\pm$100 mV corresponding to desired threshold level.

Display Time: Requires RC circuit to ground.

Nonprogrammable functions: Input attenuator, input ac/dc coupling, separate/common switch, self-test, internal/external control of time-base oscillator, and frequency adjustment of time-base oscillator.

GENERAL

Environmental: Instrument operating range, 0 to 50°C ambient.

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 32 W.

Accessories Supplied: Rack-mounting hardware set, power cord.

Accessories Available: Input probe; 1157 Scaler for measurement to 500 MHz; 1137 Data Printer, and other GR digital-data acquisition equipment.

Dimensions and Weights:

		width x height x depth	net	ship
1191-B	bench	19¾ x 4⅞ x 13 in. 500 x 125 x 330 mm	22½ 10	29 lb 13.5 kg
	rack	19 x 3½ x 10½ in. 485 x 89 x 270 mm	17¼ 8	21 lb 10 kg
1191-Z (500 MHz)	bench	19¾ x 8¾ x 15 in. 500 x 225 x 385 mm	38 17.5	45 lb 20.5 kg
	rack	19 x 7 x 13¼ in. 485 x 180 x 340 mm	38 17.5	45 lb 20.5 kg

specifications

— FOR INPUT PROBE — 1158-9600

Input Impedance: 10 MΩ shunted by approx 7 pF when used with 1191 counter.

Attenuation: $\times$10 (20 dB).

Voltage: 600 V dc or ac pk-pk, max up to 5.7 MHz; less at higher frequencies.

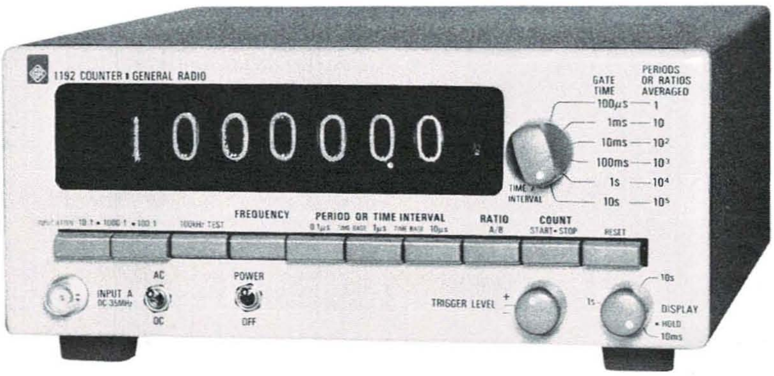
Length: 3½ ft.

Catalog Number	Description	Price in USA
	1191-B Counter	
1191-9710	Bench Model	**$1395.00**
1191-9711	Rack Model	**1395.00**
1191-9712	Bench Model with Data Output Option	**1495.00**
1191-9713	Rack Model with Data Output Option	**1495.00**
1191-9714	Bench Model with High-Precision Time-Base Option	**1695.00**
1191-9715	Rack Model with High-Precision Time-Base Option	**1695.00**
1191-9716	Bench Model with both Options	**1795.00**
1191-9717	Rack Model with both Options	**1795.00**
	1191-Z Counter (500 MHz)	
1191-9904	Bench Model with both Options	**2645.00**
1191-9905	Rack Model with both Options	**2665.00**
1158-9600	**P6006 Probe,** Tektronix Catalog No. 010-0127-00 (not sold separately)	**26.00**

Type 1192 COUNTER

- dc to 32 MHz, to 500 MHz with scaler
- 10-mV sensitivity
- stable time base
- low cost
- options: 5, 6, or 7 digits and data output

NEW



An instrument as basic and necessary as a time/frequency counter should be so versatile and low-cost that it can be justified in every laboratory. The GR 1192 is just that. IC design and fully automated testing of all functions have brought the price of the 1192 down to the level of an economy counter — but the 1192 has all the features and capabilities of a much more costly instrument.

The 1192 will measure frequency from dc to 32 MHz as well as period to a resolution of 0.1 μs (single and multiple), time interval, and frequency ratio, and do simple counting too. It is equipped with an internal crystal time base with better than average stability against time, temperature, and line-voltage variations. Its input sensitivity is 10 times that of similar units and the input circuits give the operator control of the trigger threshhold level and attenuation for greater immunity to input noise and more accurate measurements.

Options permit selection of the right model for the application. If 7-digit precision is not required, a saving can be realized by selection of either a 6-digit or 5-digit model that is similar to the full-house model in all other respects but price. For manual use and economy, models are offered with only visual readout; for system applications and automatic data reduction, other models have BCD data outputs.

1192-Z with Option 1, rack mounting.

500-MHz OPERATION

The small size of the 1192 makes for easy handling in bench use, and allows the 1157-B Scaler to be mounted alongside in a relay rack assembly or in a single bench cabinet. With the 1157-B, the frequency range of the 1192 Counter is extended to 500 MHz with 100:1 prescaling and to 320 MHz with 10:1 prescaling. Mounted together in a single cabinet, the combination is identified as the 1192-Z Counter.

The 1192 is easy to use. The readout is clear and bright and includes the units of measurement, an automatically positioned decimal point, and lights that signal counting and spillover. The counter modes are controlled by simple and unambiguous push buttons, the gate-time intervals by a single control. Internal storage that permits the readout to display only the final result can be disabled to permit the operator to see that actual count occurring; control is provided for the display time in this mode.

Many features make the 1192 more broadly useful. A second input channel permits the measurement of normalized frequencies by the insertion of an external time base of arbitrary frequency. Time interval and counting measurements can be externally controlled by a variety of signals. With auxiliary connections, time interval range can be extended, the time base phase locked to an external standard frequency, and internal standard frequencies can be brought out.

Scaler page 200

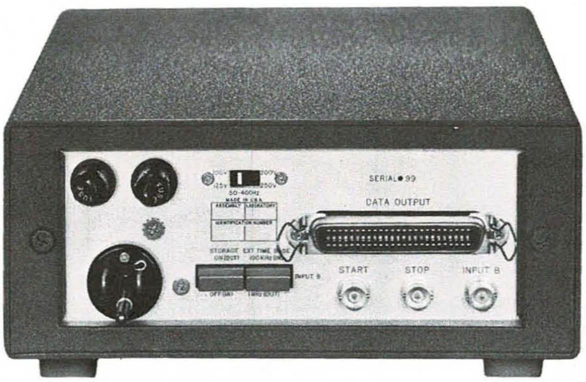
— See **GR Experimenter** for July-August 1969.

specifications

MEASUREMENT RANGES AND ACCURACY

Frequency: Dc to 32 MHz; 100-μs to 10-s counting gate times; displays Hz, kHz, MHz units with positioned decimal point. Accuracy, ± 1 count ± time-base accuracy.

Period: 0.1-μs resolution; single and multiple period to 10^5; displays μs, ms, ns with positioned decimal point; counts 10-MHz time base, 1 MHz, and 100 kHz. Accuracy, depends on signal-to-noise ratio of input signal, input noise, and the ± 1count error divided by number of periods counted.



The rear of the 1192 contains inputs for time-interval and frequency-ratio measurements and, for models with BCD data-output option, contains provision for the external equipment.

Frequency Ratio: 1 to 10^5. Frequency "A", dc to 32 MHz, is measured over 1 to 10^5 periods of frequency "B", 50 Hz to 10 MHz. Accuracy, ± 1 count of "A" ± trigger error of "B" divided by number of ratios counted.

Note — Trigger error in time measurements: ±0.3% of one period ÷ number of periods averaged, for a 40-dB input signal-to-noise ratio. This assumes no noise internal to the counter. For input signals of extremely high signal-to-noise ratio, the trigger error in μs will be <0.0003 ÷ the signal slope in V/μs.

Time Interval: 0.1, 1, or 10-μs resolution measured by counting 10-, 1-, or 0.1-MHz signal from internal clock; displays ms with positioned decimal point. Accuracy, ± 1 count ± time-base accuracy. Interval measured is between separate commands supplied to "start" and "stop" BNC connectors on rear panel. Measures duration of pulse applied to "start" terminal with "stop" terminal grounded. Storage is disabled in this mode. Counter will also totalize many time intervals.

Count: Register capacity, 10^7, 10^6, 10^5 depending on model. Events at up to 32-MHz rate accumulated between start/stop commands from manual panel button, or externally between separate "start" and "stop" commands applied to rear BNC connectors or only during "start" command pulse with "stop" terminal grounded. Counter will also totalize all the events during many openings of the gate.

INPUT

Frequency: Channel "A", dc to 32 MHz (3 Hz to 32 MHz ac-coupled); channel "B", 50 Hz to 10 MHz.

Sensitivity: Channel "A", 10 mV rms (sine wave) dc to 20 MHz, 20 mV rms to 32 MHz; channel "B", 100 mV rms (sine wave) 400 Hz to 10 MHz, 1 V rms down to 50 Hz. "A" trigger level adjustable ± 100 mV, "B" trigger level fixed; "A" slope negative-going for period, positive-going for frequency, ratio, and count; "B" slope positive-going.

Attenuator: Channel "A" only, x1, x10, x100, x1000 (0, 20, 40, 60 dB). Low-capacitance 10:1 probe available.

Voltage Rating: Input should not exceed 400 V pk ac or dc, channel "A". Channel "B" input should not exceed 400 V dc or 80 V rms.

Impedance (all attenuator settings): "A" approx 1 MΩ shunted with 25 pF. With low-capacitance probe, 10 MΩ shunted with 7 pF. Channel "B" approx 10 kΩ shunted with 20 pF.

Start/Stop Inputs: Contact closure to ground or saturated NPN transistor capable of 6-mA max sink, or pulse input with data "0" <+0.3 V and data "1" >+2.0 V: should not exceed 1 W into 50 Ω (−7 V dc and + 12 V dc or ± 70 V for short, 1%-duty-ratio pulses).

10-MHZ TIME BASE

Stability: <±2 x 10^{-6} per month. Room-temperature crystal coefficient, <±3 x 10^{-7}/°C from 0° to 55°C. Total deviation from frequency, <±4 x 10^{-6} from 0° to 55°C. With 10% line-voltage variation, <±2 x 10^{-8}.

Manual Adjustment Range: ± 1 x 10^{-5} with internal control.

Internal Phase Lock: Time-base oscillator can be locked to external standard frequencies at 1 MHz and 100 kHz of ≥100 mV rms into 10kΩ. Lock range is wider than ±1 x 10^{-5}.

Output: 100 kHz and 1 MHz.

DATA PRESENTATION

Display: 5, 6, or 7 digits, long-life, high-intensity neon readout with automatically positioned decimal point and measurement dimensions. Also on panel, spill indicator that lights if register capacity is exceeded, and a counting indicator light.

Storage: Display and spill-indicator can be either stored or not, as controlled by rear panel push button.

Measurement Rate: Time between measurements adjustable from 10 ms to >10 s and ∞.

Data Output (optional): Fully buffered 1-2-4-8 BCD output at standard DTL levels (9-mA sink current). Data "0" is 0.5 V max, data "1" is +5 V behind 6 kΩ.

GENERAL

Environmental Operating Range: 0 to 55°C ambient.

Power Required: 100 to 125, 200 to 250 V, 50 to 400 Hz, 22 W.

Accessories Available: 1157-B Scaler for extending frequency range to 500 MHz, data printer, digital-to-analog converter, and GR to 500 MHz, data printer, digital-to-analog converter, and GR digital-data acquisition equipment. Also low-capacitance 10:1 Input Probe 1158-9600.

Mechanical: Convertible-Bench cabinet. *Dimensions* (w x h x d): Bench, 8.5 x 3.88 x 12.6 in. (216 x 99 x 320 mm); rack, 19 x 3.5 x 12.6 in. (483 x 89 x 320 mm). *Weight:* Bench, 8.4 lb (3.9 kg) net, 10.6 lb (4.9 kg) shipping; rack, 11 lb (5 kg) net, 15 lb 7 kg) shipping.

Specifications (1192-Z)

1192-Z specifications are same as for 1192 except:
Frequency: Dc to 500 MHz.

INPUT (to 1157-B Scaler) for frequencies above 32 MHz.
Minimum Amplitude: 0.3 V pk-pk (0.1 V rms), most sensitive range.
Maximum Signal: 7 V rms (1 W).
Impedance: AC-coupled, 50 Ω.

GENERAL

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 36 W.

Dimensions (width x height x depth): Bench, 17 x 3⅞ x 14 in. (435 x 99 x 355 mm); rack, 19 x 3½ x 12¾ in. (485 x 89 x 325 mm).

Weight: Net, 14 lb (6.5 kg); shipping (est), 18 lb (8.5 kg).

Catalog Number	Description	Price in USA
	1192 Counter (32 MHz), Bench models	
	5-digit readout	**$575.00**
	6-digit readout	**675.00**
	7-digit readout	**775.00**
	1192-Z Counter (500 MHz, incl Scaler) Bench models	
	5-digit readout	**1425.00**
	6-digit readout	**1525.00**
	7-digit readout	**1625.00**
	Options for 1192 and 1192-Z	
	Option 01 Relay rack mounting	**add 20.00**
	Option 02 BCD Data Output	**add 50.00**
1158-9600	**P6006 Probe,** Tektronix Catalog No. 010-0127-00 (not sold separately)	**26.00**

Type 1159 RECIPROMATIC® COUNTER

- 0.6 Hz to 30 MHz; to 500 MHz with scaler
- 6-digit resolution
- <0.2 second per measurement
- fully automatic ranging; programmable controls
- integrated-circuit design

The Type 1159 Recipromatic® counter uses a built-in computer to combine the resolution and speed of a period measurement with the convenience of direct frequency readout. The computer also selects the measurement range automatically so that the result is always displayed as a 6-digit number with the measurement units correctly labeled and the decimal point correctly positioned.

In measuring several widely spaced frequencies with previous counters, it was necessary either to change range or to accept less-than-maximum resolution at the lower frequencies. Furthermore, in measuring low frequencies, high-resolution readings required either long measurement intervals or the need to make period measurements and then to calculate frequency. In manual measurement systems, these considerations slow down accurate measurements and increase the likelihood of operator error, while in automatic systems they lead to greater system complexity and often to poorer system performance.

By contrast, the 1159 measures the period of the unknown signal and computes the reciprocal for display in units of frequency. A full six-digit reading is always displayed, regardless of frequency, because the counter automatically selects the appropriate period multiples and clock frequency to ensure maximum resolution.

SIMPLICITY OF OPERATION

In using the 1159, the operator simply applies the unknown frequency to the counter input and reads the result. The front panel contains only the power switch and reset button. The display-time controls and a few controls useful in accommodating adverse input-signal conditions are concealed behind a hinged panel.

PROGRAMMED OPERATION

When the 1159 is used as a system component, its essentially automatic operation minimizes the need for external programming. The few manual controls are fully programmable and BCD data output is provided for operation of a printer or other data-handling equipment. An additional feature is the ability to control the readout dimensions so that correct data will be obtained when the 1159 is preceded by a scaler.

TIME BASE

The time base of the 1159 is controlled by a stable 10-MHz crystal in a proportional-controlled oven. Its rapid warmup and high-stability characteristics ensure that the full accuracy of the 1159 is available promptly and will be maintained for long periods between recalibrations. The oscillator can also be phase-locked to an external 100-kHz or 1-MHz reference.

APPLICATIONS

The 1159 can be used in any frequency measurement where both speed and accuracy are needed. It is especially useful in accelerating the test and calibration of frequency sources such as oscillators, signal generators, and voltage-to-frequency converters, particularly at low frequencies. The 1159's automatic ranging capability can be used at frequencies up to 500 MHz by use of the GR 1157-B Scaler.

— See **GR Experimenter** for June-July 1968.

specifications

Frequency-Measurement Range: 0.6 Hz to 30 MHz. In the fast mode, 6 Hz to 30 MHz; in the slow mode, 0.6 Hz to 9.99999 MHz. Extend range to 500 MHz without loss of accuracy with 1157-B Scaler.

Frequency-Measurement Accuracy: ± 0.5 in least significant digit $\pm 1 \times 10^{-6} \pm$ clock accuracy $\pm$ noise (see note).

Measurement Rate: Sum of adjustable display time, 0.02 to 10 s and ∞, and measurement time of about 100 ms in fast mode or 1 s in slow mode.

INPUT

Sensitivity: 10 mV rms to 10 MHz, 20 mV rms to 20 MHz, 50 mV rms to 30 MHz.

Bandwidth: Ac-coupled input, −3 dB at approx 1 Hz. Bandwidth switch sets −3 dB points at approx 10 or 1 MHz, 100, 10, or 1 kHz.

Impedance: 1 MΩ//27 pF for up to 5-V pk-pk input; 0.67 MΩ//30 pF for up to 200 V pk-pk. Input capacitance can be reduced by disconnecting either unused front- or rear-panel input connector. Front only, 20 pF; rear only, 17 pF.

Trigger Threshold: ± 20 mV, adjustable.

Slope: Positive- or negative-going, switch-selected.

CLOCK

Internal: 10-MHz, third-overtone quartz-crystal oscillator in proportional-controlled oven.

Temperature Effects: $<1 \times 10^{-6}$ from 0 to 50°C ambient.

Warmup: Within 1×10^{-6} after 10 minutes at 25°C ambient.

Stability: Better than 3×10^{-9} per day after 1 month of operation; better than 1×10^{-6} per year.

External Control: Internal clock oscillator can be phase-locked to external 100-kHz or 1-MHz signal of at least 1 V rms.

GENERAL

Programmability: All control functions can be programmed by contact closures to ground (2- to 4-mA sink current required) except display time, which requires an external resistance of 0 to 100 kΩ, and trigger level, which requires 0 to ± 5 V dc for ± 20-mV control.

Note — Noise affects precision of frequency measurement. For additive noise on signal measured, the error in measurement will be $\epsilon = \frac{N}{\pi S n}$ where N is the noise level and S the signal level in the same units; n is the number of periods averaged. Internally produced noise in the counter will determine the limiting error level. For the 1159, this internal noise is approx 50 μV rms.

Data Output: 1-2-4-8 BCD-DTL output for 6 digits of data, decimal point, and measurement units. Data zero is 0.5 V max (12-mA current sinking capability); data one is approx 5 V behind 6 kΩ.

Display: Six neon readout tubes, automatically positioned decimal point, and measurement units. Dimensions can be multiplied by 1, 10, or 100 with rear-panel switch for use with 10:1 or 100:1 prescaler.

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 60 W.

Accessories Supplied: Power cord, mounting hardware with rack models.

Accessories Available: GR 1157-B (10:1 or 100:1) Scaler, 1137 Data Printer, 1136 Digital-to-Analog Converter, other GR data-handling equipment.

Mounting: Bench model (in metal cabinet) or rack model.

Dimensions (width x height x depth): Bench, 19¾ x 4⅞ x 15 in. (500 x 125 x 385 mm); rack, 19 x 3½ x 13¼ in. (485 x 89 x 340 mm).

Net Weight: Bench, 26 lb (12 kg); rack, 19 lb (9 kg).

Shipping Weight: Bench, 35 lb (16 kg); rack, 28 lb (13 kg).

Catalog Number	Description	Price in USA
	1159 Recipromatic® counter	
1159-9700	Bench Model	**$2100.00**
1159-9701	Rack Model	**2100.00**

PATENTS APPLIED FOR.

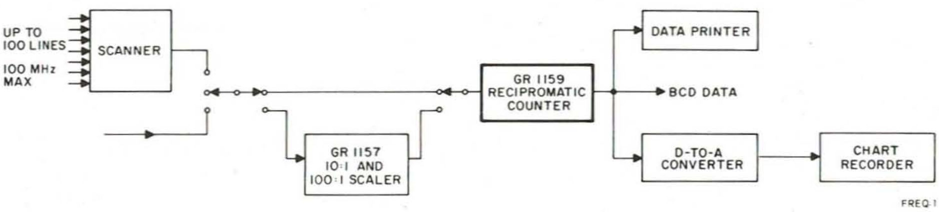
Automatic Frequency-Measuring Systems

The 1159 Recipromatic Counter is excellent for use in automatic frequency-measuring systems. Its ability to change range automatically means that external instructions to the counter are minimal and infrequent as they concern only secondary functions. Thus, frequency-measuring systems that include the 1159 can be greatly simplified.

Automatic ranging facilitates use of an input scanner to measure many widely diverse frequencies with full readout resolution, an impossible task with most counters unless an operator or external ranging program is employed. As many as 100 signal lines can be scanned by the Scanner System.

The BCD data output can be used to plot, record, or compute from the measurement results. The Data Printer will produce a permanent printed record of up to 12 digits, enough capacity for counter data as well as such corrolary information as channel numbers from an input scanner. The Digital-to-Analog Converter will provide the frequency data to a recorder in suitable analog form to plot, for example, frequency as a function of temperature.

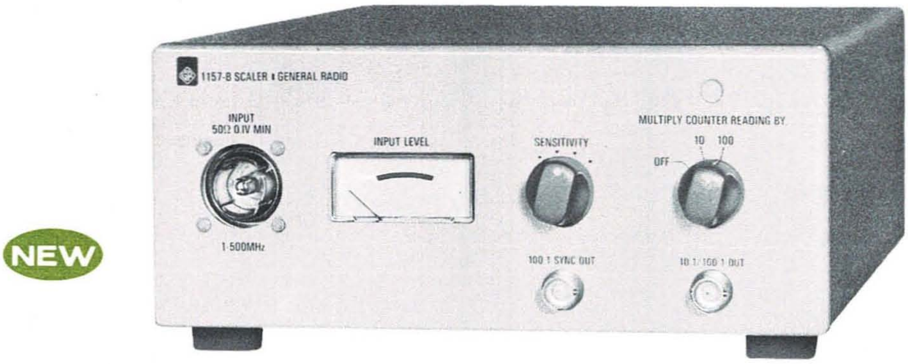
We are interested in discussing any specialized requirements you may have; custom measurement systems can be supplied designed to meet your particular needs.



Some possible frequency-measuring-system combinations using the 1159 Recipromatic Counter.

Type 1157-B SCALER (500 MHz)

- inputs up to 500 MHz
- 100-mV rms input sensitivity
- 1-V output behind 50 Ω



The GR 1157-B Scaler will divide input frequencies up to 500 MHz by 10:1 or 100:1. Used as a prescaler, it will extend the upper frequency limit of counters to as much as 500 MHz. It can be mounted side-by-side with the new GR 1192 Counter to extend its range to 320 MHz or 500 MHz with 10:1 or 100:1 prescaling.

A perfect companion to the 1192 Counter, the 1157-B extends the counter's range to 500 MHz. Equally useful with the 1191-B Counter.

The 1157-B Scaler is a two-decade digital frequency divider complete with input-level meter, attenuator, and internal power supply. One output can be switched for either 1/10 or 1/100 of the input frequency; a sync output supplies 1/100 of the input continuously.

— See **GR Experimenter** for July-August 1969.

specifications

INPUT

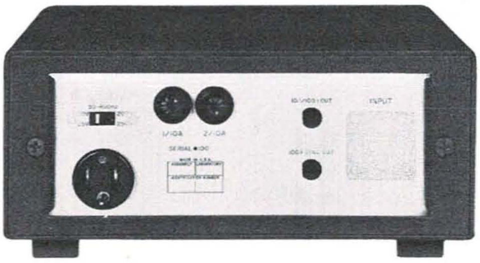
Frequency: 1 to 500 MHz.

Minimum Amplitude: 0.3 V pk-pk (0.1 V rms) on most sensitive setting of attenuator.

Maximum Signal: 7 V rms (1 W).

Impedance: AC-coupled, 50 Ω.

Attenuator (sensitivity control): Panel switch of x1, x2, x5 or x10 attenuation.



The input and output connectors can be moved to the rear for systems applications.

Meter: Green sector indicates adequate signal level for easy adjustment of sensitivity control.

Connector: GR874® locking connector; can be moved to rear panel.

OUTPUTS

Switched Output: DC-coupled positive pulse, > 1 V behind 50 Ω. Repetition rate is input frequency divided by 10 or 100 depending on setting of panel switch. Duty ratio is 60% for 1/10 output, 40% for 1/100 output.

Sync Output: Positive pulse, > 1 V behind 50 Ω. Repetition rate is input frequency divided by 100. Duty ratio, 60%.

Connector: BNC; can be moved to rear panel.

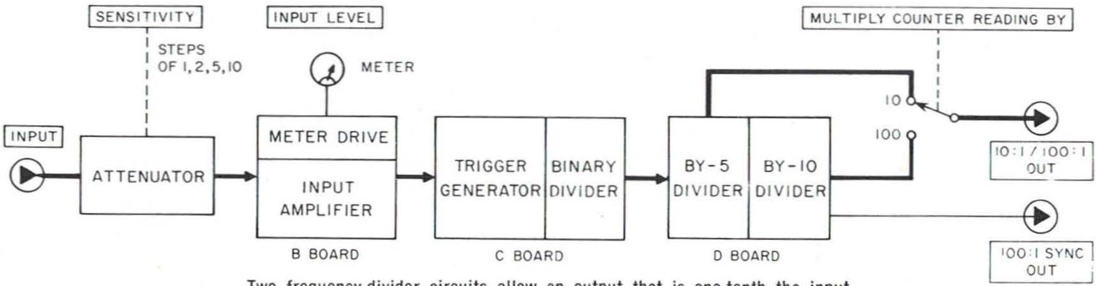
GENERAL

Power Required: 100 to 125 or 200 to 250 V, 14 W.

Accessories Supplied: Power cord, patch cord to 1192 Counter.

Mechanical: Convertible-Bench cabinet. *Dimensions* (w x h x d): Bench, 8.5 x 3.5 x 12.6 in. (216 x 89 x 320 mm); rack, 19 x 3.88 x 12.6 in. (483 x 99 x 320 mm). *Weight*: Bench, 7 lb (3.2 kg) net, 10 lb (4.6 kg) shipping; rack, 9.6 lb (4.1 kg) net, 13 lb (5.9 kg) shipping.

Catalog Number	Description	Price in USA
	1157-B Scaler (500 MHz)	
1157-9700	Bench Model	**$850.00**
1157-9701	Rack Model	**870.00**



Two frequency-divider circuits allow an output that is one-tenth the input frequency or one-hundredth of it.

Type 1399 DIGITAL DIVIDER/ PERIOD AND DELAY GENERATOR

- divides frequency continuously by any number from 3 to 99,999,999
- <100-ns recovery for continuous division
- fully programmable
- 100-mV sensitivity

The 1399 is a high-resolution digital delay generator that also serves as a frequency divider. Its internal 10-MHz clock establishes a 0.1-μs period, which is the basis for delays of from 0.3 μs to 10 s. With an external signal of 100 Hz to 12 MHz replacing the internal clock signal, the 1399 acts as a frequency divider capable of producing, for example, an arbitrary fractional frequency from an integral standard frequency or the reverse. Full control is provided over the input-circuit characteristics of both the external-clock and delay-start channels, permitting the 1399 to accept a variety of signals and to define the reference time in the delay mode.

Full programmability of all controls enables the 1399 to be a flexible component in automatic instrumentation systems operating in either the time or frequency domain. It will serve equally well as a time-interval generator and as the primary component in systems involving digital frequency synthesis.

The 1399 enables a frequency counter to be used in either of two preset modes. Acting as the time base, the 1399 can supply a frequency of any arbitrary value to normalize the counter readout to be direct reading in any desired units. Or the 1399 can count events and gate the counter to read elapsed time, as in rate-table control applications.

As a stable and precise delay generator, the 1399, with an oscilloscope, is an invaluable aid in trouble-shooting complex programs. Locked to a computer's clock, the instrument will act as a coherent, jitter-free, high-resolution sweep delay. The accuracy of delay is independent of the total delay set on the 1399's thumb wheels. The precision possible with this generator also enhances its use as a timing source for the generation of precision pulses and in the measurement of delays and time intervals by substitution methods.

— See **GR Experimenter** for January-February 1969.

specifications

Frequency Divider Ratio: 3:1 to 99,999,999:1. Delay range, 3 to 99,999,999 clock time-intervals, i.e. 0.3 μs to 9.9999999 s with 10-MHz clock.

Delay Accuracy: Delay interval varies from 0 to 1 clock interval when clock and start signals are not coherent.

INPUT CHARACTERISTICS Clock and delay-start inputs are identical except for max frequency (rate).

Rate: Delay-start input, 100 Hz to 2.5 MHz. Ext clock input, max >10 MHz, typically 12 MHz; min, 100 Hz for 1-V pk-pk sensitivity, lower frequency with reduced sensitivity.

Sensitivity: 100 mV rms; will accept waveform of arbitrary shape.

Input Impedance: Approx 100 kΩ //30 pF.

Trigger Threshold: ±1 V dc offset.

Trigger Polarity: Positive or negative, switch-selected.

INTERNAL CLOCK OSCILLATOR

Frequency Control: 10-MHz third-overtone quartz crystal in proportional-control oven.

Temperature: <1 ppm, 0°C to 50°C.

Line-Voltage Effects: Negligible.

Warmup: Within 1 ppm from room temperature in 10 min.

Short-Term Stability: 1×10^{-7} for 1-s sampling interval.

Long-Term Stability: 1×10^{-6} per year; with oscillator running continuously, $<3 \times 10^{-9}$ per day after one month of operation.

Internal Clock Output: 1 V rms into 50 Ω.

Output Pulse: 5 V behind 50 Ω, positive and negative available simultaneously. Duration approx 15 ns.

PROGRAMMABILITY All functions and control settings, except trigger threshold, controlled by single contact closures to chassis ground. Max current, 2 mA through closed contact; max voltage drop, 150 mV across closed contact.

Divider/Delay Control: 1-2-4-8 BCD; DTL logic levels or contact closures.

Trigger Threshold: 0 to +10 V into approx 100 kΩ produces −1 to +1 V threshold detection

Power Required: 100 to 125 or 200 to 250 V switch selected, 50 to 400 Hz, 20 W.

Accessories Supplied: Power cord, spare fuses, and mounting hardware with the rack model.

Mounting: Bench model (in metal cabinet) or rack model.

Dimensions (width x height x depth): Bench, 19½ x 4⅞ x 17 in. (495 x 125 x 435 mm); rack, 19 x 3½ x 16 in. (485 x 89 x 410 mm).

Net Weight: Bench, 28 lb (13 kg); rack, 21 lb (10 kg).

Shipping Weight (est): Bench, 43 lb (20 kg); rack, 36 lb (16.5 kg).

Catalog Number	Description	Price in USA
	1399 Digital Divider/Period and Delay Generator	
1399-9801	Bench Model	**$1900.00**
1399-9811	Rack Model	**1900.00**

PATENT NOTICE. See Note 10.

GENERATORS

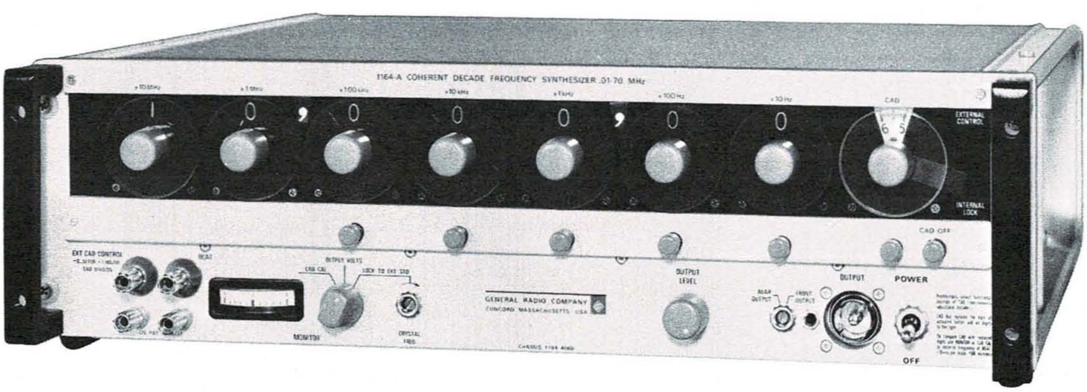
FREQUENCY SYNTHESIZERS
STANDARD-SIGNAL GENERATORS
LOW-FREQUENCY OSCILLATORS and ATTENUATORS
HIGH-FREQUENCY OSCILLATORS
PULSE GENERATORS

ENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO

COHERENT DECADE FREQUENCY SYNTHESIZERS

Types 1161, 1162, 1163, and 1164

- sine-wave outputs to 70 MHz
- single-crystal frequency control
- unlimited frequency selection
- resolution to at least 9 significant figures
- calibrated sweep/search, manual and electrical
- programmed or manual digit selection
- low cost — all-solid-state — 80-model choice
- ac or battery operation



The frequency synthesizer is, in essence, a sine-wave oscillator that has the stability characteristic of a crystal-controlled oscillator (which it is) yet is tunable over a wide frequency range with high resolution. Or, it can be considered a tunable frequency standard.

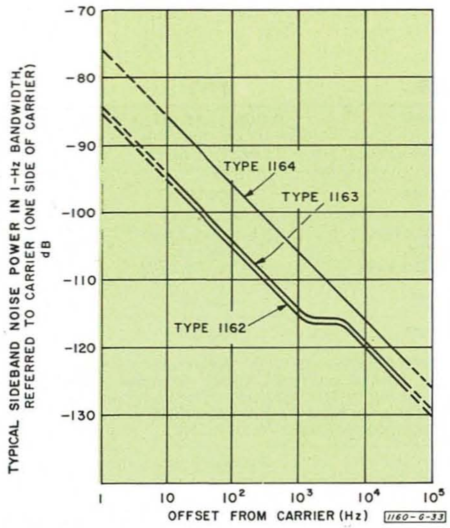
MANUAL AND ELECTRICAL TUNING

Like a decade box, the synthesizer has its output frequency set on decimal-digit switches ensuring precise resettability. Owing to its unique method of generating frequency, the synthesizer has great versatility. A calibrated, continuously adjustable decade can be substituted for most of the step decades, giving the instrument manual-search and electrical-sweep capabilities with any desired degree of fineness. GR synthesizers equipped with this continuously adjustable decade (CAD) can be manually or electrically swept over a span of from 1.2 MHz to as little as a part in 10^9 of the instrument's top frequency, a minimum sweep of 0.0001 Hz in some models.

The frequency dial of the CAD is calibrated and can be read to 2 places directly; the step decades in positions less-significant than the CAD-replaced digit are disabled and have no effect on the output frequency. However, their output is diverted to an internal comparison circuit by which the CAD setting can be calibrated readily to 4 significant places against the settings of the replaced step decades.

PROGRAMMABILITY

Each synthesizer model is available in either a manual or manual/programmable version. With the latter, as many as 7 digits of a frequency can be preprogrammed and set precisely, quickly and automatically from a remote controller. The sweep capability of GR synthesizers is, of course, also a remote-control function. The broad programmability of these instruments makes them a boon to fully automatic testing of a host of frequency-sensitive instruments and components.



Typical phase-noise power-density distribution in GR 1160-series synthesizers. See **GR Experimenter** for January 1967 for full discussion of phase noise in synthesizers.

It is fully tunable yet, once set to a desired frequency, is rock-solid — virtually a frequency standard supplying your choice of frequency. Your frequency can be set to 7 significant figures on decade-box-like dials or can be continuously tuned with a single control that can have megahertz to millihertz resolution. It's a sweep oscillator with stable markers and center frequency, with sweep width adjustable from over a megahertz to less than a millihertz. For automated measurements and computer control, any GR synthesizer can be remotely controlled — tuned to any frequency from a preset program control or as directed by a computer. In short, there are few jobs for an oscillator that a synthesizer can't do better.

RECEIVER AND HIGH-Q-FILTER TESTING

For measurements on sharply tuned devices, the stability and resolution provided by a synthesizer are absolutely necessary; the half-power points are only 50-ppm away from the resonant frequency in a crystal filter with a Q of 10,000. The dial calibration of the continuously adjustable decade obviates the need for a companion frequency counter. In sweep operation, crystal-controlled markers are available. In addition, the ability to select or to scan preset frequencies and to search or to sweep regions around them, all automatically, means faster production and acceptance testing at more frequencies than ever before possible.

RESONANCE PHYSICS

The growing areas in physical research that are coming to depend upon high-precision frequency determination for studying physical events (nuclear magnetic resonance, electron paramagnetic resonance, etc) will find great value in the synthesizer's unique combination of virtues: wide frequency range with extremely narrow-band sweeps, high-resolution frequency settability, and the ability of the synthesizer to be locked to an external signal either by a dc voltage applied to the CAD or by a 5-MHz (or a submultiple) signal applied directly to phase-lock the internal crystal oscillator.

OPTIONS

Modular construction of the GR synthesizers, besides simplifying servicing, permits GR to offer a wide choice of options to satisfy budgets and performance requirements for resolution, sweepability, and programmability. You can buy to suit initial needs; add modules later for augmented capability with no price penalty.

All step-decade modules in the 0.01-Hz to 100-kHz-per-step positions are identical and interchangeable (regardless of synthesizer model) and are readily replaceable with the programmable step-decade modules. The 1-MHz- and 10-MHz-per-step modules are peculiar to specific synthesizer models and are available in interchangeable manual or manual/programmable versions.

QUARTZ-CRYSTAL FREQUENCY SOURCE

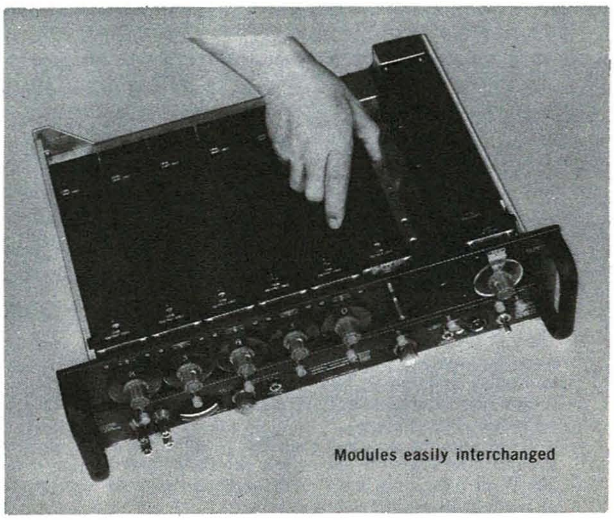
All frequencies are synthesized, coherently, from a primary oscillator employing a hermetically sealed AT-cut crystal, without oven. Temperature coefficient is low at normal operating range. In many applications where extreme precision is not required, substantial savings in cost, space, and weight are achieved.

When maximum stability is required, the synthesizer's internal standard oscillator can be readily phase-locked to an external standard frequency such as that available from the GR 1115 Standard-Frequency Oscillator.

WHY BUY A SYNTHESIZER?

Almost daily, the synthesizer is being "discovered" by people who need something better from an oscillator. Why? Because the synthesizer will do nearly everything better.

— See **GR Experimenter** for May-June 1969. Also request "Applications for Coherent Decade Frequency Synthesizers," (Form 3218).



Modules easily interchanged

specifications

Type	1161	1162	1163	1164
Output Frequency:	0 to 100 kHz	0 to 1 MHz	30 Hz to 12 MHz	10 kHz to 70 MHz
Digital Frequency Selection (per step):	0.01 Hz to 10 kHz	0.1 Hz to 100 kHz	1 Hz to 1 MHz	10 Hz to 10 MHz
Smallest Directly Indicated Frequency Increments on CAD* Dial:	0.0001 Hz	0.001 Hz	0.01 Hz	0.1 Hz
Incremental Frequency Range of CAD: (manually tuned)	-10 to $+100$ kHz down to -0.001 to $+0.011$ Hz	-0.1 to $+1.1$ MHz down to -0.01 to $+0.11$ Hz	-0.1 to $+1.1$ MHz down to -0.1 to $+1.1$ Hz	-0.1 to $+1.1$ MHz down to -1 to $+11$ Hz
RMS Phase-Noise Modulation re 1 Radian:**	-70 dB	-52 dB	-52 dB	-52 dB
RMS Amplitude-Noise Modulation re 100% Carrier:**	-70 dB	-70 dB	-60 dB	-60 dB
Reference-Frequency Source:	Internal, room-temperature, quartz-crystal oscillator with temperature coefficient typically $<2 \times 10^{-7}/°C$ from 20 to 50°C. Frequency control on front panel provides adjustment range of ±7 to ±10 ppm. For better accuracy and stability the internal oscillator can be phase-locked to an external standard-frequency source supplying 0.25 to 5 V rms (into 1 kΩ at lowest levels, dropping to 50 Ω at high) at 5 MHz or any submultiple down to 100 kHz.			

RMS Fractional Frequency Deviation:†		1161		1162		1163		1164	
	Output Frequency	Averaging Time		Averaging Time		Averaging Time		Averaging Time	
		1 s	10 ms	1 s	10 ms	1 s	10 ms	1 s	10 ms
	70 MHz							3×10^{-11}	7×10^{-10}
	50 MHz							3×10^{-11}	1×10^{-9}
	10 MHz					3×10^{-11}	3×10^{-9}	5×10^{-11}	5×10^{-9}
	5 MHz					6×10^{-11}	6×10^{-9}	1×10^{-10}	1×10^{-8}
	1 MHz			3×10^{-10}	3×10^{-8}	3×10^{-10}	3×10^{-8}	5×10^{-10}	5×10^{-8}
	0.1 MHz	3×10^{-10}	3×10^{-8}	3×10^{-9}	3×10^{-7}	3×10^{-9}	3×10^{-7}	5×10^{-9}	5×10^{-7}

Type		1161	1162	1163	1164
Spurious Signals (discrete nonharmonic):		<-80 dB	<-60 dB	<-60 dB	<-60 dB
Harmonic Signals (at max output):		<-40 dB	<-40 dB	<-30 dB	<-30 dB
Output Voltage: Monitoring Accuracy: ±0.2 V (±0.1 V above 100 kHz for 1164)		**Coupling Switch at ac:** 0 to 2 V rms, metered at output connector. 50-Ω load or higher flat to within ±1 dB above 50 Hz. **Coupling Switch at dc:** 0 to 0.8 rms, not metered, into high impedance (>100 kΩ) flat to within ±0.2 dB from 0 to 10 kHz.		**Output Impedance Switch at 50 Ω:** 0 to 2 V rms, metered behind 50 Ω $\pm10\%$. **Output Impedance Switch at 0:** 0 to 2 V rms, metered at output connector. Flat to within ±1.5 dB above 50 Hz, 50-Ω load.	0.2 to 2 V rms, metered and leveled behind 50 Ω $\pm5\%$. Output switch selects front-panel or rear connector. Leveling $\pm3\%$ ±0.02 V above 100 kHz, $\pm5\%$ ±0.02 V from 10 kHz to 100 kHz. Level is externally programmable.
Operating Temperature Range:		0 to 50°C, ambient temperature			
Power Required:		100 to 125 or 200 to 250 V, 50 to 400 Hz; or 20 to 28 V dc, 1.8 A approx			
		55 watts			60 watts
Dimensions (width x height x depth):	Bench	19 x 5½ x 15½ in. (485 x 145 x 395 mm)			19¼ in. (490 mm) deep
	Rack	19 x 5¼ x 13 in. (485 x 135 x 330 mm)			17 in. (435 mm) deep
Weight:	Net	38 lb (17.5 kg)			45 lb (20.5 kg)
	Shipping	45 lb (20.5 kg)			52 lb (24 kg)

* The CAD (Continuously Adjustable Digit) provides a frequency indication on its dial accurate to two significant figures in the internal locked mode. In the external control mode $\pm1\frac{1}{2}$ V, approx, into 6 kΩ from an external source provides frequency control over at least ±5 major divisions centered on any manual digit setting (except that in highest rank position of CAD, sweep should not exceed limits of manual tuning). Approx -0.3 V produces a + frequency change equal to one step of digit unit at pushbutton selected position of the CAD. An internal calibrating mixer produces a beat frequency proportional to the frequency difference between the CAD and the digit units it replaces (10 kHz per Δf = digit step of selected position). This beat frequency covers 0 to 110 kHz, and a level of at least 0.5 V behind 3 kΩ is provided at the BEAT terminals. The panel meter can be switched to monitor the beat frequency, providing a self-contained calibration system that can be used to set the CAD frequency to at least four significant figures.

** Phase- and amplitude-modulation noise measured in a 0.5-Hz to 15-kHz band, after the detector, without predetection filtering. These measurements are commonly expressed by signal-to-noise ratios in a 30-kHz band centered on the signal, excluding a 1-Hz band in the center. The absolute values of the figures given are identical to these ratios (in dB).

† Period measurements on low beat frequencies between the synthesizer and a low-noise standard-freqency oscillator. Beat frequency filtered by 15-kHz low-pass filter ahead of counter. Synthesizer locked to external GR 1115 Standard-Frequency Oscillator. Signal from unlocked synthesizer may be poorer for 1-s averaging time unless in a perfectly stabilized ambient temperature, but figures given for 10 ms apply.

Programmability: Programmable models (-AR) contain digit-selection units that can be remotely programmed as well as locally set. Programming speed is <200 μs to establish new frequency and cycle life is unlimited.

Programming accomplished by circuit closure to common (at ground potential) for each digit selected. Max circuit resistance, 100 Ω, or max drop, 1.3 V. Connections made by multiple-contact filter plugs at rear of instruments.

Output level of 1164 is externally programmable over a range of up to 20 dB by resistance or voltage, 5 to 25 kΩ or 6 to 10 V dc into 5 kΩ. A level change is 95% completed in 10 ms after a programmed step. Connection is provided by a type BNC connector at rear of instrument.

Auxiliary Outputs

Primary Outputs (GR874® connectors at rear of instrument — all four models): 100 kHz and 5 MHz (0.5 V rms, min into 50 Ω).

Secondary Outputs (submin connectors at rear panel):

All Types Freq	Level	Load	1162 Freq	Level	Load	1163 Freq	Level	Load	1164 Freq	Level	Load
1 MHz	0.4 V	1 kΩ	50 MHz	0.1 V	1 kΩ	39/50 MHz 1-MHz steps	0.1 V	1 kΩ	40/49 MHz 1-MHz steps	0.1 V	1 kΩ
5 MHz	0.1 V	1 kΩ	50/51 MHz	0.1 V	1 kΩ	50/51 MHz	0.1 V	1 kΩ	30 MHz	50 mV	50 Ω
5/5.1 MHz reference	0.1 V	1 kΩ							50/51 MHz	25 mV	50 Ω
5/5.1 MHz*	0.1 V	1 kΩ							90 MHz	50 mV	50 Ω
42 MHz	0.1 V	1 kΩ							ALC (input)	0-15 mA	1 kΩ (input)
dc	+18 V	0.2 A									

*Output of replaced DI modules.

Main Output and Input Connectors

Front Panel: Main output connector, recessed locking GR874; external CAD control, ¾-in.-spacing binding posts; beat output, ¾-in.-spacing binding posts.

Rear Panel: Type BNC connectors duplicating front-panel connections.

Accessories Supplied: 874-R22LA Patch Cord, bridging unit (substitute for DI-1 during maintenance) with panel insert, power cord.

Cabinet: Rack-bench; end frames for bench mounting and fittings for rack mounting are included.

COHERENT DECADE FREQUENCY SYNTHESIZERS

		with MANUAL/PROGRAMMABLE STEP DECADES — OUTPUT FREQUENCY RANGE				with MANUAL STEP DECADES — OUTPUT FREQUENCY RANGE				
	Smallest Step	0-100 kHz	0-1 MHz	30 Hz-12 MHz	10 kHz-70 MHz	0-100 kHz	0-1 MHz	30 Hz-12 MHz	10 kHz-70 MHz	
Continuously Adjustable Search/Sweep Decade (CAD) Included	0.01 Hz	**1161-AR7C** 1161-9527 **$6785.00**				**1161-A7C** 1161-9597 **$6420.00**				Type Catalog No. Price
	0.1 Hz	**1161-AR6C** 1161-9526 **$6290.00**	**1162-AR7C** 1162-9527 **$6940.00**			**1161-A6C** 1161-9596 **$5975.00**	**1162-A7C** 1162-9597 **$6575.00**			Type Catalog No. Price
	1.0 Hz	**1161-AR5C** 1161-9525 **$5795.00**	**1162-AR6C** 1162-9526 **$6445.00**	**1163-AR7C** 1163-9527 **$6920.00**		**1161-A5C** 1161-9595 **$5530.00**	**1162-A6C** 1162-9596 **$6130.00**	**1163-A7C** 1163-9597 **$6605.00**		Type Catalog No. Price
	10 Hz	**1161-AR4C** 1161-9524 **$5300.00**	**1162-AR5C** 1162-9525 **$5950.00**	**1163-AR6C** 1163-9526 **$6425.00**	**1164-AR7C** 1164-9527 **$7695.00**	**1161-A4C** 1161-9594 **$5085.00**	**1162-A5C** 1162-9595 **$5685.00**	**1163-A6C** 1163-9596 **$6160.00**	**1164-A7C** 1164-9597 **$7430.00**	Type Catalog No. Price
	100 Hz	**1161-AR3C** 1161-9523 **$4805.00**	**1162-AR4C** 1162-9524 **$5455.00**	**1163-AR5C** 1163-9525 **$5930.00**	**1164-AR6C** 1164-9526 **$7200.00**	**1161-A3C** 1161-9593 **$4640.00**	**1162-A4C** 1162-9594 **$5240.00**	**1163-A5C** 1163-9595 **$5715.00**	**1164-A6C** 1164-9596 **$6985.00**	Type Catalog No. Price
	1 kHz		**1162-AR3C** 1162-9523 **$4960.00**	**1163-AR4C** 1163-9524 **$5435.00**	**1164-AR5C** 1164-9525 **$6705.00**		**1162-A3C** 1162-9593 **$4795.00**	**1163-A4C** 1163-9594 **$5270.00**	**1164-A5C** 1164-9595 **$6540.00**	Type Catalog No. Price
	10 kHz			**1163-AR3C** 1163-9523 **$4940.00**	**1164-AR4C** 1164-9524 **$6210.00**			**1163-A3C** 1163-9593 **$4825.00**	**1164-A4C** 1164-9594 **$6095.00**	Type Catalog No. Price
	100 kHz				**1164-AR3C** 1164-9523 **$5715.00**				**1164-A3C** 1164-9593 **$5650.00**	Type Catalog No. Price
Step Decades Only	0.01 Hz	**1161-AR7** 1161-9507 **$6210.00**				**1161-A7** 1161-9417 **$5845.00**				Type Catalog No. Price
	0.1 Hz	**1161-AR6** 1161-9506 **$5715.00**	**1162-AR7** 1162-9507 **$6365.00**			**1161-A6** 1161-9416 **$5400.00**	**1162-A7** 1162-9417 **$6000.00**			Type Catalog No. Price
	1.0 Hz	**1161-AR5** 1161-9505 **$5220.00**	**1162-AR6** 1162-9506 **$5870.00**	**1163-AR7** 1163-9507 **$6345.00**		**1161-A5** 1161-9415 **$4955.00**	**1162-A6** 1162-9416 **$5555.00**	**1163-A7** 1163-9417 **$6030.00**		Type Catalog No. Price
	10 Hz	**1161-AR4** 1161-9504 **$4725.00**	**1162-AR5** 1162-9505 **$5375.00**	**1163-AR6** 1163-9506 **$5850.00**	**1164-AR7** 1164-9507 **$7120.00**	**1161-A4** 1161-9414 **$4510.00**	**1162-A5** 1162-9415 **$5110.00**	**1163-A6** 1163-9416 **$5585.00**	**1164-A7** 1164-9417 **$6855.00**	Type Catalog No. Price
	100 Hz	**1161-AR3** 1161-9503 **$4230.00**	**1162-AR4** 1162-9504 **$4880.00**	**1163-AR5** 1163-9505 **$5355.00**	**1164-AR6** 1164-9506 **$6625.00**	**1161-A3** 1161-9413 **$4065.00**	**1162-A4** 1162-9414 **$4665.00**	**1163-A5** 1163-9415 **$5140.00**	**1164-A6** 1164-9416 **$6410.00**	Type Catalog No. Price
	1 kHz		**1162-AR3** 1162-9503 **$4385.00**	**1163-AR4** 1163-9504 **$4860.00**	**1164-AR5** 1164-9505 **$6130.00**		**1162-A3** 1162-9413 **$4220.00**	**1163-A4** 1163-9414 **$4695.00**	**1164-A5** 1164-9415 **$5965.00**	Type Catalog No. Price
	10 kHz			**1163-AR3** 1163-9503 **$4365.00**	**1164-AR4** 1164-9504 **$5635.00**			**1163-A3** 1163-9413 **$4250.00**	**1164-A4** 1164-9414 **$5520.00**	Type Catalog No. Price
	100 kHz				**1164-AR3** 1164-9503 **$5140.00**				**1164-A3** 1164-9413 **$5075.00**	Type Catalog No. Price

PATENT NOTICE. See Note 28.

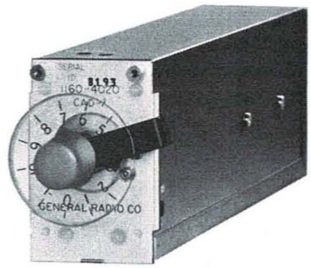
Prices in USA only.

1163-AR4C
- C — CAD Included
- 4 — Number of Step Decades Included
- R — All Step Decades Programmable
- 1163 — Basic Synthesizer type number

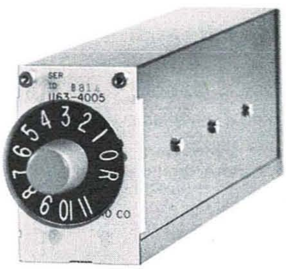
SYNTHESIZER MODULES

1160-RDI-1B

Sold only as replacements or to fill out partially equipped synthesizers.



1160-CAD-1



1163-RDI-4
others similar

1160-CAD-1 — CONTINUOUSLY ADJUSTABLE DECADE MODULE

The 1160-CAD-1 Continuously Adjustable Decade module is available to add increased versatility and extended resolution to **any** synthesizer purchased without this decade. The CAD adds two calibrated digits to the readout directly and three or more if it is first calibrated against the step decades. It can convert any step decade (and all to its right) to continuously adjustable operation at the push of a button. The capability of instantaneous self-check is another advantage furnished a synthesizer to which the CAD is added. The module is complete and ready to plug into the decade station at the right-hand end of any of the synthesizers. The change takes only minutes and requires no special tools.

Net Weight: 1¾ lb (0.8 kg).

1160-RDI — PROGRAMMABLE STEP-DECADE MODULES

The 1160-RDI Digit-Insertion Units (remote or manual control) are offered to permit programmed frequency selection in the step decades of **any** of the synthesizers. They can fill out partially complete synthesizers or convert manual instruments, partially or fully, to programmed operation. The modules are complete and ready to plug in. The change takes only minutes and requires no special tools. A filter-plug at the rear can be cabled to a programmer for fast, automatic operation. Control-cable filtering circuits are included in the plug.

FOUR MODELS

The 1160-RDI-1B unit will operate in any station of any synthesizer up to the X1-MHz position from a 10-line command input. The 1163-RDI-4 operates in the X1-MHz position of an 1163 synthesizer, controlled from a 12-line input. The 1164-RDI-2 replaces the manual step-decade module in the X1-MHz position of an 1164-series synthesizer. The 1164-RDI-3 operates in the X10-MHz position in the 1164 model synthesizers with a 7-line command input for full programmability to 70 MHz.

Net Weight: 1½ lb (0.7 kg).

HOOK-UP CABLE FOR RDI

A special, 12-conductor, shielded cable is recommended for connection of the 12-pin filter-plug to remote equipment. One 50-foot roll of cable is furnished with each synthesizer containing an RDI unit but is not supplied with an individually purchased RDI. Additional 50-foot lengths can be ordered.

Net Weight: 2½ lb (1.2 kg).

1160-P2 — SWEEP AND MARKER GENERATOR

This instrument permits advantage to be taken of the sweep capability of any GR synthesizer that contains the CAD continuously adjustable decade. The 1160-P2 sweeps the CAD frequency over a width adjustable from ±1 to ±5 CAD divisions (up to ±10 divisions with CAD at center of dial). The actual sweep width can range from 1.2 MHz to ±1/10 the frequency interval-per-step of the least significant decade and, except for widest sweeps, can be centered on any frequency in the synthesizer's normal operating range. The oscilloscope-horizontal sweep voltage provided is independent of the frequency sweep width selected. Slow automatic and manual sweep speeds, very narrow sweep widths, and stable center frequency and markers make this system particularly useful for testing high-Q devices.

The 1160-P2 generates a synthesized marker that occurs at the frequency to which the step decades are set. Side markers can be located symmetrically 1.0 to 5.9 CAD divisions from the center marker. Actual frequency spacing of these markers depends upon the functional position of the CAD unit.

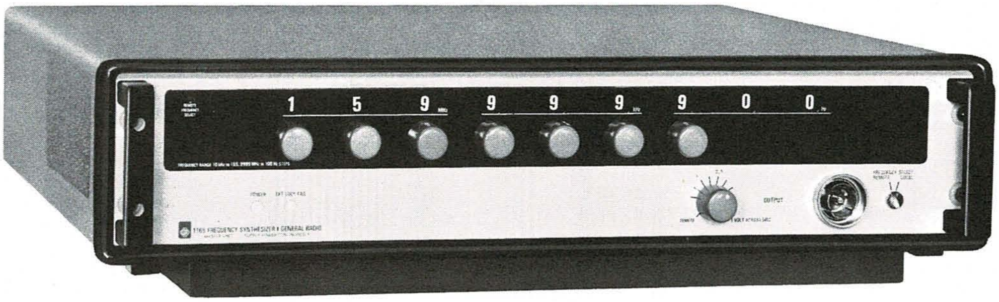
— See **GR Experimenter** for January 1967.

Net Weight: 12 lb (5.5 kg).

Catalog Number	Description	Price in USA
1160-9485	**1160-RDI-1B Digit-Insertion Unit,** without filter plug	**$455.00**
1160-9432	**1160-CAD-1 Continuously Adjustable Decade** (includes Calibrating Mixer Unit)	**585.00**
	Programmable Digit-Insertion Units	
1160-9480	**1160-RDI-1B,** with filter plug, up to 100 kHz/step, all synthesizer models	**505.00**
1163-9479	**1163-RDI-4,** 1 MHz/step, in 1163 models	**600.00**
1164-9479	**1164-RDI-2,** 1 MHz/step, in 1164 models	**575.00**
1164-9489	**1164-RDI-3,** 10 MHz/step, in 1164 models	**600.00**
1160-9650	**Hook-Up Cable** for all RDI's, 50-ft, 12-conductor, shielded	**15.00**
1160-9600	**1160-P2 Sweep and Marker Generator**	**550.00**

Type 1165 FREQUENCY SYNTHESIZERS

- 10 kHz to 160 MHz
- 100-Hz steps, 7-dial resolution
- 100-mV to 1-V calibrated output
- low drift, $\approx 1 \times 10^{-9}$ per day
- manual or programmable frequency and output selection
- phase-modulation provision



The Type 1165 Frequency Synthesizers provide highly stable, accurate frequencies, manually adjustable or remotely programmable over a range of 10 kHz to 159.9999 MHz. Accuracy and stability are those of a single-frequency driving source.

MANUAL OR REMOTE FREQUENCY SELECTION

Panel dials provide direct decimal setting of the output frequency with 100-Hz resolution. Control can be transferred to external 1-2-4-8 BCD selection of each digit by a single selector located on the front panel. The logic levels are 0 and +5 volts nominal and are compatible with standard DTL or TTL integrated logic circuits. For the two most-significant digits, all 16 digits of the binary code are used.

MANUAL OR REMOTE OUTPUT-LEVEL CONTROL

An output level of 100 mV to 1 V rms into 50 ohms from an effective 50-ohm internal source can be set by a calibrated panel control or remotely controlled by an externally applied dc voltage exactly four times the desired rms output voltage.

PHASE MODULATION

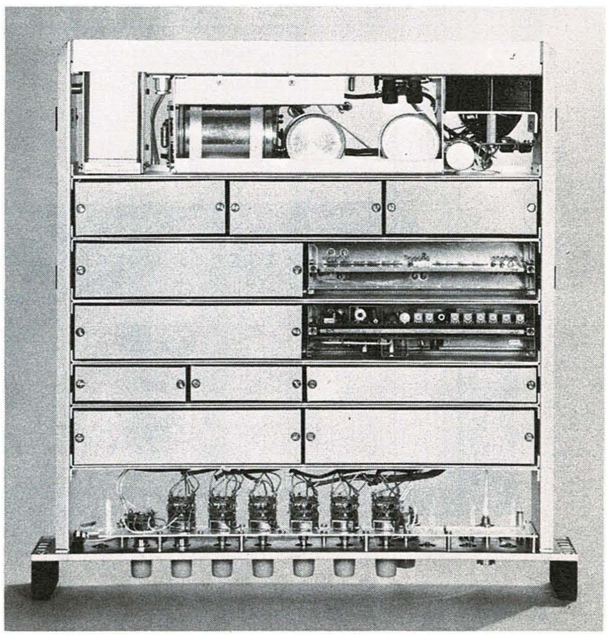
Phase modulation at rates from dc to 1 MHz can be applied.

MASTER OR SLAVE VERSIONS

Two versions of the instrument are available, master and slave. The master version contains a built-in precision quartz crystal oscillator. It can be locked to an external frequency standard or an external source can be substituted for the internal oscillator. The slave version contains no internal oscillator. It must be driven by an external source which can be the auxiliary 10-MHz output of a master version, another slave version, or any other precision 5- or 10-MHz source. Any number of slave versions can be cascaded if the first one is driven from a suitable external source.

MODULAR CONSTRUCTION

With the exception of the power supply and precision oscillator or input-drive circuit, all circuits are carried by plug-in etched-circuit boards. These plug into a number of tightly shielded enclosures whose covers are forced on or off by captive screws for quick accessibility. Most enclosures carry two related circuit boards.



COMPACT UNCLUTTERED PANEL

Large in-line numerals behind windows in the 3½-inch-high panel indicate the manually selected frequency. An indicator lamp shows when the frequency is to be selected by remote control. Another lamp warns of failure to lock to an external source if such operation is selected by the connection of a patch cable to the external-lock input connector at the rear of a master version. A power indicator lamp shows that power is being supplied. The output connector can be transferred between the front and the rear of the instrument as desired, with a filler plug occupying the unused position. Relay-rack or bench mounting is available.

specifications

Frequency: 10kHz to 159.9999 MHz. Controlled by one 2-position and six 10-position in-line readout dials or by external binary and 1-2-4-8 BCD signals (two most-significant digits use all 16 combinations of binary, remaining digits are BCD). Logic 1 must be 0 to +0.5 V at 3 mA; logic 1 must be allowed to rise to +5V (internal pullup ≈ 2 kΩ). Signals are applied to rear-panel Amphenol Type 57 connector. Manual or remote control is selected by a single panel control operated by a screwdriver or coin. *Programming time:* <200 μs for 100-kHz steps and above, <50 ms for 10-kHz steps and below.

Accuracy: Equal to that of drive source. Drive source is internal, external lock, or external drive for master version; external drive only for slave version. *Internal oscillator* is 10-MHz precision oscillator in proportional-control oven; *adjustment range,* $\pm 2 \times 10^{-6}$ at rear-panel control; *stability,* $<2 \times 10^{-10}/°C$ from 0 to 50°C when operated continuously; *drift,* $\pm 1 \times 10^{-8}$/wk, $\approx 1 \times 10^{-9}$/day after one month of continuous operation; *with 10% line-voltage variation,* $<2 \times 10^{-10}$; *restabilizes* to within $\approx 1 \times 10^{-8}$ two hours after power interruption.

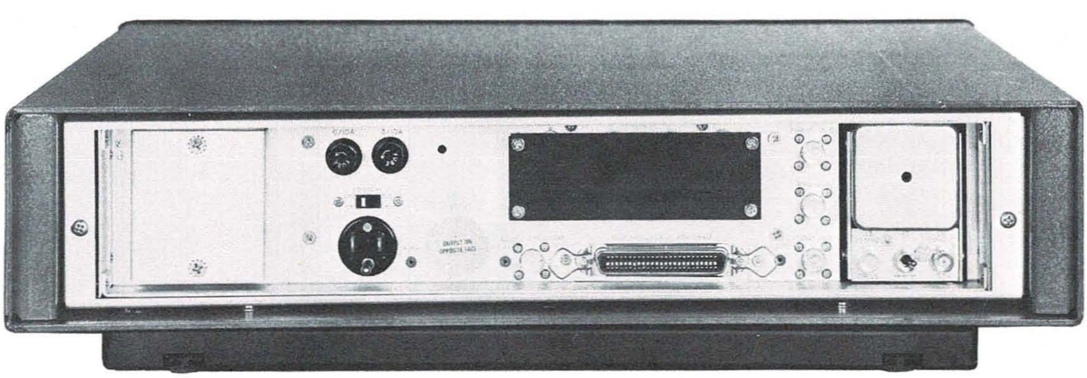
Master-Version External Lock: Internal oscillator can be locked to external signal of 5 MHz (or integer sub-multiple down to 100 kHz), 0.1 V rms min into 1 kΩ, 3 V max into 50 Ω, applied to rear-panel BNC connector. After power interruption, 25 m warm-up required for oscillator to stabilize within lock range.

Master-Version External Drive: A switch permits choice of internal drive or external drive at 10 MHz, 1 ± 0.1 V rms into 50 Ω, applied to rear-panel BNC connector.

Slave-Version External Drive: Slave version requires external drive of 5 MHz or 10 MHz, 0.125 V min to 3 V max into 50 Ω, applied to rear-panel BNC connector. Drive can be supplied by master-version 10-MHz output or by another slave version.

Output: 0.1 to 1 V into 50 Ω, 50-Ω source, available at GR874® recessed locking connector that can be mounted on front or rear panel. Level set by calibrated panel control or by an external dc control signal equal to +4 × desired output voltage (rms) into 100 kΩ. *Programming time,* <10 ms to within 0.5 dB. *Accuracy of control,* ± 2 dB. (See table below.)

	10 kHz	100 kHz	1 MHz	10 MHz	110 MHz	150 MHz	160 MHz
Fractional Frequency Deviation, rms							
10-ms averaging time		5×10^{-7}	5×10^{-8}	5×10^{-9}		7×10^{-10}	
1-s averaging time		5×10^{-9}	5×10^{-10}	5×10^{-11}		3×10^{-11}	
Output Level, full output	± 0.5 dB	± 0.3 dB					
Output Level, 1/10 output	± 1.5 dB	± 1.3 dB					
Harmonics, full output	−25 dB	−30 dB					
Discrete Non-Harmonics	−60 dB				−55 dB		
Noise Modulation phase, rms	−48 dB, re 1 radian, ±0.5 Hz to 15 kHz						
amplitude, rms	−58 dB, re 100% carrier, ±0.5 Hz to 15 kHz						



Phase Modulation: Output can be phase modulated ± 3 radians from dc to 300 kHz, ± 1 radian at 1-MHz modulation frequency, by external signal of 1 V/radian at dc, flat within 2 dB to 300 kHz, into 7.5 kΩ applied to rear-panel BNC connector.

Auxiliary Outputs: 10 MHz at 0.5 V rms into 50 Ω and 1 MHz at ≥2 V pk-pk into 10 kΩ available at rear-panel BNC connectors; +18 V at 100 mA max, + 5.6 V at 100 mA max, and −12 V at 100 mA max available at rear-panel phone tip jacks.

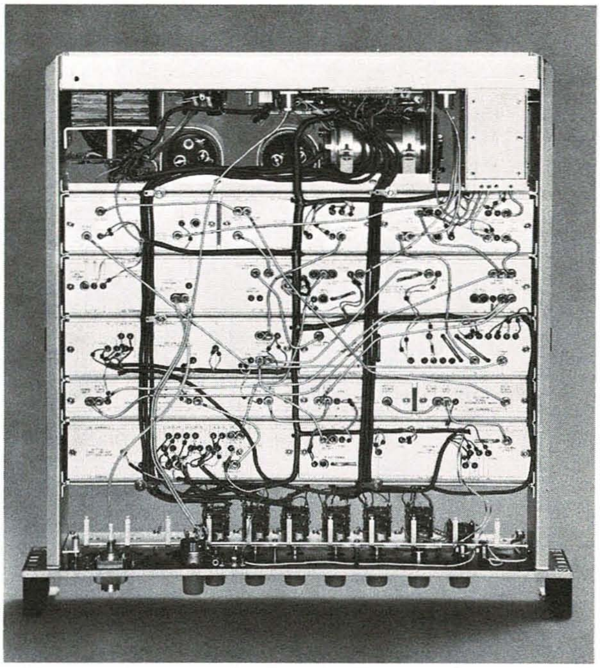
Supplied: Power cord, 874-R22LA Patch Cord for output.

Available: GR874 adaptors, 1115-C Standard-Frequency Oscillator as external lock or external drive source.

Power: 100 to 125 or 200 to 250 V, 50 to 60 Hz, 50 W.

Mechanical: Rack or bench mount. *Dimensions* (w x h x d): Bench, 19½ x 3⅞ x 20⅞ in. (495 x 99 x 535 mm); rack, 19 x 3½ x 18¼ in. (485 x 89 x 465 mm).

Catalog Number	Description	Price in USA
	1165 Frequency Synthesizer, master version	
1165-9720	Bench	**$5900.00**
1165-9721	Rack	**5900.00**
	1165 Frequency Synthesizer, slave version	
1165-9722	Bench	**5300.00**
1165-9723	Rack	**5300.00**



Standard-Frequency Oscillator
page 190

STANDARD-SIGNAL GENERATORS

A standard-signal generator is a source of alternating-current energy of accurately known characteristics. The carrier, or center, frequency is indicated by a dial setting, the output voltage by a meter reading and associated attenuator setting, and the modulation by a meter reading set by appropriate control knobs. Common types of modulation signals are sine-wave, square-wave, and pulse; the output signal may be either frequency- or amplitude-modulated by these signals. When the frequency-modulation system produces a considerable excursion in frequency at a relatively low-cyclical rate, the instrument is known as a sweep-frequency generator and is particularly useful for automatic data display. Standard-signal generators are used for testing radio receivers, as voltage standards over the range from fractional microvolts to about a volt, and generally as power sources in measurement of gain, bandwidth, signal-to-noise ratio, standing-wave ratio, and other circuit properties.

For use as a standard-signal generator, the oscillator must be stable, have reasonably constant output over any one frequency range, have good waveform, and have no appreciable hum or noise modulation. Careful over-all shielding of the generator is essential in order to minimize stray fields.

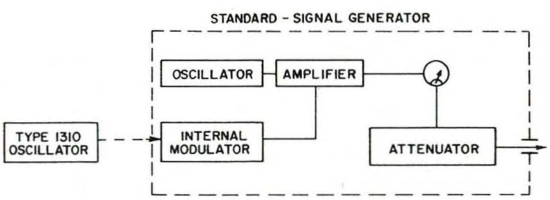


Figure 1. Elements of a standard-signal generator.

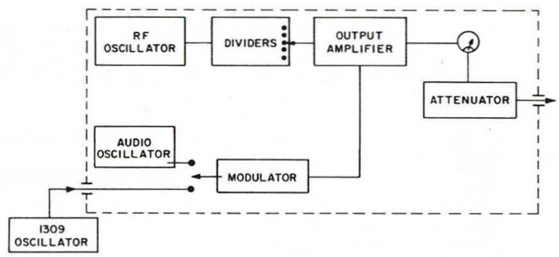


Figure 2. High-stability standard-signal generator.

The elements of a typical amplitude-modulated standard-signal generator are shown in Figure 1. A standard-signal generator, which is capable of unusual frequency stability, is shown in Figure 2.

AMPLITUDE-MODULATED SIGNAL GENERATORS

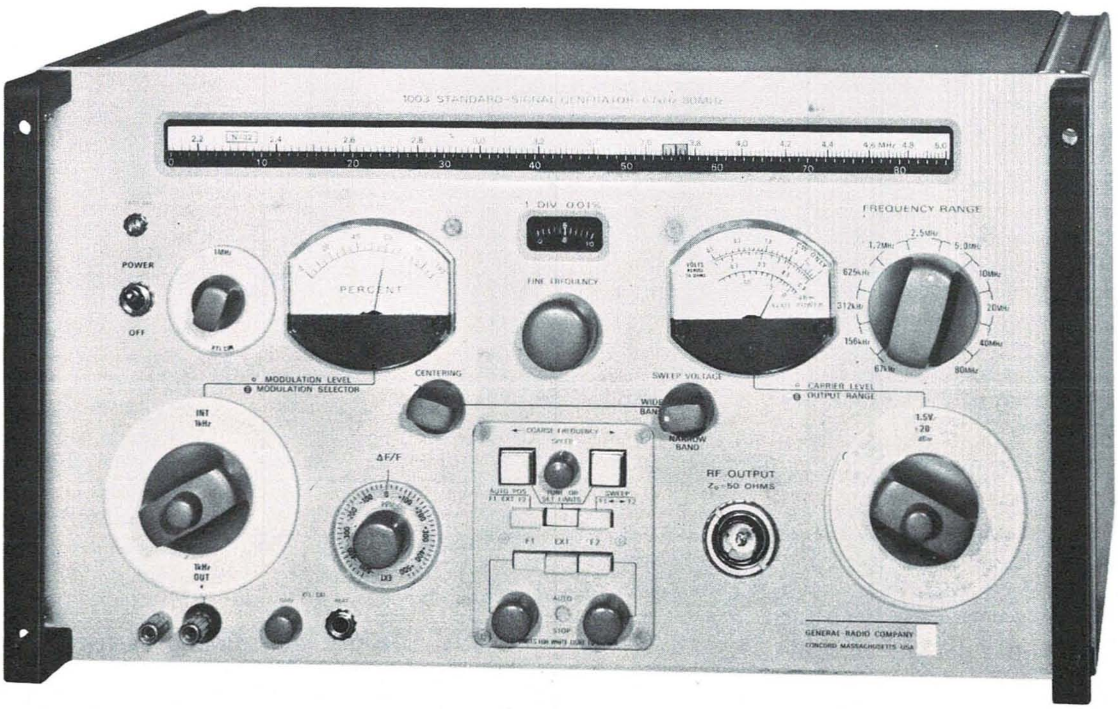
The three General Radio amplitude-modulated standard-signal generators are general-purpose, wide-tuning-range instruments covering the range from 5 kHz to 500 MHz. Amplitude modulation is provided from an internal, fixed-frequency, sine-wave generator or from an external audio-frequency source. In addition to a choice of frequency ranges, the GR generators offer a wide selection of performance features: high output, excellent shielding for accurate low-level output, levelling, modulation versatility, and unusually good stability. Each instrument offers a well balanced combination of features that allow the user to make fast and accurate measurements over a wide range of test conditions.

	Type	Frequency Range	Output Voltage	Output Impedance	Modulation
Standard-Signal Generators	**1001-A**	5 kHz to 50 MHz	0.1 μV to 200 mV*	10 Ω, 50 Ω	0-80%
	1003	67 kHz to 80 MHz	0.05 μV to 3 V†	50 Ω	0-95%
	1026	9.5 to 500 MHz	0.05 μV to 5 V†	50 Ω	0-95%
Accessories	**1000-P4**	Dummy Antenna			
	1000-P5	VHF Transformer (50 ohms grounded to 300 ohms balanced)			
	1000-P10	Test Loop			

* Open circuit. † Across 50 Ω.

Type 1003 STANDARD-SIGNAL GENERATOR

- 67 kHz to 80 MHz
- 1 ppm typical over-all stability
- variable-speed sweep
- optional programmability and crystal calibrator
- 180 mW output (3 V across 50 Ω)
- 0 to 95% a-m



An innovation in signal-generator-circuit concepts in the GR 1003 brings about a 10-to-1 improvement in frequency stability without sacrificing the other performance features expected in a fine signal generator. The frequency-generating system is a single-range, highly stable oscillator followed by frequency dividers to provide the successively lower ranges. Thus the high stability of one range is the stability of all, and range switching is accomplished without any transient instability.

All-solid-state design ensures both low-drift warmup to the 1003's ultimate stability and high reliability expected from cool-running components.

APPLICATIONS

Important in the testing of devices with steep-slope frequency characteristics are the stability, residual fm, and settability of the signal source. Noise, drift, or poor resolution can make it impossible to determine the test frequency accurately enough. The 1003 eliminates these obstacles without introducing spurious outputs, tuning complications, and potential signal leakage.

SWEEP OPERATION AND AUTOMATIC TUNING

Two models of the 1003 contain the Auto-Control/Sweep Unit which enables the generator to be tuned automatically on command to within 0.1% of any preset frequencies. Two frequencies, which will also act as limits for sweep operation, can be set on front-panel controls; additional frequencies can be preset externally for automatic tuning. In the swept mode, the sweep rate can be set from 0.05 to 5% per second and the sweep limits from 0.2% of the center frequency to the full width of the frequency range in use. Two potentiometers generate horizontal-sweep voltages with resolution suitable for both narrow- and wide-band sweeping. The rf output is blanked during return sweep and an external blanking voltage is also generated.

The simpler manual-control models use a fast, fixed-speed drive motor for rapid coarse tuning and a very fine manual vernier; this combination justifies the use of a long, high-resolution frequency scale.

FREQUENCY CONTROL

Vital to the use of a standard-signal generator is the accuracy with which frequency can be determined, both absolute and relative. The long slide-rule scale of the 1003 is calibrated to within 0.25% for absolute frequency readings; this main tuning control also has a vernier scale that permits small changes and interpolation between crystal-calibrator frequencies to be made to a resolution of 0.01%.

A separate front-panel Δf control, calibrated in ppm, tunes electronically over a ±500-ppm range with a resolution of 2 ppm. External control of this electronic tuning facilitates phase locking the generator frequency and gives a limited fm capability.

With external counters, for which outputs are provided, these high-resolution capabilities can be further extended to absolute frequency settability.

Thus, the excellent stability and control of the 1003 ensures that its frequency will change only when, and by the exact amount, desired by the operator.

MODULATION

Internal 400- and 1000-Hz a-m is adjustable and metered 0 to 95%; it has very low distortion owing to the use of envelope feedback. External a-m is provided for with a 20-kHz ac mode and a direct-coupled mode for remote level control and low-frequency square-wave modulation. Incidental fm is unusually low.

— See **GR Experimenter** for July-August 1967 and September-October 1969.

specifications

FREQUENCY

Range: 67 kHz to 80 MHz in 10 ranges: 67 to 156, 135 to 312, 270 to 625, 540 to 1250 kHz, 1.08 to 2.5, 2.16 to 5, 4.32 to 10, 8.64 to 20, 17.28 to 40, and 34.56 to 80 MHz.

Calibration Accuracy: ±0.25%, typically ±0.1%; scale logarithmic, 140 in. total length. Logging scale with vernier, 8500 div, 0.01%/div.

Mechanical Tuning (all models): Manual fine tuning, 1% per revolution of frequency control, calibrated in .01% increments. Fast tuning by push-button-controlled drive motor.

Auto-Control Tuning (in Auto-Control models only): Tunes on command to preset frequencies (two settable by front-panel controls, others by external voltages or voltage dividers). Tuning speed approx 5% per second; positioning accuracy, 0.1%.

Sweep Operation (in Auto-Control models only): Sweep width adjustable from 0.2% of center frequency to full width of selected range. Sweep rate adjustable from Δf/f of 0.05% to 5% per second. Sweep-voltage output, 1.0 V per 1% frequency change for sweep widths up to 4% (±2% of center frequency). For wide sweeps, output is approx 65 mV for 1% frequency change. Either output can be centered with respect to ground. Blanking voltage, +9 V behind 15 kΩ (separate from sweep voltage) available during return sweep.

Analog Output (in Auto-Control models only): Voltage proportional to shaft position or logging scale, positive-going from approx —7 V behind 7500 Ω to approx 0 V or about 82 mV per 1% frequency change.

Electronic Tuning: Internal, ±500 ppm nominal, settable to better than 2 ppm; external, approx 60 ppm/volt up to ±1000 ppm typical, limited fm capability. Max input ±15 V into 15 kΩ (+ volts increase frequency).

Stability: After warmup <5 ppm per 10 min, typically 1 ppm. Frequency will vary less than 1 ppm as a result of ±10% line-voltage changes, range switching (instant restabilization), rf-level adjustments, or load variations. Warmup drift typically 150 ppm in 3 h at 20°C.

Crystal Calibrator (in some models): Markers at 50-kHz, 200-kHz, and 1-MHz intervals, accurate to 20 ppm. Beat level adjustable and suitable for sweep-calibration purposes.

Carrier Distortion: < 5% typical.

Noise: A-M due to hum and noise within 15 kHz down at least 80 dB relative to carrier. Residual fm, < 3 Hz pk at high-frequency end and < 1 Hz pk at low-frequency end.

RF OUTPUT

Range: CW, 0.05 μV to 3 V across 50 Ω; —133 to +22.6 dBm (180 mW). Modulated, 0.05 μV to 1.5 V across 50 Ω; —133 to +16.6 dBm (45 mW).

Source Impedance: 50 Ω. SWR is <1.02 with attenuator set for 0 dBm or less, <1.05 for +10 dBm, <1.20 for +20 dBm.

Level Control: Total range, 155 dB. Step attenuator, 140 dB in 10-dB steps; continuously adjustable level control, >10 dB additional.

Accuracy of Leveled Output Power: ±1 dB at any frequency and termination. Attenuator, ±0.1 dB per 10-dB step, max accumulated error, ±0.5 dB.

Level Stability: Warmup drift <0.3 dB, temperature effects <0.01 dB/°C, line-voltage variations <0.02 dB.

Meter: Reads volts across 50 Ω and dBm.

MODULATION

Level: 0 to 95%, continuously adjustable. Stable within ±1 dB independent of carrier or modulation frequency (within modulation bandwidth) and output level.

Modulation Bandwidth: At 100-kHz carrier, max modulation frequency is 500 Hz for 95% a-m and 2 kHz for 30% a-m. Above 1-MHz carrier, max is 3 kHz for 95%; above 2.5-MHz carrier, max is 10 kHz for 50%.

Meter: Reads 0 to 100%. Accuracy ±5% fs with int mod, ±10% fs with ext mod, 0 to 95% within modulation bandwidth.

Incidental Angle Modulation: <0.1 radian pk at 30% a-m.

Internal

Frequency: 400 and 1000 Hz, ±0.5%. Output of 2 V behind 100 kΩ available at panel connector.

Envelope Distortion: <1% at 50% a-m, <2% at 70% a-m.

External

AC-Coupled: 20 Hz to 20 kHz, 2 V into 2.5 kΩ for 95% modulation within modulation bandwidth.

Direct Coupled: Dc to 20 kHz. Carrier off with 0-volt input; 1.5-V output into 50 Ω with +5V into 10 kΩ. Max input 10 V pk.

AUXILIARY MONITORING OUTPUTS

Main-Output Frequency: At least 0.5 V pk-pk into 50 Ω (cw) at output carrier frequency.

Subharmonic Frequency: At least 0.3 V pk-pk (approx square wave) behind 150 Ω. Frequency (between 67 and 156 kHz) is coherent with and integrally related to carrier frequency by factor N shown on main dial.

GENERAL

Leakage: Effects negligible on measurements of receiver sensitivity down to 0.1 μV.

Environment: 10 to 50°C ambient for specified performance.

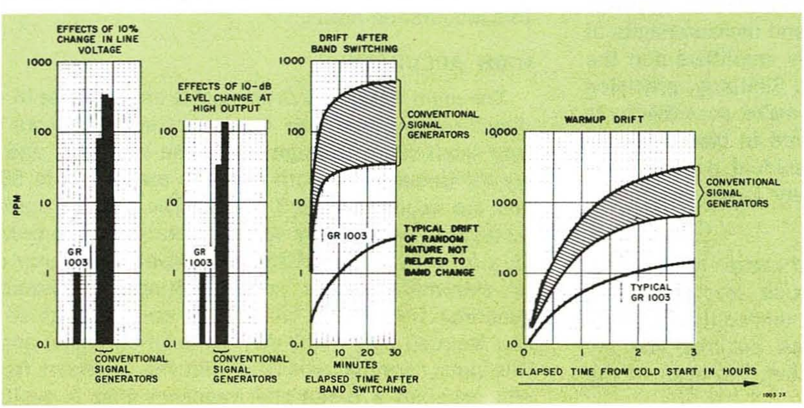
Accessories Supplied: 874-R22LA Patch Cord, power cord, two 12-terminal connectors for external controls, hardware for both bench and rack mounting.

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 60 Hz, 20 W (33 with motor running). Auto-Control models only, 50 to 400 Hz, 28 W with motor running.

Dimensions (width x height x depth): Bench, 19 x 11 x 15¼ in. (485 x 280 x 390 mm); rack, 19 x 10½ x 12¾ in. (485 x 270 x 325 mm).

Weight (approx): Net, 64 lb (30 kg); shipping, 87 lb (40 kg).

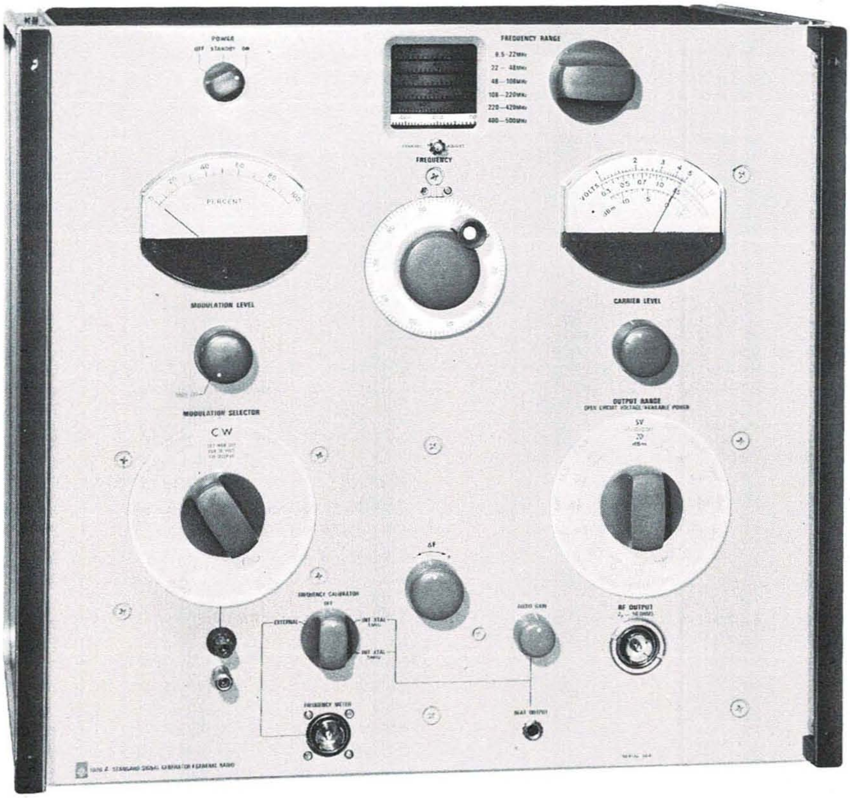
Catalog Number	Description	Price in USA
	1003 Standard-Signal Generator	
1003-9701	basic model	**$2940.00**
1003-9702	with Auto-Control/Sweep Unit	**3300.00**
1003-9703	with Crystal Calibrator	**3150.00**
1003-9705	with Auto-Control and Crystal Calibrator	**3510.00**



The stability of the 1003 compared with that of other signal generators.

Type 1026 STANDARD-SIGNAL GENERATOR

- 9.5 to 500 MHz, single-dial tuning
- 5-V output across 50 Ω (500 mW), leveled
- crystal calibrator
- incidental fm <1 ppm + 100 Hz
- audio, video, and pulse a-m
- fm and phase-lock capability



This vhf signal generator was designed to meet the most exacting requirements for measurements on a-m receivers, filters, attenuators, and other components and incorporates many convenience features to let the operator give his full attention to the measurement rather than the instrumentation. The ease of operation and outstanding performance of the 1026 in the most critical applications must be experienced to be appreciated.

Unusually high-level output signals are available for antenna-pattern and impedance measurements, receiver overload and cross-modulation tests, and measurements of large insertion losses without auxiliary amplifiers and the attendant setup and tuning problems. Similarly, precision attenuation and excellent shielding make possible tests with the very low signal levels required in other receiver measurements. Carrier distortion, residual a-m and fm, and incidental fm are all kept to very low levels.

LEVELING

High-gain feedback of the detected carrier to the modulation amplifier provides very precise leveling in all modes of operation, modulated and unmodulated. With audio modulation, envelope feedback ensures low envelope distortion; with pulse modulation, the peak of the pulsed carrier is leveled.

MODULATION VERSATILITY

Amplitude modulation up to 95% can be imposed on the carrier from a highly stable internal 1-kHz oscillator or from an external audio source. The dc-coupled modulation input eliminates low-frequency phase-shift modulation. The characteristics are suitable for glide-slope and omni-range receivers. In addition, the generator has provisions for wide-band external modulation to 300 kHz and for pulse modulation with an on-off ratio typically greater than 40 dB at full output. An accurate panel meter monitors modulation levels.

HIGH ACCURACY

The main frequency drum scales are accurate to ±0.5% direct reading and can be calibrated even more closely over small spans through use of the internal 1 and 5 MHz crystal frequencies, both of which are usable to 500 MHz and are accurate to ±0.001%. The fiducial mark is adjustable to permit easy scale calibration. Also provided is an auxiliary output sufficient to drive a frequency counter for extreme precision in the setting and measuring of generator frequency. This output can be disabled at will and isolated by > 100 dB. An external signal applied to this same terminal will beat with the generator frequency and generate a difference frequency that is available at the BEAT output jack; thus the 1026 will serve as a heterodyne frequency meter as well.

FM AND PHASE-LOCKED OPERATION

The generator frequency can be electrically controlled by an external dc or audio frequency signal. Good linearity is attained for narrow-band fm throughout the carrier frequency range; in the important 88-108 MHz range, peak deviations up to 100 kHz are readily obtainable. Using an external phase detector and dc amplifier, one can phase-lock the generator frequency to an external frequency standard for stability.

CONVENIENT

Many features are included which not only mean convenience for the operator but will also reduce potential errors and permit operation by less-skilled personnel. True single-dial frequency control speeds frequency setting and eliminates the misadjustments possible with signal generators in which the amplifier tracking depends upon auxiliary-trimmer adjustment by the operator. A parallax-free fiducial mark and illumination of only the scale in use reduce possible error in frequency readings. All controls and indicators are grouped by function, and their use is self-evident, obviating frequent reference to operating instructions. Output connectors are easily convertible to practically any common coaxial connectors with GR874® adaptors.

— See **GR Experimenter** for March 1967.

specifications

FREQUENCY

Range: 9.5 to 500 MHz in 6 ranges: 9.5 to 22, 22 to 48, 48 to 108, 108 to 220, 220 to 420, and 400 to 500 MHz.

Manual Control: Main frequency control, spinner knob with 100-division vernier dial (25 turns per range) drives main drum-type dial. Illuminated scale indicates selected range. Parallax-free fiducial mark is adjustable for fine calibration. Scales to 108 MHz are linear. An uncalibrated Δf control spans typically ±0.003% at low end of range to ±0.015% at high end (actual spans may vary 2:1 depending on frequency range).

Scale Characteristics (scales on 3 lower ranges are linear):

Frequency Range (MHz)	Main Scale Interval	kHz per Vernier Division	Scale Length (in.)
9.5-22	100 kHz	5	14¼
21.2-49.6	200 kHz	11	14¼
47.4-111	500 kHz	25	14¼
100-220	1.0 MHz	45-60	13
216-430	2.0 MHz	80-150	10½
400-500	2.0 MHz	150	4

External Electrical Fine Frequency Control: Applied voltage of ±20 V dc varies frequency typically ±0.04% at low end of range to ±0.2% at high end (actual variation may differ by 2:1 depending on frequency range).

Stability: After 1-h warmup, drift rate is typically <50 ppm per 10 min for carrier frequencies <400 MHz; from 400 to 500 MHz, rate is typically <100 ppm per 10 min. Following frequency change <10 min is required for restabilization.

Calibration Accuracy: ±0.5% direct reading, after initial adjustment of fiducial. With internal crystal calibrator, ±0.01% at 1.0-MHz intervals, typically ±0.05% by interpolation.

Calibration Provisions: Internal crystal frequency, accurate to ±0.001%, provides calibration at intervals of 1 and 5 MHz over entire frequency range. Calibration by external counter provided for by output of about 0.1 to 1 V behind 50 Ω. When not needed, this output can be disabled with > 100-dB isolation; external counter can be simultaneously disabled by a contact closure provided to eliminate interference from the counter's internal signals.

Harmonic Output: At least 30 dB below carrier.

RF OUTPUT

Range: CW, 0.05 μV to 5 V across 50 Ω, ½ W into 50 Ω (—133 to +27 dBm); modulated 0.05 μV to 2.5 V across 50 Ω (—133 to +21 dBm). Load SWR > 2.0 may restrict the max output available at some frequencies.

Control: Step attenuator, 140 dB in 10-dB steps, voltage and dBm calibration. Continuous interpolation with metered level control.

Meter Scales: 0.15 to 0.8 V, 0.5 to 2.5 V, and —13 to +1 dBm. Scale extensions (in red), for cw use only, to 5 V and to +7 dBm.

Accuracy: Metering, ±5% to 108 MHz; above 108 MHz, harmonics can add ±3% and rectifier characteristic can add ±2%. Attenuator, ±1% (±0.1 dB) per step to —110 dBm; ±2% (±0.2 dB) from —110 to —120 dBm; max accumulated error ±0.5 dB.

RF Interference: Leakage has negligible effect on measurements of receiver sensitivity down to 0.1 μV.

Leveling: CW output is held at preset level to within ±3% (0.3 dB) up to 108 MHz and to within ±5% (0.5 dB) to 500 MHz as frequency is varied, including effects due to range switching. Effectiveness of leveling under modulated operation is a function of modulation mode and frequency.

Stability: At any given frequency, in cw operation or internal 1-kHz modulation mode, and after 2-hour warmup, output will typically remain constant within ±0.0025 dB per minute, or ±0.01 dB over any 15-min period. Also under these conditions, variation due to ±10% line-voltage fluctuation is < ±0.005 dB.

Effective Generator Impedance (at panel jack): 50 Ω resistive; SWR is < 1.05 with output attenuator set for 0 dBm or less. At higher outputs, source impedance viewed as Thévenin generator has a SWR < 1.2.

MODULATION

Modes: Amplitude Modulation is provided in four modes:

1. Internal 1 kHz. Modulation level adjustable 0 to > 95% and metered to within ±3% of reading ±2% of full scale. Envelope feedback provides leveling and holds distortion to < 1% at 30% modulation and < 3% at 80% modulation. Modulating frequency, 1 kHz ±0.5%; after 2-hour warmup stable to better than 0.1% over 8-hour period or for line-voltage variations of ±10%. 1-kHz signal available at MOD binding posts, about 2.5 V behind 100 kΩ.

2. External Audio. Response flat to dc, down < 0.5 dB at 10 kHz. Square-wave response 0 to 10 kHz; rise and fall time < 10 μs; overshoot < 10%; rampoff negligible. Modulation is adjustable 0 to > 95% for dc to 5-kHz input, to > 70% at 10 kHz, and is metered to within ±5% of reading ±5% of full scale for sine-wave inputs from 20 Hz to 10 kHz. For 95% modulation < 3 V, peak required into 3 kΩ. Envelope feedback provides leveling and holds distortion at 30% modulation to < 1% up to 1 kHz, < 5% up to 10 kHz.

3. External Wide Band. Modulation level adjustable 0 to > 80%. Response flat to ±3 dB for 50-Hz to 300-kHz inputs at carrier frequencies above 108 MHz. Average carrier is leveled and metered, but modulation depth and linearity should be monitored externally. For full modulation, about 0.6 to 3.5 V (depending on carrier frequency) is required into 3 kΩ.

4. External Pulse. Required input pulses, at least 10 V peak, positive going (max 30 V); repetition rate 500 Hz to 150 kHz; duration 1 to 300 μs (min 3 μs on 9.5- to 22-MHz range); max 50% duty ratio. Input impedance 3 kΩ. Output pulse, duration within ±0.5 μs of input; rise and fall times < 1 μs each on all ranges but 9.5 to 22 MHz (up to 3 μs); rampoff < 5%. On-off ratio > 30 dB; at max output setting of carrier level is typically > 40 dB. Peak amplitude of pulses is leveled and metered to within ± 1 dB added to accuracy specified for cw leveling.

Incidental FM (accompanying a-m); < 1 ppm + 100 Hz, peak, at 1 kHz, 50% a-m.

Residual FM: < 0.05 ppm, peak.

Residual A-M: A-m due to hum and noise in 15-kHz bandwidth is at least 70 dB below carrier level in cw, internal 1-kHz, and external audio modes.

GENERAL

Power Required: 105 to 125 or 200 to 250 V, 50 to 60 Hz, 90 W.

Terminals: RF and counter outputs are GR874 coaxial connectors, recessed and locking; for rapid conversion to other common types, use locking GR874 adaptors. Modulation connection is to front-panel binding posts and rear-panel multiterminal connector. Audio (BEAT) output from front-panel telephone jack. Electrical frequency control is through rear-mounted 12-pin connector.

Accessories Supplied: 874-R22LA Patch Cord (GR874-to-GR874), phone plug, 12-pin connector plug, power cord, hardware for bench and rack mounting.

Mounting: Rack-bench cabinet.

Dimensions (width x height x depth): Bench, 19 x 17¾ x 15¼ in. (485 x 450 x 390 mm); rack, 19 x 17½ x 13 in. (485 x 445 x 330 mm).

Weight: Net, 96 lb (44 kg); shipping, 156 lb (72 kg).

Catalog Number	Description	Price in USA
1026-9701	**1026 Standard-Signal Generator**	**$7150.00**

Type 1001-A STANDARD-SIGNAL GENERATOR

- 5 kHz to 50 MHz
- 0 - 80% a-m

The 1001-A is a laboratory instrument for use in determining the performance of receivers and other equipment at ultrasonic and radio frequencies. Its sturdy construction and simplicity of operation make it suitable for production testing. Because of its small size, light weight, and low power consumption, it can be adapted for use in field-strength measurements.

The oscillator frequency varies logarithmically with dial rotation, so that the precision of frequency setting is constant; the vernier dial is calibrated directly in percentage frequency increments.

A buffer amplifier between the oscillator and the low-impedance output circuits can be amplitude modulated from zero to 80%. Loose coupling between the oscillator and the amplifier minimizes incidental frequency modulation. The output circuit is coupled to the amplifier through a high-pass filter, to reduce modulation-frequency voltages in the output.

A 400-Hz RC oscillator supplies internal modulation voltage. The panel meter can be switched to monitor either carrier-level input to the attenuator or modulation percentage.

specifications

CARRIER FREQUENCY

Range: 5 kHz to 50 MHz in 8 ranges: 5 to 15 kHz, 15 to 50 kHz, 50 to 150 kHz, 150 to 500 kHz, 0.5 to 1.5 MHz, 1.5 to 5 MHz, 5 to 15 MHz, and 15 to 50 MHz. Logarithmic scale up to 15 MHz, departs slightly from logarithmic at higher frequencies. Vernier-dial frequency increment is 0.1% per dial division up to 15 MHz.

Accuracy: ±1% of reading.

Stability: Warmup drift is of the order of 0.25%. Half the maximum drift is reached in approx 1½ hours.

Leakage: Stray fields at 1 MHz are less than one microvolt per meter two feet from the generator.

Distortion and Noise Level:

Envelope Distortion: Less than 8% at 80% amplitude modulation.

Carrier Noise Level: Corresponds to about 0.1% modulation.

Carrier Distortion: Of the order of 7% on all except 5 to 15 kHz range, where it may increase to about 15%.

MODULATION

Amplitude Modulation: 0 to 80%, continuously variable, indicated on the panel meter to ±10% of reading with possible additional error of 2% modulation.

Internal Modulation Frequency: 400 Hz ±5%.

External Modulation Characteristic: For carrier frequencies above 400 kHz, modulation is flat within ±1 dB from 20 Hz to 15 kHz; for those below 400 kHz, modulation is flat within ±1 dB from 20 Hz to 1 kHz; 12 V into 4 kΩ for 80% modulation.

Incidental Frequency Modulation: 30 to 300 ppm at 80% amplitude modulation, over all ranges except 15 to 50 MHz where it may be 3 times as great; approximately proportional to modulation percentage at low modulation percentages.

OUTPUT

Voltage Range: At ATTEN terminal, 0.1 μV to 200 mV, open circuit; 0.05 μV to 100 mV with output cable terminated at both ends. Output continuously variable. At 2 VOLTS terminal, 2 V, open circuit, up to at least 15 MHz, with output meter set to reference mark.

Voltage Accuracy: At ATTEN terminal, ±(6% + 0.1 μV), 150 kHz to 10 MHz with output dial near full scale or 1/10 full scale (error may be 4% greater with output dial set to mid-scale region); ±(10% + 0.3 μV) above 10 MHz with output dial near full scale (error may be 10% larger or smaller at other output dial settings). At 2 VOLTS terminal, ±3% at mid-frequencies.

Impedance: At ATTEN terminal, 10 Ω; 50 Ω when series unit is used; 50 Ω at highest output position of attenuator; 25 Ω at end of terminated cable. At 2 VOLTS terminal, 300 Ω. Type 1000-P4 Dummy Antenna provides a standard (IEEE) test impedance. A known induction field is obtainable with the Type 1000-P10 Test Loop (for testing loop receivers).

GENERAL

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 40 to 60 Hz, 65 W; 115 to 125 V up to 400 Hz.

Terminals: GR874® coaxial connectors. For connection to type N, BNC, TNC, SC, C, or UHF connector, use a GR874 locking adaptor.

Accessories Supplied: 874-R22LA Coaxial Cable, 1000-P1 50-Ohm Termination Unit, 1000-P2 40-Ohm Series Unit, 874-Q2 Adaptor, TO-44 Adjustment Tool (stored in cabinet), 274-MB Plug, CAP-22 Power Cord.

Accessories Available: 1000-P4 Standard Dummy Antenna, the 1000-P10 Test Loop.

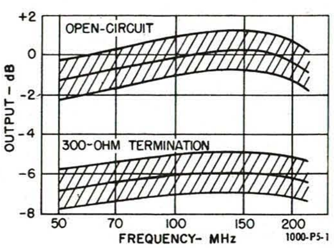
Mounting: Lab-Bench Cabinet.

Dimensions (width x height x depth): 20¼ x 13¾ x 11 in. (515 x 350 x 280 mm).

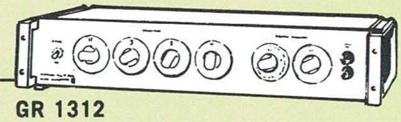
Weight: Net, 54 lb (25 kg); shipping, 67 lb (31 kg).

Catalog Number	Description	Price in USA
1001-9701	**1001-A Standard-Signal Generator**	**$1450.00**

SIGNAL-GENERATOR ACCESSORIES

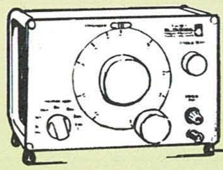
	Description	Catalog Number	Price in USA
	**Type 1000-P4 DUMMY ANTENNA** Connected to the terminated output of a 50-ohm generator, this dummy antenna provides the output characteristics specified by the IEEE in "Standards on Radio Receivers, Methods of Testing Amplitude-Modulation Broadcast Receivers," 1948 (now USASI Standard C16.19-1951). **Dimensions:** Diameter ⅞, length 4⅜ in. (23, 115 mm). **Weight:** Net, 3¼ oz (0.1 kg); shipping, 1 lb (0.5 kg). **1000-P4 Dummy Antenna**	1000-9604	**$35.00**
	**Type 1000-P5 VHF TRANSFORMER** **50 to 220 MHz** The 1000-P5 plugs into a 50-ohm standard-signal generator to produce an equal, balanced, open-circuit voltage behind a 300-ohm balanced impedance for measurements of fm and TV receivers. One terminal fits the Alden HA902P Connector for standard 300-ohm line, the other a GR874® coaxial connector. **Dimensions:** Diameter, ⅞, length 4⅜ in. (23, 115 mm). **Weight:** Net, 3½ oz (0.1 kg); shipping, 1 lb (0.5 kg). **1000-P5 VHF Transformer**	1000-9605	**50.00**
	**Type 1000-P10 TEST LOOP** For testing radio receivers with loop antennas by the preferred method of the 1948 "Standards on Radio Receivers, Methods of Testing Amplitude-Modulation Broadcast Receivers," published by the IEEE (now USASI Standard C16.19-1951). The 3-turn loop is enclosed in aluminum tubing for electrostatic shielding. The field strength in volts per meter, 19 inches from the loop, is one-tenth the generator output in volts, with a 50-ohm generator. **Frequency:** 3 MHz, max. **Accuracy:** ±10% (±5% is typical); with 1001-A Standard-Signal Generator, ±15% (±10% is typical). **Dimensions:** Width 11¾, height 16½, depth 3½ in. (300, 420, 89 mm), over-all. **Weight:** Net, 4½ lb (2.1 kg); shipping, 6 lb (2.8 kg). **1000-P10 Test Loop**	1000-9610	**110.00**

LOW-FREQUENCY OSCILLATORS — 2 Hz - 2 MHz



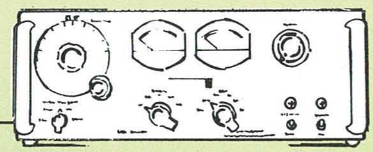
GR 1312

- In-line frequency readout ■ 10 Hz to 1 MHz
- 20 V ■ 80-dB step attenuator



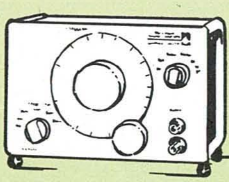
GR 1310

- 2 Hz to 2 MHz
- 20 V ■ 0.25% distortion



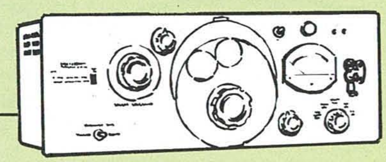
GR 1308-A

- 200 VA ■ 400 V or 5 A
- 20 Hz to 20 kHz ■ transformer output



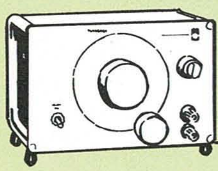
GR 1309-A

- 0.05% distortion ■ sine and square waves
- 10 Hz to 100 kHz ■ 5 V ■ 60-dB step attenuator



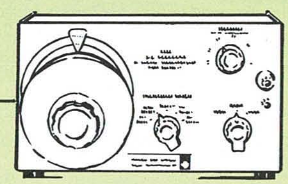
GR 1304-B

- 20 Hz to 20 kHz in one logarithmic sweep
- 1 watt ■ transformer output



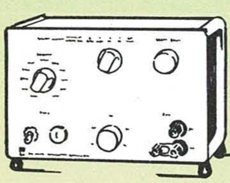
GR 1313-A

- 10 Hz to 50 kHz in one range
- sine and square waves



GR 1210-C

- 20 Hz to 500 kHz ■ sine and square waves
- 45 V



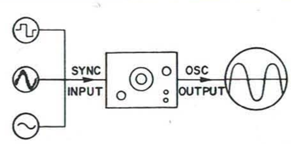
GR 1311-A

- 1 watt ■ 100 V or 4 A ■ transformer output
- 50 Hz to 10 kHz ■ discrete frequencies

General Radio's low-frequency oscillators are of the RC Wien-bridge type, which, when designed using modern solid-state devices, can provide a combination of wide frequency range, low noise distortion, and stable output in a reliable and inexpensive instrument. The Type 1304-B Beat-Frequency Audio Oscillator is the single exception to RC design.

In the Wien-bridge oscillator the frequency is determined by passive resistors and capacitors; both can be made very stable with time and temperature. Tuning is accomplished with a variable air capacitor, which provides continuous adjustment without jumps, or with switched resistances that vary frequency in discrete steps. Both offer advantages, depending upon the application: infinite resolution or fast, repeatable frequency selection.

For greater frequency stability, the oscillator can have its frequency locked to an external signal by means of a synchronization input. All the oscillator's output characteristics are maintained and the long-term frequency stability is the same as the external signal.[1] By this means, also, the oscillator can filter out noise and distortion in an applied signal, while providing the output amplitude and shortability of the normal oscillator. Short-term frequency instability or jitter can be reduced also.



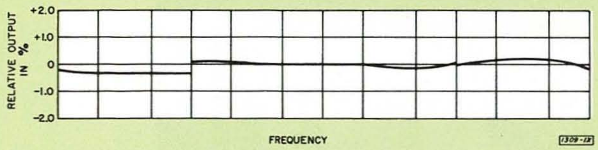
Oscillator filters, amplifies, isolates, multiplies frequency

With a unique type of amplitude regulator circuit,[2] the output of an RC oscillator is held very constant, regardless

[1] See GR Instrument Note IN-109, "Principles and Applications of RC Oscillator Synchronization," 1966.

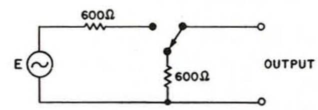
[2] R. E. Owen, "Solid State RC Oscillator Design for Audio Use", Journal of the Audio Engineering Society, January 1966, available from GR as reprint A-125.

of changes in the output frequency. This new regulator circuit operates without increasing distortion, and the output is so constant that an analog voltmeter will not move as the frequency is changed, providing that the oscillator is properly terminated so reactive loading effects are insignificant.



Constant output voltage vs frequency change

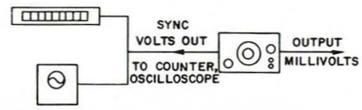
The oscillator output may be made available through a constant-impedance attenuator, a tapped transformer, or a combination. The constant-impedance attenuator is most common because of its convenience in controlling loading effects — cable-capacitance shunting or low-impedance loads, for example. Also convenient is an attenuator position that removes the oscillator voltage yet maintains the output impedance. Thus one can set the output to zero without changing the variable control setting or shorting shielded connections. Since the impedances all remain the same, the effects of ground loops and other noise sources are unchanged, yet they are easier to locate with the oscillator output removed.



Zero-output position on attenuator

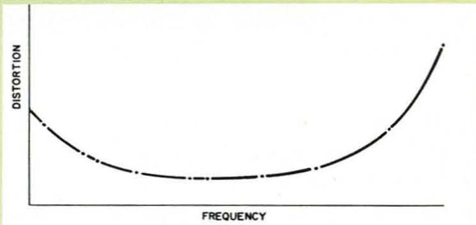
Transformer outputs offer a selection of output impedances for maximizing power into a load or for maintaining a sinusoidal current or voltage with nonlinear loads. Further, they provide isolation of the output for ungrounded or balanced operation and are a low-impedance direct-current path through the source.

The synchronization jack also provides an output of the order of one volt, a convenience for triggering a counter or an oscilloscope as it is independent of a varying or low output level.



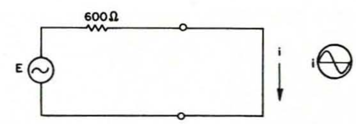
Using sync output

The distortion in the output of a solid-state RC oscillator can be quite low with a properly designed amplitude regulator. It will be lowest in the middle of its frequency range and increase at the extremes in a manner similar to many devices apt to be tested.



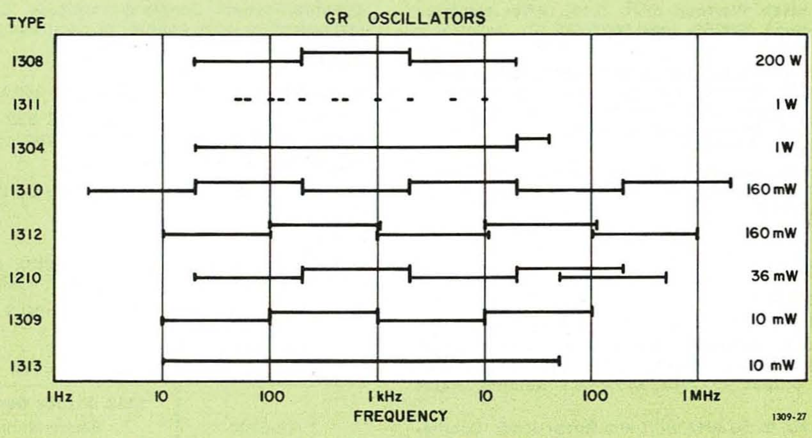
Distortion is lowest at frequencies that matter most

Maintaining low distortion under all load conditions is desirable and is made practical with solid-state design. Output waveform will not be clipped even when short-circuited at maximum output.



No clipping of output current, even into a short circuit

These many features have been combined in the eight oscillators described in the following pages. The combination in each case attempts to satisfy the requirements of broad application areas. As the chart below reveals, frequency range alone is not the greatest distinction between them.



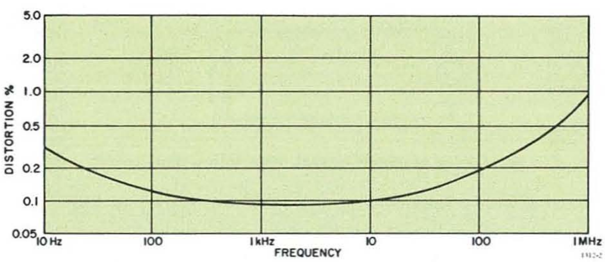
Type 1312 DECADE OSCILLATOR

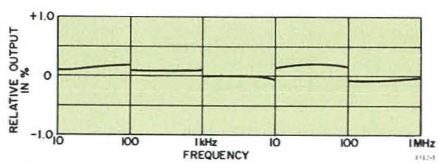
- 10 Hz to 1 MHz
- 20-V output, 80-dB step attenuator
- low distortion and hum
- decade controls, in-line readout

The 1312 permits frequency to be set fast, yet accurately, and with little chance of operator error. Thus it is the ideal oscillator for the many production and quality-control tests that demand laboratory performance and easy operation. Like a decade resistor or capacitor, the 1312 can be set to the desired frequency with two step decades and one continuously adjustable dial; selected frequency is displayed digitally in line, with decimal point and frequency units.

Although the 1312 is economical, it represents no performance compromises. The 20-volt output is held constant to within ±2%, without degrading the low distortion. For measurements of attenuation and gain, output level can be changed in precise increments with the precision 80-dB step attenuator, while a continuous control permits setting to any desired level. Output impedance of 600 ohms is maintained at all voltage levels, including the zero-volt setting of the attenuator provided for ease in locating sources of hum and noise in a measurement setup. The output of the 1312 is isolated from the chassis to reduce the effects of ground loops.

— See **GR Experimenter** for January 1968.





Typical low distortion (left) and uniform output level (above), shown as functions of frequency.

specifications

FREQUENCY

Range: 10 Hz to 1 MHz in five decade ranges.

Accuracy: ±1% of setting.

Stability (typical at 1 kHz): Warmup drift, 0.1%. After warmup: 0.001% short term (10 min), 0.005% long term (12 h). Resettable within 0.005%.

Control: Step control of two most significant digits, continuously adjustable third digit with detented zero position. In-line readout with positioned decimal point and frequency units. Most significant digit 1 through 10, second digit 0 through 9 with uncalibrated X for 10, third digit 0 through 9.

Synchronization: Frequency can be locked to external signal. Lock range ±3% per volt rms input up to 5 V. Frequency controls function as phase adjustment.

OUTPUT

Voltage: >20 V open circuit.

Power: >160 mW into 600 Ω.

Impedance: 600 Ω. Isolated from chassis by 10 Ω across 0.1 μF.

Attenuation: Continuously adjustable attenuator with >20-dB range, and 80-dB step attenuator with 20 dB per step. Intermediate steps reduce output to zero while maintaining 600-Ω output impedance.

Distortion: <0.25%, 50 Hz to 50 kHz with any linear load. Oscillator will drive a short circuit without clipping.

Hum: <0.04% of max output or 4 μV, whichever is greater.

Amplitude vs Frequency: ±2%, 10 Hz to 100 kHz with ≥600-Ω load; ±2%, 100 kHz to 1 MHz with ≤600-Ω load.

Synchronization: Constant-amplitude (0.8-V) high-impedance (27-kΩ) output to drive counter or oscilloscope.

GENERAL

Power Required: 100 to 125, 200 to 250 V, 50 to 400 Hz, 13 W.

Terminals: Front-panel output, GR 938 Binding Posts; rear-panel output, female BNC connector. Sync, rear-panel, female BNC.

Accessories Supplied: Power cord.

Accessories Available: 776-A Patch Cord (BNC to shielded double plug).

Mounting: Rack-bench cabinet.

Dimensions (width x height x depth): Bench, 19 x 3⅞ x 11 in. (485 x 99 x 330 mm); rack, 19 x 3½ x 8⅞ in. (485 x 89 x 225 mm).

Weight: Net, 13¼ lb (6.5 kg); shipping, 17 lb (8 kg).

Catalog Number	Description	Price in USA
	1312 Decade Oscillator	
1312-9700	Bench Model	**$495.00**
1312-9701	Rack Model	**495.00**

Type 1310-B OSCILLATOR

- 2 Hz to 2 MHz
- 20-V, constant output, ±2%
- 0.25% distortion

NEW

The superior characteristics of this oscillator make it an exceptionally useful laboratory signal source.

Constant output over a very wide frequency range facilitates frequency-response measurements.

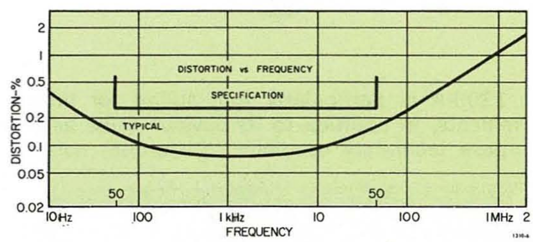
High-resolution dial and exceptional amplitude and frequency stability are important for measurements of filters and narrow-band devices.

Equally useful in 600-ohm and 50-ohm circuits, since distortion is independent of load, even a short circuit.

When phase-locked to a frequency standard, the oscillator can deliver a high-level standard-frequency output with adjustable amplitude and low distortion.

DESCRIPTION

A capacitance-tuned, RC Wien-bridge oscillator drives a low-distortion output amplifier, which isolates the oscillator from the load and delivers a constant voltage behind 600 ohms. All solid-state circuits ensure long, trouble-free life.



A jack is provided for introduction of a synchronizing signal for phase locking or to furnish a signal, independent of the output attenuator setting, to operate a counter, or to synchronize an oscilloscope or another oscillator.

specifications

FREQUENCY

Range: 2 Hz to 2 MHz in 6 decade ranges. Overlap between ranges, 5%.

Accuracy: ±3% of setting.

Stability (typical at 1 kHz): Warmup drift, 0.1%. After warmup: 0.003% short term (10 min), 0.03% long term (12 h).

Controls: Continuously adjustable main dial covers decade range in 305°, vernier in 4 turns.

Synchronization: Frequency can be locked to external signal. Lock range ±3% per volt rms input up to 10 V. Frequency dial functions as phase adjustment.

OUTPUT

Voltage: 20 V open circuit, nominal.

Power: >160 mW into 600 Ω.

Impedance: 600 Ω. One terminal grounded.

Attenuation: Continuously adjustable attenuator with >46-dB range.

Distortion: <0.25%, 50 Hz to 50 kHz with any linear load. Oscillator will drive a short circuit without clipping.

Hum: <0.02%, independent of attenuator setting.

Amplitude vs Frequency: ±2%, 20 Hz to 200 kHz, into open circuit or 600-Ω load.

Synchronization: Constant-amplitude (0.8-V), high-impedance (27-kΩ) output to drive counter or oscilloscope.

GENERAL

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 400 Hz, 12 W.

Terminals: Output, GR 938 Binding Posts; sync, side-panel telephone jack.

Accessories Supplied: Power cord.

Accessories Available: Adaptor cable 1560-P95 (telephone plug to double plug); rack-adaptor set.

Mounting: Convertible-bench cabinet.

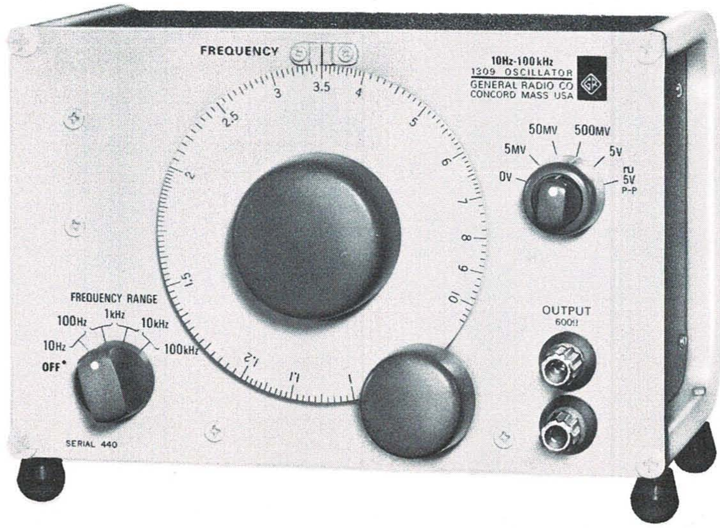
Dimensions (width x height x depth): 8 x 6 x 8⅛ in. (205 x 155 x 210 mm).

Weight: Net, 7¾ lb (3.6 kg); shipping, 10 lb (4.6 kg).

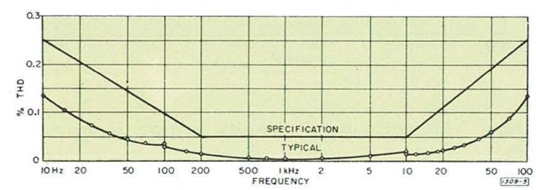
Catalog Number	Description	Price in USA
1310-9702	**1310-B Oscillator** specify 115-, 220-, or 230-V line operation	**$295.00**
1560-9695	**1560-P95 Adaptor Cable**	**4.00**
0480-9838	**480-P308 Rack-Adaptor Set**	**11.00**

Type 1309-A OSCILLATOR

- 10 Hz to 100 kHz
- 0.05% distortion
- 5-V output, 60-dB step attenuator
- sine- or square-wave output



The 1309-A is particularly well suited for distortion measurements, in addition to its obvious value as a general-purpose laboratory oscillator. Distortion, noise, and hum are exceptionally low, and output is flat over the entire frequency range.



The output attenuator can be set for zero volts behind 600 ohms, a useful condition for measuring low-level noise and extraneous signals.

A square wave with 40-ns rise time is also available for transient-response tests. It has good symmetry at all frequencies and no low-frequency tilt.

— See **GR Experimenter** for March 1966.

specifications

FREQUENCY

Range: 10 Hz to 100 kHz in 4 decade ranges. Overlap between ranges, 5%.

Accuracy: ±2% of setting.

Stability (typical at 1 kHz): Warmup drift, 0.3%. After warmup: 0.001% short term (10 min), 0.01% long term (12 h).

Controls: Continuously adjustable main dial covers decade range in 305°, vernier in 4 turns.

Synchronization: Frequency can be locked to external signal. Lock range ±3% per volt rms input up to 10 V. Frequency dial functions as phase adjustment.

OUTPUT

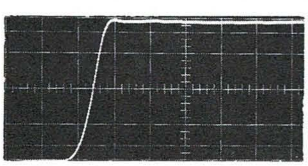
Sine Wave

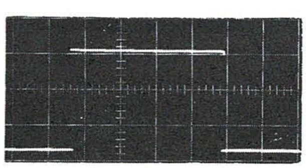
Voltage: 5.0 V ±5% open circuit.

Power: >10 mW into 600 Ω.

Impedance: 600 Ω. One terminal grounded.

Attenuation: Continuously adjustable attenuator with >20-dB range, and 60-dB step attenuator with 20 ±0.2 dB per step and a zero-volt position with 600-Ω output impedance maintained.





(Left) 10 kHz square-wave into 50 ohms. 50 ns/div, horiz. (Right) Direct-coupled 10-Hz, square-wave. Note flat top. 10 ms/div, horiz.

Distortion: <0.05%, 200 Hz to 10 kHz, increasing to <0.25% at 10 Hz and 100 kHz, into open circuit or 600-Ω load.

Hum: <50 μV independent of attenuator setting (<0.001% of full output).

Amplitude vs Frequency: ±2% for loads of ≧600 Ω.

Synchronization: Constant-amplitude (1.5-V), high-impedance (12-kΩ) output to drive counter or oscilloscope.

Square Wave

Voltage: >+5.0 V pk-pk open circuit. Dc-coupled output.

Impedance: 600 Ω. One terminal grounded.

Rise Time: <100 ns into 50-Ω load. Typically 40 ns at full output.

Symmetry: ±2% (48 to 52% duty ratio).

Attenuation: Continuously adjustable attenuator with >20-dB range.

GENERAL

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 6 W.

Terminals: Output, GR 938 Binding Posts; sync, side-panel telephone jack.

Accessories Supplied: Power cord.

Accessories Available: Adaptor cable 1560-P95 (telephone plug to double plug), rack-adaptor set.

Mounting: Convertible-bench cabinet.

Dimensions (width x height x depth): 8 x 6 x 8⅛ in. (205 x 155 x 210 mm).

Weight: Net, 6¾ lb (3.1 kg); shipping, 9 lb (4.1 kg).

Catalog Number	Description	Price in USA
1309-9701	**1309-A Oscillator**	**$375.00**
1560-9695	**1560-P95 Adaptor Cable**	**4.00**
0480-9838	**480-P308 Rack-Adaptor Set**	**11.00**

Type 1313-A OSCILLATOR

- 10 Hz to 50 kHz in one range
- 5-V output, 60-dB step attenuator
- sine- or square-wave output

The single-range tuning of the 1313-A permits fast, transient-free, unambiguous frequency selection, all of which are highly desirable features in production-type testing of many devices. Amplifiers, loudspeakers, and other audio, acoustic, and ultrasonic equipment must be response- and distortion-tested quickly, surely, and without overdriving. The 1313-A is the ideal source for such applications.

The 1313 can be manually swept with ease for quick checks, in addition to detailed analyses, of cross-over and resonance frequencies, of equalization and other filter performance, and of mechanical and acoustical transducers and systems.

— See **GR Experimenter** for February 1967.

specifications

FREQUENCY

Range: 10 Hz to 50 kHz in one range.

Accuracy: ±4% of setting or ±1 Hz, whichever is greater.

Controls: Continuously adjustable main dial covers range in 322.5°, vernier in 4 turns. Vernier can be disengaged for rapid setting of main dial.

Synchronization: Frequency can be locked to external signal. Lock range ±1% to ±40% per volt rms input, depending on frequency.

OUTPUT

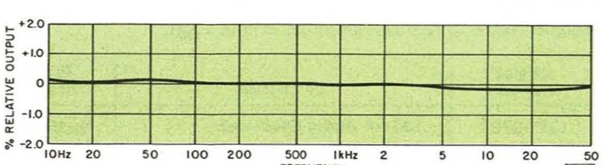
Sine Wave

Voltage: 5.0 V ±5% open circuit.

Power: >10 mW into 600 Ω.

Impedance: 600 Ω. One terminal grounded.

Attenuation: Continuously adjustable attenuator with >20-dB range, and 60-dB step attenuator with 20 ±0.2 dB per step and a zero-volt position with 600-Ω output impedance maintained.



Typical uniformity of output level as 1313-A is tuned through entire frequency range.

Distortion: <0.5%, 100 Hz to 10 kHz, into open circuit or 600-Ω load.

Hum: <0.05% of max output at 1 kHz.

Amplitude vs Frequency: ±2% for ≥600-Ω loads.

Square Wave

Voltage: >+5.0 V pk-pk open circuit. Dc-coupled output.

Impedance: 600 Ω. One terminal grounded.

Rise Time: <100 ns into 50-Ω load. Typically 40 ns at full output.

Symmetry: ±2% (48 to 52% duty ratio).

Attenuation: Continuously adjustable with >20-dB range.

GENERAL

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 6 W.

Terminals: Output, GR 938 Binding Posts; sync, side-panel telephone jack.

Accessories Supplied: Power cord.

Accessories Available: Adaptor cable 1560-P95 (telephone plug to double plug), rack-adaptor set.

Mounting: Convertible-bench cabinet.

Dimensions (width x height x depth): 8 x 6 x 8⅛ in. (205 x 155 x 210 mm).

Weight: Net, 7 lb (3.2 kg); shipping, 9¼ lb (4.2 kg).

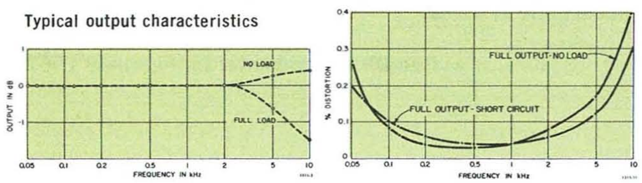
Catalog Number	Description	Price in USA
1313-9701	**1313-A Oscillator**	**$350.00**
1560-9695	**1560-P95 Adaptor Cable**	**4.00**
0480-9838	**480-P308 Rack-Adaptor Set**	**11.00**

Type 1311 AUDIO OSCILLATOR

- 50 Hz to 10 kHz, discrete frequencies
- 1 W, 100-V or 4-A output
- transformer output

The 1311 oscillators offer high-power output and load-matching through a multitap output transformer that ensures at least ½ watt into any load from 0.08 to 8000 ohms. Thus, it is ideal for driving impedance bridges where high sensitivity is required at extreme measurement limits and for driving directly such low-impedance devices as acoustic transducers. For bridge measurements, the shielded output-transformer secondary minimizes circulating ground currents. The 1311-A is supplied in an assembly with the 1232 Tuned Amplifier and Null Detector as the 1240 Bridge Oscillator-Detector. The 1311-A is also included in many GR impedance-measuring systems.

Typical output characteristics



AUDIOMETRY

The high output and low distortion of the 1311 recommend its use in the calibration of audiometric equipment. For this application, the 1311-AU is available with 12 frequencies commonly used in audiometry, including the octave series based on 125 Hz specified by the American National Standards Institute for "general diagnostic purposes" in Z24.5-1951. All other specifications are the same as the 1311-A.

specifications

FREQUENCY

Range: 1311-A, 50 Hz to 10 kHz. Eleven fixed frequencies, 50, 60, 100, 120, 200, 400, and 500 Hz, 1, 2, 5, and 10 kHz. One other frequency can be added at an unused switch position. 1311-AU, 50 Hz to 10 kHz. Twelve fixed frequencies, 125. 250, 400, 500, and 750 Hz, 1, 1.5, 2, 3, 4, 6, and 8 kHz. Both models, a Δf control provides ±2% continuous adjustment.

Accuracy: ±1% of setting with Δf control at zero.

Stability (typical at 1 kHz): Warmup drift, 0.3%. After warmup: 0.008% short term (10 min), 0.02% long term (12 h).

Synchronization: Frequency can be locked to external signal. Lock range ±3% per volt rms up to 10 V. The Δf control functions as phase adjustment.

OUTPUT

Voltage: Continuously adjustable from 0 to 1, 3, 10, 30, or 100 V open circuit (E_{oc}).

Power: >1.0 W into matched load, >0.5 W into any resistive load between 80 mΩ and 8 kΩ.

Current: Continuously adjustable from 0 to 40, 130, 400, 1300, or 4000 mA, into approx short circuit (I_{sc}).

Impedance: One to three times $\frac{E_{oc}}{I_{sc}}$, depending on output amplitude. Output isolated from ground.

Distortion: <0.5% with any linear load. Oscillator will drive a short circuit without clipping.

Hum: <0.01%, independent of output setting.

Synchronization: Constant-amplitude (1-V), high-impedance (4.7-kΩ) output to drive counter or oscilloscope.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 22 W.

Terminals: Output, GR 938 Binding Posts and ground terminal with shorting link; sync, side-panel telephone jack.

Accessories Supplied: Power cord.

Accessories Available: Adaptor cable 1560-P95 (telephone plug to double plug), rack-adaptor set.

Mounting: Convertible-bench cabinet.

Dimensions (width x height x depth): 8 x 6 x 7¾ in. (205 x 155 x 200 mm).

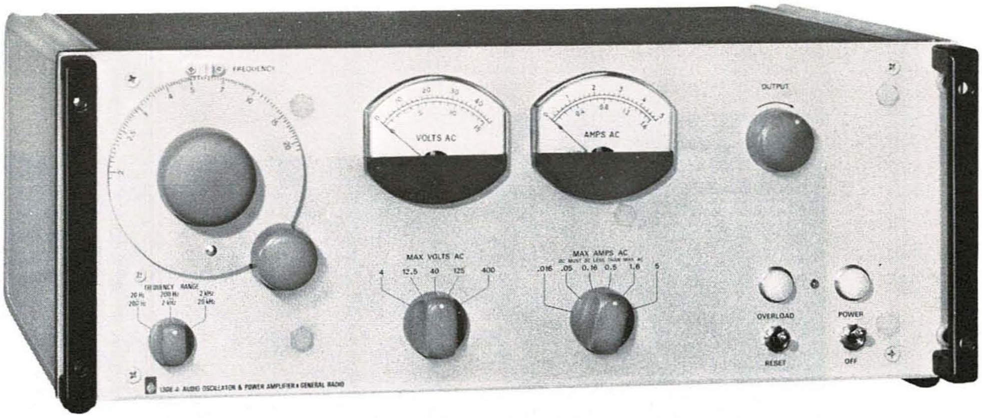
Weight: Net, 6 lb (2.8 kg); shipping, 9 lb (4.1 kg).

Catalog Number	Description	Price In USA
1311-9701	**1311-A Audio Oscillator**	**$295.00**
	1311-AU Audiometric Oscillator,	
1311-9703	for 115-V	**295.00**
1311-9704	for 230-V	**295.00**
1560-9695	**1560-P95 Adaptor Cable**	**4.00**
0480-9838	**480-P308 Rack-Adaptor Set**	**11.00**

PATENT NOTICE. See Note 1.

Type 1308-A AUDIO OSCILLATOR AND POWER AMPLIFIER

- 200-VA, 400-V or 5-A output
- 20 Hz to 20 kHz
- transformer output

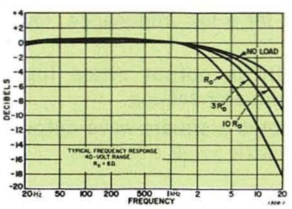


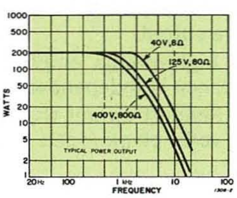
The 1308-A Audio Oscillator and Power Amplifier is an ac power source covering the audio range. It is an excellent power source for the 1633-A Incremental-Inductance Bridge. Its low dynamic output impedance enhances its usefulness as a power source for testing other devices over a wide range of supply frequencies. This instrument will provide a low-distortion signal (not clipped) to non-linear loads, such as capacitor-input rectifier systems. It can also be used to drive small shake tables and to isolate sensitive equipment from power-line transients.

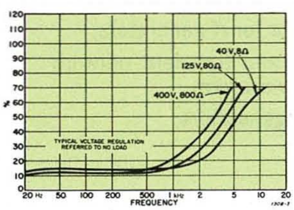
This instrument also finds many uses as an audio-frequency power amplifier. When it is used with the 1396 Tone-Burst Generator, high-power tone bursts are provided for testing sonar projectors, amplifiers, etc.

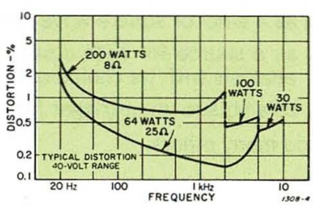
This instrument combines a capacitor-tuned, Wien-bridge oscillator, a low-distortion power amplifier, and a tapped output transformer. The output is monitored by an overload circuit, which turns off the output when it exceeds safe limits.

— See **GR Experimenter** for January 1964.









specifications

FREQUENCY

Range: 20 Hz to 20 kHz in 3 ranges.

Accuracy: ±3% of setting or ±1 Hz, whichever is greater.

Stability (typical at 1 kHz): Warmup drift at full load, 0.3%. After warmup: 0.003% short term (10 min), 0.03% long term (12 h), 0.04% from no load to full load.

Controls: Continuously adjustable main dial covers decade range in 157.5°, vernier in 2 turns.

OUTPUT

Voltage Ranges: Max of 4, 12.5, 40, 125, and 400 V open circuit, continuously adjustable from 0 to max.

Power: 200 VA max, 50 Hz to 1 kHz.

Current Ranges: Max of 0.016, 0.05, 0.16, 0.5, 1.6, and 5.0 A.

Regulation: <20%, no load to full load, 20 Hz to 1 kHz. Output impedance is typically 0.3, 0.8, 1.6, 19, and 220 Ω, depending on voltage range, 20 Hz to 1 kHz. Output transformer can pass dc current equal to max of ac current range. Output isolated from ground.

Load Impedances: Will drive short circuit or non-linear loads. Load impedances of 0.8, 2.5, 8, 80, or 800 Ω, depending on voltage range, are optimum for max available power.

Load Power Factor: Continuous operation at max VA for any power factor 0 to 1 with ambient up to 25°C. Power factor of 0.7 to 1.0 for continuous operation to 40°C ambient. Intermittent operation to 50°C.

Distortion (linear load): <1%, 100 Hz to 10 kHz; <2%, 50 Hz to 100 Hz at max power and 115-V supply.

Hum: <0.3% of max output.

Meters: Indicate output terminal voltage and current.
Voltmeter: 5, 15, 50, 150, and 500 V ±3% full scale.
Ammeter: 0.016, 0.05, 0.16, 0.5, 1.6, and 5 A ±3% full scale.

Overload Protection: Electronic overload trips at approx 1.5 × max of current range (manual reset), thermal cut-out on transistor heat sink (automatic reset).

AMPLIFIER

Sensitivity: <2.0 V for full output.

Input Impedance: 10 kΩ.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz, 70 to 500 W, depending on load.

Terminals: Output, GR 938 Binding Posts and four-terminal socket on rear panel; input, GR 938 Binding Posts on rear panel.

Accessories Supplied: Power cord and four-terminal plug.

Mounting: Rack-bench cabinet.

Dimensions (width x height x depth): Bench, 19 x 7 x 16¼ in. (485 x 180 x 414 mm); rack, 19 x 7 x 15 in. (485 x 180 x 385 mm).

Weight: Net, 91 lb (42 kg); shipping, 145 lb (67 kg).

Catalog Number	Description	Price in USA
	1308-A Audio Oscillator and Power Amplifier	
1308-9801	Bench Model	**$1575.00**
1308-9811	Rack Model	**1575.00**

PATENT NOTICE. See Note 1.

Type 1210-C UNIT R-C OSCILLATOR

- 20 Hz to 500 kHz
- 45-V output
- sine or square wave

Oscillator and power supply can be rigidly clamped together.

This popular oscillator generating high output voltage at audio, ultrasonic, and radio frequencies has found application in many areas:

- as a sine- or square-wave modulator for rf generators,
- as a source for both steady-state and transient network analysis with its choice of output waveform,
- as a square-wave trigger for pulse generators,

and many others.

An RC network determines the frequency and drives three different switch-selected output circuits for added usefulness:

1. A cathode-follower amplifier for a low-impedance, low-voltage output.
2. A high-voltage amplifier with an output whose high impedance is independent of attenuator setting.
3. A Schmitt circuit that generates a square-wave output of 30 volts pk-pk (open circuit) with ½-μs rise time.

specifications

FREQUENCY

Range: 20 Hz to 500 kHz in 5 decade ranges.

Accuracy: ±3% of setting.

Control: Vernier covers decade in 4½ turns.

OUTPUT (no load condition)

Sine Wave — 0 to 7-V range

Impedance: 1250 Ω max, varies with attenuator setting.

Distortion: <1.5%.

Hum: <0.1%, independent of attenuator setting.

Amplitude vs Frequency: ±1 dB, 20 Hz to 200 kHz.

Sine Wave — 0 to 45-V range

Impedance: 14 kΩ.

Distortion: <5%, 200 Hz to 200 kHz.

Hum: <0.3% of max output.

Amplitude vs Frequency: ±1 dB, 200 Hz to 150 kHz.

Square Wave — 0 to 30-V pk-pk range

Rise Time: <0.35 μs into 1 kΩ with max output at 500 kHz.

Impedance: 2.5 kΩ max, decreases with attenuator setting.

GENERAL

Power Required: 50- to 400-Hz power into either Unit Power Supply 1203-B (115 to 125 V) or 1203-BQ18 (230 to 250 V) or Unit Regulated Power Supply 1201-C (105 to 125 V) or 1201-CQ18 (195 to 250 V).

Terminals: Output, GR 938 Binding Posts. One terminal grounded.

Accessory Required: Power supply, see above.

Accessory Available: Rack-adaptor panel.

Mounting: Unit-Instrument Cabinet.

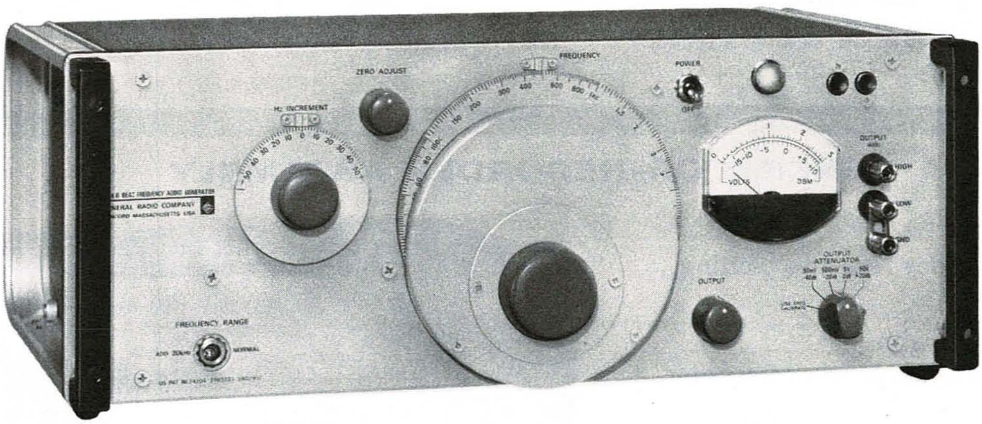
Dimensions (width x height x depth): 15 x 5¾ x 7 in. (385 x 150 x 180 mm); with power supply.

Weight: Net, 10½ lb (4.8 kg); shipping, 18 lb (8.3 kg).

Catalog Number	Description	Price in USA
1210-9703	**1210-C Unit R-C Oscillator**	**$255.00**
	Unit Power Supply, unreg.	
1203-9702	**1203-B,** 115-125 V	**85.00**
1203-9818	**1203-BQ18,** 230-250 V	**85.00**
	Unit Regulated Power Supply	
1201-9703	**1201-C,** 105-125 V	**120.00**
1201-9824	**1201-CQ18,** 195-250 V	**120.00**
0480-9986	**480-P4U3 Rack-Adaptor Panel**	**14.00**

Type 1304-B BEAT-FREQUENCY AUDIO GENERATOR

- 20 Hz to 20 kHz, one logarithmic range
- 1 W into 600 Ω; 80-dB metered output
- automatic frequency tests with 1521 Recorder



The many features of this generator make it especially well suited for amplitude-frequency tests on audio-frequency equipment — lines, amplifiers, filters, equalizers, transducers, and other networks. It finds constant use in the electronics laboratory as a power source for acoustical tests, as a power source for bridge measurements, and as a modulator for rf signal generators.

Frequency-response characteristics of circuits and devices can be recorded by the Type 1521-B Graphic Level Recorder. The graphic level recorder drives the generator dial through a chain-and-gear system, and the response is plotted on chart paper whose frequency scale matches that of the oscillator.

An assembly of generator and graphic level recorder is listed on the next page.

DESCRIPTION

The oscillator output level is continuously adjustable, and the output can be either balanced or grounded. The unbalanced circuit contains a three-step calibrated attenuator. The output voltmeter is calibrated in dBm and open-circuit output volts.

The frequency dial carries a logarithmic frequency scale for the range 20 Hz to 20 kHz and is driven by a gear-reduction drive, essentially free from backlash.

Rotation is continuous over 360°, to facilitate automatic recording. A hertz-incremental dial varies the frequency over a range of ±50 Hz at any setting of the main dial.

The 20- to 40-kHz range is selected by a single panel switch.

1304-P1 MUTING SWITCH

The muting switch short circuits the generator output during rotation through the blank portion of the dial and thus eliminates any low-frequency signals that might damage the recorder or the device under test when the recorder is swept continuously. The switch can be adjusted to mute the blank portion of the dial plus any range of frequencies from 20 Hz to 1.5 kHz.

The switch mounts on the main-dial assembly of the generator and connects to the generator output terminals by means of a cable and plug.

specifications (1304-B Beat-Frequency Audio Oscillator)

FREQUENCY

Range: 20 Hz to 40 kHz in two ranges, 20 Hz to 20 kHz and 20 kHz to 40 kHz.

Accuracy: ±(1% + 0.5 Hz) after standardization by zero-beat or line frequency. The 20-kHz increment for high range, ±0.5%. Frequency increment dial, ±1 Hz.

Stability: Warmup drift, <7 Hz in first hour at zero beat.

Controls: Main dial with logarithmic scale from 20 Hz to 20 kHz, 80° per decade with 360° continuous rotation, driven with 10:1 vernier. Toggle switch adds 20 kHz to main dial. Linear frequency-increment dial covers −50 Hz to +50 Hz.

OUTPUT

Voltage: >50 V open circuit.

Power: >1 W into 600-Ω load.

Impedance: 600 Ω ±2%. One side grounded, or balanced with respect to ground at max output setting of step attenuator.

Attenuation: Continuously adjustable attenuator from zero to max output, 60-dB step attenuator wth 20 ± 0.2 dB per step with one side of output grounded.

Distortion: <0.25%, 100 Hz to 10 kHz; <1.0%, 10 to 40 kHz.

Recorders page 51 ff

Hum: <0.1% for meter readings above 10% of full scale.

Amplitude vs Frequency: ±0.25 dB, 20 Hz to 20 kHz; ±0.5 dB, 20 to 30 kHz; ±1.0 dB, 30 to 40 kHz; all with 600-Ω load.

Voltmeter: Measures voltage into step attenuator. Calibrated in dBm and open-circuit output voltage. Accuracy is ±5% of reading above 10% of full scale.

GENERAL

Power Required: 105 to 120 or 210 to 250 V, 50 to 60 Hz, 90 W.

Terminals: Output, GR 938 Binding Posts and Western Electric double jack on front panel, four-terminal socket on rear.

Accessories Supplied: Power cord, four-terminal plug.

Accessories Available: 1521 Graphic Level Recorder, Muting Switch Type 1304-P1.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): 19 x 7½ x 15¼ in. (485 x 190 x 390 mm); rack, 19 x 7 x 13¼ in. (485 x 180 x 340 mm).

Weight: Net, 39 lb. (18 kg); shipping, 43 lb (20 kg).

Catalog Number	Description	Price in USA
	1304-B Beat-Frequency Audio Generator	
1304-9802	Bench Model, 115 V ac	**$1275.00**
1304-9803	Bench Model, 230 V ac	**1275.00**
1304-9812	Rack Model, 115 V ac	**1275.00**
1304-9813	Rack Model, 230 V ac	**1275.00**
1304-9601	**1304-P1 Muting Switch**	**55.00**

PATENT NOTICE. See Notes 5, 9, 14, and 15.

Type 1350-A GENERATOR-RECORDER ASSEMBLY

- automatic frequency-response plotting
- 20 Hz to 20 kHz
- combines 1304-B with 1521 Graphic Level Recorder

Constant generator output and uniform recorder response make this an excellent assembly for measuring the response of filters, attenuators, networks, loud-speakers, amplifiers, microphones, transducers, and complete acoustic systems.

The complete assembly includes the following:

1304-B Beat-Frequency Audio Generator with accessories, end frames and rack supports.

1521-B Graphic Level Recorder with accessories (including a 40-dB potentiometer), 1521-P19 motor, end frames and rack supports.

1521-9427 Chart Paper, 10 rolls
274-NP Patch Cord
1521-P10B Drive Unit
1521-P15 Link Unit
1521-P16 Sprocket Kit
1560-P95 Adaptor Cable
1304-P1 Muting Switch

The blank parts on the chart paper correspond to the length of the blank portion on the generator dial so that many charts can be recorded with complete synchronization of the chart and the dial frequency.

— See **GR Experimenter** for September 1964.

specifications

Power Required: 105 to 125 or 210 to 250 V, 60 or 50 Hz, 135 W.

Dimensions (width x height x depth): 19 x 16½ x 15¼ in. (485 x 420 x 390 mm).

Weight: Net, 89 lb (41 kg); shipping, 165 lb (76 kg).

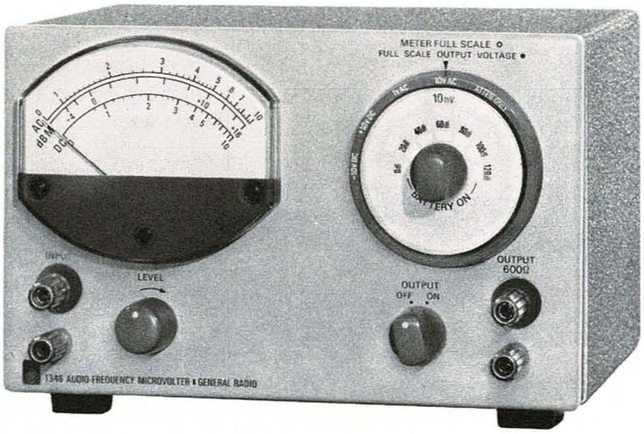
Catalog Number	Description	Price in USA
	Generator-Recorder Assembly	
1350-9701	**1350-A,** for 60-Hz supply	**$3060.00**
1350-9494	**1350-AQ1,** for 50-Hz supply	**3060.00**

ATTENUATORS

Calibrated attenuators and voltage dividers are basic instruments for the measurement of voltage ratios, linearity, circuit gain or loss, transmission efficiency, and for the calibration of meters, adjustable attenuators, and other devices.

Described in this section are resistive decade attenuators calibrated in decibels, precise voltage dividers, and a precision decade transformer with exceptional linearity that can be calibrated by the National Bureau of Standards and used as the standard in calibrating other attenuators and dividers.

Type 1346 AUDIO-FREQUENCY MICROVOLTER*



- self-contained dc source
  1 μV to 10 V
- calibrated ac attenuator to 100 kHz
  0.1 μV to 10 V
- use with sine-, square-waves, noise, bursts

The GR1346 Audio-Frequency Microvolter is a metered, calibrated attenuator that can be used as a self-contained low-level dc source and, in conjunction with an appropriate oscillator, as a source of from 0.1 μV to 10 V of any ac waveform with a spectrum up to 100 kHz.

The input to the 1346 can be a dc voltage from the instrument's internal battery or from an external dc or ac source. An input attenuator provides continuous control of the voltage, which is applied to a 20-dB-per-step output attenuator. A total of 140-dB attenuation is provided by the two controls. The meter, in ac operation, is average responding, calibrated in rms volts and in dBm.

An on-off switch reduces the output to zero without disturbing other controls or shorting the output; the source impedance remains 600 Ω. This is convenient, especially at these low levels where shielding must be maintained. The zero-volt condition is useful in incremental dc-gain measurements and in locating noise sources and ground loops in critical low-level measurements.

The 1346 is not line operated, permitting the instrument to "float" in a test setup, e.g., to add the output of the Microvolter to another signal. Front-panel terminals are gold-plated-copper binding posts for low thermal emf.

— See **GR Experimenter** for August-September 1968.

specifications

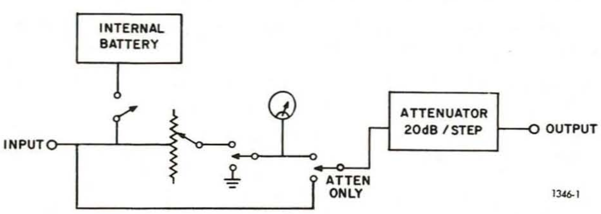
Function	10 V ac	1 V ac	+10 V dc	—10 V dc	Atten Only
Open-Circuit Output Voltage Range	1.0 μV to 10 V ac	0.1 μV to 1.0 V ac	1.0 μV to 10 V dc		0 to —120 dB, 20 dB/step
Accuracy at 23°C (above 10% of dc full scale)	±(4% +0.2 μV) 10 Hz to 100 kHz	±(4% +0.02 μV)	±(3% +0.2 μV)		±(0.04 dB/step +154 dB below input level) dc to 100 kHz
Source	External ac required 10.0 V into 595 Ω	1.0 V into 550 Ω	Internal battery or ext dc source 10 V max		Ext ac or dc source 10 V max input
Input Impedance (approx) †	595 Ω to 25 kΩ	550 Ω to 25 kΩ	610 Ω to 25 kΩ, int battery removed		550 Ω to 5 kΩ

† Varies with setting of input level control, step attenuator, and load. Can be adjusted to remain constant with step-attenuator changes for load impedance of ≥50 ohms.

Distortion (at 1 kHz): <0.01% in 1-V-ac mode, <0.05% in 10-V-ac mode, with level control at max setting.

Output Impedance: 600 Ω ±0.5%.

Accessories Supplied: Battery, mounting hardware with rack model.



Microvolter controls permit continuous and step output control, zero-volt 600-Ω output, and bypassing of meter and continuous attenuator for operation as step attenuator only.

Accessories Available: GR 1309 and 1310 Oscillators, 1396 Tone-Burst Generator, 1381, 1382, and 1383 Random-Noise Generators.

Power Required: None required for 10-V-ac range. In other modes, 12-V dry battery: Eveready 228, RCA VS329, or Burgess PM8. Approx life, 33 hours at 2h/day in either dc mode, 316 hours at 2h/day in 1-V-ac mode.

Mounting: Convertible-bench cabinet.

Dimensions (width x height x depth): Bench, 8½ x 5⅝ x 7½ in. (220 x 145 x 190 mm); rack, 19 x 5¼ x 6 in. (485 x 135 x 155 mm).

Net Weight: Bench, 5 lb (2.3 kg); rack, 8 lb (3.7 kg).

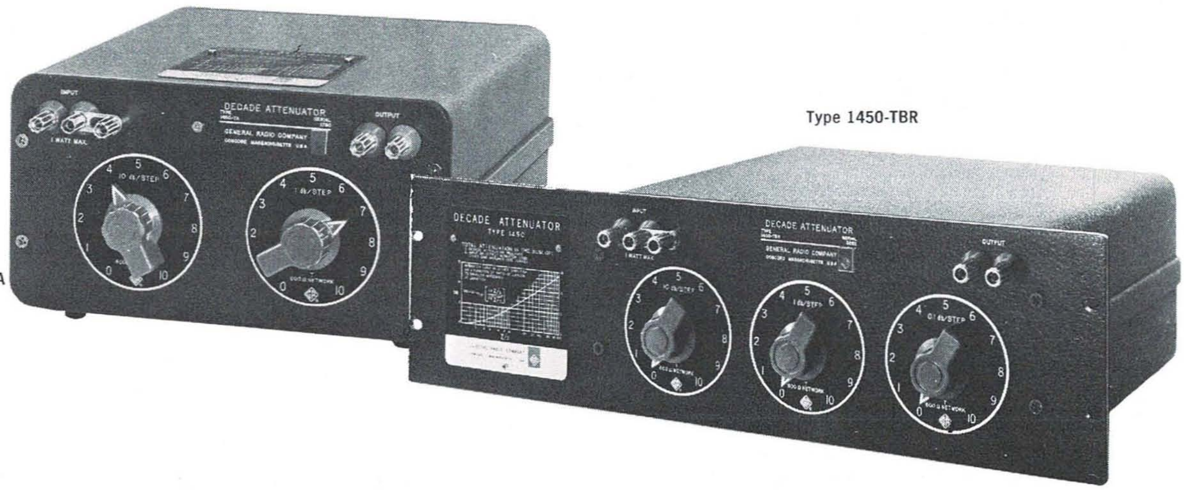
Shipping Weight: Bench, 7 lb (3.2 kg); rack, 10 lb (4.6 kg).

Catalog Number	Description	Price in USA
	Audio-Frequency Microvolter *	
1346-9700	Bench Model	**$310.00**
1346-9701	Rack Model	**340.00**
8410-1380	**Replacement Battery**	**1.50**

* Trademark registered in USA.

Type 1450 ATTENUATOR DECADE

- 0-110 dB in 1.0- or 0.1-dB steps
- 600-ohm input and output impedance
- accuracy: ±0.02 dB ±0.25%
- usable to 1 MHz



Type 1450-TBR

Type 1450-TA

The 1450 Decade Attenuator provides accurate steps of attenuation for power-level measurements, transmission-efficiency tests, and gain or loss measurements on transistors, filters, amplifiers, and similar equipment. It can also be used as a power-level control in circuits not equipped with other volume controls.

Each decade consists of four individually shielded, series-connected, T-pads. The switches have eleven positions, 0 to 10 inclusive, so the decades overlap. There are no stops on the 0.1- and 1-dB-per-step decades, so that quick return from full to zero attenuation is facilitated.

specifications

Attenuation Range: 110 or 111 dB in steps of 1 or 0.1 dB, respectively.

Terminal Impedance: 600 Ω in either direction. An etched plate indicates the mismatch loss for other than 600-Ω circuits.

Accuracy: Each individual resistor is adjusted within ±0.25% of its correct value. The low-frequency error in attenuation is less than ±0.02 dB ±0.25% of indicated dB setting plus a switch-resistance error of 0.003 dB (for -TA) or 0.005 dB (for -TB), when attenuator is terminated at both ends in a pure resistance of 600 Ω. For differences in attenuation between any two settings, switch-resistance error virtually disappears. To maintain accuracy at high attenuations, special wiring methods are employed to the "low" INPUT post.

Frequency Discrimination (with low terminal at panel potential): Less than 0.1 dB ±1% of the indicated value at frequencies below 200 kHz. For increments in attenuation, the 1% tolerance extends to approximately 1 MHz.

Maximum Input Power: 1 W.

Switches: Cam-type switches are used with twelve positions covering 360°. Dials are numbered from 0 to 10 inclusive, and the twelfth point is also connected to 0. Stops are provided in the switch mechanism for the 100-dB decade. No stops are provided to prevent complete rotation of the 10- and 1-dB decades, but spacers, which are provided, can be used under the mounting screws to act as stops for the knob, if desired.

Characteristic Impedance: 600 Ω both directions. One end must be terminated in 600 Ω.

Terminals: Low-thermal-emf jack-top binding posts with ¾-inch spacing; common terminal insulated from chassis; ground terminal provided.

Shielding: Each decade is individually shielded, and all shields are connected to the panel, to which the "G" post is also connected. Terminals are insulated from the panel, the "low" ones being connected together. The user is thus given free choice of grounding point for the "low" side, including connection to the panel post by the link provided.

Mounting: Lab-Bench Cabinet. Available for rack mounting.

Dimensions (width x height x depth): Bench models, 2-dial 1450-TA, 10 x 5¾ x 12¼ in. (255 x 150 x 315 mm); 3-dial 1450-TB, 12 x 5¾ x 12¼ in. (305 x 150 x 315 mm). Rack models 19 in. (485 mm) wide, same height and depth as bench models.

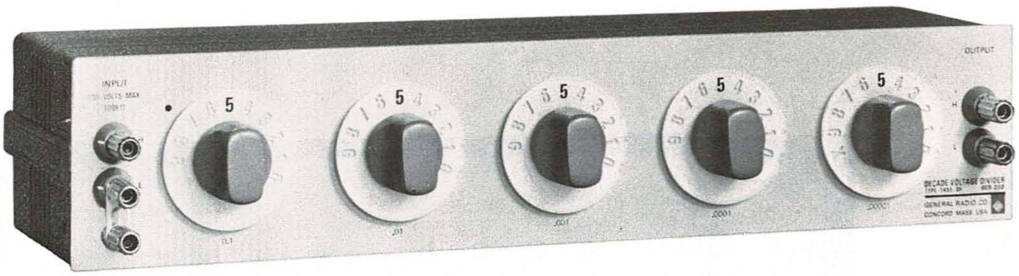
Net Weight: 1450-TA, 10¾ lb (4.9 kg); -TB, 14½ lb (7 kg); -TAR, 12 lb (5.5 kg); -TBR, 15½ lb (7.5 kg).

Shipping Weight: 1450-TA, 17 lb (8 kg); -TB, 20 lb (9.5 kg); -TAR, 22½ lb (10.5 kg); -TBR, 26 lb (12 kg).

Catalog Number	Description	Attenuation Total	Steps	Mount	Price in USA
	Decade Attenuator				
1450-9891	**1450-TA**	110 dB	1 dB	Bench	**$485.00**
1450-9894	**1450-TAR**	110 dB	1 dB	Rack	**485.00**
1450-9893	**1450-TB**	111 dB	0.1 dB	Bench	**650.00**
1450-9895	**1450-TBR**	111 dB	0.1 dB	Rack	**650.00**

Type 1455 DECADE VOLTAGE DIVIDER

- linearity better than 20 ppm (5-dial model)
- input impedance: 1, 10, or 100 kΩ
- high-frequency model, down 3 dB at 7.5 MHz



The GR 1455 Decade Voltage Dividers provide accurately known voltage ratios from 0.00001 to 1.00000 for use in many common measurements:

- voltage gain or attenuation,
- linearity of potentiometers and other controls,
- frequency response of audio and rf networks,
- transformer turns ratio,
- voltmeter calibration.

A resistive divider of the Kelvin-Varley type, the 1455 has precision resistors throughout rather than in selected positions only for over-all high accuracy. Linearity is as low as 0.02 ppm of input.

Match your needs exactly. Select input impedance, voltage rating, frequency range, 4- or 5-dial resolution, bench or rack mounting.

— See **GR Experimenter** for April 1967.

specifications

Type	1455-AH	-A	-AL	-BH	-B
Dials:	4	4	4	5	5
Input Resistance (accuracy given below):	100 kΩ	10 kΩ	1 kΩ	100 kΩ	10 kΩ
Input Voltage Rating (may be 20 ppm linearity change at full rating, see below):	700 V	230 V	70 V	700 V	230 V
Frequency Response (unloaded, at max output resistance setting), frequency at 3 dB down:	85 kHz	850 kHz	7.5 MHz	69 kHz	690 kHz
Resolution (in ppm of input):	100	100	100	10	10
LINEARITY					
Absolute Linearity (in ppm of input). Output taken with respect to output zero-setting at low audio frequencies with input voltage <½ rating:					
Ratio					
0.00001 to 0.00010	—	—	—	±0.02	±0.03
0.00010 to 0.00100	±0.2	±0.3	±0.7	±0.2	±0.3
0.00100 to 0.01000	±2	±2	±3	±2	±3
0.01000 to 0.10000	±15	±15	±20	±10	±10
0.10000 to 1.00000	±30	±30	±50	±20	±20
Terminal Linearity (in ppm of input). Add to absolute linearity.					
Four-Terminal (output with respect to low output terminal):	±0.004	±0.04	±0.4	±0.004	±0.04
Three-Terminal (low terminals common or output with respect to low input terminal):	±0.02	±0.2	±2	±0.02	±0.2
Max Output Resistance (input shorted):	27.9 kΩ	2.79 kΩ	333 Ω	28.8 kΩ	2.88 kΩ
Effective Output Capacitance (typical, unloaded):	67 pF	67 pF	67 pF	80 pF	80 pF

Frequency Characteristic: Acts like simple RC circuit below f_o so that

$$\frac{E_o}{E_{in}} \approx \frac{\text{reading}}{\sqrt{1+\left(\frac{f}{f_o}\right)^2}}.$$

Tabulated value of f_o is at setting that gives max output resistance so that f_o at all other settings is higher. At $0.044f_o$, response is down <0.1%.

Accuracy of Input Resistance: +0.015%, except for 1455-AL, which is +0.025%.

Temperature Coefficient: <20 ppm for each resistor. Since voltage ratios are determined by resistors of similar construction, net ambient temperature effects are very small.

Dimensions (width x height x depth): Rack models, 19 x 3½ x 4⅝ in. (485 x 89 x 120 mm); 4-dial bench models, 14¾ x 3½ x 6 in. (375 x 89 x 155 mm); 5-dial bench models, 17$\frac{15}{16}$ x 3½ x 6 in. (455 x 89 x 155 mm).

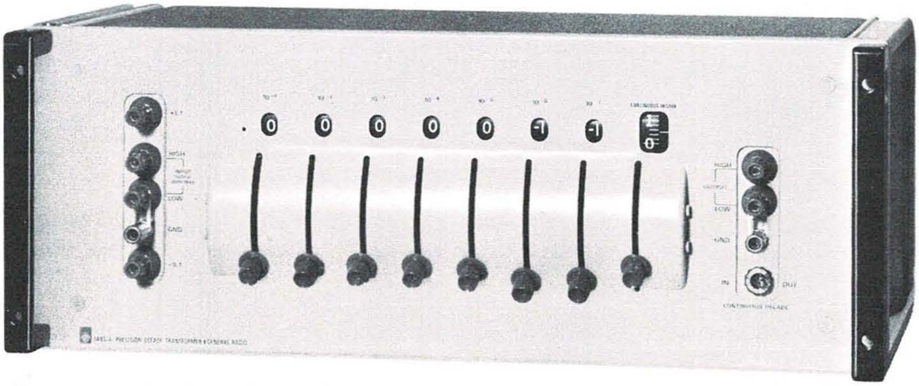
Net Weight: Bench models, 4-dial, 6¾ lb (3.1 kg); 5-dial, 7¾ lb (3.6 kg).

Shipping Weight: Bench models, 4-dial, 8 lb (3.7 kg); 5-dial, 9 lb (4.1 kg). Add 1 lb (0.5 kg) to net and shipping weights for rack models.

Catalog Number	Description	Price in USA
	1455 Decade Voltage Divider	
	Bench Models	
1455-9700	1455-A, 4-dial, 10-kΩ	$270.00
1455-9702	1455-AH, 4-dial, 100-kΩ	270.00
1455-9704	1455-AL, 4-dial, 1-kΩ	270.00
1455-9706	1455-B, 5-dial, 10-kΩ	330.00
1455-9708	1455-BH, 5-dial, 100-kΩ	330.00
	Rack Models	
1455-9701	1455-A, 4-dial, 10-kΩ	280.00
1455-9703	1455-AH, 4-dial, 100-kΩ	280.00
1455-9705	1455-AL, 4-dial, 1-kΩ	280.00
1455-9707	1455-B, 5-dial, 10-kΩ	340.00
1455-9709	1455-BH, 5-dial, 100-kΩ	340.00

Type 1493 PRECISION DECADE TRANSFORMER

- 9-figure resolution
- linearity: ±2 digits in 10^{-7} decade
- continuous 10^{-8} decade



High accuracy and resolution, essentially infinite settability, and an added measure of convenience set the GR 1493 Precision Decade Transformer apart from other "ratio boxes." All eight decade controls are easy-balancing levers with in-line readout of the type used in the GR 1615 Capacitance Bridge. The last decade is continuously adjustable for interpolating between steps of the 10^{-7} decade and providing essentially infinite resolution. It can be switched out for calibration of the step decades. All step decades are adjustable from −1 to X (or 10) to permit easy steps backward or forward through the awkward "many-zeroed" values.

1311 Oscillator page 226

1232 Detector page 134

Acceptable for calibration by the National Bureau of Standards, the 1493 can be used as a primary standard to calibrate other ratio transformers. Beyond this, in educational and experimental laboratories the 1493 can be used as two of the ratio arms in a variety of transformer bridge circuits for high-accuracy impedance measurements. To gain full use of the 1493 resolution in any application requires an oscillator and null detector with adequate combined sensitivity. The GR 1311-A Audio Oscillator with 100-V output and GR 1232-A Tuned Amplifier and Null Detector with better than 0.1-μV sensitivity are recommended as capable of providing the necessary 1 part in 10^9 sensitivity.

— See **GR Experimenter** for April 1967 and May 1968.

specifications

Range: −0.1111111 to +1.11111110 with 7 step decades adjustable from −1 to X (10) and one continuous decade from 0 to X.

Terminal Linearity (reference conditions 100 V, 1 kHz): Indicated ratios from 0 to 1 agree to 0.2 ppm with National Bureau of Standards calibration stated to be accurate to ±0.2 ppm. Furthermore, independent measurements indicate that these settings are accurate to ±0.2 ppm of true ratio. Normal operating conditions, 100 Hz to 2 kHz: Indicated ratio within 0.5 ppm of true ratio (within 1 ppm at 50 Hz). Slide-wire linearity ±1% of max value.

Phase Shift (at 1 kHz): <±6 microradians for ratio settings from 0.1 to 1.0; <±40 μrad for 0.01 to 0.1; <±125 μrad for 0.001 to 0.01.

Max Voltage: 350 V; below 1 kHz, $0.35f_{Hz}$ V.

Impedance: >100 kΩ at 1 kHz; >10 kΩ from 100 Hz to 10 kHz.

Direct Current: No dc should be applied to input for best accuracy; <1 ppm error from 1 mA at 100 V, 1 kHz.

OUTPUT

Impedance (dependent on ratio setting): Max: 3.5 Ω, 62 μH; min: 0.5 Ω, 6 μH. With slide-wire decade switched out, max resistance is reduced to 2.7 Ω.

Max Output Current: 1 A.

Terminals: Gold-plated GR 938 Binding Posts.

Accessories Available: Recommended generator and null detector for precise comparison or bridge applications: the 1311-A Audio Oscillator and 1232-A Tuned Amplifier and Null Detector or the combination 1240-A Bridge Oscillator-Detector.

Cabinet: Rack-bench. End-frames for bench mount or rack-mounting hardware included.

Dimensions (width x height x depth): Rack, 19 x 7 x 8⅜ in. (485 x 180 x 215 mm); bench, 19 x 7⅜ x 10¾ in. (485 x 190 x 275 mm).

Net Weight: Rack, 28 lb (12.7 kg); bench, 30 lb (13.6 kg).

Shipping Weight: Rack, 41 lb (18.7 kg); bench, 43 lb (19.6 kg).

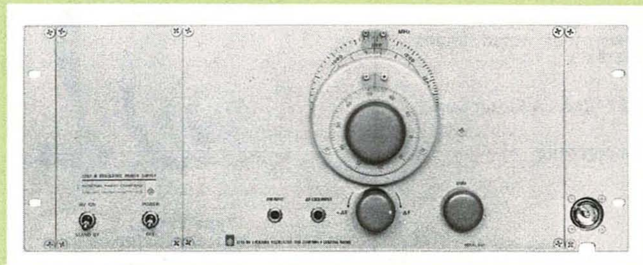
Catalog Number	Description	Price in USA
	1493 Precision Decade Transformer	
1493-9801	Bench Model	**$1100.00**
1493-9811	Rack Model	**1100.00**

HIGH-FREQUENCY OSCILLATORS

0.5 to 4100 MHz

These compact, low-priced oscillators provide continuous coverage from 500 kHz to 4.1 GHz, with single-dial control and output in the order of several hundred milliwatts. By appropriate choice of power supply the user can secure from these oscillators (1) maximum power, (2) optimum frequency stability with minimum residual fm and a-m, (3) pulse and square-wave modulated output, (4) amplitude-regulated output for sweeping applications, or use them as local oscillators in heterodyne detector systems.

Power supplies and oscillators are designed for semi-permanent attachment for bench use or relay-rack mounting. Accessories suitable for use with these oscillators are also listed.



Oscillator with 1269 or 1267 power supply.

specifications for 500-kHz—2000-MHz Oscillators
(Types 1211, 1215, 1218-BV, 1361, 1362, and 1363)

Frequency Control: Gear-driven precision dials.

Output Power: Output power obtainable with 1269, 1264 or 1267 Power Supplies is shown in the figure accompanying the description of each oscillator.

With the 1263-C Amplitude-Regulating Power Supply, the max useful power output is 20 mW. The available power is adequate for practically all laboratory measurements with bridges, slotted lines, admittance and transfer-function meters, tuned circuits, etc.

Output System: A short coaxial line brings the output from an adjustable coupling loop (in the 1211-C and 1363 from a fixed loop and potentiometer) to a locking GR874® coaxial connector. The output connector is located at the rear of the oscillator except on the 1361, 1362, and 1363, which have it on the front panel. Max power can be delivered to load impedances normally encountered in coaxial systems. Adaptors are available to convert the GR874 connector to any other common type. These adaptors lock securely in place, yet are easily removed.

Power Supply: The external power supply should be chosen from the group listed in the Summary of Power-Supply Characteristics. Operation from 400-Hz lines is possible with many of these power supplies with all oscillators.

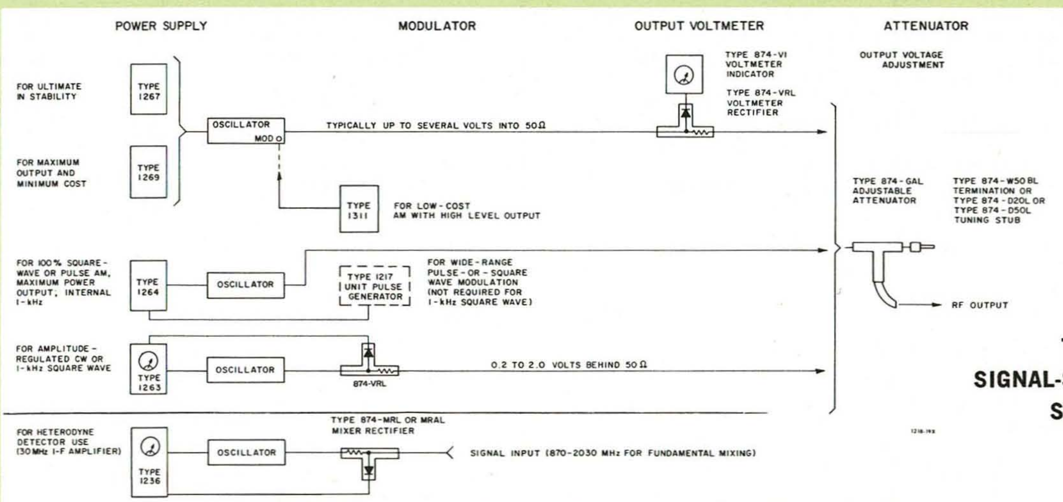
Modulation: For amplitude modulation over the audio range, a modulating voltage is imposed on the plate supply. A jack is provided for this purpose. The audio source must be capable of carrying the dc plate current of the oscillator. The 1311 Audio Oscillator is recommended as a modulator. For 30% a-m, incidental fm in this system is of the order of 0.01% at the lower part of the tuning range, and increases to about 0.05% at the high-frequency end.

Square-wave or pulse modulation can be obtained on all oscillators, except the 1211-C, by use of the 1264-B Modulating Power Supply. All oscillators except the 1211-C can be square-wave modulated at 1 kHz supplied by the 1263-C Amplitude-Regulating Power Supply.

Mounting:

Bench Use — Any of the oscillators can be used on the bench with any of the recommended power supplies; interconnecting cables are supplied. All oscillators and all power supplies are 7 in. high and can be attached to each other with the hardware supplied to form a rigid assembly.

Relay-Rack Use — Any oscillator except the 1218 can be relay-rack mounted together with a 1263, 1264, 1267, or 1269 Power Supply in 7 inches of rack height. The 1218-BV requires 7 inches of rack height when mounted with a 1267 Power Supply, or 14 inches of rack height when used with 1263 or 1264 Power Supply. Accessories required for rack mounting are listed elsewhere in this section. For complete assemblies of oscillator and power supply for either rack mount or bench mount, see following pages.



TYPICAL SIGNAL-SOURCE SYSTEMS

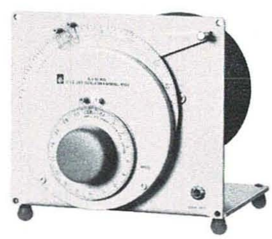
HF, VHF, UHF, Microwave Oscillators

See preceding page for general specifications

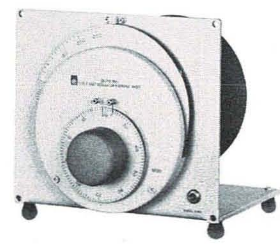
Supplied with each oscillator, except as noted under "Remarks":

Type 874-R22LA Patch Cord

Telephone Plug



Type 1211-C Unit Oscillator



Type 1215-C Unit Oscillator

Type 1363 VHF Oscillator

	Type 1211-C Unit Oscillator	Type 1215-C Unit Oscillator	Type 1363 VHF Oscillator
Catalog Number	1211-9703	1215-9703	1363-9701
Frequency	0.5 to 50 MHz	50 to 250 MHz	56 to 500 MHz
Tuned Circuit	Variable L and C	Semi-Butterfly	Variable L and C
Calibration Accuracy	±2%	±1%	±2%
Warmup Frequency Drift (Typical)	0.4%	0.2%	0.8%

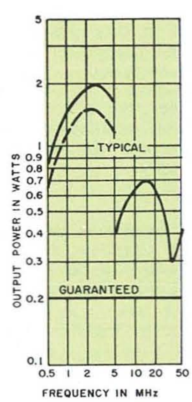
Power Output into 50 ohms using Power Supply:

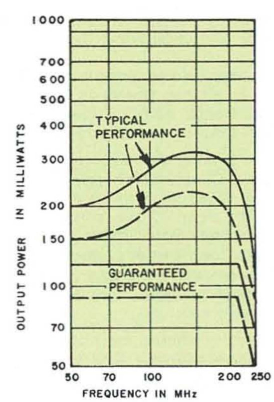
— Type 1269

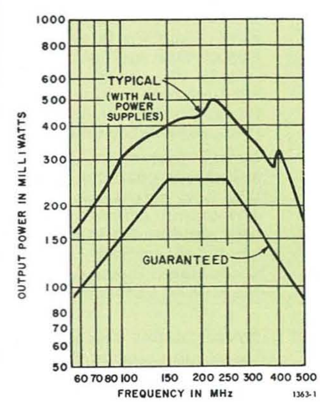
- - - Type 1264 or 1267

[Types 1203 and 1201 Power Supplies can also be used.]

1360-B has internal power supply.







	Type 1211-C	Type 1215-C	Type 1363
Cabinet[1]	Unit	Unit	Convertible Bench
Panel Dimensions	8 × 7 in. (205 x 180 mm)	8 × 7 in. (205 x 180 mm)	8 × 7 in. (205 x 180 mm)
Depth Behind Panel	9¾ in. (250 mm)	7½ in. (190 mm)	8¼ in. (210 mm)
Net Weight	11½ lb (5.5 kg)	7¼ lb (3.3 kg)	7½ lb (3.4 kg)
Shipping Weight	19 lb (9 kg)	10 lb (4.6 kg)	10 lb (4.6 kg)
Price in USA	**$495.00**	**$325.00**	**$495.00**

ACCESSORIES AVAILABLE

	Type 1211-C	Type 1215-C	Type 1363
Modulating Power Supply **Type 1264-B**	No	Yes[2]	Yes
Amplitude-Regulating Power Supply **Type 1263-C**	Yes	Yes	Yes
Remarks	874-Q2 Adaptor supplied	No Sliding Contact	Sliding Contact

[1] Relay-rack mount, see page 242.

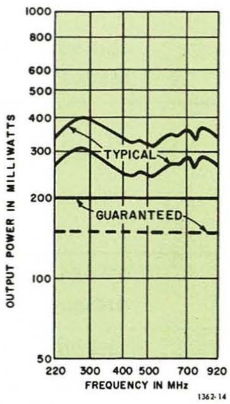
[2] Requires Adaptor Cable 1264-P1 (see page 240).

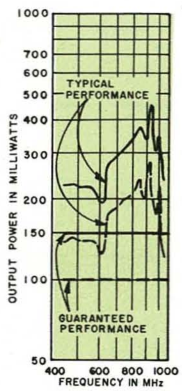
HF, VHF, UHF, Microwave Oscillators

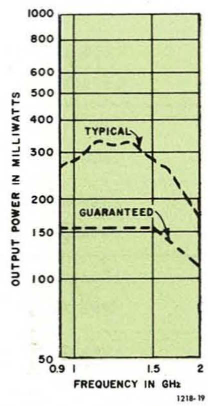
See next page for complete combinations of oscillators and power supplies.

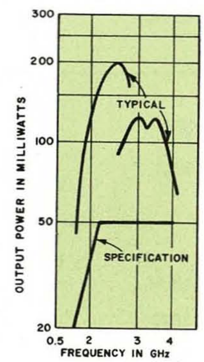



Type 1362 UHF Oscillator	**Type 1361-A UHF Oscillator**	**Type 1218-BV Lockable Oscillator**	**Type 1360-B Microwave Oscillator**
1362-9701	1361-9701	1218-9724	1360-9802
220 to 920 MHz	450 to 1050 MHz	900 to 2000 MHz	1.7 to 4.1 GHz
Butterfly	Butterfly	Adjustable Lines	Coaxial Cavity
±1%	±1%	±1%	±1%
0.2%	0.2%	0.1%	0.15%









Convertible Bench	Convertible Bench	Unit	Rack-Bench
8 × 7 in. (205 x 180 mm)	8 × 7 in. (205 x 180 mm)	12 × 7 in. (305 x 180 mm)	19 × 7 in. (485 x 180 mm)
8¼ in. (210 mm)	8¼ in. (210 mm)	7½ in. (190 mm)	13 in. (330 mm)
8 lb (3.6 kg)	7 lb (3.2 kg)	14 lb (6.5 kg)	38 lb (17.5 kg)
11 lb (5 kg)	11 lb (5 kg)	26 lb (12 kg)	75 lb (35 kg)
$495.00	**$445.00**	**$995.00**	**$1750.00**

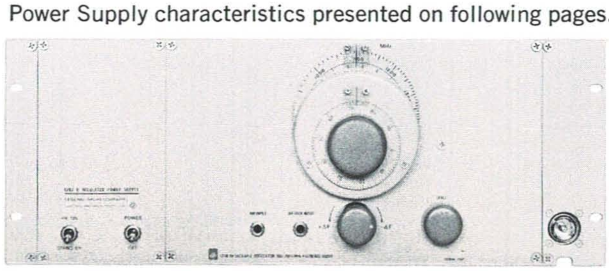
ACCESSORIES AVAILABLE

Yes	Yes	Yes	Not required
Yes	Yes	Yes	Not required
No Sliding Contacts. Low external field. Calibrated attenuator.	Logarithmic frequency scale. Low external field. Calibrated attenuator. No sliding contact.	Sliding contacts. Fine frequency control. Phase lockable. Not to be used with 1269 Power Supply.	Full specifications given on page 243

OSCILLATOR-POWER-SUPPLY COMBINATIONS

Frequency Range and (Oscillator Type) ↓	Mount ↓	Performance → (Power Supply Type)	Maximum power; lowest cost (1269-A)	Best cw stability; very low residual fm (1267-B)	Stable cw; 100% square-wave & pulse modulation; stable internal 1-kHz square-wave (1264-B)	Amplitude-leveled output behind 50-Ω source impedance; metered output level; 1-kHz square-wave modulation, or cw (1263-C)
		Input Line Voltage	105 to 125 V or 195 to 250 V	105 to 125 V or 195 to 250 V	105 to 125 V or 210 to 250 V	105 to 125 V or 210 to 250 V
0.5-50 MHz (Type 1211-C)	Bench	Catalog No.	1211-9439	1211-9437	Not Available	1211-9433
		Price in USA	**$605.00**	**$720.00**		**$1095.00**
	Rack	Catalog No.	1211-9579	1211-9577		1211-9573
		Price in USA	**$645.00**	**$760.00**		**$1130.00**
50-250 MHz (Type 1215-C)	Bench	Catalog No.	1215-9439	1215-9437	1215-9434	1215-9433
		Price in USA	**$435.00**	**$550.00**	**$850.00**	**$925.00**
	Rack	Catalog No.	1215-9579	1215-9577	1215-9574	1215-9573
		Price in USA	**$475.00**	**$590.00**	**$890.00**	**$965.00**
56-500 MHz (Type 1363)	Bench	Catalog No.	1363-9419	1363-9417	1363-9414	Not Available
		Price in USA	**$605.00**	**$720.00**	**$990.00**	
	Rack	Catalog No.	1363-9509	1363-9507	1363-9504	
		Price in USA	**$645.00**	**$760.00**	**$1030.00**	
220-920 MHz (Type 1362)	Bench	Catalog No.	1362-9419	1362-9417	1362-9414	1362-9413
		Price in USA	**$605.00**	**$720.00**	**$990.00**	**$1095.00**
	Rack	Catalog No.	1362-9509	1362-9507	1362-9504	1362-9503
		Price in USA	**$645.00**	**$760.00**	**$1030.00**	**$1135.00**
450-1050 MHz (Type 1361-A)	Bench	Catalog No.	1361-9419	1361-9417	1361-9414	1361-9413
		Price in USA	**$555.00**	**$670.00**	**$940.00**	**$1045.00**
	Rack	Catalog No.	1361-9509	1361-9507	1361-9504	1361-9503
		Price in USA	**$595.00**	**$710.00**	**$980.00**	**$1085.00**
900-2000 MHz (Type 1218-BV)	Bench	Catalog No.	1218-9429	1218-9427	1218-9424	1218-9423
		Price in USA	**$950.00**	**$1065.00**	**$1335.00**	**$1440.00**
	Rack	Catalog No.	1218-9549	1218-9547	1218-9544	1218-9543
		Price in USA	**$990.00**	**$1105.00**	**$1390.00**	**$1495.00**

Power Supply characteristics presented on following pages.



Rack Mount

OSCILLATOR POWER SUPPLIES

Type 1269-A

Type 1267-B

Power-supply characteristics are frequently a determining factor in the performance of an oscillator. For such applications as parametric-amplifier pumps, oscillators must be stable against all power-line variations and free of modulation from power-supply ripple. For these extreme requirements, both plate and heater supplies should be regulated, well-filtered dc, as in the 1263, 1264, and 1267 power supplies. In any application, use of these power supplies is desirable as they ensure conservative operating conditions resulting in long oscillator-tube life.

For noncritical applications, unregulated dc plate and ac heater supplies are adequate and represent a saving. The 1269 Power Supply is of this type.

AMPLITUDE MODULATION

Other applications require power supplies in which the plate-supply voltage is controllable to modulate or to regulate the oscillator output. The 1264-B Modulating Power Supply provides 100% amplitude modulation at high level by square-waves or pulses as well as cw operation. The 1-kHz modulation frequency is highly stable. Both plate and heater supplies are electronically regulated.

RF LEVEL AND MODULATION

The 1263-C Amplitude-Regulating Power Supply includes a feedback loop to maintain constant oscillator output as the oscillator frequency is varied. Constant output not only speeds and simplifies measurements where the oscillator is tuned manually but is essential when making sweep measurements. The 1263-C Amplitude-Regulating Power Supply has an internal 1-kHz oscillator for square-wave modulation. The heater supply is electronically regulated.

SUMMARY OF OSCILLATOR POWER-SUPPLY CHARACTERISTICS

Type	Applications	Panel Width	Price in USA
1267-B	Ultimate stability for cw	4″	**$225.00**
1269-A	Max output and low cost for cw	4″	**110.00**
1264-B[1]	100% square wave and pulse a-m	8″	**495.00**
1263-C	Amplitude-regulated cw or 1-kHz square-wave output	8″	**600.00**
1236	Heterodyne detector	8″	**835.00**

[1]Requires Type 1264-P1 Adaptor Cable when used with 1215-C Unit Oscillator.

For complete combinations of Oscillator and Power Supply, see page 238.

Type 1267 REGULATED POWER SUPPLY
Type 1269-A POWER SUPPLY

The 1269 is a general-purpose, unregulated 300-volt dc and 6.3-volt ac supply. In the 1267, both heater and plate supplies are regulated to provide complete freedom from line-voltage variations, minimum residual modulation and frequency drift, and long oscillator-tube life.

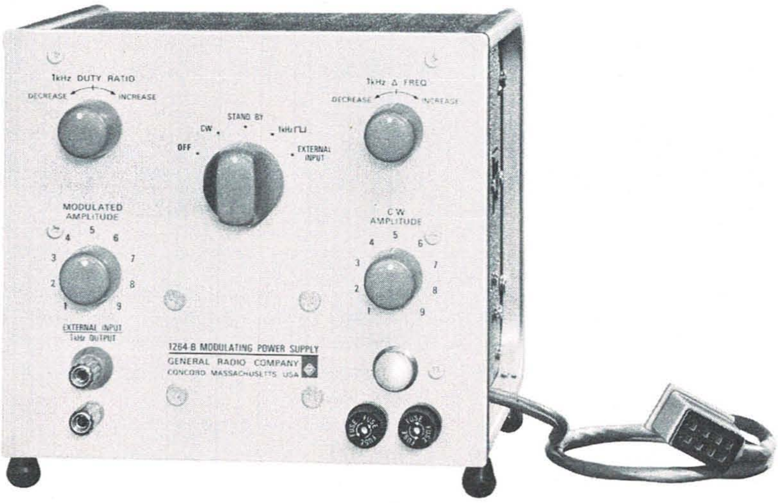
specifications

			TYPE 1269-A	TYPE 1267-B
Output	Dc		At nominal input line voltage, 300 V ±5% at 50 mA; approx 410 V at no load; 50 mA, max.	300 V, 70 mA max; can be disconnected by standby switch. Regulation, ±0.25% for line and load changes.
	Ripple		Less than 80 mV rms at full load	Less than 1 mV rms at full load
	Low Voltage		6.3 V ac, unregulated, at 3 A	6.5 V dc at 1 A; regulation, ±0.25 % for line-voltage changes. Output resistance 35 mΩ, approx.
Input	V		105 to 125, 195 to 235, or 210 to 250	105 to 125, 195 to 235 or 210 to 250
	Hz		50 to 60 or 400*	50 to 60 or 400*
	W		50	75
Connectors			Permanently attached 3-wire line cord, 4-terminal output socket	4-terminal output socket
Accessories Supplied			Mating plug for output	3-wire line cord, mating plug for output
Convertible-Bench Cabinet		Dimensions	Width 4¼, height 7⅝, depth 9¼ in. (110, 195, 235 mm)	
		Weight	Net, 5¾ lb (2.7 kg); shipping, 8 lb (3.7 kg)	Net, 7¾ lb (3.6 kg); shipping, 10 lb (4.6 kg)
Catalog Number			1269-9701	1267-9702
Price in USA			**$ 110.00**	**$225.00**

* At 400 Hz, minimum input line-voltage requirements are increased 5%.

Type 1264-B MODULATING POWER SUPPLY

- for use with GR high-frequency oscillators
- stable 1-kHz square-wave modulation
- 20-Hz to 100-kHz pulse mod from external source
- adjustable, regulated dc supply



Oscillators page 235 ff

The 1264-B produces 100% pulse and square-wave modulation of vhf and uhf oscillators, 1361-A, 1362, 1363, 1215-C, and 1218-BV. In addition, it can be used as an adjustable regulated power supply for the oscillator plate and as a source of regulated heater power.

It is available in combination with the above oscillators.

The 1264-B comprises an electronically regulated, adjustable-output, high-voltage, dc supply; a dc-coupled, series-type power modulator driven by a Schmitt trigger circuit; and a 1-kHz multivibrator. A switch permits selection of cw, standby (only heaters energized), 1-kHz square-wave modulated (internally generated), or externally modulated operation. Independent panel controls vary the regulated supply voltage for cw operation and the modulator amplitude for square-wave and pulse operation. Controls are also provided to adjust the frequency of the internal 1-kHz multivibrator and the duty ratio to produce a true square wave.

The input trigger circuit accepts single or multiple positive pulses, which are reproduced at the modulator output. It also accepts square waves at rates up to 100 kHz, or sine waves up to 50 kHz, from any 20-volt source such as the 1217-C Unit Pulse Generator or the 1310 Oscillator and produces square waves at the modulator output. No adjustment of triggering is necessary. The stable 1-kHz multivibrator provides ideal square-wave modulation for use with sharply selective amplifiers following the signal detector.

— See **GR Experimenter** for June-July 1968.

specifications

REGULATED DC OUTPUT (Unmodulated)

Output: Adjustable 200 to 300 V; 50 mA, max.

Regulation: Output voltage at any rated load will change <0.5 V for 10-V line-voltage change. Dc output resistance, <5 Ω (typically 2 Ω).

Ripple: <1 mV rms with B− grounded; <5 mV rms with B+ grounded.

HEATER POWER OUTPUT

Output: 6.5 V dc, regulated; adjustable, ±0.3 V, 1 A, max.

Regulation: For 6.2- to 6.5-V output, voltage will change <5 mV for 10-V line-voltage change. Dc output resistance, <40 mΩ (typically 20 mΩ).

Ripple: <5 mV rms at full load.

MODULATED OUPUT (Internally or Externally Driven)

Transition Times (10 to 90% points): <1.5 μs when driving 300 pF across 15 kΩ or less.

Ramp-off: None.

SQUARE-WAVE OUTPUT (Internally Generated)

Amplitude: Adjustable, approx 160 to 210 V.

Frequency: Adjustable, 850 to 1150 Hz. Can be set to within 0.3 Hz of desired value.

Stability: Frequency will change <0.1% (typically 0.04%) for 10-V line-voltage change.

Duty Ratio: 0.5, adjustable ±5%.

SQUARE-WAVE OUTPUT (Driven by External Sine-Wave Source)

Amplitude: Adjustable, approx 160 to 210 V.

Driver Requirement: 20 to 50 V rms, 20 Hz to 50 kHz.

PULSE OUTPUT (Driven by External Pulse Generator)

Amplitude: Adjustable, approx 160 to 210 V.

Duration (between half-amplitude points): 1.5 μs to square waves, determined by external source.

Driver Requirement: +20 to +50 V, 100,000 pps, max.

Synchronization: Internal square-wave generator can be synchronized to a sine- or square-wave signal applied to the EXTERNAL INPUT/1 KHZ OUTPUT binding posts. Sync range is >±1% for a 5-V-rms, 1-kHz sine wave. A sync output of >2 V pk-pk behind 18 kΩ is delivered to these binding posts in internal 1-kHz square-wave mode of operation.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 85 W.

Accessories Supplied: Power cord, connector plug.

Recommended Oscillators: 1361-A (450-1050 MHz); 1215-C (50-250 MHz); 1362 (220-920 MHz); 1363 (56-500 MHz); and 1218-BV (900-2000 MHz). An adaptor cable is required for use with 1215-C.

Accessories Available: 1264-P1 Adaptor Cable to connect to 1215-C Oscillator; rack-adaptor sets for 19-in. relay-rack mounting, panel height 7 in.

Mounting: Convertible-Bench Cabinet.

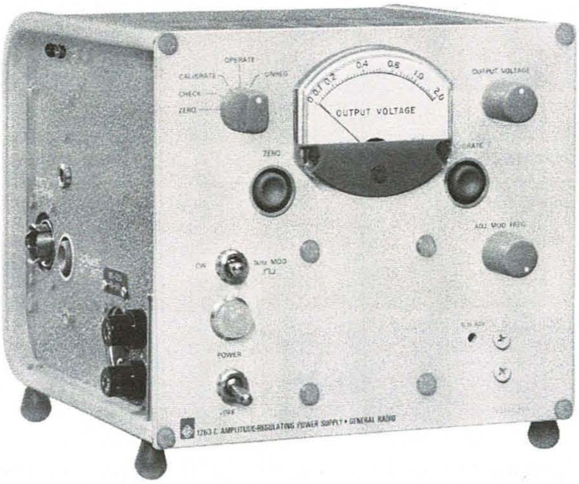
Dimensions (width x height x depth): 8 x 7 x 9¼ in. (205 x 180 x 235 mm).

Weight: Net, 12 lb (5.5 kg); shipping, 15 lb (7 kg).

Catalog Number	Description	Price in USA
	1264-B Modulating Power Supply	
1264-9702	115-V Model	$495.00
1264-9703	230-V Model	495.00
1264-9601	**1264-P1 Adaptor Cable** for 1215-C	30.00

Type 1263-C AMPLITUDE-REGULATING POWER SUPPLY

- for use with GR high-frequency oscillators
- levels output within ±0.5 dB
- supplies 1-kHz square-wave modulation
- meters rms output voltage of oscillator




874-R22LA


874-VRL

Rectifier and patch cord are included

USES: The 1263-C automatically maintains the output of vhf and uhf oscillators at a preset value in spite of incidental amplitude variations that may occur both with supply-voltage variations and with changes in oscillator frequency.

Its very-high-speed response is particularly useful when the oscillator dial is mechanically driven.

This power supply will modulate an oscillator with 1-kHz square waves, thus eliminating incidental frequency modulation and permitting the use of an untuned detector with a sensitive audio amplifier. Regulation of average output level is maintained in this mode of operation so that swept measurements at very low rf detector levels can be made.

The dc potential developed by the oscillator output rectifier (874-VRL) is compared with an adjustable dc reference in a feedback system. A rapid correction is applied to the plate current to hold the oscillator output to a preset level. Rf blanking can be accomplished by external shorting of the reference potential.

Oscillators page 235 ff

For 1-kHz modulation, the voltage regulated is the average value of the square-wave envelope. An external synchronous detector can be gated from a voltage provided, to maintain a high signal-to-noise ratio in low-level measurements.

— See **GR Experimenter** for July 1967.

specifications

Rf Output Voltage: 0.2 to 2.0 V behind 50 Ω for any recommended oscillator (see below). With 1-kHz square-wave modulation, 0.2 to 1.0 V (average value of rms carrier level) behind 50 Ω.

Rf Output Regulation: Below 500 MHz, rf output of 1211, 1215, and 1362 oscillators is held to within ±5% including the effects of harmonics. This regulation can be attained up to 2000 MHz if proper low-pass rf filters are used and a correction applied for the rectifier frequency characteristic.

Modulation

Frequency: 1-kHz square-wave, adjustable ±5%, stable within 5 Hz over the rated range of line voltage.

Duty Ratio: 0.5 to 0.53, adjustable to compensate for oscillator-starting delay.

Rise and Decay Times: 50 μs each.

Overshoot: None. **Ramp-off:** Less than 0.5%.

Gate Voltage: Synchronized with "off" interval of modulation, exceeds 1 V into the recommended load of 30 kΩ shunted by 300 pF. Rise and decay times are less than 50 μs. Gate output during "on" interval of modulation is less than 0.01 V.

Plate Supply Output: 0 to 300 V at 30 mA.

Heater Supply Output: 6.5 V dc at 1 A, regulated. **Ripple:** <1 mV rms (120 Hz) at full load. **Dc Output Impedance:** Approx 35 mΩ. **Response Time:** For a 2-to-1 step variation in oscillator output, correction is completed within 0.5 ms with cw operation, 50 ms with 1-kHz modulation. Recovery time after blanking is less than 2 ms with cw operation, 200 ms with 1-kHz square-wave modulation.

Hum and Noise: Peak residual hum and noise modulation, less than ±0.3% on cw, ±3% with 1-kHz square-wave modulation.

Output Voltmeter: With 1-kHz square-wave modulation, meter reads average value of rms carrier level. Internal standardizing circuit is provided. Accuracy after standardization is better than ±10% of indication when a correction is applied for rectifier characteristic at extremely high frequencies.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz, 55 W.

Accessories Supplied: 874-VRL Voltmeter Rectifier, 874-EL-L 90° Ell, 874-R22LA Patch Cord for connecting output rectifier, power cord, connector cable for modulation jack on oscillator.

Accessories Required: 874-T Tee for oscilloscope connection in sweeping applications.

Recommended Oscillators: 1215-C (50 to 250 MHz), 1363 (56-500 MHz), 1362 (220 to 920 MHz), 1361-A (450 to 1050 MHz), 1218-BV (900 to 2000 MHz); for cw operation only, 1211-C (0.5 to 50 MHz).

Accessories Available: GR874® coaxial accessories. Panel adaptor plate sets for 19-in. relay-rack mounting, panel height 7 in.

Mounting: Convertible-Bench Cabinet.

Dimensions (width x height x depth): 8 x 7 x 9¼ in. (205 x 180 x 235 mm).

Weight: Net, 14½ lb (7 kg); shipping, 18 lb (8.5 kg).

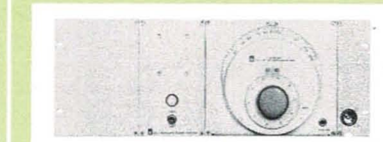
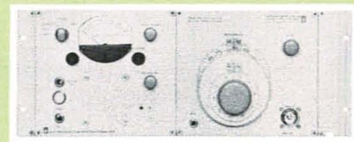
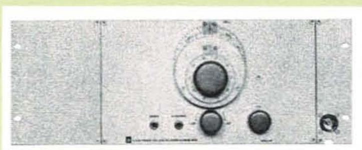
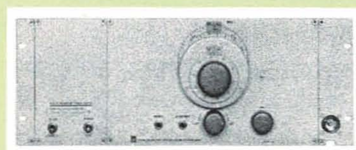
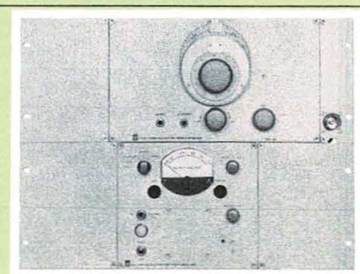
Catalog Number	Description	Price in USA
1263-9703	**1263-C Amplitude-Regulating Power Supply**	**$600.00**

PATENT NOTICE. See Note 15.

OSCILLATOR ACCESSORIES

RACK-ADAPTOR SETS For mounting oscillators and power supplies in a 19-inch rack

These adaptor sets include the necessary flanges and hardware for combining oscillator and power supply into a rigid assembly and for extending the panel width to rack size. A coaxial cable with panel connector is supplied for mounting on the right-hand adaptor panel to provide alternate front or rear output connections.*

Oscillator Type	Adaptor Set for Oscillator Only	Adaptor Set for Oscillator and either 1267 or 1269 Power Supply	Adaptor Set for Oscillator and either 1263 or 1264 Power Supply
1211-C **1215-C** **1361-A** **1362** **1363**	 Catalog No. 0480-9848 Type 480-P408 **Price in USA: $19.00**	 Catalog No. 0481-9842 Type 481-P412 **Price in USA: $30.00**	 Catalog No. 0481-9846 Type 481-P416 **Price in USA: $29.00**
1218-BV	 Catalog No. 0481-9842 Type 481-P412 **Price in USA: $30.00**	 Catalog No. 0481-9846 Type 481-P416 **Price in USA: $29.00**	 Catalog No. 0482-9842 Type 482-P412† **Price in USA: $44.00**

*Not supplied with Type 480-P408.

†Consists of one set for oscillator and one for power supply.

Type 1218-BV LOCKABLE OSCILLATOR (900 to 2000 MHz)

A new version of a popular GR oscillator, the 1218-BV has electronic frequency control as an added capability, making it valuable in a host of additional uses. By phase locking the 1218-BV to an external reference signal, the oscillator output can have high power, inherently low noise, and the stability of the reference signal against warmup drift and microphonics.

In heterodyne systems, where a difference signal must be stable to remain within the bandwith of a tuned detector, the 1218-BV can be used as the local oscillator. With a phase detector operating at the difference frequency, the 1218-BV can track small changes in the frequency of the test oscillator and hold the difference frequency steady.

— See **GR Experimenter** for November-December 1968.

specifications

Frequency Range: 900 to 2000 MHz.

Frequency Calibration Accuracy: ±1%.

Warmup Frequency Drift: 0.1% total drift, typical.

ΔF Control (Internal): >±2 MHz by ⅞ turn of front-panel knob.
Power-Level Pulling (by ΔF control): <± 0.5 dB for ±2 MHz ΔF.

ΔF Control (Remote): By dc voltage applied at front or rear jacks.
Frequency: >4 MHz total range for 50-V change.
Voltage: Typical useful range ±25 V; ΔF control sets center value from +10 to −20 V. Positive-going voltage causes frequency decrease. Applied voltage ±50 V max.
Interface Characteristic: Equivalent to 10 kΩ, 150 pF, and −1.3 mA current source in parallel across terminals, one of which is grounded. Ext source should have <1000 Ω internal impedance; can be ac coupled.
Step-Response Time: <1 μs, typical.

Output Power (into 50 Ω, with 1264 or 1267 power supply): >160 mW, 0.9 to 1.5 GHz; drops linearly to >110 mW at 2.0 GHz.

Output Connector: Locking GR874® connector at rear panel. Adaptors available to other connector types.

Level Control: Full output to at least 20-dB attenuation set by uncalibrated front-panel control.

Modulation: AM INPUT jack at front panel for external audio-frequency plate modulation; approx 30 V rms into 6 kΩ required for 30% amplitude modulation. GR 1311 Audio Oscillator recommended as modulator.

Dimensions (width x height x depth): Bench, 12 x 7⅝ x 9 in. (305 x 195 x 230 mm); rack (with 1267 power supply), 19 x 7 x 7 in. (485 x 180 x 180 mm), 1263 or 1264 power supply adds 7 in. to rack height.

Weight (less power supply): Net, 14 lb (6.5 kg); shipping, 25 lb (11.5 kg).

Catalog Number		Description	Price in USA	
1218-9724		**1218-BV Lockable Oscillator**	**$995.00**	
Bench	**Rack**	**Oscillator/Power Supply Combinations**	**Bench**	**Rack**
1218-9901	1218-9902	with 1263-C Amplitude-Regulating PS	**$1595.00**	**$1645.00**
1218-9903	1218-9904	with 1264-B Modulating PS	**1490.00**	**1540.00**
1218-9905	1218-9906	with 1267-B Regulated PS	**1220.00**	**1255.00**

Type 1360-B MICROWAVE OSCILLATOR

- 1.7 to 4.1 GHz
- output >100 mW, most of range
- stability 5 ppm over 10 min
- internal 1-kHz square-wave mod and sweep

The many modulation capabilities of this oscillator make it a most useful power source for microwave measurements. It is a suitable driver for slotted lines and a stable local oscillator for heterodyne detectors.

The oscillator is a reflex klystron in a coaxial cavity with a noncontacting plunger. The two frequency ranges, 1.7 to 2.8 GHz and 2.6 to 4.1 GHz, are selected automatically by the main frequency dial. The scales are in different colors; a pilot light indicates the scale in use.

The output is adjustable and monitored against overcoupling.

Cathode, repeller, and bias voltages are well regulated, and the klystron heater supply is dc. Tube replacements, including the klystron, require no tools. Long-life Teflon* bearings are used for the plunger.

— See **GR Experimenter** for Jan-Feb 1962 and Aug 1964.

* Registered trademark of the E. I. duPont de Nemours and Company.

specifications

FREQUENCY

Range: 1.7 to 4.1 GHz in two ranges, 1.7 to 2.8 GHz, covered in 5½ turns of tuning control, and 2.6 to 4.1 GHz, covered in 9 turns; 100-division interpolation of scale.

Fine Frequency Control (ΔF): Order of 1 MHz, but not functioning for square-wave modulation.

Accuracy: ±1%.

Stability: Warmup drift under laboratory conditions is approx 0.15% during the first hour, total drift approx 0.25%. After warmup, average frequency observed in a 1-s measurement interval is stable within approx 5 ppm over a 10-minute period.

Residual FM: Approx 3 ppm pk with 115-V, 60-Hz power; 6 ppm pk with 230 V, 50 Hz. Peak deviation increases substantially at high line voltage.

OUTPUT

Power: At least 20 mW from 1.7 to 2.1 GHz; at least 50 mW from 2.1 to 4.1 GHz. Individual instruments may vary 2:1 from typical curve.

Attenuator: Relative calibration only.

Terminal: GR874® coaxial connector, recessed, locking. For connection to other type connectors, use a GR874 locking adaptor.

INTERNAL MODULATION

Narrow-Band Sweep: At least 0 to 1 MHz at either 1 kHz or line-frequency rate. Max sweep width up to 3 MHz depends on carrier frequency. Negative pulse for oscilloscope sync provided.

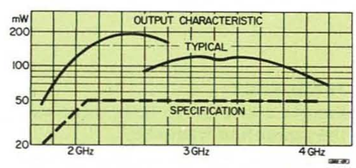
Square-Wave: 1 kHz, adjustable ±5%.

EXTERNAL MODULATION

FM: Sensitivity approx 0.2 MHz per V; input impedance, 400 kΩ and 70 pF (ac only).

Square-Wave: 50 Hz to 200 kHz, 12 V rms sine wave or 20 V pk-pk, square wave; 20% min duty cycle from external source. Impedance >100 kΩ.

Output-power characteristic.



Pulse: Rise and fall times approx 0.2 μs, min length approx 0.5 μs. Input impedance 100 kΩ; driving-pulse amplitude, 20 V pk-pk; max duty cycle 20%.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz, 85 W. Instrument will operate satisfactorily (except for line-frequency sweep) at power-line frequencies up to 400 Hz.

Accessories Supplied: 874-R22LA Patch Cord, power cord.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench model, 19 x 7½ x 15½ in. (485 x 195 x 395 mm); rack model, 19 x 7 x 13 in. (485 x 180 x 330 mm).

Weight: Net, 38 lb (17.5 kg); shipping, 75 lb (35 kg).

Catalog Number	Description	Price in USA
	1360-B Microwave Oscillator	
1360-9802	Bench Model	**$1750.00**
1360-9812	Rack Model	**1750.00**

Type 1330-A BRIDGE OSCILLATOR

- 400 Hz to 50 MHz
- 0.5-watt output over most of rf range
- excellent shielding

The 1330-A is an economical, general-purpose laboratory source of audio and radio frequencies. It covers the major part of the frequency range of the 1606-B Radio-Frequency Bridge and also supplies 400 and 1000 Hz. Its power output is adequate for most direct-deflection-type measurements with resonant circuits.

The circuit and the mechanical construction are similar to those of the 1001-A Standard-Signal Generator. Tuning capacitor and inductors are ruggedly constructed to assure frequency stability, the oscillator circuits are doubly shielded to minimize stray fields, and a modulating circuit of unusual design provides excellent modulation characteristics over the radio-frequency range.

Modulation is available at two audio frequencies and at two levels, selected by switches.

specifications

FREQUENCY

Range: 5 kHz to 50 MHz, continuous, plus 1000 Hz, 400 Hz, and the power-line frequency.

Calibration: Direct reading for eight 3:1 ranges. Calibration is logarithmic, and vernier dial indicates increments of 0.1% per division from 5 kHz to 15 MHz.

Accuracy: 400 and 1000 Hz, ±5%; frequencies below 150 kHz, ±3%; above 150 kHz, ±2%, all at no load. Frequency shift with 50-Ω load, 5% at low carrier frequencies; $<$1% above 150 kHz.

OUTPUT

Voltage: Audio, 12 V ±20%, open circuit; rf, adjustable, maximum across 50 Ω is: $>$1.5 V at any frequency, $>$2.5 V below 15 MHz, and $>$5 V from 50 kHz to 5 MHz.

Power: Audio, $>$500 mW into 50-Ω load; rf into 50-Ω load is: $>$45 mW at any frequency, $>$125 mW below 15 MHz, $>$500 mW from 50 kHz to 5 MHz.

Impedance: Audio jack, 50 ±20 Ω; rf, $<$80 Ω with output control at max setting.

Distortion: Rf, with max output into 50 Ω, about 3.5%, except at the lower frequencies, where it reaches 7%. Audio, 5%.

Leakage: Stray fields are $<$50 μV/m at 2 ft from oscillator.

Modulation: Internal only, at 400 and 1000 Hz, 25% and 50%.

Envelope Distortion: Less than 6% at 50% modulation; less than 4% at 25% modulation.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 Hz; 30 W.

Terminals: GR874® coaxial connectors, locking. For connection to other popular types, use a GR874 locking adaptor, which locks securely in place yet is easily removed.

Accessories Supplied: 874-R22LA Coaxial Cable, 874-Q2 Adaptor, TO-44 Adjustment Tool (mounted on rf shield cover), CAP-22 Power Cord.

Mounting: Lab-Bench Cabinet. Cabinet can be removed for rack mounting (panel 19 x 7 in.).

Dimensions (width x height x depth): 21¾ x 7½ x 11¼ in. (560 x 190 x 290 mm).

Weight: Net, 38 lb (17 kg); shipping, 50 lb (23 kg).

Catalog Number	Description	Price in USA
1330-9701	**1330-A Bridge Oscillator**	**$1150.00**

PULSE GENERATORS

Much of today's electronic engineering effort is devoted to the development of circuits and systems operating in the time domain. Switching, pulse, and digital circuits predominate in modern computing, navigation, and data-communication systems. In the laboratory, the oscilloscope and pulse generator replace the voltmeter and sinusoidal oscillator of yesterday as detector and source.

A pulse generator is, in essence, a highly versatile and controllable switch. Two parameters of interest that must be controlled are the pulse repetition frequency, or switching rate, and the pulse duration, or length of time the switch is closed (or open). The rise time, or speed of switching, is also an important parameter. In addition to the characteristics of the switch, specific applications will require particular characteristics for the energy source switched. The output impedance, open-circuit voltage, and available current must all be known and specified to fit a given pulse generator to a specific application.

Computational and data rates rise as rapidly as device development will permit. Pulse repetition rates can now range from nearly dc to over 100 MHz, and durations from seconds to less than 1 nanosecond. For computation and data-transmission systems, most of the applications can be served by relatively low power outputs, while radar and certain magnetic data-storage systems may require pulses of extremely high energy. It appears that a pulse generator that will meet all requirements, even in the laboratory, is out of the question.

The series of pulse generators offered in this catalog are pulse-signal sources of as general a type as economics will permit. The 1217-C produces pulses ranging from 0.1 μs to 1 s over a repetition rate range from dc to 2 MHz. It, like all the General Radio pulse-generator line, contains an internal prf oscillator with continuous range from 3 Hz to 1.2 MHz. Both pulse polarities are simultaneously available, and output circuits are dc coupled, an absolutely necessary characteristic when pulses of long duration must be produced. This high level of performance is achieved at nominal cost.

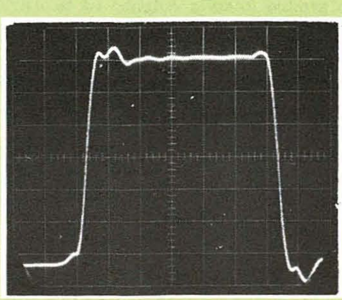
One of the most versatile and reasonably-priced pulse generators available today is the 1340. Even many substantially-higher-priced units fail to match the performance it offers: prf's from 0.2 Hz to 20 MHz, durations from 25 ns to 2.5 s, and both positive and negative amplitudes available simultaneously with independent amplitude and offset controls. It is a natural for IC testing and will provide the standard 5-volt logic level with a 50-Ω source impedance. The ability to sweep or linearly program the pulse amplitude, duration, and period makes the 1340 useful in automatic and semi-automatic measurements.

For the utmost in flexibility we offer the 1395-A Modular Pulse Generator. This hybrid system has duration ranges, rise times, and prf ranges similar to the 1217-C but permits, in one package, interconnection of various modules to produce a pulse generator of almost infinite variety. An input circuit module either serves as a prf oscillator or processes an external driving signal from dc to 2 MHz to produce a standardized system-synchronizing pulse. A second module produces pulses or delayed 0.1-μs synchronizing pulses in the range from 0.1 to 1 s with rise times of 15 ns. A single input module and three pulse/delay modules will form an excellent double-pulse generator, while 5 pulse/delay modules will provide a triple-pulse. A third module, timed from a pulse/delay module, will produce pulses with linear and independently variable rise and fall times over a range from 0.1 μs to 1 s. A fourth module produces up to 16-bit pulse words. A power amplifier with up to 0.4-ampere output at limited duty-ratio is the fifth module. Another module will convert the pulse words to NRZ (non-return-to-zero) form and act as a sampler.

The 1396-A Tone-Burst Generator, a new type of pulse instrument, operates as a coherent gate for an externally introduced signal. It has many applications in sonar, the design and test of amplifiers, transducers, filters, meters, as well as in acoustical measurements.

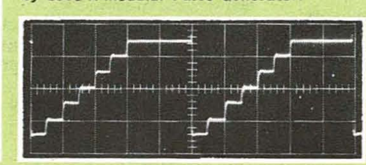
PULSE GENERATORS

Type	Name	Remarks
1217-C	Unit Pulse Generator	Low cost — high performance
1340	Pulse Generator	Low cost — general purpose — highly versatile
1395-A	Modular Pulse Generator	Generates complex pulse waveforms — ultimate in flexibility
1396-A	Tone-Burst Generator	Coherent gate — adjustable on and off intervals

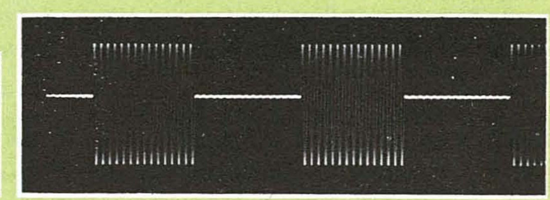


0.12-μs pulse from 1217-C Unit Pulse Generator.

Staircase waveform generated by 1395-A Modular Pulse Generator.

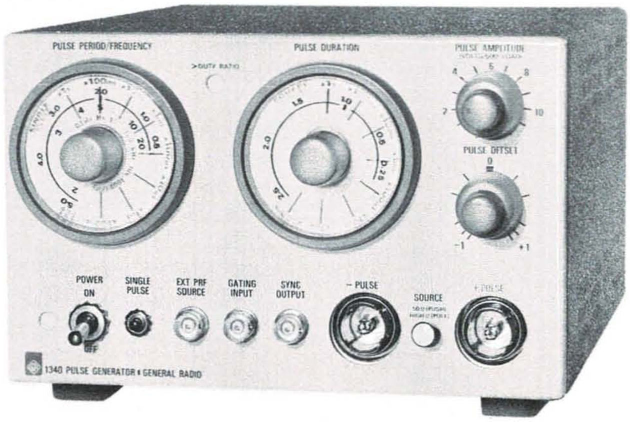


Tone-burst pattern from 1396-B Tone-Burst Generator. Input, 3 kHz; 16 cycles on; 16 cycles off.



Type 1340 PULSE GENERATOR

- 0.2 Hz to 20 MHz
- 2.5-s to 25-ns duration
- 5-ns rise time
- 10-V output with ±1-V offset
- amplitude, period, duration modulation



The GR 1340 Pulse Generator demonstrates that an economical, general-use instrument need not be mediocre. The 1340 provides, at low cost, wide ranges of repetition frequency and duration, high output, and many performance and convenience features never before available in a single pulse generator.

A full eight decades of period and duration make the 1340 the widest-range pulse generator in its price class. A panel lamp indicates settings that exceed the generous duty-ratio limits. External signals can be used to control prf, to gate the output, and to modulate the amplitude, period, duration of the output pulses.

Both positive and negative ground-based pulses of up to 10 volts are produced simultaneously. Their amplitudes and offsets can be independently set with continuously adjustable front-panel controls. Control is also provided of output impedance, single pulsing, input threshold for external prf sources, and for generating square waves.

The sync output of the 1340 is a square wave. This not only permits pretriggering of an oscilloscope but ensures more positive triggering since input circuits operate best with a signal that keeps reasonable duration and constant dc level at all repetition rates.

INTEGRATED-CIRCUIT TESTING

Many features of the GR 1340 have been incorporated to aid in the testing of integrated circuits. Its 20-MHz operation, adjustable offset, square-wave output, and ability to operate at the standard 5-volt logic level with a 50-Ω source impedance are all of especial value in IC testing. The ability to sweep or program linearly the pulse amplitude, duration, and period makes the 1340 useful in automatic and semi-automatic measurements.

— See **GR Experimenter** for November-December 1968.

specifications

PULSE PERIOD (PRF)

Internally Generated: 50 ns to 5 s (20 MHz to 0.2 Hz) in 8 decade ranges. Single-pulse push button on panel.

Externally Controlled: 1 Hz to 20 MHz; triggers on any waveform of >3 V pk-pk. Input resistance approx 100 kΩ. Output pulse is started by negative-going transition. Period control acts as input trigger-level control in external mode.

Accuracy (at 25°C, X2 setting): 10% for 10-μs to 10-ms ranges; 15% for 1-μs range; 20% for 100-ns and 1-s ranges.

Jitter (max pk-pk): 0.2% at 500 ns, 5 ms, and 50 ms; 0.5% at 50 ns.

OUTPUT-PULSE CHARACTERISTICS

Duration: 25 ns to 2.5 s in 8 decade ranges, or square wave.

Rise and Fall Times: 5 ns ± 2 ns at 5 V, 50-Ω load, and 50-Ω source resistance.

Amplitude: Positive and negative ground-based pulses available simultaneously with independent amplitude and offset control. Source current continuously adjustable to at least 0.2 A (i.e., across 50-Ω load, 10 V from high source resistance or 5 V from 50-Ω source).

Source Resistance: 50 Ω, or high (approx 1 kΩ) shunting current source.

Offset: Continuously adjustable source current from −20 to +20 mA.

Distortion: Preshoot, overshoot, ringing, etc, <0.5 V (5% of max output).

Duty Ratio: Duty ratios of over 70% can be obtained on all ranges except decreasing to approx 50% at 50-ns period in 50-to-500-ns range.

Accuracy (at 25°C, X1 setting): 10% for 1-μs to 1-ms ranges; 15% for 10-ms range; 20% for 100-ns, 100-ms, and 1-s ranges.

Jitter (max pk-pk): 0.3% at 0.4 μs.

SYNCHRONIZING PULSE

Waveform: Square wave. Negative transition precedes start of output pulse by approx 35 ns; positive transition can be used for half-period pretriggering.

Amplitude: 2.5-V pk-pk positive square wave behind 500-Ω source impedance.

MODULATION AND GATING

Modulation: Period and duration are linearly controllable by an external voltage between −0.5 and −5.0 V. Amplitude of the positive-pulse output is linearly controllable by an external voltage of 0 to +5.0 V, the negative pulse by 0 to −5.0 V.

Period and duration are modulatable over the decade range set by range switches; amplitude can be modulated over its full range. Amplitude modulation can be used for noncoherent gating of output pulse.

Gating: Switch closure to ground or equivalent inhibits period generator, thus providing phase-coherent gating of output pulses. An impedance of ≤600 Ω to ground inhibits output; +4 to +8 V allows normal output; 1340's gate 1340's.

GENERAL

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 30 W.

Accessories Supplied: Power cord.

Accessories Available: GR874® coaxial components, attenuators, terminations, tees, etc.

Mounting: Convertible-Bench Cabinet.

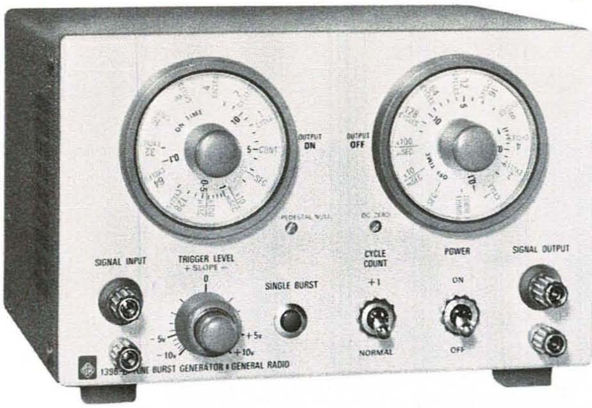
Dimensions (width x height x depth): Bench, 8½ x 5⅝ x 13 in. (220 x 145 x 330 mm); rack, 19 x 5¼ x 11¼ in. (485 x 135 x 290 mm).

Weight: Net, 9¼ lb (4.2 kg); shipping, 13 lb (6.0 kg).

Catalog Number	Description	Price in USA
	1340 Pulse Generator	
1340-9700	Bench Mount	**$395.00**
1340-9701	Rack Mount	**417.00**

Type 1396-B TONE-BURST GENERATOR

- fast, coherent switch for sine waves
- dc to 2 MHz
- signal attenuated >60 dB between bursts
- on-off times: 10 μs – 10 s or 1 – 129 periods of switched or other signal

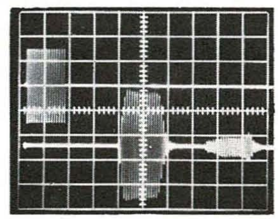


The 1396-B Tone-Burst Generator fills the gap between steady-state cw testing and step-function, or pulse, testing of amplifiers, meters, etc. It is ideally suited for applications such as the test and calibration of sonar transducers and amplifiers, the measurement of distortion and transient response of amplifiers and loudspeakers, and routine testing of filters and ac meters. Still other uses are found in the measurement of room acoustics and automatic-gain-control circuits, in the synthesis of time ticks on standard-time radio transmissions, and in psychoacoustic instrumentation.

For a full discussion of the many uses for tone-burst testing see the May 1964, **General Radio Experimenter** or write for publications A130, IN105, and IN110.

DESCRIPTION

The 1396 acts as a switch that alternately interrupts and passes an input signal, thus chopping into bursts a sine wave, or continuous tone, applied to the input. The instrument times the burst duration and interval between bursts exactly by counting the number of cycles, or periods, of the input signal. Panel controls permit these intervals to be set to a wide range of values. The exact time at which the burst starts and stops can be controlled, thus the burst is phase-coherent with the input signal.



Typical waveform produced by the Type 1396/Type 1310 oscillator combination with a 15-kHz signal turned on for 16 cycles and off for one-half second. Upper trace shows input to sonar projector; lower trace shows output from projector and subsequent echo return from wall of test tank.

Oscillators page 220 ff

Alternately, timing can be based on a separate signal, the output can be turned on continuously for alignment or calibration, or single bursts can be generated with a front-panel push button. The 1396-B can also operate with nonsinusoidal or aperiodic inputs.

— See **GR Experimenter** for October 1968.

specifications

SIGNAL INPUT (signal to be switched)

Amplitude: ±1 to ±10 V (7 V rms with 0-V dc component) for proper operation.

Frequency Range: Dc to 2 MHz.

Input Impedance: 50 kΩ, approx.

TIMING INPUT (signal that controls switch timing). Same specifications as SIGNAL INPUT except:

Input Impedance: 20 kΩ, approx.

SIGNAL OUTPUT

Output On: Replica of SIGNAL INPUT at approx same voltage level; dc coupled; down 3 dB at >1 MHz. Output current limits at >25 mA pk, decreasing to >15 mA at 2 MHz. Output source impedance typically 25 Ω increasing above 0.2 MHz. Total distortion contribution <0.3% at 1 kHz and 10 kHz.

Output Off: Input-to-output transfer (feedthrough), <10 mV (<−60 dB below full output), dc to 1 MHz, increasing above 1 MHz.

Spurious Outputs: Dc component and change in dc component due to on-off switching (pedestal) can be nulled with front-panel control. Output switching transients are typically 0.2 V pk-pk and 0.2 μs in duration (120-pF load).

ON-OFF TIMING Timing is phase-coherent with, and controlled by, either the signal at the SIGNAL INPUT connector or a different signal applied to the EXT TIMING connector. The on interval (duration of burst) and the off interval (between bursts) can be determined by cycle counting, timing, or direct external control.

Cycle-Count Mode: On and off intervals can be set independently, to be of 1, 2, 4, 8, 16, 32, 64, or 128 cycles (i.e. periods) duration or to be 2, 3, 5, 9, 17, 33, 65, or 129 cycles with +1 switch operated.

Timed Mode: The on and off times can be set independently from 10 μs to 10 s. They end at the first proper phase point of the controlling signal that occurs after the time interval set on the controls. One interval can be timed and the other counted, if desired.

Switching Phase: For either of the above modes, the on-off switching always occurs at a phase of the controlling signal which is determined by the triggering controls. The SLOPE control allows triggering on either the positive or negative slope of the controlling signal and the TRIGGER LEVEL control sets the level at which triggering occurs.

Direct External Control: A 10-V pulse applied to rear-panel connection will directly control switching.

SYNCHRONIZING PULSE: A dc-coupled pulse that alternates between approx +8 V for output on, and −8 V when off. Source resistance approx 0.8 kΩ for positive output and 2 kΩ for negative.

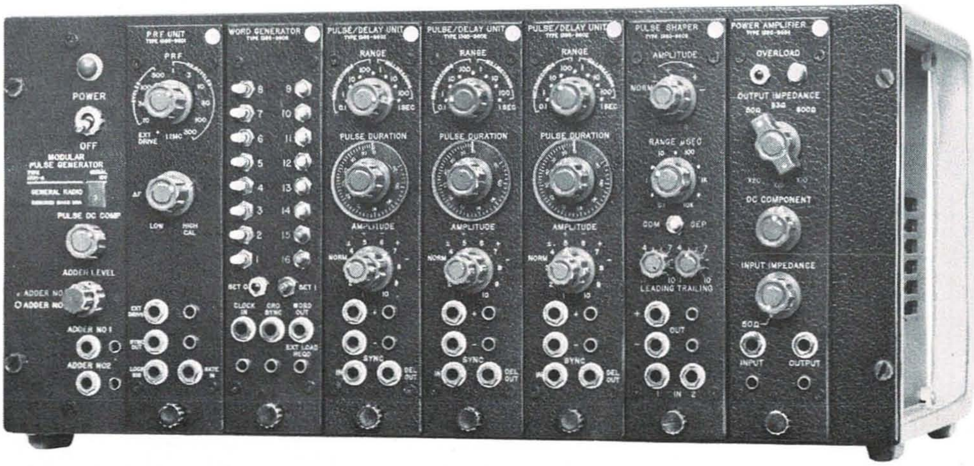
GENERAL

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 16 W.
Accessories Supplied: Power cord.
Mounting: Convertible-Bench Cabinet.
Dimensions (width x height x depth): Bench, 8½ x 5⅝ x 10 in. (220 x 145 x 255 mm); rack, 19 x 5⅝ x 10 in. (485 x 145 x 255 mm).
Weight: Bench, net, 8 lb (3.7 kg); shipping, 12 lb (5.5 kg); rack, net, 11 lb (5 kg); shipping, 15 lb (7 kg).

Catalog Number	Description	Price in USA
	1396-B Tone-Burst Generator	
1396-9702	Bench Model	**$595.00**
1396-9703	Rack Model	**620.00**

Type 1395-A MODULAR PULSE GENERATOR

- dc to 2 MHz
- limitless variety of pulses
- flexible, convenient, economical



The 1395-A Modular Pulse Generator is a pulse generating system of almost infinite possibilities. With it you can construct, to suit your requirements or your fancy, practically any pulse shapes or combinations thereof, by the appropriate selection and interconnection of a wide variety of available modules.

USES

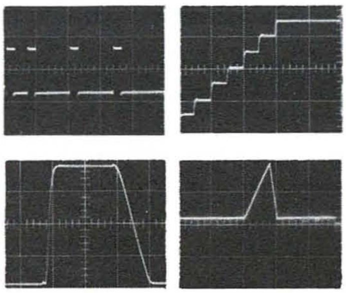
This instrument is used principally as a means for simulating the signals commonly associated with radar, telemetry, and moderate-speed digital-data handling. In addition, those working in the areas of physiological and geophysical testing find use for its low prf's and long time delays and pulse durations. With the pulse shaper module it will serve as a function generator as well.

PULSES TO ORDER

The generator consists of up to seven modules and a frame to hold them. The photograph shows only one of thousands of combinations that can be assembled from currently available modules. By selecting the appropriate number and types of plug-ins, a user actually builds his own special-purpose instrument.

The 1395-A can produce any or all of the following waveshapes:

rectangular pulses
pulse bursts
binary patterns or words
 2 to 112 bits long
single pulses
triangles
trapezoids
doublet pulses
pulses with pedestals
ascending and
 descending staircases
non-return-to-zero
 (NRZ) signals



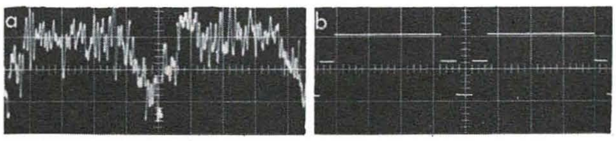
In addition it can

- give independent control over amplitudes, durations, and delays in all parts of complex pulses
- amplify the pulses it produces (up to 400 mA into 50 ohms)
- give both positive and negative polarities simultaneously
- allow noise or sine waves to be added to pulses
- lock on higher frequencies up to ratios of about 15:1
- scale, in true digital fashion, by any quantity that can be expressed as the product of up to 7 numbers between 2 and 16
- generate time delays
- make binary, coincidence decisions

The main frame of the 1395-A Modular Pulse Generator contains the power supply to operate the modules, two ADDER busses with their corresponding output controls and jacks, and a control for varying the level of the output-pulse base line. Selector switches permit the outputs of individual modules to be applied to the busses in desired polarities to generate a complex waveform at the ADDER output jacks.

Six types of modules are available plus a skeleton-frame module in which the user can install his own circuitry. The modules can be used in any combination up

(a) A noisy pulse train, taken with single sweep on the oscilloscope.
(b) The same signal without noise.



to a total of seven, of which only one may be a Power Amplifier and a maximum of three may be Pulse Shapers. To satisfy power-supply limitations, Pulse Shaper Units fit only in the three right-hand slots and the Power Amplifier only in the farthest right-hand slot.

— See **GR Experimenter** for May 1965 and write for Instrument Note IN-108, "Generation and Detection of Modulated Pulses."

specifications (MAIN FRAME)

ADDER Output Level: 0 to 1 V or more, depending on number of modules used (continuously adjustable).

ADDER Output Impedance: 100 Ω or less (100-Ω pot).

PULSE DC COMPONENT Range: 0 to +20 V (continuously adjustable).

Power Required: 105 to 125 V, 195 to 235 V, or 210 to 250 V, 50 to 60 Hz; approx 250 W, depending on quantity and type of plug-ins.

Accessories Supplied: CAP-22 Power Cord; six patch cords — one each 274-LMB and 274-LMR, two each 274-LSB and 274-LSR; four blank cover panels; one 14-conductor module extension cable.

Accessories Available: All modules in the 1395 series, 1217-P2 Single-Pulse Trigger.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench, 19 x 9⅛ x 14½ in. (485 x 235 x 370 mm); rack, 19 x 8¾ x 13¼ in. (485 x 225 x 340 mm).

Weight (without modules): Net, 29 lb (13.2 kg); shipping, 42 lb (19.5 kg).

1395-P1 PRF UNIT

This module generates the pulses that trigger the Pulse/Delay Units and provides the synchronization necessary for synthesizing complex waveforms. The maximum repetition rate is 1.2 MHz when generated internally, and at least 2 MHz with external drive. The PRF Unit acts as a synchronous divider when a signal of higher frequency is applied to the LOCK SIG jack, and a stable division of up to about 15:1 is practical. When a positive pulse is applied to the GATE IN jack, the PRF Unit is disabled for the duration of the pulse. Varying the time of occurrence and duration of this gating pulse, which can be generated by other modules, controls when and how long the PRF Unit is inoperative.

specifications

PULSE REPETITION FREQUENCY

Internally Generated: 2.5 Hz to 1.2 MHz with 12-position switch and uncalibrated ΔF control. Accuracy: ±5% of nominal.

Externally Controlled: After adjustment for maximum sensitivity, sine-wave input of 0.5 V rms required for prf from dc to 0.5 MHz, rising to 1.5 V rms at 2 MHz. Input impedance at 0.5 V is approx 100 kΩ shunted by 50 pF. Nonsinousoidal signal requires a negative-going step of 1 V.

INPUT AND OUTPUT SIGNALS

Sync Out Pulses: At least 10 V, positive, with duration between 75 and 150 ns (nominally 100 ns); rise time approx 25 ns and output impedance approx 35 Ω.

Lock Signal: PRF Unit operating at 1 kHz can be locked to a frequency of 10 kHz by 10-V positive pulses with 100-ns duration or with a sine wave of 7 V rms. Required positive-pulse amplitude increases to about 12 V to lock the 1 kHz to a frequency of 2 kHz.

Gate Input: A potential more positive than −1 V at this terminal stops the generation of SYNC OUT pulses.

Stability: Prf jitter is 0.05% when the PRF Unit is operated from the power supply in the 1395-A main frame.

GENERAL

Accessories Supplied: Six patch cords — one each of 274-LMB and 274-LMR, two each 274-LSB and 274-LSR; two insulated plugs, one each 274-DB1 and 274-DB2.

Accessories Available: 1217-P2 Single-Pulse Trigger, other 1395 modules.

Weight: Net, 1½ lb (0.7 kg); shipping, 4½ lb (2.1 kg).

1395-P2 PULSE/DELAY UNIT

Each Pulse/Delay Unit receives its input signal from a PRF Unit, external source, Word Generator module, or another Pulse/Delay Unit. Front-panel controls are provided for output-pulse amplitude and duration and for the timing of a sync pulse, which can be used to trigger other modules. The output pulse in either polarity is available at panel terminals and can be fed to the main frame ADDER busses where it can be combined with other pulses. The dc reference level of all the output pulses can be varied by a main frame control.

1395-P1

specifications

Pulse and Delay Durations: 100 ns to 1 s, accurate to ±5% of reading or ±2% of full scale, or ±35 ns, whichever is greater.

Pulse Repetition Frequency: Determined by input sync signal — range dc to 2.4 MHz. Input signals can be randomly spaced if separated by at least 400 ns.

Rise and Fall Times: Less than 15 ns with 50-Ω load. On high-voltage output (20 V into 1 kΩ), transitions are typically 80 ns + 2 ns/pF of load capacitance.

Output Voltage: ±20 V pulses into 1-kΩ internal load impedance (±1 V into 50-Ω load).

Input Sync Requirements: Positive-going pulse, 10 to 20 V, with 75- to 150-ns duration.

Delayed Output: Positive pulse of at least 10-V amplitude and 75- to 150-ns duration. Output impedance approx 125 Ω. Time between SYNC IN and DEL OUT pulses set by PULSE DURATION control.

Stability: Pulse-duration jitter is 0.05% when Pulse/Delay Unit is operated in the 1395-A main frame.

Accessories Supplied: Five patch cords — two each 274-LSB and 274-LSR, one 274-LMR; two insulated plugs, one each 274-DB1 and 274-DB2.

Weight: Net, 1¾ lb (0.8 kg); shipping, 4¾ lb (2.2 kg).

1395-P2

1395-P3 PULSE SHAPER

This unit produces pulses with straight-line leading and trailing edges whose rise and fall times can be adjusted individually by separate controls or simultaneously by a single control. The leading edge starts with the pulse that is applied to the IN 1 jack; the trailing edge starts with the pulse that is applied to the IN 2 jack. If input pulses are applied only to the IN 1 jack, the leading edge of the output pulse starts with the first input pulse and the trailing edge starts with the second pulse. Both positive and negative output pulses are produced, and the dc reference level can be varied by the PULSE DC COMPONENT control on the main frame. The output can be switched to the ADDER busses.

specifications

INPUT PULSES: 10 V to 20 V in amplitude and 75 ns minimum duration.

OUTPUT PULSES

Duration: Time between pulses at IN 1 and IN 2 plus duration of trailing edge.

Rise and Fall Times: 100 ns to 10 ms in five decade ranges with overlap between ranges, ±10% of full scale, from the 0 to 100% points. Rise and fall times can be adjusted, independently by separate controls or simultaneously by a single control, within the same decade range. To obtain times less than a few hundred nanoseconds, output must be terminated in 50 to 100 Ω.

Linearity: A leading or trailing edge voltage e(t) making a transition of E volts in time T will not at any time t depart from the equation $e = \frac{Et}{T}$ $(0 \leq t \leq T)$ by more than 0.1 E (typically better than 0.05 E). The fastest transitions will not yield this performance unless outputs are terminated in 50 to 100 Ω.

Voltage: ±20-V pulses into 1-kΩ internal load impedance (±1 V into 50-Ω load).

GENERAL

Accessories Supplied: Five patch cords — two each 274-LSB and 274-LSR, one 274-LMR; two insulated plugs, one each 274-DB1 and 274-DB2.

Weight: Net, 1¾ lb (0.8 kg); shipping, 4¾ lb (2.2 kg).

1395-P3

1395-P4 POWER AMPLIFIER

1395-P4

This amplifier is designed primarily for pulse amplification in applications where extremely fast rise time is not necessary. It delivers a 20-volt, minimum, pulse of either polarity into a 50-ohm load, and can amplify the signals from the ADDER busses or the output of any 1395 module. As a sine-wave amplifier it is useful for frequencies in the audio range and up to 1.5 MHz, or 5 MHz, depending upon the termination. Output power as a sine-wave amplifier is approximately two watts, and distortion is 5% or less. It is a suitable coupling element between the outputs of the various pulse-forming modules and the most commonly encountered impedances used in radar, video, and telephone practice.

specifications

Output Impedances: 50, 93, and 600 Ω, all ±10%.

Gains: 20, 20, and 26 dB, respectively, at the above impedances and with matched loads, all ±2 dB.

Pulse Output Voltage: ±20-V pulses into 50-Ω load with 10% duty cycle. Larger duty cycles may be used at lower output levels.

Rise and Fall Times: Less than 60 ns on all transitions with a 50-Ω load and selector switch set for 50-Ω impedance.

Sine-Wave Amplifier: Power output into 50- and 93-Ω loads is at least 2.5 W (3% distortion typical); into 600-Ω load, at least 1.5 W (distortion, 1.5% typical).

Frequency Response: Down less than 3 dB at 20 Hz and 5 MHz with 50- and 93-Ω loads; 20 Hz and 1.5 MHz with 600-Ω load.

Dc Level: Dc baseline of pulses and centerline of sine waves can be moved at least ±1.5 V dc with 50-Ω loads, and more with higher impedance loads.

Input Impedance: Adjustable from 50 to 1050 Ω, shunted by approx 45 pF.

Accessories Supplied: Four patch cords — one each 274-LMB, 274-LMR, 274-LSB, and 274-LSR; two insulated plugs, one each 274-DB1 and 274-DB2.

Weight: Net, 2 lb (1.0 kg); shipping, 5 lb (2.3 kg).

1395-P5 NRZ CONVERTER/SAMPLER

1395-P5

This module, used with the 1395-P6 Word Generator, can produce non-return-to-zero (NRZ) signals. Or, it can be used for its binary decision-making capability, indicating the binary level of a signal at the SAMPLED input at the time of an interrogating pulse applied to the SAMPLING input. It responds to each interrogation with a trigger pulse from either the ONES or ZEROS output to indicate the state of the SAMPLED input, and with an appropriate transition or nontransition of the NRZ output. It can also be used to generate random pulse trains and diphase pulse signals. Related dipulse and NRZI signals can also be produced by the 1395-A, though they do not require use of the 1395-P5.

specifications

SAMPLING INPUT

Pulses: 10 to 15 V, positive-going, 75- to 150-ns duration, dc to 2.5 MHz.

Sine Wave: At least 17 V rms, 1 to 2.5 MHz. Sine-wave sampling below 1 MHz not recommended.

Input Impedance: Approx 4500 Ω across 40 pF.

SAMPLED INPUT

Sensitivity: 0.2 V pk-pk up to 2.5 MHz, optimized by adjustment of threshold control. Input required increases at other settings.

Coupling: Ac or dc, switch-selected.

Threshold Control: Compensates for dc components between approx ±0.6 V.

Input Impedance: Approx 100 kΩ across 40 pF.

1395-P6

NRZ OUTPUTS Both positive- and negative-going transitions are available simultaneously with the dc component controlled by the 1395-A.

Amplitude: >20 V, open circuit: >1 V across 50 Ω.

Transition Times: <15 ns with 50-Ω load at max input. Typically 80 ns + 2 ns/pF of load capacitance for high-impedance loads.

Output Impedance: 1 kΩ max.

TRIGGER OUTPUTS Two outputs available simultaneously: pulse generated when SAMPLED terminal is in ONE state, another when terminal is in ZERO state.

Amplitude: >+10 V. **Duration:** Approx 70 ns.

Output Impedance: Approx 160 Ω.

Delays: Trigger and NRZ outputs are delayed approx 190 ns from the SAMPLING input.

Accessories Supplied: Eight patch cords — two each Types 274-LMB, 274-LMR, 274-LSB, 274-LSR; two double plugs, four insulated plugs.

1395-P6 WORD GENERATOR

This module produces a pattern of 16 binary digits (BITS) in accordance with the settings of the switches on the module front panel. As many as seven Word Generators can be connected in cascade, utilizing the full capacity of the 1395-A main frame, to provide an 112-bit capability in one binary word. Rear-panel switching provides conversion of the 16-bit-per-generator capacity to 14-bit capacity. Numerous options are provided by the interconnection of two or more Word Generators in cascade, or by a change in the internal wiring of a Word Generator with a patch cord.

The output pulses are trigger signals designed to operate other 1395 modules. In addition, each Word Generator provides a sync pulse coincident with the time when an output pulse would occur from switch #1, whether or not that switch is actually engaged.

specifications

INPUT

Pulse Repetition Frequency: Dc to 2.5 MHz, externally controlled by 1395-P1 PRF Unit (or similar unit).

Trigger-Pulse Requirements: 10- to 20-V positive-going pulses of 75- to 150-ns duration. Square waves can be used above 10 kHz; sine waves, above 500 kHz.

Impedance: 400 to 600 Ω, depending upon trigger amplitude.

OUTPUTS

Oscilloscope Sync: Rectangular pulse of 2-V min amplitude and duration equal to period of driving-signal prf. Occurs approx 50 ns before the switch-#1 output pulse, whether or not the switch is on.

Word Out: 10- to 20-V positive-going pulses of 75- to 150-ns duration. Output impedance approx 150 Ω, but termination in 500 to 1000 Ω is recommended.

Pattern: Set by front-panel switches. Choice of 16-bit or 14-bit capacity by rear-panel switch. One can achieve capacities other than 14 and 16 by modification of internal wiring. Interconnection of up to seven units provided by the 1395-A main frame.

GENERAL

Accessories Supplied: Five patch cords — one each 274-LSB, 274-LSR, 274-LMB, 274-LMR, and 274-LLR; two insulated plugs, one each 274-DB1 and 274-DB2.

Weight: Net, 2½ lb (1.2 kg); shipping, 5½ lb (2.5 kg).

TYPE 1395-P7 SKELETON FRAME

A blank module suitable for mounting the components of a user-designed circuit.

Weight: Net, ½ lb (0.3 kg); shipping, 3½ lb (1.6 kg).

Catalog Number	Description	Price in USA
	1395-A Modular Pulse Generator (main frame only),	
1395-9801	Bench Model	**$690.00**
1395-9811	Rack Model	**690.00**
1395-9601	**1395-P1 PRF Unit**	**165.00**
1395-9602	**1395-P2 Pulse/Delay Unit**	**195.00**
1395-9603	**1395-P3 Pulse Shaper**	**295.00**
1395-9604	**1395-P4 Power Amplifier**	**295.00**
1395-9605	**1395-P5 NRZ Converter/Sampler**	**295.00**
1395-9606	**1395-P6 Word Generator**	**375.00**
1395-9607	**1395-P7 Skeleton Frame**	**15.00**

Type 1217-C UNIT PULSE GENERATOR

1217-P2
Single-pulse trigger

- <10-ns rise/fall times
- dc to 2.4-MHz repetition frequency
- 40-mA output pulses, positive and negative
- duration adjustable 100 ns to 1.1 s

Unit pulse generator with power supply

This simple, reliable pulse generator has many applications in the laboratory and on the test bench. Its wide ranges of pulse-duration and repetition rate and its excellent output characteristics fit it for many applications ranging from high-speed computing circuits through radar to geophysical and physiological pulse simulation. It is also an excellent, low-cost instrument for the student laboratory.

specifications

PULSE REPETITION FREQUENCY

Internally Generated: 2.5 Hz to 1.2 MHz, with calibrated points in a 1-3 sequence from 10 Hz to 300 kHz, and 1.2 MHz, all ±5%. Continuous coverage with an uncalibrated control.

Externally Controlled: Aperiodic, dc to 2.4 MHz with 1-V-rms input (0.5 V at 1 MHz and lower); input impedance at 0.5 V rms approx 100 kΩ shunted by 50 pF. Output pulse is started by negative-going input transition.

OUTPUT-PULSE CHARACTERISTICS

Duration: 100 ns to 1 s in 7 decade ranges, ±5% of reading or ±2% of full scale or ±35 ns, whichever is greatest.

Voltage: Positive and negative 40-mA current pulses available simultaneously. Dc-coupled; dc component negative with respect to ground. 40 V peak into 1-kΩ internal load impedance for both negative and positive pulses. Output control marked in approx output impedance.

Transitions: At max output into 50- or 100-Ω resistive load, transitions are typically <10 ns; no transition is ever >15 ns. Overshoot typically <10% (worst case 15%). Output control permits reduction of overshoot at slight rise-time penalty. Into high-resistance loads, all transitions are <(60 ns + 2 ns/pF load capacitance), with no overshoot.

Ramp-off: Less than 1%.

Synchronizing Pulses:

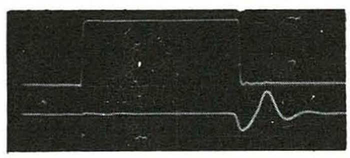
Pre-pulse: Positive and negative 8-V pulses of 150-ns duration. If positive sync terminal is shorted, negative pulse can be increased to 50 V. Sync-pulse source impedance:

positive — approx 300 Ω; negative — approx 1 kΩ.

Delayed Sync Pulse: Consists of a negative-going transition of approx 5 V and 100-ns duration coincident with the late edge of the main pulse. Duration control sets time between prepulse and delayed sync pulse. This negative transition is immediately followed by a positive transition of approx 5 V and 150 ns to reset the input circuits of a following pulse generator. (See oscillogram.)

Stability: Prf and pulse-duration jitter are dependent on power-supply ripple and regulation. With 1201 power supply and external-drive terminals short-circuited, prf jitter and pulse-duration jitter are each 0.01%. With 1203 power supply, they are 0.05% and 0.03%, respectively. (Jitter figures may vary somewhat with range switch settings, magnetic fields, etc.)

1-μs pulse into 50 ohms with delayed sync pulse.



GENERAL

Power Required: 1203 or 1201 Unit Power Supply is recommended.

Accessories Available: 1217-P2 Single-Pulse Trigger, rack-adaptor panel for both generator and power supply (19 x 7 in.).

Mounting: Unit-Instrument Cabinet.

Dimensions (with power supply) (width x height x depth): 15 x 5¾ x 6½ in. (385 x 150 x 165 mm).

Weight: Net, 9½ lb (4.4 kg); shipping, 12 lb (5.5 kg).

Catalog Number	Description	Price in USA
1217-9703	**1217-C Unit Pulse Generator**	**$325.00**
1201-9703	**1201-C Unit Regulated Power Supply** (for 115 V)	**120.00**
1201-9824	**1201-CQ18 Unit Regulated Power Supply** (for 230 V)	**120.00**
1203-9702	**1203-B Unit Power Supply** (for 115 V)	**85.00**
1203-9818	**1203-BQ18 Unit Power Supply** (for 230 V)	**85.00**
1217-9602	**1217-P2 Single-Pulse Trigger**	**35.00**
8410-0300	**Replacement Battery**	**0.20**
0480-9986	**480-P4U3 Rack-Adaptor Panel**	**14.00**

MISCELLANY

METERS

STROBOSCOPES

VOLTAGE REGULATORS

VARIAC® AUTOTRANSFORMERS

PARTS

ENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADIO GENERAL RADI

METERS

AC CURRENT

AC VOLTAGE

RESISTANCE

DC VOLTAGE

DC CURRENT

1820-A (DIGITAL) Automatically measures, with 4-digit resolution, a complete spectrum of voltages, currents, and resistances, including: ac and dc voltages from 1 μV to 1000 V, dc currents from 1 pA to 2.2 mA, ac currents from 10 μA to 6 A, and resistances from 1 Ω to 50 MΩ. Many measurements can be made at frequencies up to 1.5 GHz and the data from all measurements are presented as BCD information at the rear of the instrument, together with various input and output provisions for full system's compatibility.

Many other metering instruments are presented throughout this catalog under the guise of analyzers, sound-level and vibration meters, detectors, or frequency counters.

1806-A Measures ac and dc voltages from 100 mV to 1500 V with up to ±2% accuracy and measures resistances from 200 mΩ to 1000 MΩ with up to ±5% accuracy. Frequency range is from 20 Hz to 1.5 GHz, dc input resistance is 100 MΩ, and ac input impedance is 25 MΩ in parallel with 2 pF.

For permanent records, consider one of GR's recorders.

1808 Measures ac voltages from 150 μV to 150 V with 1% accuracy at frequencies up to 10 MHz.

For megohmmeters and resistance bridges, see Impedance section of Catalog U.

1807 Measures dc voltages from 1 μV to 1500 V and dc currents from 1 pA to 1.5 mA with accuracies to ±0.2%. Input impedance varies from 10 to 5000 MΩ, and meter includes calibrated scale expansion.

POWER

An extremely useful SWR meter, the 1234, and a unique combination of attenuator and output-voltage meter, the 1346, are offered also.

1840-A Measures ac power from 100 μW to 20 W into a self-contained load of 600 mΩ to 32 kΩ.

Digital-Voltmeter Calibrator, 1822 Provides precise dc voltages from 100 μV to 1111 V that permit reliable calibrations of accuracy, linearity, and hysteresis of nearly any voltmeter. Internally- or remotely-programmed sequences of automatically stepped voltages allow simple, rapid analysis of the voltmeter under test.

Type 1820-A DIGITAL VOLTMETER

- voltmeter, to 5 μV dc, 10 μV ac
- ammeter, to 5 pA dc, 1 μA ac
- ohmmeter, 5 mΩ to 50 MΩ
- ac measurements to 1.5 GHz
- 0.1% basic dc accuracy
- linear or log (dB) readout
- 10^{11}-Ω input impedance up to 200 V
- plug-in versatility

The 1820 Digital Voltmeter is far more than just another DVM — it's really a new breed of digital multimeter. Why? Because with it you can measure ac volts with a sensitivity of 200 mV up to 1.5 GHz or 10 μV up to 2 MHz, dc volts up to 1000 V, dc picoamperes or ac nanoamperes, and resistances from milliohms to megohms.

Only two plug-ins are required to make all these measurements but you certainly don't need both to have a very useful multifunction instrument. Which plug-in you select depends basically upon whether your need is for ultra sensitivity (1 μV) or ultra-high frequency (1.5 GHz). Compare this broad capability with that of an ordinary DVM.

There's much more. Voltage measurements can be read out directly in either volts or dB. High input impedance on each range, at least 100,000 megohms or 1000 megohms depending on plug-in, virtually eliminates voltmeter loading errors and ensures a true 0.1% measurement because there's no input attenuator to get in the way. The high input impedance also permits direct-reading resistance measurements to 50 MΩ. Since the ranges and polarity are automatically selected and no external preamp is needed, a wide variety of voltage measurements can be made rapidly without manual switching or any fussing. This autoranging feature, combined with BCD output, permits rapid printout of data that are always measured on the most appropriate range.

DC MULTIMETER/UHF VOLTMETER

The 1820-P1 plug-in measures ac voltage, dc voltage and current and resistance, to 0.1% accuracy in most cases. It is especially useful for high-frequency voltage measurements to 1.5 GHz and exhibits extremely high input impedance for all ranges of both ac and dc voltage. Voltage-measurement ranges extend from millivolts to 1000 volts, resistance to 50 megohms.

AC/DC MILLIVOLTMETER

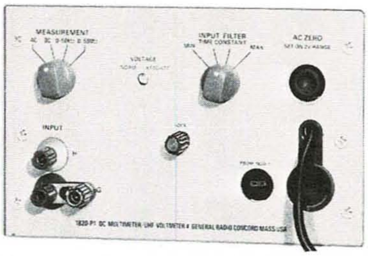
The 1820-P2 plug-in measures both ac (average) and dc with microvolt sensitivity. Dc current can be measured with picoampere resolution. With a standard oscilloscope current probe, ac current can be measured with 1-microampere resolution. For added convenience, an ohmmeter capability is also included.

DIFFERENTIAL INPUT

An adaptor, the 1820-P3, will convert the dc input of either plug-in to a true differential input, i.e., fully balanced. Common-mode rejection is about 100 dB, even with a source impedance of 100 kΩ.

— See **GR Experimenter** for May 1968.

specifications — with 1820-P1



Type 1820-P1 plug-in

DC VOLTAGE

Range: 220.0 mV to 220.0 V full scale (positive or negative), in four ranges; 1000 V with attenuator.

Impedance: 10^{11} Ω, all four ranges; 10^{7} Ω on 1000-V range.

Accuracy: ±(0.1% of full scale + 100 μV).

AC VOLTAGE

Range: 2.200 to 220.0 V, full scale reading, in three ranges. Max 200 V (1000 V with attenuator); above 200 MHz, max voltage limit varies inversely with frequency.

Effective Impedance: Approx 25 MΩ across 2 pF with probe.

Accuracy: ±(0.4 % of reading +0.1% of full scale), for readings above 10% of full scale, at 1 kHz.

Detector Response: Operates as peak voltmeter calibrated to read rms value of a sine wave or 0.707 × peak of a complex wave.

Waveform Error: For low voltage, the response gradually shifts from peak above 2 V to essentially rms below 200 mV.

Frequency Response: Within 3 dB at 10 Hz and 1.5 GHz; <1% down at 50 Hz. Probe resonance above 3 GHz.

LOG VOLTAGE FUNCTION

Range: Ac voltage, 6 to 62 dB re 100 mV in 3 ranges. Negative dc voltage, −14 to 62 dB re 100 mV in 4 ranges.

Accuracy: Ac, ±0.15 dB; neg dc, ±0.05 dB.

ISOLATION Low input terminal is by-passed and can be floated up to 400 V from ground.

RESISTANCE

Kilohm Range: 0.220, 2.200, 22.00, and 50.00 kΩ full scale.

Megohm Range: 0.220, 2.200, 22.00, and 50.00 MΩ full scale.

Max Test Voltage: −0.22, −2.2, −22, and −50 V, corresponding to above measurement ranges.

Accuracy: ±(0.1% of reading +0.1% of full scale + 100 mΩ) on 0- to 50-kΩ range; ±(0.3% of reading +0.1% of full scale + 100 Ω) on 0- to 50-MΩ range.

Noise: Less than one-half of least significant digit on most sensitive linear range.

Speed (dc, filter on min): Approx 40 ms for a step of up to 10% full scale; 70 ms for full-scale step; 200 ms per range for greater-than-full-scale step.

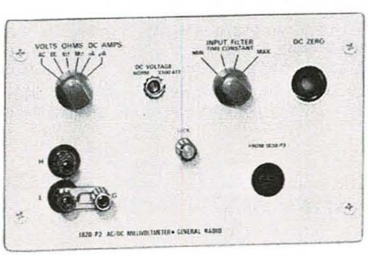
Input Filter: Four time constants, switchable, 10, 33, 100, and 300 ms.

Accessories Supplied: Probe accessories.

Accessories Available: 1806-P1 Tee for high-frequency voltage measurements.

Terminals: Front-panel input, probe and binding posts.

specifications — with 1820-P2



Type 1820-P2 plug-in.

AC/DC VOLTAGE

Linear Ranges: 2.200 mV to 220.0 V full scale, 6 ranges. With switched ×100 attenuator, 1000 V dc full scale max.

Log Ranges: 6 to 122 dB re 100 μV in six ranges.

Accuracy: Dc, ±(0.1% of full scale + 5 μV). Ac, 50 Hz to 100 kHz, ±(0.2% of reading +0.1% of full scale + 10 μV); 20 Hz to 2 MHz, ±(2% of reading +0.2% of full scale + 50 μV). Log accuracy on ac, ±(0.1 dB + 10 μV) 50 Hz to 100 kHz; ±(0.4 dB + 50 μV) 20 Hz to 2 MHz.

Input Impedance: Dc, >10^{9} Ω all ranges. Ac, 1 MΩ + 40 pF, all ranges.

Noise: 5 μV at 3σ.

Speed (dc, with filter on min): Approx 40 ms for a step of up to 10% of full scale; 70 ms for full-scale step; 200 ms per range (max 800 ms for 6 ranges) for greater-than-full-scale step.

Speed (ac, with filter on min, at 1 kHz): Approx 800 ms for full-scale step; 1 s per range (max 4 s for 6 ranges) for greater-than-full-scale step.

Input-Filter Time Constant: Dc volts, 2 ms to 0.1 s; ac, 200 ms to 1 s.

RESISTANCE

0-20 kΩ Range: 2.200 Ω to 22.00 kΩ in 5 decade ranges.

0-20 MΩ Range: 2.200 kΩ to 22.00 MΩ in 5 decade ranges.

Accuracy: 0-20 kΩ range, ±(0.1% of full scale + 0.1% of reading + 5 mΩ); 0-20 MΩ range, ±(0.1% of full scale + 0.4% of reading + 5 Ω).

CURRENT

Dc: 2.200 nA to 220.0 μA full scale, in 6 ranges, (1 MΩ). 2.200 μA to 2.200 mA full scale, in 4 ranges, (1 kΩ). Extendable with external shunts.

Accuracy: Microampere range, ±(0.1% of full scale, +0.1% of reading + 5 nA); nanoampere range, ±(0.1% of full scale +0.1% of reading + 5 pA).

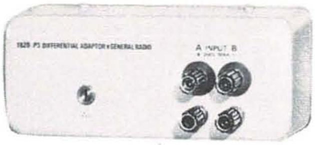
Ac: Measured with any Tektronix current probe; with type 6020 and termination, 1 mA corresponds to 1 mV or 0.1 mV.

Accuracy: ±(1% of reading + 0.2% of full scale + 10 nA) at 100 kHz. For low-frequency limit, see probe specifications; high-frequency limit, 2 MHz.

Accessories Supplied: Adaptor, binding post to BNC.

Accessories Available: Tektronix current probe for ac measurements.

specifications — 1820-P3



Type 1820-P3 plug-in

Input: Floating, symmetrical configuration.

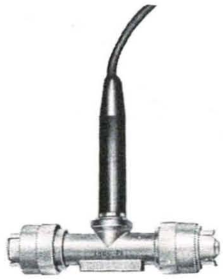
Common-Mode Rejection: >100 dB at dc; >120 dB at 60 Hz with 1-kΩ source impedance; 10 dB less with 100-kΩ source impedance.

Noise: 5 μV at 3σ.

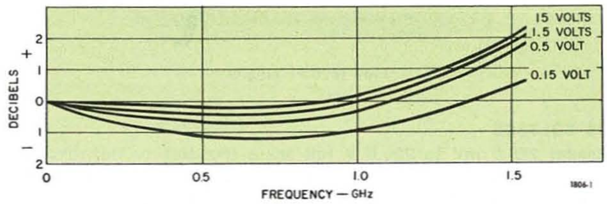
Drift: Approx 0.1 μV/°C.

Mounting: Plugs into front-panel input terminals of either 1820-P1 or 1820-P2 plug-in.

specifications — 1806-P1



A necessary attachment to the ac probe to realize the full 1500-MHz frequency range of the voltmeter with 1820-P1 plug-in. Screws onto the probe in place of the probe tip.



Typical high-frequency response characteristics of the probe and tee connector operating in a 50-ohm system.

SWR: The SWR of the tee connector and probe is less than 1.1 below 1000 MHz.

Connectors: Locking GR874® Connectors are used. Adaptors to other coaxial systems are available.

Dimensions: 4 x 1 x 1⅛ in. (102 x 25 x 28 mm).

Weight: Net, 3½ oz (100 g); shipping, 1 lb (0.5 kg).

general specifications — 1820-A

Ranging: Manual or automatic, switch selected.

Display: Four numerals (max reading 2200 on linear ranges, 62.00 on log ranges) with decimal point and units.

Sampling Rate: 0.5 to 30 Hz, adjustable. In HOLD mode, measurement can be externally initiated by positive pulse of >2 V.

DATA OUTPUT

Numerical Data: Four digits BCD 1-2-4-2 code (1-2-4-8 with slight modification).

Other Data: Range, 3 bits; polarity, 1 bit; log/linear, 1 bit.

Print Command (at completion of measurement): Transition from "1" level to "0" level, approx 15 ms duration, impedance 2 kΩ.

Signal Levels: Logical "one" is 0 V, logical "zero" −10 V, both with respect to reference line at +10 V above ground. Impedance 57 kΩ.

Accessories Supplied: Power cord, hardware for bench or rack-mounting.

Accessories Available: Plug-ins and adaptor as listed, 1806-P1 Tee Connector for high-frequency voltage measurements in coax, input scanner and other GR digital-data handling equipment. Order 1137 Data Printer and two extra modules for 8-digit capacity.

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 60 Hz, 40 W.

Terminals: At rear panel, data output, ext sampling rate, and aux input terminals.

Mounting: Rack-Bench Cabinet.

Dimensions (width x height x depth): Bench, 19 x 5⅝ x 18¾ in. (485 x 145 x 480 mm); rack, 19 x 5¼ x 17 in. (485 x 135 x 435 mm). Plug-ins approx 8 x 5 x 9 in. (200 x 130 x 230 mm).

Weight: Net, 30 lb (13.6 kg); shipping, 74 lb (33.6 kg). Plug-in (approx), net 4 lb (2 kg); shipping, 10 lb (4½ kg).

Catalog Number	Description	Price in USA
	1820-A Digital Voltmeter (no plug-in)	
1820-9700	Bench Model	**$2100.00**
1820-9701	Rack Model	**2100.00**
	Plug-Ins and Accessories	
1820-9601	**1820-P1 DC Multimeter/UHF Voltmeter**	**575.00**
1820-9602	**1820-P2 AC/DC Millivoltmeter**	**625.00**
1820-9603	**1820-P3 Differential Adaptor** (for use with 1820-P1 or -P2 Plug-ins)	**110.00**
1806-9601	**1806-P1 Tee Connector**	**55.00**

Type 1822 DIGITAL VOLTMETER CALIBRATOR

- 100-μV to 1000-V dc output
- 10-ppm stability, typical
- mobile secondary standard
- automatic stepping, programmable

No longer is it necessary to move a digital voltmeter into the standards laboratory and do long, tedious calibrations. The GR 1822 will not only go where the DVM's are, but it will make more exhaustive checks than before practical and does so quickly and without complex setups. Manually or automatically, the 1822 steps through enough voltages to check each digit in each range as well as linearity and possible hysteresis.

Digital voltmeters are now so sensitive and accurate that meaningful calibration requires assurance that the readings are unaffected by circuit loading, ac superimposed on the measured dc signal, and common-mode ac or dc signals. The 1822 makes these tests not only possible, but easy. A front-panel switch applies several interference voltages and output resistances to the DVM input; it also permits a polarity reversal to test the DVM's symmetry and short circuits the input to check the meter zero.

Owing to its ease of operation, the calibrator can be used frequently to check all DVM's, thus ensuring more reliable measurements. To facilitate its use as a mobile instrument, the 1822 was designed for high stability. The dividers are in a common oil bath; the voltage-reference is a zener diode in an oven with a very short warm-up period so that seconds after being reconnected to the power line, the 1822 will be generating voltages within very close tolerances.

Three controls determine the test-voltage output of the 1822; all are operated manually at the front panel or can be remotely controlled. A range switch sets maximum values in decade ranges of from 1 mV to 1000 V; in each range, the values set by the second control are .11111, .22222, .33333, ... 1.11110. A third control permits the last one, two, or four digits to be replaced by a zero (.33330, .33300, .30000) to match the resolution of the DVM and to allow common voltages to be set. An automatic stepping mode cycles the digit setting up to the maximum, then back to 1/10 full scale, then steps down-range one decade and cycles through that range in turn. By this means each digit in each position is checked and the linearity and accuracy of each range can all be easily verified by inspection.

specifications

OUTPUT

Output Voltage: 100 μV dc to 1111.1 V dc in 7 decade ranges.

DC Voltages Available in Each Range: 0.11111, 0.22222, 0.33333, ... to 1.11110. Zeros can be substituted for the final four, two or one digits; i.e., the output can be 0.30000, 0.33300, or 0.33330, for example.

Simulated Standard-Cell Output: 1.018700 to 1.019100 V, adjustable to match saturated-cell standard. Output similar to 1-V range except 6-month accuracy is $\pm$30 ppm.

Interference Voltages: 1, 10, 100 V $\pm$ 10%, dc and peak ac. Common-mode ac and dc (low terminal to case) and normal-mode ac (algebraically added to output). Ac voltage from line or external source (5-V pk).

Output Impedance: $<$0.5 Ω on 1-V through 1-kV ranges; 200 Ω on 1-mV through 100-mV ranges. A 1-kΩ, 10-kΩ, or 100-kΩ output resistor can be added to above impedances by front-panel selector switch.

Output Current: 10 mA at full range on 1, 10, and 100-V ranges; 1 mA on 1-kV range.

ACCURACY

Accuracy (6 months): $\pm$(30 ppm of voltage + 10 ppm of full range + 3 μV) on all ranges except $\pm$(50 ppm of voltage + 10 ppm of full range) on 1-kV range. Accuracy of rear-panel voltages $\leq$ 111 mV, $\pm$(30 ppm of voltage + 10 ppm of range + 0.5 μV).

Stability (24 hours): $\pm$(10 ppm of range + 2 μV).

Warmup (from cold start): Output within $\pm$(30 ppm + 3 μV) of final value after 3 m; within rated accuracy after 15 m.

Temperature Coefficient (5° to 45°C): $\pm$(1.5 ppm of output + 1.5 ppm of full range + 0.5 μV) per degree C, except $\pm$(3 ppm of output + 1.5 ppm of full range) per degree C in 1-kV range.

Line-Voltage Effects: $<$2 ppm for $\pm$10% line-voltage variation.

GENERAL

Noise: $<$2 ppm rms of range, 10-Hz to 1-kHz bandwidth.

Programmability: Switches controlling output range, digits, and zeros are remotely controllable by contact closures or solid-state switches with $<$50-ohm "on" impedance. "On" current, 10 mA max; "off" voltage, 15 V max.

Settling Time: Output within $\pm$30 ppm of final value in $<$300 ms, within rated accuracy in $<$500 ms, except on 1-kV range.

Stepping Rate: 0.5 to 3 seconds/step, adjustable at rear panel.

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 30 W.

Terminals: Output, front and rear panel binding posts.

Accessories Supplied: Two servicing circuit-extenders, multipin connector for remote programming input, power cord.

Accessories Available: GR 1455-BH Decade Voltage Divider (Kelvin-Varley), GR 1807 DC Microvoltmeter/Nanoammeter as a null detector, GR 1311 Audio Oscillator as external source for interference voltages.

Mounting: Bench model (in metal cabinet) or rack model.

Dimensions (width x height x depth): Bench, 19½ x 6⅝ x 21 in. (495 x 170 x 540 mm); rack, 19 x 5¼ x 18¼ in. (485 x 135 x 465 mm).

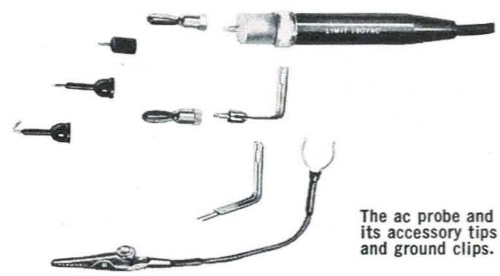
Net Weight: Bench, 41 lb (19 kg); rack, 33 lb (15 kg).

Shipping Weight: (est) Bench, 60 lb (28 kg); rack, 53 lb (25 kg).

Catalog Number	Description	Price in USA
	1822 Digital Voltmeter Calibrator	
1822-9700	Bench Model	**$2950.00**
1822-9701	Rack Model	**2925.00**

Type 1806-A ELECTRONIC VOLTMETER

- accuracy: $\pm 2\%$ of reading
- 20 Hz to 1.5 GHz
- dc voltage and resistance
- up to 1500 V in four 10:1 ranges



The ac probe and its accessory tips and ground clips.

This versatile voltmeter is an asset in the modern electronics laboratory. Its logarithmic meter scale ensures undiminished accuracy for less-than-full-scale readings and minimizes range changing as each range is useful over a more than 10:1 span of values with no reduction in accuracy. DC voltage measurements can be made to 150 volts with the "open grid" drawing less than 10^{-10} ampere.

A small probe allows convenient connection to circuit points for high-frequency measurements. Its use can be extended to 1500 volts with the 1806-P2 Range Multiplier or to 1500 MHz with the 1806-P1 Tee Connector. As an ohmmeter, the 1806-A will measure resistance from 0.2 ohm to 1000 megohms.

The heart of this instrument is a highly stable, tube-and-transistor dc amplifier. Its balanced circuit and regulated heater voltages ensure stability of meter zero. Calibration stability is excellent owing to the use of ample feedback to compensate for changes in tube or transistor characteristics.

For ac voltage measurements, a ceramic thermionic diode is used in the probe. Its small size and close electrode spacing give it a high resonant frequency and low transit time, both essential to excellent high-frequency performance.

— See also **GR Experimenter** for July 1963.

specifications

DC VOLTMETER

Voltage Range: Four ranges, 1.5, 15, 150, and 1500 V, full scale, positive or negative. Min reading is 0.005 V.

Input Resistance: 100 MΩ, ±5%. Also "open grid" on all but the 1500-V range; grid current is less than 10^{-10} A.

Accuracy: ±2% of indicated value from one-tenth of full scale to full scale; ±0.2% of full scale from one-tenth of full scale to zero. Scale is logarithmic from one-tenth of full scale to full scale, permitting constant-percentage readability over that range.

AC VOLTMETER

Voltage Range: Four ranges, 1.5, 15, 150, and 1500 V, full scale. Min reading on most sensitive range is 0.1 V.

Input Impedance: Probe, approx 25 MΩ in parallel with 2 pF; with 1806-P2 Range Multiplier, 2500 MΩ in parallel with 2 pF; at binding post on panel, 25 MΩ in parallel with 30 pF.

Accuracy: At 400 Hz, ±2% of indicated value from 1.5 V to 1500 V; ±3% of indicated value from 0.1 V to 1.5 V.

Waveform Error: On the higher ac-voltage ranges, the instrument operates as a peak voltmeter, calibrated to read rms values of a sine wave or 0.707 of the peak value of a complex wave. On distorted waveforms the percentage deviation of the reading from the rms value may be as large as the percentage of harmonics present. On the lowest range the instrument approaches rms operation.

Frequency Characteristics: Low-frequency roll-off is <3% at 20 Hz. On 1500-V range, internal voltage divider adds <2% additional error up to 500 kHz.

Probe resonant frequency is above 3000 MHz. Above several hundred megahertz, probe should be used in a 50-Ω coaxial system with the 1806-P1 Tee Connector.

OHMMETER

Range: 0.2 Ω to 1000 MΩ in four ranges with center scale values of 10 Ω, 1 kΩ, 100 kΩ, and 10 MΩ.

Test Voltage: The dc test voltage is positive and never exceeds 1.5 V. The max current (which is delivered to a short circuit on the lowest resistance range) is approx 43 mA. The max available power from the ohmmeter circuit is 16 mW.

Accuracy: ±5% of indicated value from 1 to 10 on scale, approaching ±10% of indicated value at 100 on scale.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 20 W approx. The case is grounded by the third wire in the power cord. The voltmeter circuit can be disconnected from the case and operated as much as 300 V dc off ground. The low input terminal remains by-passed to the case.

Probe Storage: A socket and reel store both probe and cable.

Accessories Supplied: An assortment of probe tips.

Mounting: Flip-Tilt Case.

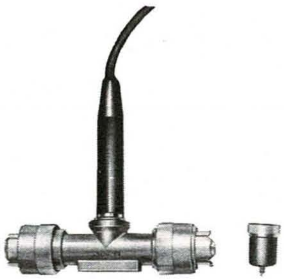
Dimensions (width x height x depth): 7½ x 8½ x 11½ in. (190 x 220 x 295 mm).

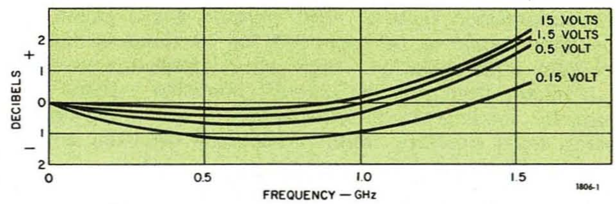
Weight: Net, 10 lb (4.6 kg); shipping, 13 lb (6 kg).

Catalog Number	Description	Price in USA
1806-9701	**1806-A Electronic Voltmeter**	**$645.00**

Type 1806-P1

TEE CONNECTOR





Typical high-frequency response characteristics of the probe and tee connector operating in a 50-ohm system.

The Tee Connector screws onto the probe in place of the regular probe tip, permitting voltage measurements to 1500 MHz across a 50-ohm coaxial line with minimum disturbance to the line.

specifications — with 1806-P1

AC Voltage: 150 V, max.

Frequency Characteristic: Low-frequency roll-off of the voltmeter and tee connector combination is <3% at 1 kHz. At high frequencies, the response is a function of voltage level because of transit-time effects, as shown in accompanying plot. Total error is <±3 dB below 1500 MHz.

SWR: The SWR of the tee connector and probe is <1.10 below 1 GHz.

Connectors: GR874® locking connectors. Adaptors to other coaxial connectors are available.

Dimensions (1806-P1): 4 x 1 x 1⅛ in. (102 x 25 x 28 mm).

Net Weight: 3½ oz (100 g).

Catalog Number	Description	Price in USA
1806-9601	**1806-P1 Tee Connector**	**$55.00**

Type 1806-P2

10:1 RANGE MULTIPLIER

Range multiplier installed on probe.

The Range Multiplier is a 10:1 capacitive voltage divider that screws onto the probe in place of the regular probe tip. It permits use of the probe (desirable above 150 kHz) for voltages from 150 to 1500 volts.

specifications — with 1806-P2

Multiplication Ratio: 10:1 ±5%. Adjustment is provided for matching 1806-P2 to voltmeter to within ±2%.

Frequency Characteristic: Low-frequency roll-off of voltmeter and multiplier combined is <3% at 10 kHz. At higher frequencies multiplier does not affect the over-all voltmeter response.

Input Impedance: Equivalent input resistance of probe-multiplier combination is approx 100 times that of probe alone. Equivalent parallel capacitance is approx 2 pF.

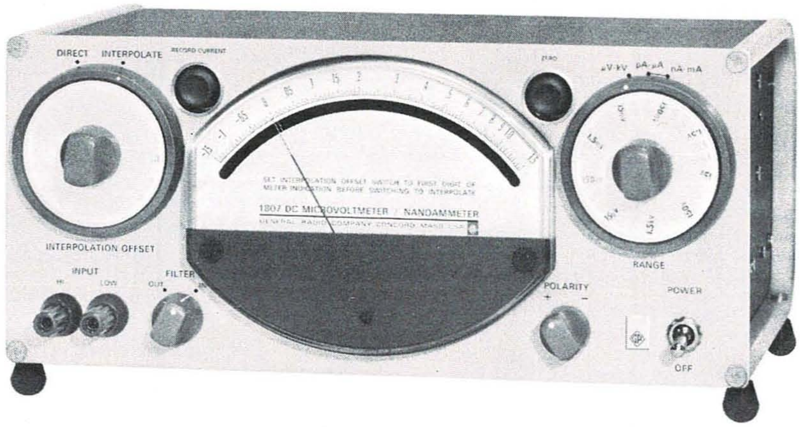
Dimensions (1806-P2): ⅝ in. dia. x 1¼ in. (16 x 32 mm).

Net Weight: ½ oz (15 g).

Catalog Number	Description	Price in USA
1806-9602	**1806-P2 10:1 Range Multiplier**	**$40.00**

Type 1807 DC MICROVOLTMETER/ NANOAMMETER

- accuracy ±0.2%
- 500-MΩ input impedance
- meter resolution 0.003 of full scale near zero
- calibrated scale expansion



The GR 1807 is a sensitive dc voltmeter and ammeter. Measurements to an accuracy of ±0.2% are made possible by an accurately calibrated interpolation-offset or zero-suppression feature. This permits any segment of the meter scale to be expanded for 10 times or better accuracy and resolution. High input impedance ensures full benefit from the instrument's precision without the need for loading-effect corrections. A single log/linear meter scale provides uniform accuracy over the entire range and high resolution near zero.

NULL INDICATION

Several characteristics of the 1807 make it especially useful as a null indicator for use with dc bridges. An isolated input, excellent rejection of both dc and 60-Hz common-mode signals, the up-scale meter zero for unambiguous null definition, high input impedance, possible operation from a battery and fine resolution near zero all contribute to this application.

CURRENT MEASUREMENTS

Minute voltages and currents (to as little as 0.5 picoampere) such as are encountered in biological, chemical, and medical research can be readily measured with the GR 1807. It will also serve well in the measurement of thermal voltages, ionization currents and similar phenomena of interest in the electronics and physics laboratory. An output is provided to drive dc recorders for plotting permanent records.

— See **GR Experimenter** for August-September 1968.

specifications

RANGE

Voltage (either polarity): 15 μV to 1500 V full scale in 9 decade ranges; 0.003 of full-scale meter resolution near zero on most sensitive range.
Current (either polarity): 15 pA to 1.5 mA full scale in 9 decade ranges; 0.003 of full-scale meter resolution near zero.

ACCURACY

Record-Current Linearity: ±(0.1% of reading + 0.5 μV).
Interpolate: ±[0.1% of full scale (range) + 0.1% of reading + 0.5 μV].
Direct: ±(1.5% of reading + 0.5 μV) above 10% of full scale. Below 10% of full scale, ±(0.15% of full scale + 0.5 μV).
Temperature Coefficients (typical)
Record-Current Zero Drift: ±(0.001% of full scale + 0.15 μV) per degree C.
Interpolate: ±(0.001% of reading + 0.001% of full scale + 0.15 μV) per degree C.
Direct: ±(0.02% of reading + 0.001% of full scale + 0.15 μV) per degree C.

INPUT IMPEDANCE

Voltage: 150-μV to 1.5-V ranges, > 500 MΩ on direct and typically 5,000 MΩ on interpolate; 15-μV range, > 50 MΩ; 15-V to 1500-V ranges, 10.5 MΩ.
Current: Internal Shunts, 1 MΩ in pA-μA ranges, 1 kΩ in nA-mA ranges.
Meter: Single scale from −1.5 to 15. Logarithmic (20 dB) above 10% of full scale.
Input Current: Less than 5 pA.
Noise: <0.5 μV for 3σ with 1kΩ across input.
Common-Mode Rejection: >160 dB for dc with up to 600 V dc max above ground; >120 dB for 60-Hz common-mode signal of <8 V pk with input filter.
Record-Current Response Time (typical): 0.1 s without input filter (1.5-Hz bandwidth), 0.3 s with filter (0.5-Hz bandwidth) on all ranges above 15 μV; 10 times slower on 15-μV range.
Maximum Overload: Voltage: 150 V on 1.5-V range and below, 1500 V on 15-V range and above. Current: 10 mA max all ranges.
Overload Recovery Time: Approx 3 s for 10^6 overload.
Recorder Output: Adjustable up to ±2.5 V open circuit for full scale meter deflection; ±1 mA into 1.5 kΩ max load.

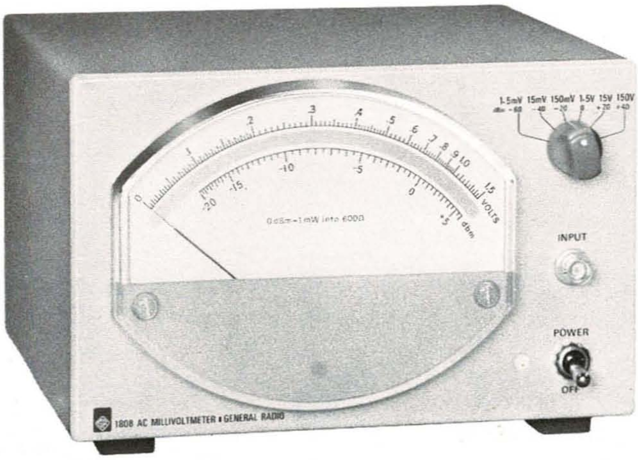
GENERAL

Terminals: Gold-plated copper binding posts on front and rear panels. Ground connection on rear panel only. Battery connection also on rear panel.
Power Required: 105 to 125, 205 to 250 V, 50 to 60 Hz, 5 W. Also operates from external 24-V dc supply; 1538-P3 Battery and Charger recommended.
Accessories Supplied: 274-QBJ adapts binding posts to BNC, power cord.
Accessories Available: Input probe, Tektronix type P6028; 1538-P3 Battery and Charger.
Mounting: Convertible-Bench Cabinet.
Dimensions (width x height x depth): Bench, 12 x 5⅞ x 10¼ in. (305 x 150 x 260 mm); rack, 19 x 5¼ x 8½ in. (485 x 135 x 220 mm).
Net Weight: Bench, 9½ lb (4.4 kg); rack, 10¾ lb (4.9 kg).
Shipping Weight: Bench, 16½ lb (7.5 kg); rack, 18 lb (8.5 kg).

Catalog Number	Description	Price in USA
	1807 DC Microvoltmeter/Nanoammeter	
1807-9700	Bench Model	**$695.00**
1807-9701	Rack Model	**695.00**
1807-9601	**P6028 Probe,** Tek Cat 010-0074-00	**18.00**

Type 1808 AC MILLIVOLTMETER

- 150 μV to 150 V rms
- 1% basic accuracy
- wide 20-dB ranges
- 10-Hz to 10-MHz bandwidth
- 10-MΩ input impedance



NEW

The 1808 AC Millivoltmeter is not just another ac voltmeter; it is a unique contribution to this basic branch of electronic measurements. Essentially, the 1808 is an average-reading voltmeter calibrated to read the rms value of sine waves. But its 10-Hz to 10-MHz bandwidth and 20-dB dynamic range per range — all for the same or less money than other less capable instruments — place it in a class apart.

An FET input buffer provides the high 10-MΩ input impedance and frequency-compensated resistive dividers add to its uniform frequency response. The heart of the instrument is an ac-to-dc converter in which any nonlinear effects of the diodes employed are eliminated from the accuracy considerations because the diodes are inside the loop of a feedback amplifier. This amplifier is another reason for the wide frequency range of the 1808 and provides a high open-loop voltage gain even at 10 MHz.

Any ac voltmeter is a general-purpose laboratory or production-line instrument and the 1808 is no exception. These normal applications need no mention here but some of the more novel uses might be of interest:

Operational amplifier second breakpoint Most operational amplifiers have an open-loop response with a second frequency breakpoint. Often it is desirable to know the frequency where this breakpoint occurs in order to optimize the stability of the design. The 1808, with its 10-MHz bandwidth, is well suited for this type of measurement.

Attenuator testing and calibration The wide dynamic range and bandwidth of the 1808 lends it to attenuator testing and calibration. To test a 10- or 20-dB attenuator, for example, no range changes are necessary.

High-resolution ac measurements Often it is desired to make ac measurements with higher resolution than the specified accuracy of the available instruments. For example, in tests of the stability of an amplifier with temperature, the absolute value of a measurement is not so important as the change in the measurement as a function of temperature.

For these applications, the dc output from the 1808 can be coupled to an 1807 DC Microvolter/Nanoammeter or 1820 Digital Voltmeter to provide a resolution ten times better than that which can be read on the meter of the 1808 alone.

Transducer measurements To measure the output of accelerometers, strain gages, microphones, or similar transducers whose equivalent voltage source is usually less than 100 mV in series with a capacitance of from a few hundred to a few thousand picofarads, it is essential to have a voltmeter with a very low input-capacitance. The 1808 with a probe and 1808-P1 Probe Adaptor form a highly useful combination for such measurements.

specifications

Range: 150 μV to 150 V (to 1500 V with X10 probe) in six 20-dB ranges. *Overload,* 100 V max on 1.5-mV to 1.5-V full-scale ranges up to 10 kHz, decreasing linearly to 10 V max at 10 MHz; 200 V max on 15-V and 150-V ranges.

Input Impedance: 10 MΩ//10 pF except 12.5 MΩ on 15-V and 150-V ranges.

DC Output: >1 V dc (floating) for full-scale deflection; proportional to meter reading. Output resistance, 10 kΩ.

Accuracy (for dc output and full-scale meter reading; for less-than-full-scale reading, add meter-tracking accuracy):

	10 Hz to 40 Hz	40 Hz to 0.5 MHz	0.5 MHz to 4 MHz
1.5-mV range	±(3% of reading +0.2% of full scale)	±(2% of reading +0.1% of full scale)	±(3% of reading +0.2% of full scale +0.05% of reading/°C)
	10 Hz to 40 Hz	**40 Hz to 5 MHz**	**5 MHz to 10 MHz**
15-mV to 150-V ranges	±(2% of reading +0.3% of full scale)	±(1% of reading +0.1% of full scale)	±(3% of reading +0.3% of full scale)

Meter-Tracking Accuracy: 0.15% of full scale from 0 to 0.15, 1.5% of reading from 0.15 to 0.5, 1% of reading from 0.5 to 1.5.

Power: 100 to 125 or 200 to 250 V, 50-60 Hz, 10 W.

Supplied: Power cable.

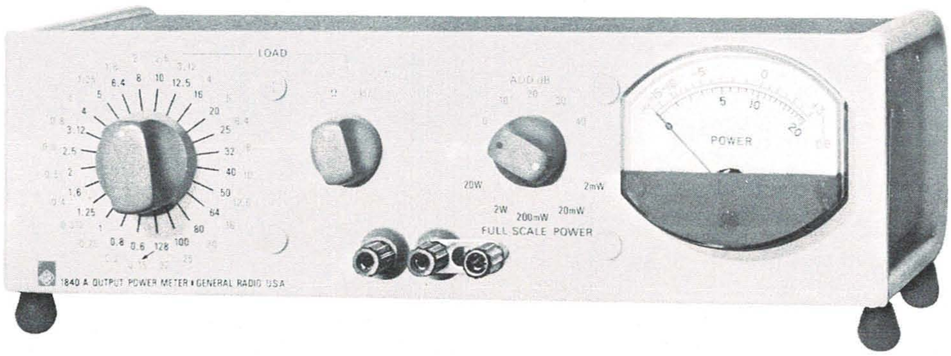
Available: 0480-9723 Rack Adaptor Set, 1808-P1 Probe Adaptor to permit use of Tektronix P6006, P6008, and (preferably) P6012 X10 probes or P6011 X1 probe.

Mechanical: Convertible-bench cabinet. *Dimensions* (w x h x d): Bench, 8.5 x 5.594 x 9.625 in. (216 x 142 x 244 mm); rack, 19 x 5.218 x 10.188 in. (483 x 133 x 259 mm). *Weight:* Bench, 6.5 lb (3 kg) net, 9.5 lb (4.4 kg) shipping; rack 9.75 lb (4.5 kg) net, 12.75 lb (6 kg) shipping.

Catalog Number	Description	Price in USA
	1808 AC Millivoltmeter	
1808-9700	Bench Model	**$295.00**
1808-9701	Rack Model	**315.00**
1808-9600	**1808-P1 Probe Adaptor**	**10.00**
0480-9723	**Rack Adaptor Set**	**25.00**

Type 1840-A OUTPUT POWER METER

- 20 Hz to 20 kHz
- 0.1 mW to 20 W
- 0.6-Ω to 32-kΩ input impedance
- true rms reading



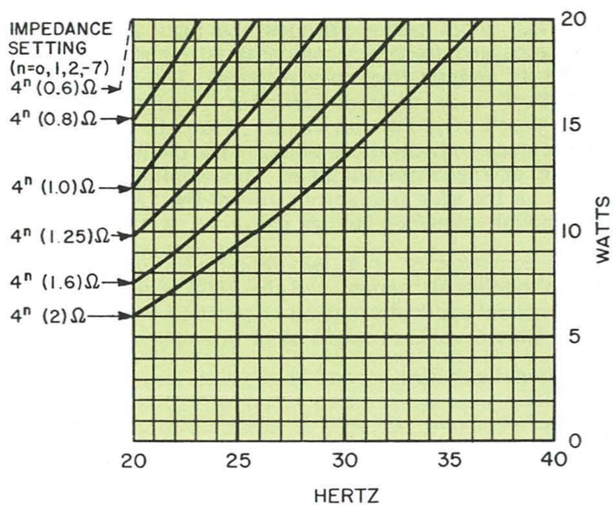
The 1840-A measures audio-frequency power into any desired load. Its important uses include the measurement of:

- Power output of oscillators, amplifiers, preamplifiers, transformers, transducers, and low-frequency lines.
- Output impedance, by adjustment of the load to yield maximum power indication.
- Frequency-response characteristics of amplifiers, transformers, and other audio-frequency devices.

This instrument is basically a multi-tapped audio-frequency transformer with a fixed secondary load. Its two front-panel switches connect eight identical primary windings and six secondary taps in various combinations to provide a total of 48 different primary impedances.

The maximum power rating can be extended for any given impedance with the use of a simple T-network attenuator, design data for which are supplied with the instrument.

— See **GR Experimenter** for January-February 1962.



Derating vs impedance setting and frequency.

specifications

RANGES

Power: 0.1 mW to 20 W, 40 Hz to 20 kHz. Below 40 Hz, max rating is reduced by up to 50% (at 25 Hz), depending on impedance selected. See curve. Auxiliary dB scale reads from −15 to +43 dB re 1 mW.

Impedance: 0.6 Ω to 32 kΩ in two ranges; yielding 48 individual impedances spaced approximately $\sqrt[3]{2}$ apart.

ACCURACY

Power: At 1 kHz, ±0.3 dB;
50 Hz to 6 kHz, ±0.5 dB;
30 Hz to 10 kHz, ±1 dB;
at 20 Hz, −1.5 dB max, −1 dB avg;
at 20 kHz, −5 dB max, ±1.5 dB avg.

Impedance: At 1 kHz, ±6% max, −0.5% avg;
70 Hz to 2.5 kHz, ±7% above 10 kΩ;
70 Hz to 5 kHz, ±7% below 10 kΩ;
at 20 Hz, −15% max, −8% avg;
at 20 kHz, ±50% max, ±12% avg.

Waveform Error: Meter will indicate true rms with as much as 20% second and third harmonics present in the input signal.

GENERAL

Mounting: Convertible-Bench Cabinet. Adaptors for rack mounting available.

Dimensions (width x height x depth): 12 x 4 x 8 in. (305 x 105 x 205 mm). Rack-adaptor panel height, 3½ in.

Weight: Net, 10¾ lb (4.9 kg); shipping, 17 lb (8 kg).

Catalog Number	Description	Price in USA
1840-9701	**1840-A Output Power Meter**	**$375.00**
0480-9622	**480-P212 Relay-Rack Adaptor Set**	**11.00**

STROBOSCOPES

THE ELECTRONIC STROBOSCOPE

The electronic stroboscope is a bright light source with an oscillator and triggering circuits that flash the light at accurately known rates. The flashing light of the stroboscope, when used to illuminate a cyclically moving object, can produce the optical illusion of stopping or slowing down the motion.

"STOPPED" AND SLOW MOTION

Motion is "stopped" when the flashing rate of the stroboscope and the cyclic rate of the object being observed are the same; from this principle stems the stroboscope's well known value as a tachometer. Motion is "slowed" when the flashing rate is offset slightly from the cyclic rate of the object. The apparent slow motion, moreover, is an exact replica of the actual high-speed motion, and the stroboscope is thus an important tool in motion and fluid-flow analysis. A complete discussion of the power of stroboscopy in motion analysis and illustrated examples of the uses for stroboscopes are available from GR in the **Handbook of Stroboscopy,** $2.00.

HIGH-SPEED PHOTOGRAPHY

The short flash of a stroboscope offers the photographer a means of reducing exposure time to about a millionth of a second, and so the stroboscope has become standard equipment in the field of ultra-high-speed photography. This subject, of increasing interest to scientists and engineers as well as to photographers, is covered fully in the **Handbook of High-Speed Photography,** $1.00.

STROBOSCOPE APPLICATIONS

The applications for the stroboscope are beyond enumeration. Wherever motion is too fast for the human eye, there is a place for a stroboscope. Here are just a few of the ways in which stroboscopes are paying for themselves many times over:

Stroboscopes are widely used by educators to demonstrate certain laws of physics, such as the relation between frequency and wavelength, the finite velocity of light, the effects of combining colors, the properties of standing waves, the laws of gravity, the principle of strobscopy itself, etc.

Stroboscopes are used to calibrate mechanical tachometers.

Stroboscopes are used in the development of loudspeakers and of other audio devices.

Stroboscopes are used to check registration on fast-moving printing presses.

Stroboscopes are used to measure the amount of slip between two shafts, between motor and belt, etc.

Stroboscopes are used throughout the textile industry to help design, monitor, and trouble-shoot looms, knitting machines, spinning frames, etc.

A stroboscope, combined with simple accessories, can be used to measure torque, belt tension, and horsepower.

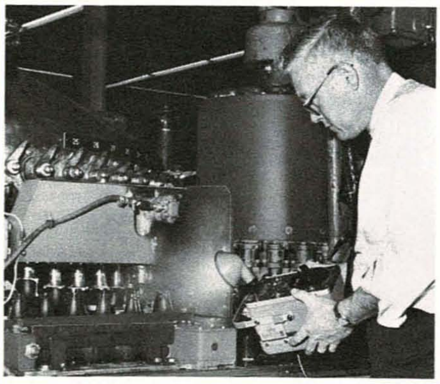
Stroboscopes are used to study the effects of cavitation on turbine blades and on other hydraulic equipment.

Stroboscopes are used in high-speed motion-picture, as well as still, photography.

Stroboscopes are used in the design, production-line checkout, and servicing of electric motors, appliances, and virtually all kinds of production, handling, and packaging machinery.

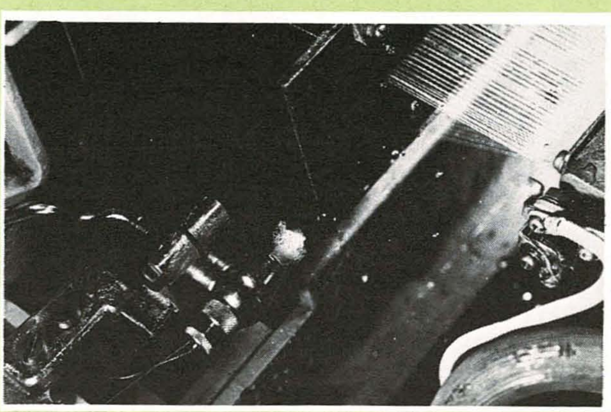
THE STROBOSCOPE AT WORK . . .

. . . . IN THE ENVIRONMENTAL TEST LAB



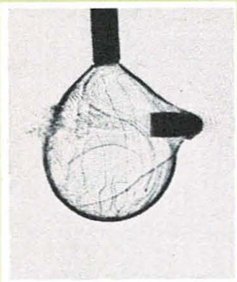
. . . . IN PACKAGING

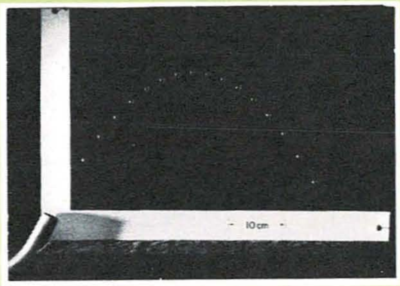
. . . . AT THE PRINTING PRESS



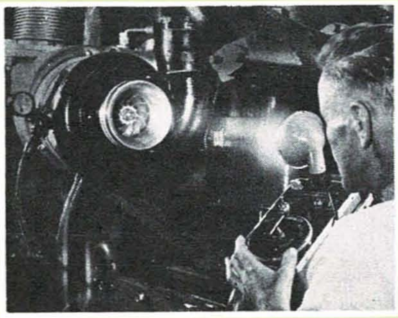
. . . . IN THE TEXTILE PLANT

STROBOSCOPES (cont'd)



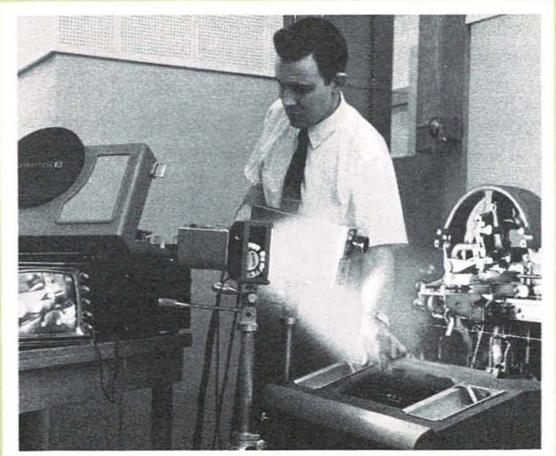


. . . . IN THE PHOTO STUDIO AND CLASSROOM



. . . . IN THE AIR-MOVING INDUSTRY

. . . . IN THE MEDICAL RESEARCH LAB



. . . . IN MACHINE DESIGN

Stroboscopes are used to help design and to trouble-shoot data-processing equipment, such as sorters, punches, etc.

A stroboscope is a versatile instrument, made even more versatile by the ingenious user. Few industries can afford to be without it.

Further information about the wide range of uses for stroboscopy is presented in **Strobotactics;** subscription is free on request.

THE GENERAL RADIO LINE OF STROBOSCOPES

General Radio's stroboscopic instruments are the result of over 30 years of continuous development engineering in this area. A major step forward in this program was the development, a few years ago, of the Type 1531 Strobotac® electronic stroboscope, which is much faster, much brighter, and yet smaller than earlier models. Thousands of these instruments are now in use in schoolrooms, research laboratories, printing plants, textile mills, chemical plants, and in virtually every type of manufacturing activity. The Type 1531-AB is an outstanding stroboscope at a low price.

For more demanding applications, General Radio offers the Type 1538-A Strobotac® electronic stroboscope. With a flashing-rate range of up to 150,000 flashes per minute, the Type 1538-A will easily keep pace with the fastest machines known. With battery or ac-line operation, this stroboscope goes wherever the action is. And with an accessory plug-in storage capacitor, this stroboscope can produce single, short flashes of light at an intensity of 44 million beam candelas (at a distance of one meter). Any one of these features — speed, battery operation, intensity — alone would make the 1538-A noteworthy. Together they put it in a class by itself.

Another member of our line of stroboscopes is the Type 1539-A Stroboslave, a stroboscopic light source that requires external control of its flashing rate. The Stroboslave, whose light output is the same as that of the Type 1531-AB Strobotac stroboscope, was designed specifically for the many applications where motion study or photography, rather than speed measurement, is required. Because of its compact size, it can easily be built into machines and systems requiring continuous stroboscopic light.

The latest addition to the expanding GR line of stroboscopes is the new Type 1540 Strobolume® electronic stroboscope. Designed for continuous operation over the same frequency ranges as the 1531-AB, the 1540 has a sizzling 20 times as much light output. The 1540 is the unit to choose when the viewing area is large or brightly lighted, or for stroboscopic photography.

STROBOSCOPE ACCESSORIES

The usefulness of a stroboscope can be multiplied many fold by a small additional investment in accessories. The photoelectric pickoffs, for example, can synchronize the stroboscope flash with almost any kind of motion, without physical connection to the object being observed. The 1537-A pickoff will directly trigger the 1538-A Strobotac and the 1539-A Stroboslave. The 1536-A pickoff with the 1531-P2 Flash Delay further extends the usefulness of any stroboscope by permitting observation of aperiodic repetitive motion at any point in its cycle. An inexpensive set of nylon disks (Type 1531-P3 Surface-Speed Wheel) converts linear speed (as, for instance, of belts, rollers, etc) into rpm for tachometric measurement with the stroboscope.

Type 1540 STROBOLUME®

ELECTRONIC STROBOSCOPE

- brilliant white light
- 0 to 25,000 flashes per minute
- wide-beam flood area for photographs

NEW

With the aid of a stroboscope you can examine the motion of machines, objects in flight or exploding, fluid spray patterns, and many other events as though they were motionless. With a calibrated stroboscope, you can measure the rate of repeating motion to a 1% accuracy up to ¼ million rpm.

With the new bright-light 1540 Strobolume, you can do all of the above under more difficult lighting conditions and even take color photographs of the strobe-stopped events. The 1540 is the first stroboscope to generate so much light, yet be fully versatile for general-purpose uses. Three control units are available; with the right one for the job, the 1540 can be flashed continuously or synchronized with the motion or camera for single flashes or bursts. Thus, it will "hold" a repeating motion in one chosen position, freeze a once-only event on film, or expose a motion to multiple-flash analysis.

Every flash, a pulse of white light lasting less than 15 microseconds, illuminates a 7 by 13-foot area at a 10-foot distance with enough light for still, movie, or, for electronic recording, TV pictures.

The flash can be triggered from a photoelectric pickoff, the opening or closing of a switch contact or camera shutter, or an electrical pulse or sine-wave signal. The flash can occur at the instant of the triggering event or be delayed by any desired time from 100 microseconds to 1 second to catch a subsequent event.

All three control units accept external signals for triggering the flash. In addition, the 1540-P4 Oscillator/Delay contains a circuit that will either oscillate to produce continuous flashing at rates from one-every-two-seconds to over 25,000 per minute or will delay external input trigger signals from 100 microseconds to 1 second. The Oscillator/Delay is well suited to photography; with it the flash of the 1540 can be synchronized with the motion **and** a camera, occurring only when the shutter is open and the moving object is in the desired position. The 1540-P1 Strobolume Oscillator provides accurate continuous flashing of the Strobolume for 1% speed measurements from 110 to 25,000 rpm. The 1540-P3 Strobolume Control Unit, simplest of the three control units, flashes the 1540 only in response to external signals.

DESCRIPTION

The working part of the 1540 Strobolume is the lamp head to which one of three control units attaches, either directly or by extension cable for remote operation. The combination is small, easily handled, and tripod mountable. It is connected to the larger power supply/carrying case by a twelve-foot cable.

In use, the lamp is aimed at the object to be studied at a distance determined by the area to be illuminated and the amount of light needed. The camera (any ordinary type with "X" flash synchronization) and photoelectric pickoff are connected to the control unit and the controls set until the motion appears stopped at the right point. Set the Strobolume for single flash, operate the shutter, and you have a picture. When not in use, all parts of the Strobolume are stored and carried in a compact Flip-Tilt case that protects the equipment from dust and damage.

1540 Strobolume shown with lamp head and all three available control units.

specifications

FLASHING-RATE RANGES

Internal: With 1540-P1 Oscillator, 110 to 25,000 flashes per minute; control calibrated with 1% accuracy. With 1540-P4 Oscillator/Delay, approx 30 to 25,000 flashes per minute in 3 overlapping decade ranges; uncalibrated control.

External: 0 to 25,000 flashes per minute.

LIGHT OUTPUT CHARACTERISTICS

Intensity at max beam width (intensity increases as beam narrows):

Range	Flash Rate (per minute)	Approximate Guide Number for ASA 160 Ektachrome
Low	0 to 700	70
Medium	0 to 4200	28
High	0 to 25,000	11

Auxiliary input provided for booster capacitor to increase single-flash intensity.

Flash Duration: 15 μs in low range, 12 μs in medium, 10 μs in high.

Beam Width: 7½ x 13 feet at 10-foot distance (40° x 65°); can be narrowed by internal adjustment to 3 x 13 ft (17° x 65°).

ELECTRICAL TRIGGERING

External Input: All control units will operate from a front-panel pushbutton, GR Photoelectric Pickoffs (the -P1 and -P3 operate from the 1537 only, the -P4 from the 1536 or 1537 pickoff), a contact closure (and/or opening for the -P4), or from a positive pulse of ≥1 V. The 1540-P4 will also trigger from a sine wave of ≥0.35 V rms, the -P1 from a sinewave of ≥0.35 V rms from 25,000 to 6000 per minute increasing to ≥3.5 V rms at 300 per minute.

Output Trigger (1540-P1 and -P4): >6-V positive pulse behind 600 Ω.

OSCILLATOR/DELAY CONTROL UNIT (1540-P4)

Delay: Time from external trigger to flash continuously adjustable approx 100 μs to 1 s in 3 overlapping ranges. Control uncalibrated.

Multiflash Mode: Flash bursts as long as front-panel pushbutton is depressed or contact closure exists at CAMERA input jack. Flashing rate set by panel controls.

Camera Input: "X" contact closure of camera causes either undelayed flash at instant of contact closure, or delayed flash synchronized to subject by external trigger signal.

GENERAL

Remote Programming: Strobolume can be controlled by external signals in place of any control unit. Intensity/range control by grounding through 28-V 60-mA rated switch contacts. Frequency control: flash triggered by positive pulse ≥0.75 V.

Cables: 12-foot flat multiconductor cable connects lamp head to power supply; extension cables available on special order. 6-foot cable supplied permits separation between lamp head and control unit.

Accessories Supplied: Adjustable neck strap, phone plug for input/output jacks, 6-ft cable for remote connection between lamp head and control unit.

Accessories Available: Control units 1540-P1, -P3, or -P4 (one required); the 1540-P2 lamp-head assembly with adjustable neck strap and handle; 1540-P5 Replacement Strobotron Flash Lamp with a glove to protect quartz lamp during installation; 1536-A and 1537-A Photoelectric Pickoffs. Cables for extra separation between power supply, lamp head, and control unit are available on special order.

Power Required: 100 to 125, or 195 to 250 V, 50 to 400 Hz, 250 W.

Mounting: Flip-Tilt case contains power supply and storage compartment for lamp head, one control unit, and cables.

Dimensions (width x height x depth): Case (closed), 19 x 8 x 13¾ in. (495 x 205 x 350 mm). Lamp head with control unit attached, 9¼ x 5½ x 8½ in. (235 x 140 x 220 mm).

Weight: Net, 36 lb. (16.5 kg); shipping, 41 lb (19 kg); lamp head and 1 control unit, 6 lb (2.8 kg), net.

The Strobolume is ideal for synchronized, single-flash high-speed photography — even in color. For example, the 1540 has a guide number of 70 when used with High-Speed Ektachrome (ASA 160).

Catalog Number	Description	Price in USA
1540-9600	**1540 Strobolume electronic stroboscope**	**$710.00**
	Requires one of following control units:	
1540-9601	**1540-P1 Strobolume Oscillator**	**185.00**
1540-9603	**1540-P3 Strobolume Control Unit**	**65.00**
1540-9604	**1540-P4 Oscillator/Delay Unit**	**265.00**
1540-9602	**1540-P2 Strobolume Lamp** (assembly)	**235.00**
1540-9605	**1540-P5 Replacement Strobotron Flash Lamp**	**35.00**

PATENT NOTICE: See Note 22.

Type 1531-AB STROBOTAC®

ELECTRONIC STROBOSCOPE

- "stops" rapid motion visually
- 1% accurate speed measurements to 250,000 rpm
- intense light source for high-speed photography
- simple to use — easy to handle

The Strobotac® electronic stroboscope is a small portable flashing-light source used to measure the speed of fast-moving devices or to produce the optical effect of stopping or slowing down high-speed motion for observation. A few of this instrument's many uses are:

- Observation and speed measurement of gears, cams, linkages, shuttles, spindles, motor rotors, and any other elements having repetitive motion.
- Observation of vibrating members, fuel-nozzle spray patterns, and vibrations of components under test in wind tunnels.
- High-speed photography of repetitive or non-repetitive motion.

The flashing-rate range of 110 to 25,000 flashes per minute is divided into three direct-reading ranges; to avoid reading errors, only the particular range in use is illuminated. The flash lamp can be triggered externally to "stop" motion for photography. The combination of the 1531-P2 Flash Delay and the 1536-A Photoelectric Pickoff can be used as an external triggering source, which also provides an adjustable delay of the stroboscope flash with respect to the triggering pulse from the photoelectric pickoff.

A built-in calibration system uses the power-line frequency for quick, easy check and readjustment of the flashing-rate calibration.

The strobotron flash lamp and reflector assembly pivots in a plane perpendicular to the panel and swivels 360 degrees on its own axis. The case is equipped with a ¼ x 20 socket for mounting the instrument on a tripod.

This instrument is listed as approved by CSA Testing Laboratories.

specifications

Flashing-Rate Range: 110 to 25,000 flashes per minute in three direct-reading ranges: 110 to 690, 670 to 4170, and 4000 to 25,000. Speeds up to 250,000 rpm can be measured.

Accuracy: ±1% of dial reading after calibration on middle range.

Calibration: Two panel adjustments permit calibration against power-line frequency.

Flash Duration: Approx 0.8, 1.2, and 3 μs for high-, medium-, and low-speed ranges, respectively, measured at ⅓ peak intensity.

Peak Light Intensity: Typical on high-, medium-, and low-speed ranges, respectively, 0.6, 3.5, and 11 million beam candelas (6×10^5, 3.5×10^6, and 11×10^6 lux at 1 meter distance at the center of the beam); for single flash, 18 million beam candelas (18×10^6 lux at 1 meter distance at the center of the beam). Photographic guide number is 30 for ASA 400 film speed and high-intensity flash.

Reflector Beam Angle: 10° at half-intensity points.

Output Trigger: 500- to 1000-V negative pulse available at panel jack.

External Triggering: The flash can be triggered by the opening of a mechanical contactor or by a 6-V pk-pk signal (2-V rms sine-wave signal down to 5 Hz).

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 35 W.

Accessories Supplied: Adjustable neck strap, plug to fit input and output jacks.

Accessories Available: 1531-P2 Flash Delay and 1536-A Photoelectric Pickoff, 1539-A Stroboslave with 1531-P4 Trigger Cable.

Mounting: Flip-Tilt Case.

Dimensions (width x height x depth): 10⅝ x 6⅝ x 6⅛ in. (270 x 170 x 160 mm).

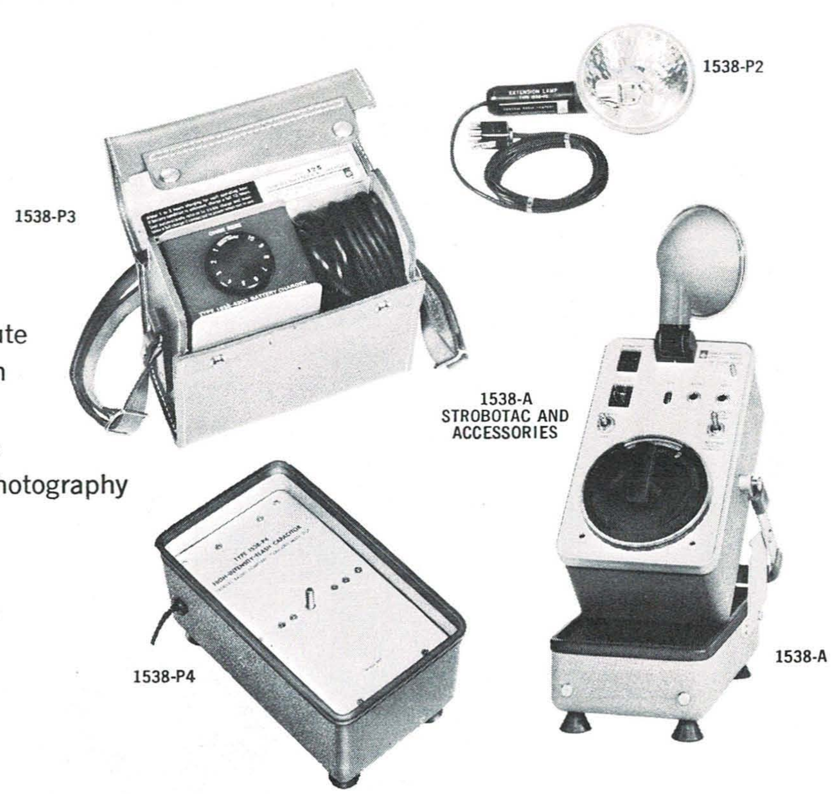
Weight: Net, 7¼ lb (3.3 kg); shipping, 9 lb (4.1 kg).

Catalog Number	Description	Price in USA
	1531-AB Strobotac® electronic stroboscope	
1531-9430	115-V ac Model	**$345.00**
1531-9440	230-V ac Model	**345.00**
1538-9601	**1538-P1 Strobotron Replacement Flash Lamp**	**15.00**

PATENT NOTICE. See Notes 6 and 22.

Type 1538-A STROBOTAC®

electronic stroboscope



- flashing rates up to 150,000 per minute
- speed measurements to 1 million rpm
- battery or power-line operation
- remote flash lamp on extension cable
- extra-high-intensity single flash for photography

The 1538-A Strobotac is able to satisfy a broader range of applications than the 1531-A. In addition to its higher maximum flashing rate, it has several accessories available for extending its performance and convenience. It can be operated from a power line, or, if there is no power outlet nearby, from the rechargeable battery pack. The accessory extension lamp is useful in illuminating hard-to-reach areas.

This stroboscope is ideally suited for photographic applications requiring a high light intensity. With the 1538-P4 High-Intensity-Flash Capacitor, it produces 8-microsecond flashes of 44 million beam candelas at one-meter distance. This results in a guide number of about 250 when a film rated at ASA 3000 is used.

The 1538-A circuits are all transistorized. This not only makes possible battery operation but also ensures greater stability of the flashing rate.

The flash can be triggered externally by a simple contact closure across the input terminals, by a positive pulse, or by a sine wave. With a photoelectric pickoff, the flash can be triggered by pulses that are synchronized with a mechanical motion. The 1537-A Photoelectric Pickoff connects directly to the 1538-A and contains a light-activated switch but no light source. The 1536-A pickoff contains a photocell and light source, for which power is supplied by the 1531-P2 Flash Delay. With this combination, an adjustable delay is introduced between the time a selected point on a moving object passes the pickoff and the time at which the Strobotac flashes. Three-way synchronization of the camera shutter, the mechanical motion, and the Strobotac flash is a very useful feature of this combination. Both the Strobotac and the 1538-P4 High-Intensity-Flash Capacitor are equipped with sockets for attaching the two together and for tripod mounting.

— See **GR Experimenter** for April 1966.

specifications

Flashing-Rate Range: 110 to 150,000 flashes per minute in four direct-reading ranges: 110 to 690, 670 to 4170, 4000 to 25,000, and 24,000 to 150,000 rpm. Speeds to 1 million rpm can be measured.

Accuracy: ±1% on all ranges after calibration on 670- to 4170-rpm range against 50- or 60-Hz line frequency.

Flash Duration: Approx 0.5, 0.8, 1.2, and 3 μs for high-to-low speed ranges, respectively, measured at ⅓ peak intensity; 8 μs for single flashes with 1538-P4 High-Intensity-Flash Capacitor.

Peak Light Intensity: Typically 0.16, 1, 5, and 15 million beam candelas (0.16, 1, 5, and 15 $\times$ 10^6 lux measured at 1 meter distance at the beam center) for high-to-low speed ranges, respectively; 44 million beam candelas at 1 meter for single flash, with 1538-P4 High-Intensity-Flash Capacitor.

Reflector Beam Angle: 10° at half-intensity points.

Output Trigger: Greater than 6-V positive pulse behind 400 Ω.

External Triggering: Either a switch closure across the input jack terminals, a 1-V (peak) positive pulse, or a 0.35-V (rms) sine wave down to 100 Hz increasing to 3.5 V (rms) at 5 Hz.

Power Required: 100 to 125 or 195 to 250 V, 50 to 400 Hz, 15 W (max) or 20 to 30 V dc, 12 W (max).

Accessories Supplied: Adjustable neck strap, phone plug for input and output jacks, power cord.

Accessories Available: 1538-P2 Extension Lamp, 1538-P4 High-Intensity-Flash Capacitor (1538-P2 and -P4 cannot be used simultaneously), 1538-P3 Battery and Charger, 1531-P2 Flash Delay, 1536-A Photoelectric Pickoff (use with flash delay), 1537-A Photoelectric Pickoff, and 1539-A Stroboslave® stroboscopic light source.

Mounting: Flip-Tilt Case.

Dimensions (width x height x depth): 10⅝ x 6⅝ x 6⅛ in. (270 x 170 x 160 mm).

Weight: Net, 7¼ lb (3.3 kg); shipping, 10 lb (4.6 kg).

Catalog Number	Description	Price in USA
	1538-A Strobotac® electronic stroboscope	
1538-9701	115-V ac Model	$545.00
1538-9702	230-V ac Model	545.00
1538-9601	**1538-P1 Replacement Strobotron flash lamp**	15.00
1538-9602	**1538-P2 Extension Lamp**	65.00
1538-9603	**1538-P3 Battery and Charger**	315.00
1538-9604	**1538-P4 High-Intensity-Flash Capacitor**	95.00
1560-2101	**1560-P76 Patch Cord,** connects output of 1538 to input of another 1538 or 1531 Strobotac, a 1539 Stroboslave, or a 1531-P2 Flash Delay.	3.00

PATENT NOTICE. See Notes 6, 22, 30.

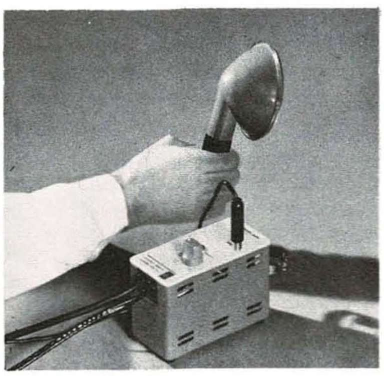
Type 1539-A STROBOSLAVE®

STROBOSCOPIC LIGHT SOURCE

- low cost, compact
- removable lamp on 5-foot cable
- high light output — same as Type 1531
- choice of trigger sources

Tripod socket is provided on Stroboslave case.

The Stroboslave is a stroboscopic light source that satisfies the basic requirements for motion studies and high-speed photography. It is suitable for all stroboscope applications except speed measurement. More than one Stroboslave can be used where there is a need for multiple light sources. When the reflector is removed from the end of the extension cord, the strobotron lamp assembly can be inserted through a hole as small as one inch, making it possible to observe objects in otherwise inaccessible areas. Locking connectors at the lamp's head permit extension-cord lengths up to 50 feet.



Lamp, at end of five-foot cable, can be held in hand as shown here or attached to case as shown above.

The Stroboslave has no internal oscillator for setting the flashing rate. It will operate directly from a switch closure, a 1537-A Photoelectric Pickoff, or a 1531-P2 Flash Delay with a 1536-A Photoelectric Pickoff. A Stroboslave with the latter two accessories is available as the 1539-Z Motion-Analysis and Photography Set for high-speed photography with conventional cameras and for visual analysis where speed need not be measured. In addition, the Stroboslave will operate from the output of the 1538-A Strobotac® electronic stroboscope directly, from the output of a 1531 Strobotac through a 1531-P4 Trigger Cable, or from any source of a positive electrical pulse of at least 2 volts peak.

The Stroboslave produces the same light output as the 1531 Strobotac and operates over the same three basic ranges from 0 to 25,000 flashes per minute. The strobotron lamp and reflector are connected to the unit by a five-foot flexible cable so that the light can be positioned close to the subject to be observed.

— See **GR Experimenter** for April 1966.

specifications

Flashing-Rate Ranges: 0 to 700, 0 to 4200, 0 to 25,000 flashes per min on high-, medium-, and low-intensity ranges, respectively.

Flash Duration: Approx 0.8, 1.2, and 3 μs, measured at ⅓ peak intensity, for the low-, medium-, and high-intensity ranges, respectively.

Peak Light Intensity: Typically 0.6, 3.5, and 11 million beam candelas (0.6, 3.5 and 11×10^6 lux measured at 1-m distance at the beam center), for low-, medium-, and high-intensity ranges, respectively. For single flash, 18 million beam candelas at 1 meter. Photographic guide number is 30 for high-intensity range and ASA 400 film speed.

Reflector Beam Angle: 10° at half-intensity points.

External Triggering: Either a switch closure across the input jack terminals or a 2-V (peak) positive pulse.

Power Required: 100 to 125 or 195 to 250 V, 50 to 400 Hz, 16 W (max) at 115 V.

Accessories Supplied: Phone plug for input, mounting bracket.

Accessories Available: 1531-P2 Flash Delay with a 1536-A Photoelectric Pickoff (available with a 1539-A as the 1539-Z Motion-Analysis and Photography Set), 1537-A Photoelectric Pickoff.

Mounting: Metal case with detachable lamp housing.

Dimensions (width x height x depth): 2½ x 8⅜ x 4⅛ in. (64 x 215 x 105 mm).

Weight: Net, 2¾ lb (1.3 kg); shipping, 8 lb (3.7 kg).

Catalog Number	Description	Price in USA
1539-9701	**1539-A Stroboslave® stroboscopic light source**	**$230.00**
1531-9604	**1531-P4 Trigger Cable** (for use with 1531 Strobotac)	**20.00**
1538-9601	**1538-P1 Replacement Strobotron flash lamp**	**15.00**
	1539-Z Motion-Analysis and Photography set	
1539-9900	for 115-V operation	**545.00**
1539-9901	for 230-V operation	**545.00**

PATENT NOTICE. See Note 6.

Type 1531-P2 FLASH DELAY

- synchronize GR stroboscopes for
  - high-speed photography with most cameras
  - controlled visual inspection
- stop motion at any point in cycle

Strobotac shown with Flash Delay and Photoelectric Pickoff.

The 1531-P2 permits GR stroboscopes to be synchronized with moving objects and provides control of the flash occurrence relative to the position of the object by introducing a variable time delay between the position-sensing transducer (photocell) and the stroboscope. This permits all phases of the motion to be studied. For photography, the camera shutter, the motion of the subject, and the strobe flash can all be synchronized.

With the pickoff, one can view and photograph moving objects having variable or unsteady speeds.

The flash delay is a valuable accessory to the 1531 Strobotac® electronic stroboscope as it amplifies and conditions the triggering pulse for reliable operation from external triggers. It will also drive the 1538-A Strobotac and the 1539-A Stroboslave® stroboscopic light source. — See **GR Experimenter** for August 1963.

specifications

Time-Delay Range: Approx 100 μs to 0.8 s in three ranges.

Output Pulse: Better than 13 V available for triggering the 1531-A and 1538-A Strobotac electronic stroboscopes and the 1539-A Stroboslave.

Sensitivity: As little as 0.3-V input will produce sufficient output to trigger the stroboscope.

Inputs: Phone jacks for triggering; jack for camera synchronization.

Accessories Supplied: Trigger cable with pushbutton, phone-plug adaptor, carrying case.

Accessories Available: 1536-A Photoelectric Pickoff.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 5 W with 1536-A connected.

Mounting: Aluminum case with bracket, which clips directly onto the Strobotac electronic stroboscope.

Dimensions (width x height x depth): 5⅛ x 3⅛ x 3¾ in. (135 x 80 x 96 mm).

Weight: Net, 2 lb (1 kg); shipping, 5 lb (2.3 kg).

Catalog Number	Description	Price in USA
1531-9602	**1531-P2 Flash Delay**	**$225.00**

Type 1539-Z MOTION-ANALYSIS AND PHOTOGRAPHY SET

The 1539-Z is an assembly of three strobe instruments into an economical stroboscope for high-speed photography and for motion-analysis applications where speed need not be measured. It is excellent for use where a stroboscope is to be permanently mounted on machinery for frequent inspections while the machine is operating.

VISUAL MOTION ANALYSIS

Having no internal oscillator, the 1539-Z depends on its photoelectric pickoff for synchronization to the motion under observation. The 1531-P2 Flash Delay, also included, permits the operator to set the time of occurrence of the flash to coincide with the desired point in the machine's operating cycle. The 1539 Stroboslave® stroboscopic light source, operating from the delay triggering, provides the intense, microsecond-long light flashes.

HIGH-SPEED PHOTOGRAPHY

For high-speed photography, the 1539-Z can also be triggered from the photoelectric pickoff or other synchonizing sensor: magnetic, acoustic, etc. The flash delay can be set to expose the photograph at precisely the desired moment with a single flash or repetitive flashes.

A most useful 92-page publication, The Handbook of High-Speed Photography, is available from General Radio on request, $1.00.

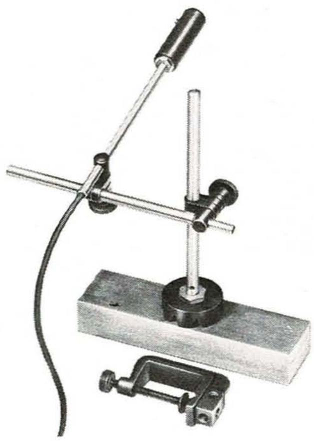
specifications

1539-Z Comprises: 1539-A Stroboslave, 1531-P2 Flash Delay, and 1536-A Photoelectric Pickoff. See full descriptions elsewhere in this section.

Weight (combined): Net, 6 lb (2.7 kg); shipping, 17 lb (7.8 kg).

Catalog Number	Description	Price in USA
	1539-Z Motion Analysis and Photography Set	
1539-9900	115-V Model	**$545.00**
1539-9901	230-V Model	**545.00**

Type 1536-A, Type 1537-A PHOTOELECTRIC PICKOFFS



- optical triggering of GR stroboscopes
- small, maneuverable, sturdy mounting
- triggering rate up to 150,000 rpm

These photoelectric pickoffs produce an output whenever the photosensitive element senses a change in light such as would be produced by a piece of reflective tape on a moving object. If the resulting pulse is used to trigger a stroboscope, the flashes will occur in synchronism with the motion and permit the object to be viewed or photographed as though stationary.

The 1536-A pickoff can be used with either the 1531-P2 Flash Delay and 1531 Strobotac® electronic stroboscope or the 1540-P4 Oscillator/Delay and 1540 Strobolume® electronic stroboscope for applications requiring control of the time of occurrence of the flash relative to the position of the moving object. The 1536 contains, in addition to its photocell and lens, a light source that requires power.

The 1531-P2 and 1540-P4 contain the power supplies for the 1536-A, plus the additional circuitry to amplify and shape the output for positive operation of the stroboscopes and to permit a time delay to be introduced between the pickoff and the stroboscope.

The 1537-A pickoff will directly trigger the 1538-A, 1539-A, 1540-P1, 1540-P3, or 1540-P4 (not the 1531), but, lacking a built-in lamp, the pickoff must be triggered from a strong external light source.

— See **GR Experimenter** for April 1966.

specifications

1536-A

Operating Rate: Approx 2500 pulses/s as limited by the 200-μs time constant of the photocell and cable combination.

Power Required: 20 to 28 V dc, 40 mA. Power is supplied by the 1531-P2 Flash Delay or 1540-P4 Oscillator/Delay.

1537-A

Operating Rate: Greater than 2500 pulses/s.

Power Required: 3 to 25 V dc; 0 to 100 μA depending on operating rate. Power is supplied by instrument with which it is used.

GENERAL

Accessories Supplied: 10-ft roll of ⅜-in. black tape; 10-ft roll of ⅜-in. silver tape; carrying case.

Mounting: C-clamp (capacity 1⅝-in., flat or round) or 1½-in. magnet, both supplied.

Dimensions: Pickoff head, 11/16-in. dia, 2 in. long. Linkage consists of two 5/16-in. diameter stainless-steel rods, 6 and 6¼ in. long, and adjustable connecting clamp. Cable is 8 ft long, terminated in phone plug.

Weight: Net, 1¼ lb (0.6 kg); shipping, 4 lb (1.9 kg).

Catalog Number	Description	Price in USA
1536-9701	**1536-A Photoelectric Pickoff**	**$90.00**
1537-9701	**1537-A Photoelectric Pickoff**	**80.00**

Type 1531-P3 SURFACE-SPEED WHEEL

The 1531-P3 is used with the 1531-A, 1538-A, and 1540 (with 1540-P1 control unit) electronic stroboscopes to make accurate measurements of the linear surface speed of belts, pulleys, wheels, drums, rollers, etc.

Two black nylon wheels of different diameters are mounted on the ends of a sectioned steel rod. The selected wheel is held against the moving object and observed with the stroboscope to determine directly the surface speed.

— See **GR Experimenter** for August 1963.

specifications

Speed Range: 10 to 2500 ft/min with small wheel and 50 to 12,500 ft/min with large wheel.

Dimensions: Wheels are 0.764 and 1.910 in. dia, respectively. Three-section shaft totals 20 in. in length.

Weight: Net, 8 oz (0.3 kg); shipping, 2 lb (1 kg).

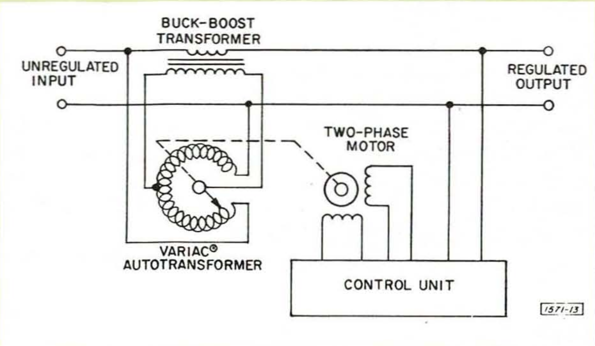
Catalog Number	Description	Price in USA
1531-9603	**1531-P3 Surface-Speed Wheel**	**$30.00**

VARIAC® AUTOMATIC VOLTAGE REGULATORS

General Radio Variac® automatic voltage regulators have many advantages for both laboratory and industrial use in any application where controlled line voltage is needed.

Variac regulators

- Regulate to 0.25% or better.
- Are not load sensitive; they work equally well on all loads from open circuit to maximum rating for continuous service.
- Have up to 10 times rating for transients.
- Introduce no distortion.
- Have no power-factor restrictions.
- Have high response speed — comparable with magnetic types.
- Use all-solid-state control circuits.
- Are available in many models, differing in power rating, correction range, voltage, frequency, and packaging.



Elementary schematic diagram of General Radio's voltage regulators. The 1591 uses no step-down transformer.

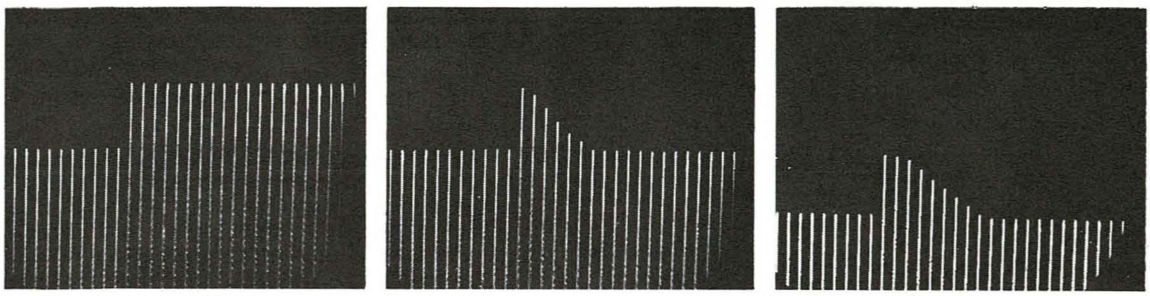
PRINCIPLE OF OPERATION

The regulator comprises a motor-driven Variac® adjustable autotransformer, an auxiliary step-down transformer in the larger models, that multiplies the power rating of the autotransformer, and a solid-state control unit, which automatically positions the autotransformer to hold the output voltage constant.

The regulator's output voltage is compared to a reference voltage; the resultant error signal controls a servo motor, providing a true proportional-control system, rather than an on-off circuit. The accompanying oscillograms illustrate a typical response to a 2% step change in line voltage. The traces are greatly expanded and show only the ac voltage peaks.

The use of a true proportional-control system provides not only fast correction but also smooth control of voltage, completely free of the voltage jumps introduced by an on-off control system. The absence of relays provides long trouble-free life, and tolerance of 1000% transient overloads is made possible by the Duratrak® commutator surface of the Variac autotransformer.

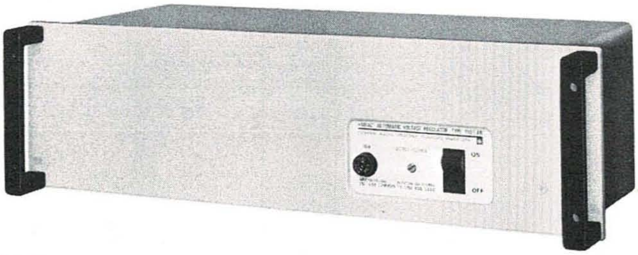
The regulators maintain an undistorted output even if the input line voltage exceeds the correction range. Prolonged use at excessive inputs, however, should be avoided because of possible damage from overheating.



Oscillograms of line-voltage peaks show response speed of Variac® automatic voltage regulators: left, 2% step change in line voltage; center and right, resulting output transients for 1581 and 1582 Regulators, respectively.

Type 1591 VARIAC® AUTOMATIC VOLTAGE REGULATOR

- 1-kVA basic capacity
- low cost, small size
- ±0.2% accuracy
- true rms detection, no distortion



Electromechanical voltage regulators have always offered large power capacity with little bulk and cost. These advantages are now available in a 1-kVA regulator, thanks to a new, simple control circuit. Still, as with the larger GR regulators, there is no distortion added to the input waveform so average- and peak-voltage values are also quite constant. Regulation accuracy is independent of line frequency, load variations, and power factor.

Output voltage is controlled by a servo-driven Variac® adjustable autotransformer so the regulator has the same ability to handle 1000% transient overloads as the Variac. The 1591 is mechanically rugged, having proven itself in severe vibration and shock tests. Its typical temperature coefficient of 75 ppm/°C is so small as to be negligible under normal operating conditions.

— See **GR Experimenter** for October 1967.

specifications

	115-V Models	230-V Models
Output kVA	1.0	0.8
Output Current	8.7 A	3.4 A
Input-Voltage Range	100 to 130 V	200 to 260 V
Output-Voltage Range (adjustable)	105 to 125 V	210 to 250 V
Max Correction	±15 V	±30 V
Frequency	57 to 63 Hz	48 to 63 Hz

Correction Time (cycles): 6 c + 1.5 c/V for 115-V models, 6 c + 0.7 c/V for 230-V models.

Output-Voltage Accuracy: ±0.2% for any combination of line voltage or frequency, load, or power factor.

Power Factor: 0 to 1, leading or lagging.

Response: Rms.

Distortion: None added.

Power Dissipation (approx): No load, 40 W; full load, 95 W.

ENVIRONMENT

Ambient Temperature (operating): −20 to +52°C, rack model; −20 to +40°C, portable model.

Vibration: Rack model, 30 mils pk-pk at 10 to 55 Hz, three planes, 15 min each plane.

Shock (rack model, operating and nonoperating): AF bench-drop test; 30 g for 11 ms.

GENERAL

Dimensions (width x height x depth): Portable, 12¾ x 9½ x 5⅜ in. (325 x 245 x 140 mm); rack, 19 x 5¼ x 6⅜ in. (485 x 135 x 165 mm).

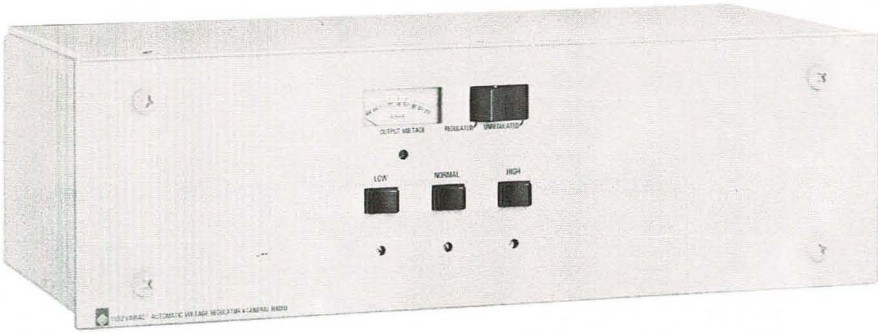
Net Weight: Portable, 17 lb (8 kg); rack, 22 lb (10 kg).

Shipping Weight: Portable, 25 lb (11.5 kg); rack, 31 lb (14.5 kg).

Catalog Number	Description	Price in USA
	Variac® Automatic Voltage Regulator	
1591-9700	**1591-A,** 115 V, Portable Model	**$345.00**
1591-9701	**1591-AH,** 230 V, Portable Model	**370.00**
1591-9712	**1591-AR,** 115 V, Rack Model	**385.00**
1591-9713	**1591-AHR,** 230 V, Rack Model	**410.00**

Type 1592 VARIAC® AUTOMATIC VOLTAGE REGULATORS

- lowest cost regulator available per kVA
- up to 10 kVA
- 120 to 480 V, single- or 3-phase systems
- ±5 to ±20% correction range
- 0.2% basic accuracy
- fast response, no distortion added



NEW

Regardless of load or line variations, the 1592 supplies the voltage necessary for the proper operation and longevity of your equipment — any equipment from light bulbs to computers — because the regulator adds no distortion and operates independently of power factor.

It is virtually unaffected by temperature, extremely fast responding, and so efficiently engineered and built that only two basic models (120 V and 230/240 V) handle all requirements for 120 to 480-volt, single or multi-phase systems and bench, rack, or wall-mount installations. It is also a versatile test instrument whose output can be selected by means of front-panel pushbuttons for any one of three preset voltages.

The 1592 is an electro-mechanical regulator and therefore provides its tight regulation accuracy without regard to line frequency, load variations, or power factor. Its output is controlled by a servo-driven Variac® adjustable autotransformer with a long history of engineering refinements and an ability to handle 1000% transient overloads. The control circuitry is ultra simple and exceptionally reliable due to a unique concept introduced by GR and field-proven, including severe shock and vibration tests, for over three years. This circuitry also allows the output voltage to be remotely sensed and controlled.

specifications

Output Characteristics and Control: *Power factor,* 0 to 1, leading or lagging. *Response,* rms. *Distortion,* none added. *Accuracy,* accuracy specified applies for any combination of line voltage or frequency, load, or power factor. *Control,* output can be any one of three values as selected by front-panel pushbuttons, each independently adjustable by front-panel screwdriver controls or, for remote-control applications, by external resistors connected to rear by push-on terminals. Voltage can also be sensed remotely, by two leads connected to rear by push-on terminals, to ensure desired voltage *at the load.*

Meter: Front-panel pushbutton permits meter to read input or output voltage.

Electrical: There are two basic models, 120-V and 230/240-V input, whose only major difference is the meter and Variac adjustable autotransformer. The various versions of each model are achieved by internal wiring changes that can be effected simply in the field if desired. *Power dissipation,* ≈ 45 W no load, ≈ 120 W full load.

Mechanical: Bench, rack, and wall mount (brackets, handles, and hardware supplied for conversion). *Dimensions* (w x h x d): 17 x 5¼ x 11 in. (435 x 135 x 280 mm). *Weight:* 42 lb (19.5 kg) net, 56 lb (26 kg) shipping.

Catalog Number	Description	Price in USA
	1592 Variac® automatic voltage regulator	
1592-9700	120-V ±10% input	**$525.00**
1592-9701	120-V ±20% input	**525.00**
1592-9702	230/240-V ±5% input	**525.00**
1592-9703	230/240-V ±10% input	**525.00**
1592-9704	230/240-V ±20% input	**525.00**

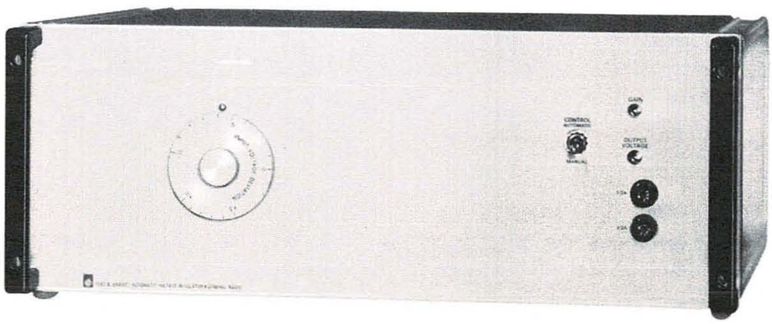
Input			Output				Range	
Voltage		Frequency	Voltage and Accuracy	Current	kVA	Correction Rate [1]	Output (adjustable)	Input (as % of output)
120 V	**±10%**	60 Hz [2]	120 V ±0.2%	44 A	5.3	25 ms/V	90 to 130 V [3]	±10% [3]
120 V	**±20%**	60 Hz [2]	120 V ±0.4%	20 A	2.4	13 ms/V	90 to 130 V [3]	±20% [3]
		The above models can be used in 208-to-240-V, **3-phase,** wye systems (3 regulators required)						
230/240 V	**±5%**	50-60 Hz [4]	230/240 V ±0.15%	42 A	10	50 ms/V	180 to 260 V [4]	±5% [4]
230/240 V	**±10%**	50-60 Hz [4]	230/240 V ±0.2%	18 A	4.3	25 ms/V	180 to 260 V [4]	±10% [4]
230/240 V	**±20%**	50-60 Hz [4]	230/240 V ±0.4%	8.5 A	2	13 ms/V	180 to 260 V [4]	±20% [4]
		The above models can be used in 208-to-480-V, **2-phase,** open-delta systems (2 regulators required), or **3-phase,** closed-delta or wye systems (3 regulators required)						

[1] Correction rate is slew speed at 60-Hz operation.
[2] Can be operated at 50-Hz if output is limited to 115 V.
[3] Can be increased to 138 V (for use in 240-V, 3-phase, 4-wire systems) with 9 and 18% input ranges, respectively.
[4] Can be increased to 277 V (for use in 60-Hz, 480-V, 3-phase, 4-wire systems) with 5, 9, and 18% input ranges, respectively.

VARIAC® AUTOMATIC VOLTAGE REGULATORS

Types 1581-A and 1582-A

- fast response, high accuracy
- distortionless regulation
- large power-handling capacity
- output voltage independent of load
- no power-factor restriction
- tolerates 1000% transient overloads



1582-A, bench model

The 1581-A and 1582-A all-solid-state regulators automatically compensate for ac line-voltage fluctuations to provide a reliable constant-voltage source over a specified correction range. These units combine high accuracy with large capacity for both laboratory use and industrial installations. They are especially useful in maintaining stable operating conditions for computers, measurement systems, transmitter supplies, and critical industrial processes.

Power output of the standard models ranges from 2 to 20 kVA, depending upon the model selected. Several models are available in each of the 115-, 230-, and 460-volt classifications and in four different styles: bench, rack, wall, or without case.

Any of the 60-Hz models can be connected for 50-to 60-Hz operation by a connection change on the Variac autotransformer. This will affect the correction ranges, as indicated on the chart.

THREE-PHASE LINES

Standard single-phase regulators, as listed, can be used to regulate three-phase lines. Three such regulators can be connected in a wye or closed-delta configuration or two in an open delta, sensing line-to-neutral or line-to-line voltages. The individual regulators should be selected based on the voltage magnitude to be sensed and the individual line currents to be carried.

PRINCIPLE OF OPERATION

The regulator comprises a motor-driven Variac® adjustable autotransformer, an auxiliary step-down transformer, which multiplies the power rating of the autotransformer, and a solid-state control unit, which automatically positions the autotransformer to hold the rms output voltage constant.

The use of a true proportional control system provides both fast correction and smooth control.

— See **GR Experimenter** for January 1966.

specifications

Frequency: 60-Hz models operate from 57 to 63 Hz but can be modified by a connection change to operate from 48 to 63 Hz (50 to 60, nominal); 400-Hz models operate from 350 to 450 Hz.

Response: Rms. **Distortion:** None added.

Power Dissipation (approx): Type 1581-A — no load, 35 W; full load, 115 W. Type 1582-A — no load, 45 W; full load, 120 W.

Ambient Temperature: Operating, −20° to +52°C; in storage, −54° to 85°C.

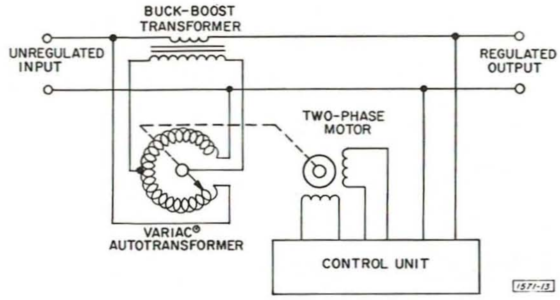
Mechanical Data:

TYPE 1581

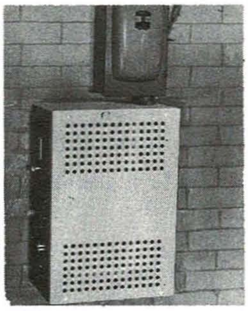
	Width		Height		Depth		Net Wt		Ship Wt	
	in.	mm	in.	mm	in.	mm	lb	kg	lb	kg
Without case	19	485	7	180	10½	270	41½	19	92	42
Bench	19	485	7⅜	190	12	305	51	23.5	100	46
Rack	19	485	7	180	11¾	300	51	23.5	100	46
Wall	19½	495	8⅛	210	11¼	290	54	24.5	104	48

TYPE 1582

	Width		Height		Depth		Net Wt		Ship Wt	
	in.	mm	in.	mm	in.	mm	lb	kg	lb	kg
Without case	19	485	7	180	14¼	365	61	28	110	50
Bench	19	485	7⅜	190	16	410	71	33	121	55
Rack	19	485	7	180	15¾	400	71	33	121	55
Wall	19½	495	8⅛	210	16	410	77	35	126	58



Elementary schematic diagram of General Radio's voltage regulators, Types 1581, 1582, 1583 and 1571.



View of wall-mounted regulator. This model is used to regulate line voltages in the General Radio development and testing laboratories.

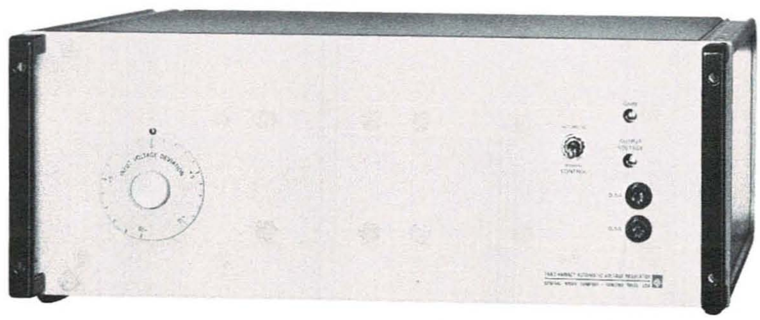
Output Voltage	Correction Range* %	Output Current (A)	KVA	Correction Time in cycles (c) **	Accuracy (% of output V)	Mounting or Style	60 Hz Type Number	60 Hz Catalog Number	60 Hz Price in USA	400 Hz Type Number	400 Hz Catalog Number	400 Hz Price in USA
115 V Adjustable ±10%	90 to 110	50	5.8	2.5 c + 1.5 c/V	0.25	No cabinet	1581-AL	1581-9831	$625.00	1581-ALJ	1581-9551	$675.00
						Bench	1581-ALM	1581-9964	670.00	1581-ALMJ	1581-9552	720.00
						Rack	1581-ALR	1581-9974	660.00	1581-ALRJ	1581-9554	710.00
						Wall	1581-ALW	1581-9980	660.00	1581-ALWJ	1581-9555	710.00
		85	9.8	2.5 c + 3.0 c/V	0.25	No cabinet	1582-AL	1582-9831	695.00	1582-ALJ	1582-9551	745.00
						Bench	1582-ALM	1582-9964	745.00	1582-ALMJ	1582-9552	795.00
						Rack	1582-ALR	1582-9974	735.00	1582-ALRJ	1582-9554	785.00
						Wall	1582-ALW	1582-9980	735.00	1582-ALWJ	1582-9555	785.00
	82 to 124	25	2.9	2.5 c + 0.7 c/V	0.5	No cabinet	1581-AL2	1581-9898	625.00	1581-AL2J	1581-9556	675.00
						Bench	1581-ALM2	1581-9901	670.00	1581-ALM2J	1581-9557	720.00
						Rack	1581-ALR2	1581-9923	660.00	1581-ALR2J	1581-9558	710.00
						Wall	1581-ALW2	1581-9924	660.00	1581-ALW2J	1581-9559	710.00
		42.5	4.9	2.5 c + 1.5 c/V	0.5	No cabinet	1582-AL2	1582-9898	695.00	1582-AL2J	1582-9556	745.00
						Bench	1582-ALM2	1582-9901	745.00	1582-ALM2J	1582-9557	795.00
						Rack	1582-ALR2	1582-9923	735.00	1582-ALR2J	1582-9558	785.00
						Wall	1582-ALW2	1582-9924	735.00	1582-ALW2J	1582-9559	785.00
230 V Adjustable ±10%	95 to 105	40	9.2	2.5 c + 1.5 c/V	0.25	No cabinet	1581-AH5	1581-9516	625.00	1581 AH5J	1581-9530	675.00
						Bench	1581-AHM5	1581-9517	670.00	1581-AHM5J	1581-9531	720.00
						Rack	1581-AHR5	1581-9518	660.00	1581-AHR5J	1581-9532	710.00
						Wall	1581-AHW5	1581-9521	660.00	1581-AHW5J	1581-9533	710.00
		85	19.7	2.5 c + 3.0 c/V	0.25	No cabinet	1582-AH5	1582-9516	695.00	1582-AH5J	1582-9530	745.00
						Bench	1582-AHM5	1582-9517	745.00	1582-AHM5J	1582-9531	795.00
						Rack	1582-AHR5	1582-9518	735.00	1582-AHR5J	1582-9532	785.00
						Wall	1582-AHW5	1582-9521	735.00	1582-AHW5J	1582-9533	785.00
	90 to 110	20	4.6	2.5 c + 0.7 c/V	0.25	No cabinet	1581-AH	1581-9817	625.00	1581-AHJ	1581-9522	675.00
						Bench	1581-AHM	1581-9951	670.00	1581-AHMJ	1581-9523	720.00
						Rack	1581-AHR	1581-9961	660.00	1581-AHRJ	1581-9524	710.00
						Wall	1581-AHW	1581-9971	660.00	1581-AHWJ	1581-9525	710.00
		42.5	9.8	2.5 c + 1.5 c/V	0.25	No cabinet	1582-AH	1582-9817	695.00	1582-AHJ	1582-9522	745.00
						Bench	1582-AHM	1582-9951	745.00	1582-AHMJ	1582-9523	795.00
						Rack	1582-AHR	1582-9961	735.00	1582-AHRJ	1582-9524	785.00
						Wall	1582-AHW	1582-9971	735.00	1582-AHWJ	1582-9525	785.00
	82 to 124	10	2.3	2.5 c + 0.4 c/V	0.5	No cabinet	1581-AH2	1581-9770	625.00	1581-AH2J	1581-9526	675.00
						Bench	1581-AHM2	1581-9771	670.00	1581-AHM2J	1581-9527	720.00
						Rack	1581-AHR2	1581-9772	660.00	1581-AHR2J	1581-9528	710.00
						Wall	1581-AHW2	1581-9773	660.00	1581-AHW2J	1581-9529	710.00
		21.3	4.9	2.5 c + 0.7 c/V	0.5	No cabinet	1582-AH2	1582-9770	695.00	1582-AH2J	1582-9526	745.00
						Bench	1582-AHM2	1582-9771	745.00	1582-AHM2J	1582-9527	795.00
						Rack	1582-AHR2	1582-9772	735.00	1582-AHR2J	1582-9528	785.00
						Wall	1582-AHW2	1582-9773	735.00	1582-AHW2J	1582-9529	785.00
460 V Adjustable ±10%	95 to 105	34	15.6	2.5 c + 1.5 c/V	0.25	No cabinet	1582-AK5	1582-9535	695.00	1582-AK5J	1582-9546	745.00
						Bench	1582-AKM5	1582-9536	745.00	1582-AKM5J	1582-9547	795.00
						Rack	1582-AKR5	1582-9537	735.00	1582-AKR5J	1582-9548	785.00
						Wall	1582-AKW5	1582-9538	735.00	1582-AKW5J	1582-9549	785.00
	90 to 110	17	7.8	2.5 c + 0.7 c/V	0.25	No cabinet	1582-AK	1582-9819	695.00	1582-AKJ	1582-9541	745.00
						Bench	1582-AKM	1582-9534	745.00	1582-AKMJ	1582-9542	795.00
						Rack	1582-AKR	1582-9426	735.00	1582-AKRJ	1582-9544	785.00
						Wall	1582-AKW	1582-9821	735.00	1582-AKWJ	1582-9545	785.00
	82 to 124	8.5	3.9	2.5 c + 0.4 c/V	0.5	No cabinet	1582-AK2	1582-9391	695.00	1582-AK2J	1582-9395	745.00
						Bench	1582-AKM2	1582-9392	745.00	1582-AKM2J	1582-9396	795.00
						Rack	1582-AKR2	1582-9393	735.00	1582-AKR2J	1582-9397	785.00
						Wall	1582-AKW2	1582-9394	735.00	1582-AKW2J	1582-9398	785.00

*Range is given as % of output voltage and for 57- to 63-hertz operation. For 48- to 63-hertz operation, corresponding correction ranges are 95 to 105%, 91 to 109%, and 84 to 119%.

**Time given in cycles of line frequency for 50- or 60-Hz. Correction rate of 400-Hz models is approx same, so cycles given in table must be multiplied by 7.

Type 1583 VARIAC® AUTOMATIC VOLTAGE REGULATOR

- 3-phase voltage regulation
- fast, accurate, distortionless
- large power-handling capacity
- no power-factor limitation
- tolerates 1000% transient overloads



Like the GR 1581 and 1582 single-phase regulators, the 1583 employs the servo-driven buck/boost principle, extending its economy, reliability, and high performance to the control of three-phase power without significant increase in size or cost.

The 1583 offers wide selection of voltage (and frequency), power-handling capacity, and physical mounting. Other combinations are available on special order.

The two, ganged, servo-operated Variac® autotransformers apply opposing or aiding voltages to two series-regulating step-down transformers that are connected in an open delta. Because of this configuration, the 1583 is rated in terms of line-to-line voltages and line current. Care should be taken not to confuse this with the more common use of line-to-neutral or phase voltages in rating wye-connected loads and regulators.

— See **GR Experimenter** for October 1967.

specifications

Frequency: 60-Hz models operate from 57 to 63 Hz, and can be modified by a connection change for 48 to 63 Hz; 400-Hz models operate from 350 to 450 Hz.

Power Dissipation: No load, 45 W; full load. 120 W.

No-Load Power: 45 W.

Ambient Temperature: Operating, −20°C to +52°C; storage, −54°C to +85°C.

Dimensions (width x height x depth):
Uncased, 19 x 7 x 14¾ in. (485 x 180 x 375 mm);
Bench, 19 x 7⅜ x 16 in. (485 x 190 x 410 mm);
Rack, 19 x 7 x 15 in. (485 x 180 x 385 mm);
Wall, 19½ x 8⅛ x 16 in. (495 x 210 x 410 mm).

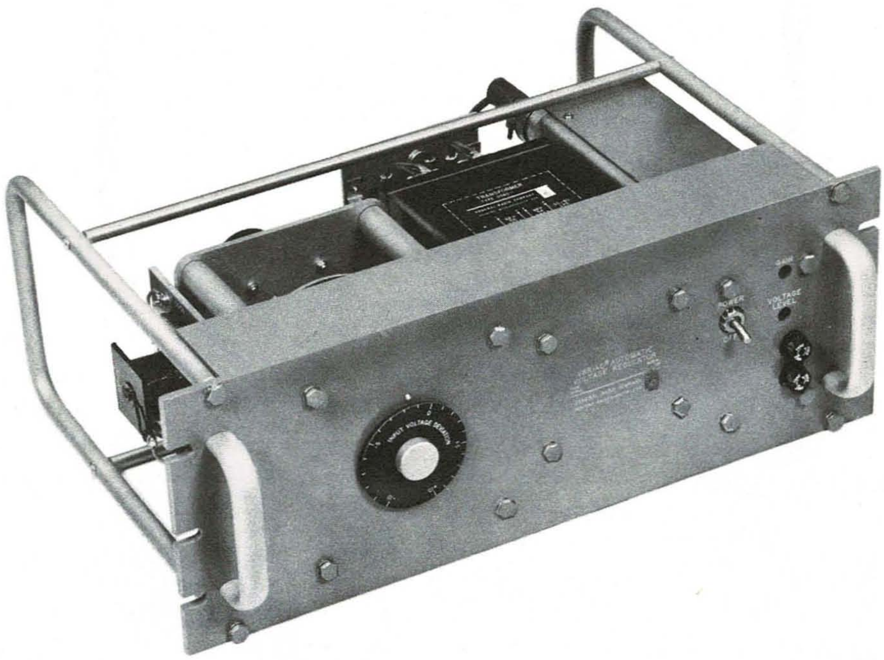
Weight:
Uncased, Net, 54 lb (24.5 kg); shipping, 104 lb (47.5 kg);
Bench, Net, 64 lb (29 kg); shipping, 114 lb (52 kg);
Rack, Net, 64 lb (29 kg); shipping, 114 lb (52 kg);
Wall, Net, 70 lb (32 kg); shipping, 120 lb (54.5 kg).

Output Voltage (line-to-line)	Correction Range * (%)	Line Current (A)	Load kVA	Correction Time in cycles (c)	Accuracy (% of output V)	Mounting or Style	Type Number	Catalog Number	Price in USA
230-volt (line-to-line), 60-Hz models									
230 V Adjustable ±10%	95 to 105	34.0	13.7	2.5 c + 3.0 c/V	0.25	Uncased	**1583-H5**	1583-9516	**$695.00**
						Bench	**1583-HM5**	1583-9517	**745.00**
						Rack	**1583-HR5**	1583-9518	**735.00**
						Wall	**1583-HW5**	1583-9521	**735.00**
	90 to 110	17.0	6.8	2.5 c + 1.5 c/V	0.25	Uncased	**1583-H**	1583-9817	**695.00**
						Bench	**1583-HM**	1583-9951	**745.00**
						Rack	**1583-HR**	1583-9961	**735.00**
						Wall	**1583-HW**	1583-9971	**735.00**
	82 to 124	8.5	3.4	2.5 c + 0.7 c/V	0.5	Uncased	**1583-H2**	1583-9770	**695.00**
						Bench	**1583-HM2**	1583-9771	**745.00**
						Rack	**1583-HR2**	1583-9772	**735.00**
						Wall	**1583-HW2**	1583-9773	**735.00**
115-volt (line-to-line), 400-Hz models									
115 V Adjustable ±10%	90 to 110	42.5	8.5	18 c + 20 c/V	0.25	Uncased	**1583-LJ**	1583-9551	**745.00**
						Bench	**1583-LMJ**	1583-9552	**795.00**
						Rack	**1583-LRJ**	1583-9554	**785.00**
						Wall	**1583-LWJ**	1583-9555	**785.00**
	82 to 124	21.2	4.2	18 c + 10 c/V	0.5	Uncased	**1583-L2J**	1583-9556	**745.00**
						Bench	**1583-LM2J**	1583-9557	**795.00**
						Rack	**1583-LR2J**	1583-9558	**785.00**
						Wall	**1583-LW2J**	1583-9559	**785.00**

* Ranges listed are for 57- to 63-Hz operation; for 48- to 63-Hz operation, corresponding correction ranges are 95 to 105%, 91 to 109%, and 84 to 119%.

Type 1571-A VARIAC® AUTOMATIC VOLTAGE REGULATOR

- militarized
- fast response, high accuracy
- distortionless regulation
- large power-handling capacity
- output voltage independent of load
- no power-factor restriction
- tolerates 1000% transient overloads



The 1571-A is a militarized version of the 1581-A described on the preceding pages. It is designed to meet the appropriate sections of military specifications MIL-E-4158B and MIL-E-16400C. These models are particularly useful where mechanical shock or vibration is encountered. Models are available for use on ac line frequencies of either 400 Hz or 60 Hz (50 to 60 Hz by a change in connection on the autotransformer), and with various output currents and correction ranges. All units are designed for relay-rack mounting.

— See **GR Experimenter** for January 1966.

specifications

Output Voltage: Adjustable over a range of ±10% from a base value of 115 V, set by a front-panel screwdriver adjustment.

Frequency: 60-Hz models operate from 57 to 63 Hz but can be modified by connection change to operate from 48 to 63 Hz; 400-Hz models operate from 350 to 450 Hz.

Response: Rms.

Distortion: None added.

Power Dissipation (approx): No load, 35 W; full load, 115 W.

Ambient Temperature: Operating, −29° to +52°C; in storage, −54° to 85°C.

Dimensions (width x height x depth): 19 x 7 x 12 in. (485 x 180 x 305 mm).

Weight: Net, 52½ lb (24.5 kg); shipping, 103 lb (47 kg).

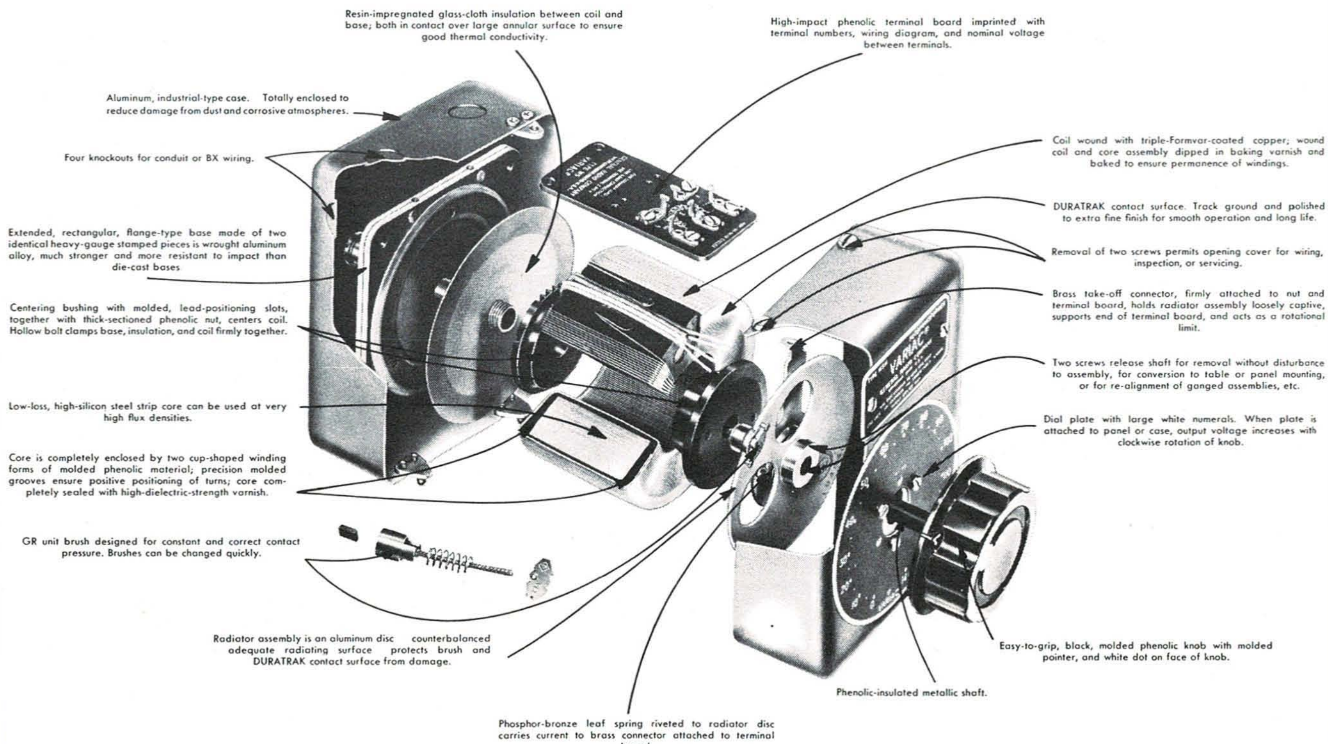
							60 Hz			400 Hz		
Output Voltage	Correction Range* %	Output Current (A)	KVA	Correction Time in cycles (c) **	Accuracy (% of output V)	Mounting	Type Number	Catalog Number	Price in USA	Type Number	Catalog Number	Price in USA
115 V Adjustable ±10%	90 to 110	50	5.8	2.5 c + 1.5 c/V	0.25	Rack	**1571-AL**	1571-9831	**$795.00**	**1571-ALJ**	1571-9551	**$795.00**
	82 to 124	25	2.9	2.5 c + 0.7 c/V	0.5	Rack	**1571-AL2**	1571-9898	**795.00**	**1571-AL2J**	1571-9556	**795.00**

*Range is given as % of output voltage and for 57- to 63-Hz operation. For 48- to 63-Hz operation, corresponding correction ranges are 95 to 105%, 91 to 109%, and 84 to 119%.

**Time given in cycles of line frequency for 50- or 60-Hz. Correction rate of 400-Hz models is approx same, so cycles given in table must be multiplied by 7.

VARIAC®

ADJUSTABLE AUTOTRANSFORMERS



Since General Radio introduced the first adjustable autotransformer 35 years ago and branded it "Variac,"* over a million of these units have seen service in virtually every industry. They control ac voltage and thus in turn anything powered by ac voltage. Light, heat, motor speed — all are controlled smoothly, dependably, by VARIAC® autotransformers.

The autotransformer has important advantages over other methods of voltage control: It does not waste power by dissipating heat; it can withstand as high as 1000 percent short-term overload; and it does not distort waveform or power factor. To these basic advantages the VARIAC adds the value of 35 years of continuous refinement by General Radio and 35 years of proved performance in industry.

Wherever ac voltage is to be adjusted, there is a use for the VARIAC autotransformer. Some typical applications are:

- Lighting control in theaters, auditoriums, photographic studios, and darkrooms.
- Control of electric heaters and ovens in laboratory, pilot plant, and production line.
- Motor-speed control.
- Control of ac voltage in test and development work.
- Overvoltage and undervoltage tests.
- Meter calibration by voltage control.

The VARIAC autotransformer consists of a single layer winding on a toroidal silicon-steel core. As the control knob is rotated, a graphitic brush traverses the winding, tapping a portion of the total voltage across the winding. The brush is in continuous contact with the winding, and the voltage between turns is always less than 1 volt, even in the largest model; in the smallest model it is only about 0.3 volt. The brush always spans more than one turn, and the change in voltage as the brush moves is practically continuous. The brush is so designed that excessive heating cannot occur in the turns that it spans.

Duratrak®† All VARIAC autotransformers feature the DURATRAK contact surface, a uniform silver-alloy coating to prevent injurious high-temperature oxidation and resultant brush-track deterioration. The track shows no significant wear after 1,000,000 cycles of brush operation from zero to maximum and return. Because of DURATRAK contact surface, the life of a VARIAC autotransformer is essentially the same as that of a fixed-ratio power transformer.

FEATURES:

- **Regulation:** Output voltage is substantially independent of load.
- **Smooth Control:** Can be set very closely to any voltage in its range. Output voltage is continuously adjustable from zero to maximum.
- **Efficiency:** Low losses under all load conditions.
- **Long Life:** Life is essentially the same as that of a fixed-ratio transformer.
- **Linear Output Voltage:** Output voltage varies linearly with dial rotation.
- **Overvoltage:** Maximum output voltage is greater than input voltage.
- **Low Maintenance:** Occasional cleaning of contact surface ensures long, trouble-free operation.

* "Variac" is the registered trade name of the General Radio brand of adjustable autotransformers and associated control equipment in which these adjustable autotransformers are used.
† "Duratrak" is the registered trade name for the contact surface applied to the brush tracks of Variac autotransformers.

general specifications and terminology

Frequency: W series, 50 to 60 Hz; M series, 350 to 1200 Hz, except as otherwise noted. Most W models can also be operated at rated current and voltage at line frequencies of 50 to 400 Hz. Models designed for 240-volt, 50- to 60-Hz service can be used on a 25-Hz supply at full current rating and one-half their voltage and kVA ratings.

Protective Devices: MT and MT3 types have built-in circuit breakers with manual resets. Types W5L, W20H, W30, W30H, W50, and W50H have built-in fuse-type protectors. However, these should not be considered a substitute for normal fusing practices.

Overload Ratings: Rated currents can be safely exceeded with short-term overolads (see curves). The shaded area shows the limits for models with built-in fuse-type protective devices.

Temperature Effects: Ratings are based on a temperature rise of not more than 50°C above ambient temperature. For operation in ambient temperatures above 50°C, see derating chart.

Dials: Dial plates are reversible: 0 to 120 volts on one side, 0 to 140 volts on the other. Dials on H models are marked 0 to 240 and 0 to 280. Dials for ganged assemblies are marked 0 to 10. All models have 320-degree rotation and include knob and dial unless otherwise specified.

Terminals: The following types have combination soldering and screw-type terminals: W2, W5, W5L, W8, W8L, W10, W10H, W30H, and W50H. The W30 and W50 models use clamp-type terminals to accommodate the larger conductors required. MT3 types have NEMA-standard three-wire connectors.

Overvoltage Connection is that connection which gives an output voltage range of zero to 117 percent of input voltage.

Line-Voltage Connection is that connection which gives an output voltage range of zero to input (line) voltage.

Rated Current is the current that can be drawn at any output voltage.

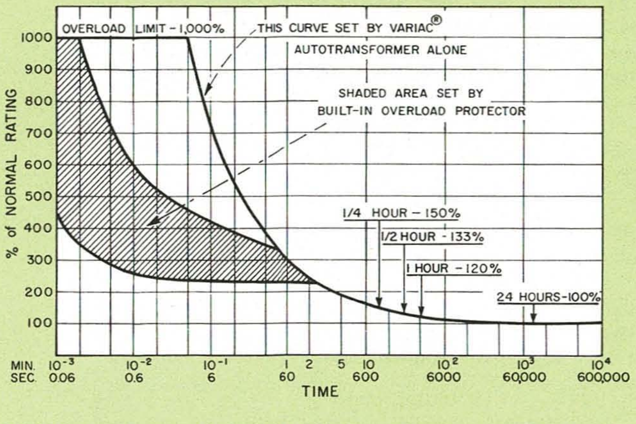
Maximum Current is the current that can be drawn at maximum output voltage when the line-voltage connection is used.

Output Voltage Range is the range of voltage available at the output terminals when the stated input voltage is applied to the input terminals.

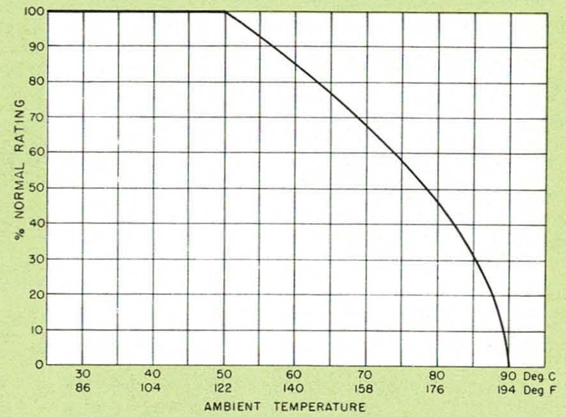
KVA Load Rating is the maximum current multiplied by the nominal input line voltage. At any lower voltage setting, a Variac autotransformer can handle a constant-impedance load that draws a current no greater than maximum current with rated input voltage.

Driving Torque is the torque required to turn the shaft.

For a complete description of principles, circuits, and uses, refer to **The Handbook of Voltage Control,** available free on request from General Radio Company.

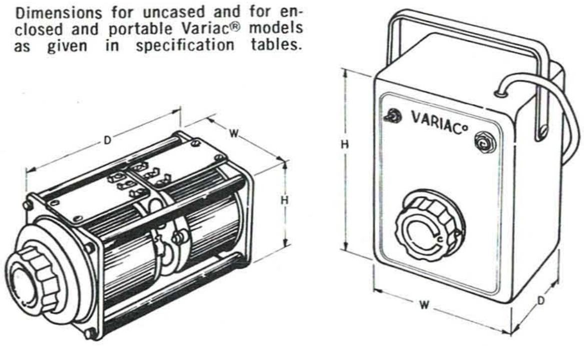


Short-time overload limits. For high initial surge current (as with motors, incandescent lamps, etc.) and other short-time overloads, the rated current may be exceeded as shown, when line-voltage connection is used.



For ambient temperatures above 50°C, ratings should be decreased according to this curve.

Dimensions for uncased and for enclosed and portable Variac® models as given in specification tables.



General Radio Variac® adjustable autotransformers are available in virtually unlimited variety to answer the electrical and mechanical needs of almost any application with combinations of line voltage and frequency, output current or power, 1- or 3-phase, method of mounting, metering, and manual or motor drive. The many models for choosing are grouped on the following pages as follows:

Manual operation
For mounting on panel, wall, etc.
50-60 Hz, single-phase, 120-V input — page 283
240-V input — page 284
50-60 Hz three-phase, 208-, 240-, 480-, 560-V — page 284
350-1200 Hz, 1- and 3-phase — page 286
Portable and metered/portable models — page 286
Motor-driven models — page 287

Once the correct page has been determined from the above considerations, the specific model can be selected from the table on the basis of current or power output required, enclosure, and physical size.

HIGH-FREQUENCY MODELS — 350 to 1200 Hz

The M-series Variac® autotransformers are mechanically similar to the 60-Hz model, but are smaller and lighter, and manufactured to conform to military specifications for shock, vibration, salt-spray, tropicalization, and wide-temperature-range lubrication. The regulation obtained from the M-series models is considerably better at 400 Hz than that of 60-Hz models operated at 400 Hz. The smallest, 2-ampere model, M2, has 400 turns giving adequate resolution for many computing and controlling applications. Nonstandard versions available on special order.

PORTABLE AND METERED MODELS

A wide selection of single-phase units is offered as fully-enclosed portable models with carrying handle, attached power cord and output receptacle, switch, and, in some models, meters for convenient monitoring of output volts, amperes, or watts. These handy, compact units have many uses in the laboratory and on the test bench, among them over- and undervoltage tests, and trouble shooting. The meters have expanded scales for easy reading and are accurate to ±3% of full scale, except for 5% ammeters in the W20-size models.

MOTOR-DRIVEN MODELS

For remote-adjustment applications, all W- and M-series Variac® autotransformers can be supplied with motor drives. The motor-driven assemblies include a totally enclosed, two-phase, gear-reduction motor of the servo type, limit switches, a phase-shift capacitor, and a Variac autotransformer equipped with ball bearings.

Limit switches are included on all models and are adjusted to limit the traverse to approximately 320°.

The W-series, motor-driven models are available as either open or totally enclosed assemblies; the M-series models are available in open mounting only. Non-standard, motor-driven models are available on special order.

MOTOR SPECIFICATIONS

Supply: 120 V, 60 Hz.
Impedance: 2500 Ω.
Inductive Resistance: 2200 Ω.
Ac Resistance: 1300 Ω.
(Impedance, Inductive Resistance, Ac Resistance: for each winding, at 60 Hz.)
Dc Resistance: 575 Ω.
Traverse: 320°.
Traverse Times Available: 2, 4, 8, 16, 32, 64, and 128 seconds at 60 Hz. For 50-Hz supply, multiply time by 6/5.

W50-P1 PARALLELLING CHOKE

Many of the Variac® autotransformers listed on the following pages are indicated to require one or more Type W50-P1 Choke. This unit is used when two or more autotransformer outputs are to be connected in parallel; it prevents the flow of potentially damaging currents from one unit to the other. Instructions for proper interconnecting are included with each unit.

Catalog Number	Description	Price in USA
3150-5016	**W50-P1 Choke**	**$16.00**

REPLACEMENT BRUSHES

Occasionally, as a result of accident or excessive wear or current, it may be necessary to replace the autotransformer's carbon brush or brushes. They may be ordered from the table below.

Catalog Number	Description	Price in USA
3200-5901	**VB-1 Brush,** for M2, W2, W5H	**$1.40**
3200-5900	**VB-2 Brush,** for M5, W5, W5L	**1.25**
3200-5923	**VB-3 Brush,** for W8, W8L	**2.20**
3200-5910	**VBT-10 Brush,** for M10, W10	**2.10**
3200-5911	**VBT-11 Brush,** for W10H	**2.00**
3200-5908	**VBT-8 Brush Set,** for M20, W20	**3.95**
3200-5912	**VBT-12 Brush Set,** for W20H	**3.70**
3200-5913	**VBT-13 Brush Set,** for W30	**6.30**
3200-5914	**VBT-14 Brush Set,** for W30H	**5.35**
3200-5906	**VBT-6 Brush Set,** for W50	**13.00**
3200-5907	**VBT-7 Brush Set,** for W50H	**9.80**

BALL BEARINGS

W-series and M-series models can be supplied with ball bearings, which provide more precise alignment with slightly lower and more nearly constant torque.

When ordering Variac® autotransformers equipped with ball bearings, add the suffix "BB" to the type number, and add the price shown in the tables.

Ball bearings are standard equipment on motor-driven units and on 4- and 6-gang, W30 and W50 models, and are included in the price.

SPECIAL VARIAC® AUTOTRANSFORMERS

Special models can be supplied to meet specific requirements, such as additional winding taps, fungicide treatment, special shaft lengths, or with voltage outputs or ranges differing from those of standard models. They can also be supplied on special order less knob, dial, etc., at lower net prices and with slightly extended delivery time.

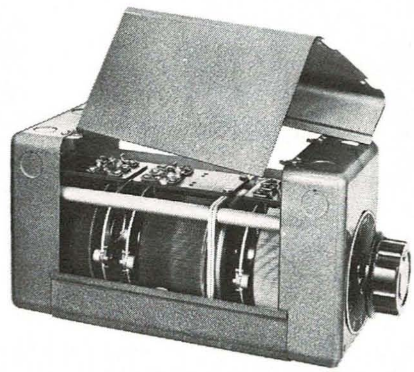
The General Radio Company encourages inquiries on special models.

VARIAC®
ADJUSTABLE AUTOTRANSFORMERS

W5
(Open)

W5M
(Enclosed)

W5LG3M
(3-Gang)



Single-phase, 120-volt input, 50-60 Hz

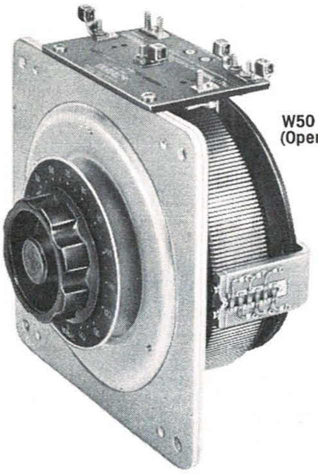
Output: Rated Current Amperes	Output: Max Current Amperes	Output: Output Voltage	Type	Description: Mounting	Description: Notes	Description: W50-PI Chokes Req'd for parallel operation	Catalog Number	Price in USA	Add for Ball Bearings	Net Weight lb	Shipping Wt lb	Outline Dimensions (inches): W	Outline Dimensions (inches): H	Outline Dimensions (inches): D
2.0	2.6	0-140	**W2M**	Encl			3010-5111	**$ 27.25**	**$ 8.00**	4	9	4 1/8	5 9/16	4 3/8†
2.4	3.1	0-140	**W2**	Open			3010-5110	**17.25**	**8.00**	3	4	3 1/4	3 11/16	3 15/16†
5.0	6.5	0-140	**W5M**	Encl			3030-5111	**31.00**	**8.00**	7	13	4 7/8	6 9/16	4 3/8*†
6.0	7.8	0-140	**W5**	Open			3030-5110	**21.00**	**8.00**	6	8	4 1/2	4 15/16	3 15/16*†
7.1	9.2	0-120	**W5LM**	Encl	60 Hz only		3050-5111	**31.00**	**8.00**	7	13	4 7/8	6 9/16	4 3/8
8.5	11.0	0-120	**W5L**	Open	60 Hz only		3050-5110	**21.00**	**8.00**	7	8	4 1/2	4 15/16	4 11/16*
8.5	11.0	0-140	**W8**	Open			3038-5110	**23.00**	**8.00**	8	9	4 1/2	4 15/16	4 7/16
10.0	13.0	0-120	**W8L**	Open	60 Hz only		3058-5110	**23.00**	**8.00**	8	12	4 1/2	4 15/16	4 7/16
10.0	13.0	0-140	**W10**	Open			3060-5110	**38.00**	**9.00**	12	13	5 3/4	6 5/16	3 15/16*†
10.0	13.0	0-140	**W10M**	Encl			3060-5111	**55.00**	**9.00**	15	17	6 3/4	9 1/2	5 1/4*†
20.0	26.0	0-140	**W20**	Open			3090-5110	**56.00**	**9.00**	21	24	7 1/2	8 1/16	4 5/8*†
20.0	26.0	0-140	**W20M**	Encl			3090-5111	**73.00**	**9.00**	24	29	8 5/8	11 15/16	5 3/8†
20.0	26.0	0-120	**W8LG2**	Open	60 Hz only	1	3058-5120	**53.00**	**13.00**	17	19	4 1/2	4 15/16	9 5/16
28.0	32.0	0-140	**W30M**	Encl			3120-5111	**118.00**	**12.00**	37	47	11	14 3/4	5 3/4
30.0	36.0	0-140	**W30**	Open			3120-5110	**96.00**	**12.00**	30	38	10	11 13/16	4 1/8
40.0	45.0	0-140	**W50M**	Encl			3150-5111	**181.00**	**12.00**	57	74	13 7/16	16 7/8	7 1/4*†
50.0	50.0	0-140	**W50**	Open			3150-5110	**148.00**	**12.00**	50	57	12 1/2	13 3/4	6 1/4*†
56.0	64.0	0-140	**W30G2M**	Encl		1	3120-5121	**256.00**	**18.00**	67	90	11 3/8	14 15/16	10 1/16
60.0	72.0	0-140	**W30G2**	Open		1	3120-5120	**212.00**	**18.00**	61	80	10	11 13/16	9 7/8
60.0	78.0	0-140	**W20G3M**	Encl		3	3090-5131	**216.00**	**18.00**	71	82	9	12 1/16	13 15/16
60.0	78.0	0-140	**W20G3**	Open		3	3090-5130	**182.00**	**18.00**	65	71	7 1/2	8 1/16	13 3/4
80.0	90.0	0-140	**W50G2M**	Encl		1	3150-5121	**373.00**	**18.00**	123	160	13 13/16	17 1/16	14 11/16
84.0	96.0	0-140	**W30G3M**	Encl		3	3120-5131	**356.00**	**22.00**	99	125	11 3/8	14 15/16	14 11/16
90.0	108.0	0-140	**W30G3**	Open		3	3120-5130	**312.00**	**22.00**	93	113	12 1/2	13 3/4	20 7/8
100.0	100.0	0-140	**W50G2**	Open		1	3150-5120	**318.00**	**18.00**	112	147	12 1/2	13 3/4	14 1/2
120.0	135.0	0-140	**W50G3M**	Encl		3	3150-5131	**528.00**	**22.00**	179	221	13 13/16	17 1/16	21 1/16
150.0	150.0	0-140	**W50G3**	Open		3	3150-5130	**473.00**	**22.00**	163	206	12 1/2	13 3/4	20 7/8
160.0	180.0	0-140	**W50G4BBM**	Encl		4	3150-5241	**740.00**	included	240	313	13 13/16	17 1/16	27 7/16
200.0	200.0	0-140	**W50G4BB**	Open		4	3150-5240	**663.00**	included	215	288	12 1/2	13 3/4	27 1/4
240.0	270.0	0-140	**W50G6BBM**	Encl		6	3150-5261	**1095.00**	included	355	430	13 13/16	17 1/16	40 3/16
300.0	300.0	0-140	**W50G6BB**	Open		6	3150-5260	**996.00**	included	325	400	12 1/2	13 3/4	40

* Listed under Re-examination Service of the Underwriters' Laboratory.

† Approved by the Canadian Standards Association.

VARIAC®

ADJUSTABLE AUTOTRANSFORMERS



W50 (Open)

W20M (Enclosed)

W8G2 (2-Gang)

Single-phase, 240-volt input, 50-60 Hz

Output: Rated Current Amperes	Output: Max Current Amperes	Output: Output Voltage	Type	Description: Mounting	Description: Connection	Description: W50-PI Chokes Req'd for parallel operation	Catalog Number	Price in USA	Add for Ball Bearings	Net Weight lb	Shipping Wt lb	Outline Dimensions (inches): W	H	D
2.0	2.6	0-280	**W5H**	Open			3040-5110	**$ 24.00**	**$ 8.00**	6	8	4 1/2	4 15/16	3 15/16†
2.0	2.6	0-280	**W5HM**	Encl			3040-5111	**34.00**	**8.00**	7	13	4 7/8	6 9/16	4 3/8†
4.0	5.2	0-280	**W10H**	Open			3070-5110	**39.00**	**9.00**	11	12	5 3/4	6 5/16	4 11/16†
4.0	5.2	0-280	**W10HM**	Encl			3070-5111	**56.00**	**9.00**	14	17	6 3/4	9 1/2	5 1/4†
8.0	10.4	0-280	**W20H**	Open			3100-5110	**58.00**	**9.00**	20	23	7 1/2	8 1/16	4 5/8*†
8.0	10.4	0-280	**W20HM**	Encl			3100-5111	**75.00**	**9.00**	23	28	8 5/8	11 15/16	5 3/8*†
12.0	15.6	0-280	**W30H**	Open			3130-5110	**96.00**	**12.00**	29	36	10	11 13/16	4 1/8
12.0	15.6	0-280	**W30HM**	Encl			3130-5111	**118.00**	**12.00**	36	45	11	14 3/4	5 3/4
20.0	31.0	0-280	**W50HM**	Encl			3160-5111	**181.00**	**12.00**	60	76	13 7/16	16 7/8	7 1/4*†
25.0	32.5	0-280	**W50H**	Open			3160-5110	**148.00**	**12.00**	53	60	12 1/2	13 3/4	6 1/4*†
40.0	62.0	0-280	**W50HG2M**	Encl	Parallel	1	3160-5121	**373.00**	**18.00**	126	165	13 13/16	17 1/16	14 11/16
50.0	65.0	0-280	**W50HG2**	Open	Parallel	1	3160-5120	**318.00**	**18.00**	116	153	12 1/2	13 3/4	14 1/2
60.0	93.0	0-280	**W50HG3M**	Encl	Parallel	3	3160-5131	**528.00**	**22.00**	183	230	13 13/16	17 1/16	21 1/16
75.0	97.5	0-280	**W50HG3**	Open	Parallel	3	3160-5130	**473.00**	**22.00**	167	214	12 1/2	13 3/4	20 7/8
80.0	124.0	0-280	**W50HG4BBM**	Encl	Parallel	4	3160-5241	**740.00**	included	255	328	13 13/16	17 1/16	27 7/16
100.0	130.0	0-280	**W50HG4BB**	Open	Parallel	4	3160-5240	**663.00**	included	230	300	12 1/2	13 3/4	27 1/4
120.0	186.0	0-280	**W50HG6BBM**	Encl	Parallel	6	3160-5261	**1095.00**	included	385	458	13 13/16	17 1/16	40 3/16
150.0	195.0	0-280	**W50HG6BB**	Open	Parallel	6	3160-5260	**996.00**	included	355	428	12 1/2	13 3/4	40

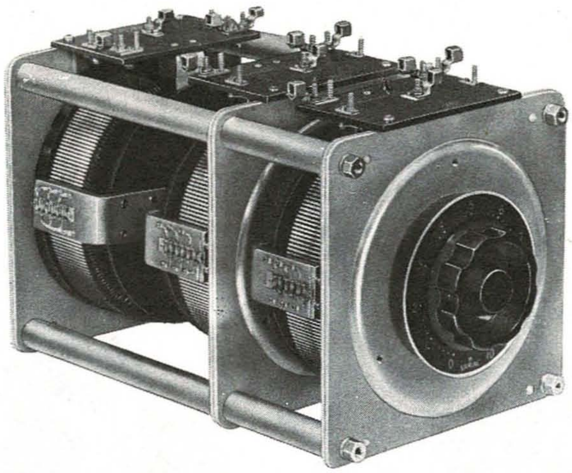
* Listed under Re-examination Service of Underwriters' Laboratory. † Approved by Canadian Standards Association.

Three-phase, 208-volt input, 60-Hz only

Output: Rated Current Amperes	Output: Max Current Amperes	Output: Output Voltage	Type	Description: Mounting	Description: Connection	Description: W50-PI Chokes Req'd for parallel operation	Catalog Number	Price in USA	Add for Ball Bearings	Net Weight lb	Shipping Wt lb	Outline Dimensions (inches): W	H	D
7.1	9.2	0-208	**W5LG3M**	Encl	Wye		3050-5131	**$ 92.00**	**$ 15.00**	22	32	5 1/8	6 3/4	12 1/4
8.5	11.0	0-208	**W5LG3**	Open	Wye		3050-5130	**72.00**	**15.00**	20	23	4 1/2	4 15/16	12 1/8
10.0	13.0	0-208	**W8LG3**	Open	Wye		3058-5130	**77.00**	**15.00**	25	27	4 1/2	4 15/16	13 5/16

VARIAC®

ADJUSTABLE AUTOTRANSFORMERS



W50G3

Three-phase, 208/240-volt input, 50-60 Hz

Except for open-delta connection, overvoltage not recommended. For 208-volt input, overvoltage may be used.

Output: Rated Current Amperes	Output: Max Current Amperes	Output: Output Voltage	Type	Description: Mounting	Description: Connection	Description: W50-PI Chokes Req'd for parallel operation	Catalog Number	Price in USA	Add for Ball Bearings	Net Weight lb	Shipping Wt lb	Outline Dimensions (inches): W	Outline Dimensions (inches): H	Outline Dimensions (inches): D
2.0	2.6	0-280	**W5HG2**	Open	Open Delta		3040-5120	**$ 56.00**	**$ 13.00**	13	15	4 1/2	4 15/16	8
2.0	2.6	0-280	**W5HG2M**	Encl	Open Delta		3040-5121	**76.00**	**13.00**	15	23	5 1/8	6 3/4	8 1/8
2.0	2.6	0-240	**W2G3M**	Encl	Wye		3010-5131	**80.75**	**15.00**	12	21	4 3/8	5 3/4	12 1/8
2.4	3.1	0-240	**W2G3**	Open	Wye		3010-5130	**60.75**	**15.00**	11	13	3 1/4	3 11/16	12
4.0	5.2	0-280	**W10HG2**	Open	Open Delta		3070-5120	**86.00**	**15.00**	24	27	5 3/4	6 5/16	9 5/16
4.0	5.2	0-280	**W10HG2M**	Encl	Open Delta		3070-5121	**119.00**	**15.00**	29	33	7 1/8	9 11/16	9 1/2
5.0	6.5	0-240	**W5G3M**	Encl	Wye		3030-5131	**92.00**	**15.00**	22	32	5 1/8	6 3/4	12 1/4
6.0	7.8	0-240	**W5G3**	Open	Wye		3030-5130	**72.00**	**15.00**	20	22	4 1/2	4 15/16	12 1/8
8.0	10.4	0-280	**W20HG2**	Open	Open Delta		3100-5120	**127.00**	**15.00**	41	46	7 1/2	8 1/16	9 3/16
8.0	10.4	0-280	**W20HG2M**	Encl	Open Delta		3100-5121	**160.00**	**15.00**	45	54	9	12 1/16	9 3/8
8.5	11.0	0-240	**W8G3**	Open	Wye		3038-5130	**77.00**	**15.00**	25	27	4 1/2	4 15/16	13 15/16
10.0	13.0	0-240	**W10G3**	Open	Wye		3060-5130	**123.00**	**18.00**	37	40	5 3/4	6 5/16	14
10.0	13.0	0-240	**W10G3M**	Encl	Wye		3060-5131	**156.00**	**18.00**	43	47	7 1/8	9 11/16	14 3/16
12.0	15.6	0-280	**W30HG2**	Open	Open Delta		3130-5120	**212.00**	**18.00**	59	76	10	11 13/16	9 7/8
12.0	15.6	0-280	**W30HG2M**	Encl	Open Delta		3130-5121	**256.00**	**18.00**	64	87	11 3/8	14 15/16	10 1/16
20.0	26.0	0-240	**W20G3**	Open	Wye		3090-5130	**182.00**	**18.00**	65	71	7 1/2	8 1/16	13 3/4
20.0	26.0	0-240	**W20G3M**	Encl	Wye		3090-5131	**216.00**	**18.00**	71	82	9	12 1/16	13 15/16
20.0	31.0	0-280	**W50HG2M**	Encl	Open Delta		3160-5121	**373.00**	**18.00**	126	165	13 13/16	17 1/16	14 11/16
25.0	32.5	0-280	**W50HG2**	Open	Open Delta		3160-5120	**318.00**	**18.00**	116	153	12 1/2	13 3/4	14 1/2
28.0	32.0	0-240	**W30G3M**	Encl	Wye		3120-5131	**356.00**	**22.00**	99	125	11 3/8	14 15/16	14 11/16
30.0	36.0	0-240	**W30G3**	Open	Wye		3120-5130	**312.00**	**22.00**	93	113	12 1/2	13 3/4	20 7/8
40.0	45.0	0-240	**W50G3M**	Encl	Wye		3150-5131	**528.00**	**22.00**	179	221	13 13/16	17 1/16	21 1/16
50.0	50.0	0-240	**W50G3**	Open	Wye		3150-5130	**473.00**	**22.00**	163	206	12 1/2	13 3/4	20 7/8
40.0	62.0	0-280	**W50HG4BBM**	Encl	Open Delta	2	3160-5241	**740.00**	included	255	328	13 13/16	17 1/16	27 7/16
50.0	65.0	0-280	**W50HG4BB**	Open	Open Delta	2	3160-5240	**663.00**	included	230	300	12 1/2	13 3/4	27 1/4
80.0	90.0	0-240	**W50G6BBM**	Encl	Wye	3	3150-5261	**1095.00**	included	355	430	13 13/16	17 1/16	40 3/16
100.0	100.0	0-240	**W50G6BB**	Open	Wye	3	3150-5260	**996.00**	included	325	400	12 1/2	13 3/4	40
*150.0	150.0	0-240	**W50G9BB**	Open	Wye (chokes included)		3150-5876	on req.	included	600	720	39	35	17
*200.0	200.0	0-240	**W50G12BB**	Open	Wye (chokes included)		3150-5886	on req.	included	760	880	39	41	17

Three-phase, 480-volt input, 50-60 Hz

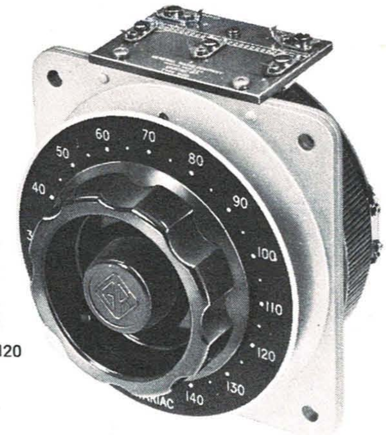
(Overvoltage connection not recommended)

2.0	2.6	0-480	**W5HG3**	Open	Wye		3040-5130	**$ 81.00**	**$ 15.00**	20	22	4 1/2	4 15/16	12 1/8
2.0	2.6	0-480	**W5HG3M**	Encl	Wye		3040-5131	**101.00**	**15.00**	22	31	5 1/8	6 3/4	12 1/4
4.0	5.2	0-480	**W10HG3**	Open	Wye		3070-5130	**126.00**	**18.00**	36	39	5 3/4	6 5/16	14
4.0	5.2	0-480	**W10HG3M**	Encl	Wye		3070-5131	**154.00**	**18.00**	42	46	7 1/8	9 11/16	14 3/16
8.0	10.4	0-480	**W20HG3**	Open	Wye		3100-5130	**188.00**	**18.00**	61	68	7 1/2	8 1/16	13 3/4
8.0	10.4	0-480	**W20HG3M**	Encl	Wye		3100-5131	**222.00**	**18.00**	67	79	9	12 1/16	13 15/16
12.0	15.6	0-480	**W30HG3**	Open	Wye		3130-5130	**312.00**	**22.00**	90	107	12 1/2	13 3/4	20 7/8
12.0	15.6	0-480	**W30HG3M**	Encl	Wye		3130-5131	**356.00**	**22.00**	97	120	11 3/8	14 15/16	14 11/16
20.0	31.0	0-480	**W50HG3M**	Encl	Wye		3160-5131	**528.00**	**22.00**	183	230	13 13/16	17 1/16	21 1/16
25.0	32.5	0-480	**W50HG3**	Open	Wye		3160-5130	**473.00**	**22.00**	167	214	12 1/2	13 3/4	20 7/8
40.0	62.0	0-480	**W50HG6BBM**	Encl	Wye	3	3160-5261	**1095.00**	included	385	458	13 13/16	17 1/16	40 3/16
50.0	65.0	0-480	**W50HG6BB**	Open	Wye	3	3160-5260	**996.00**	included	355	428	12 1/2	13 3/4	40
* 75.0			**W50HG9BB**	Open	Wye (chokes included)		3160-5876	on req.	included	610	730	39	35	17
*100.0			**W50HG12BB**	Open	Wye (chokes included)		3160-5886	on req.	included	806	926	39	41	17

Three-phase, 560-volt input, 50-60 Hz available on request

* Motor drive only.

VARIAC® ADJUSTABLE AUTOTRANSFORMERS



M20

W8MT3A

W8MT3VM

M-Series for 350- to 1200-Hz Service (can be used at 50-to-60 Hz with 50-volt input)

Output: Rated Current Amperes	Output: Max Current Amperes	Output: Output Voltage	Description: Type	Description: Mounting	Description: Connection	Catalog Number	Price in USA	Add for Ball Bearings	Net Weight lb	Shipping Wt lb	Outline Dimensions (inches): W	H	D
Single-Phase, 120-volt, 400-Hz													
2.4	3.1	0-140	**M2**	Open		3410-5110	**$ 20.00**	**$ 8.00**	2	3	3 1/4	3 11/16	2 11/16†
6.0	7.8	0-140	**M5**	Open		3430-5110	**24.00**	**8.00**	3	4	4 1/2	4 15/16	2 11/16†
10.0	13.0	0-140	**M10**	Open		3460-5110	**43.00**	**9.00**	6	8	5 3/4	6 5/16	3 7/16†
20.0	26.0	0-140	**M20**	Open		3490-5110	**64.00**	**9.00**	13	15	7 1/2	8 1/16	3 5/8†
Three-phase, 120-volt, 400-Hz													
1.39	1.8	0-140	**M2G2**	Open	Open Delta	3410-5120	**$ 48.00**	**$ 13.00**	4	5	3 1/4	3 11/16	5 7/16
3.47	4.5	0-140	**M5G2**	Open	Open Delta	3430-5120	**56.00**	**13.00**	7	8	4 1/2	4 15/16	5 1/2
5.77	7.5	0-140	**M10G2**	Open	Open Delta	3460-5120	**94.00**	**15.00**	12	16	5 3/4	6 5/16	6 13/16
11.6	15.0	0-140	**M20G2**	Open	Open Delta	3490-5120	**136.00**	**15.00**	26	30	7	8 1/16	7 3/16
Three-phase, 120/208/240-volt, 400-Hz													
2.4	3.1	0-Line	**M2G3**	Open	Wye	3410-5130	**$ 69.00**	**$ 15.00**	5	7	3 1/2	3 11/16	8 1/4
6.0	7.8	0-Line	**M5G3**	Open	Wye	3430-5130	**81.00**	**15.00**	10	12	4 1/2	4 15/16	8 3/8
10.0	13.0	0-Line	**M10G3**	Open	Wye	3460-5130	**138.00**	**18.00**	19	23	5 3/4	6 15/16	10 1/4
20.0	26.0	0-Line	**M20G3**	Open	Wye	3490-5130	**201.00**	**18.00**	38	43	7 1/2	8 1/16	10 3/4

17% overvoltage connection is permitted on 120/208, three-phase lines.

Portable and Metered/Portable

Rated Current Amperes	Max Current Amperes	Output Voltage	Type	Meter Ranges (full scale): Amperes	Watts	Volts	2- or 3-wire cord and receptacle	Catalog Number	Price in USA	Add for Ball Bearings	Net Weight lb	Shipping Wt lb	W	H	D
Single-phase, 120-volt input, 50-60 Hz															
5.0	—	0-140	**W5MT**	—	—	—	2	3030-5118	**$ 39.00**	—	8	15	4 7/8	6 9/16	4 3/8*†
5.0	—	0-140	**W5MT3**	—	—	—	3	3030-5119	**39.00**	—	8	15	4 7/8	6 9/16	4 3/8*†
5.0	—	0-140	**W5MT3VM**	—	—	150	3	3030-5015	**71.00**	—	8	19	4 7/8	6 9/16	4 3/8
5.0	—	0-140	**W5MT3A**	1/5	—	150	3	3030-5012	**115.00**	—	11	19	6 3/4	9 1/2	5 1/4
5.0	—	0-140	**W5MT3W**	—	150/750	150	3	3030-5013	**142.00**	—	12	19	6 3/4	9 1/2	5 1/4
5.0	—	0-140	**W5MT3AW**	1/5	150/750	150	3	3030-5014	**181.00**	—	12	21	11 15/16	8 5/8	5 3/8
7.1	—	0-120	**W5LMT3**[1]	—	—	—	3	3050-5119	**39.00**	—	8	18	4 7/8	6 9/16	4 3/8
10.0	—	0-140	**W8MT3**	—	—	—	3	3038-5119	**44.00**	—	10	16	5 3/8	7	6 1/8
10.0	—	0-140	**W8MT3VM**	—	—	150	3	3038-5015	**76.00**	—	10	16	5 3/8	7	6 1/8
10.0	—	0-140	**W10MT**	—	—	—	2	3060-5118	**68.00**	—	16	24	6 3/4	9 1/2	5 1/4†
10.0	—	0-140	**W10MT3**	—	—	—	3	3060-5119	**68.00**	—	16	24	6 3/4	9 1/2	5 1/4†
10.0	—	0-140	**W10MT3A**	2/10	—	150	3	3060-5012	**136.00**	—	18	30	8 5/8	11 15/16	5 3/8
10.0	—	0-140	**W10MT3W**	—	300/1500	150	3	3060-5013	**169.00**	—	18	30	8 5/8	11 15/16	5 3/8
18.0	—	0-140	**W20MT3A**	20	—	150	3	3090-5012	**158.00**	—	27	34	8 5/8	11 15/16	5 3/8
18.0	—	0-140	**W20MT3**	—	—	—	3	3090-5119	**108.00**	—	20	23	8 5/8	11 15/16	5 3/8†
Single-phase, 240-volt input, 50-60 Hz															
2.0	—	0-280	**W5HMT**	—	—	—	2	3040-5118	**$ 41.00**	—	8	15	4 7/8	6 9/16	4 3/8†
4.0	—	0-280	**W10HMT**	—	—	—	2	3070-5118	**69.00**	—	15	24	6 3/4	9 1/2	5 1/4
4.0	—	0-280	**W10HMT3**	—	—	—	3	3070-5119	**69.00**	—	15	24	6 3/4	9 1/2	5 1/4
8.0	—	0-280	**W20HMT3**	—	—	—	3	3100-5119	**110.00**	—	27	35	8 5/8	11 15/16	5 3/8†
8.0	—	0-280	**W20HMT3A**	10	—	300	3	3100-5012	**160.00**	—	25	31	8 5/8	11 15/16	5 3/8

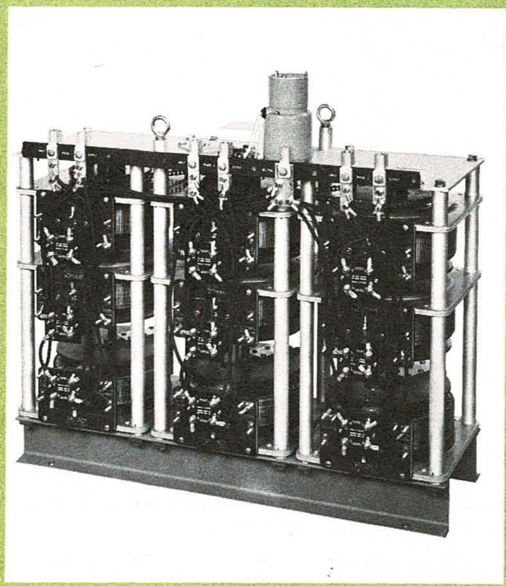
[1] 60 Hz only

Types MT and MT3 have overvoltage connections and corresponding dial scales, but can be supplied on special order with line-voltage connections and dial scales.

* Listed under Re-examination Service of Underwriters' Laboratory. † Approved by Canadian Standards Association.

VARIAC® ADJUSTABLE AUTOTRANSFORMERS

PRICE LIST FOR MOTOR-DRIVEN VARIAC® AUTOTRANSFORMERS[1]



All motor traverse times shown are for 60-Hz operation. With 50-Hz operation, times will be increased approx 20%.

We encourage inquiries on special models.

SYMBOLS FOR MOTOR-DRIVEN ATTACHMENTS

Motor Drive Only	D
Capacitor	C
Limit Switches	K
Case	M

EXAMPLE:

W5HG3D8CKM

W5H, three-gang, motor drive, 8-second sweep, capacitor, limit switches, and case. Price: $199.00 plus $42.00 for case.
Total $241.00

Dimensions: Width and height are same as for component Variac. Depth is approx 6 inches greater than that of equivalent manually operated model.

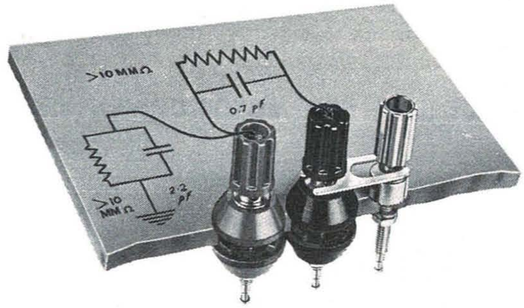
Traverse times are nominal for 60-Hz supply. Actual speeds may vary ±15% from these values; with 50-Hz operation, times increase about 20%. Specify speed on order (e.g., D4, D32, etc). so = Available on special order. yes = Available from stock. . . . = Not available.

Ball bearings included in price shown

Seconds for 320° Traverse	2	4	8	16	32	64	128	Price in USA	Add for enclosure
M2	yes	yes	yes	yes	yes	yes	. . .	$130.00	. . .
M2G2	yes	yes	yes	yes	yes	yes	. . .	164.00	. . .
M2G3	. . .	yes	yes	yes	yes	yes	. . .	187.00	. . .
M5	yes	yes	yes	yes	yes	yes	. . .	134.00	. . .
M5G2	yes	yes	yes	yes	yes	yes	. . .	172.00	. . .
M5G3	. . .	yes	yes	yes	yes	yes	. . .	199.00	. . .
M10	yes	yes	yes	yes	yes	yes	yes	177.00	. . .
M10G2	so	yes	yes	yes	yes	yes	yes	234.00	. . .
M10G3	so	so	yes	yes	yes	yes	yes	281.00	. . .
M20	. . .	yes	yes	yes	yes	yes	yes	203.00	. . .
M20G2	so	so	yes	yes	yes	yes	yes	284.00	. . .
M20G3	so	so	yes	yes	yes	yes	yes	350.00	. . .
W2	yes	yes	yes	yes	yes	yes	. . .	127.29	$ 32.00
W2G2	yes	yes	yes	yes	yes	yes	. . .	158.50	42.00
W2G3	. . .	yes	yes	yes	yes	yes	. . .	178.75	42.00
W5	yes	yes	yes	yes	yes	yes	. . .	131.00	32.00
W5G2	yes	yes	yes	yes	yes	yes	. . .	166.00	42.00
W5G3	. . .	yes	yes	yes	yes	yes	. . .	190.00	42.00
W5H	yes	yes	yes	yes	yes	yes	. . .	134.00	32.00
W5HG2	yes	yes	yes	yes	yes	yes	. . .	172.00	42.00
W5HG3	. . .	yes	yes	yes	yes	yes	. . .	199.00	42.00
W5L	yes	yes	yes	yes	yes	yes	. . .	131.00	32.00
W5LG2	yes	yes	yes	yes	yes	yes	. . .	166.00	42.00
W5LG3	. . .	yes	yes	yes	yes	yes	. . .	190.00	42.00
W8	yes	yes	yes	yes	yes	yes	. . .	123.00	. . .
W8G2	yes	yes	yes	yes	yes	yes	. . .	158.00	. . .
W8G3	. . .	yes	yes	yes	yes	yes	. . .	184.00	. . .
W8L	yes	yes	yes	yes	yes	yes	. . .	123.00	. . .
W8LG2	yes	yes	yes	yes	yes	yes	. . .	158.00	. . .
W8LG3	. . .	yes	yes	yes	yes	yes	. . .	184.00	. . .
W10	yes	yes	yes	yes	yes	yes	yes	161.00	39.00
W10G2	so	so	yes	yes	yes	yes	yes	213.00	55.00
W10G3	so	so	yes	yes	yes	yes	yes	255.00	55.00
W10H	yes	yes	yes	yes	yes	yes	yes	162.00	39.00
W10HG2	so	yes	yes	yes	yes	yes	yes	215.00	55.00
W10HG3	so	so	yes	yes	yes	yes	yes	258.00	55.00
W20	so	yes	yes	yes	yes	yes	yes	184.00	39.00
W20G2	so	so	yes	yes	yes	yes	yes	258.00	55.00
W20G3	so	so	yes	yes	yes	yes	yes	319.00	55.00
W20H	so	yes	yes	yes	yes	yes	yes	186.00	39.00
W20HG2	so	so	yes	yes	yes	yes	yes	262.00	55.00
W20HG3	so	so	yes	yes	yes	yes	yes	325.00	55.00
W30	so	yes	yes	yes	yes	yes	yes	244.00	44.00
W30G2	. . .	so	so	yes	yes	yes	yes	366.00	66.00
W30G3	. . .	. . .	so	so	yes	yes	yes	470.00	66.00
W30H	so	yes	yes	yes	yes	yes	yes	244.00	44.00
W30HG2	. . .	so	so	yes	yes	yes	yes	366.00	66.00
W30HG3	. . .	. . .	so	so	yes	yes	yes	470.00	66.00
W50	. . .	so	so	yes	yes	yes	yes	301.00	55.00
W50G2	. . .	. . .	so	so	yes	yes	yes	478.00	77.00
W50G3	. . .	. . .	so	so	yes	yes	yes	637.00	77.00
W50G4	. . .	. . .	so	so	so	so	yes	803.00	99.00
W50G6	. . .	. . .	so	so	so	so	yes	1136.00	121.00
W50G9	. . .	. . .	. . .	. . .	. . .	yes	. . .	on request	. . .
W50G12	. . .	. . .	. . .	. . .	. . .	yes	. . .	on request	. . .
W50H	. . .	so	so	yes	yes	yes	yes	301.00	55.00
W50HG2	. . .	. . .	so	so	yes	yes	yes	478.00	77.00
W50HG3	. . .	. . .	so	so	yes	yes	yes	637.00	77.00
W50HG4	. . .	. . .	so	so	so	so	yes	803.00	99.00
W50HG6	. . .	. . .	so	so	so	so	yes	1136.00	121.00
W50HG9	. . .	. . .	. . .	. . .	. . .	yes	. . .	on request	. . .
W50HG12	. . .	. . .	. . .	. . .	. . .	yes	. . .	on request	. . .

Type 938 BINDING POSTS

- wide selection
  - gold-plated copper for low thermal emf or nickel-plated brass for economy
  - five colors in metal and plastic
- excellent electrical characteristics



The excellent electrical properties and ingenious mechanical design of the GR 938 Binding Posts provide all the properties needed for modern electronic instruments. Two styles are available: nickel-plated brass for economy, and gold-plated copper for high conductivity and low thermal emf with connection to copper wires. Both styles are available with either metal or insulated tops designed for easy hand-tightening, or ⅜-in., 12-point wrenches can be used for more permanent connections. The polycarbonate insulation has high insulation resistance and low dissipation factor and is available in red, black, and gray for color coding.

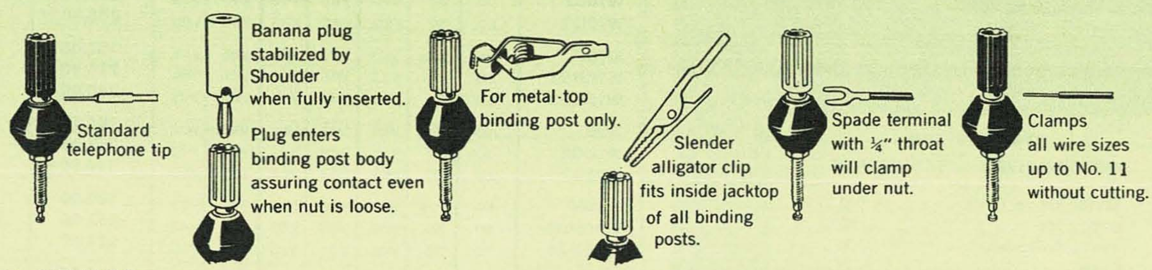
These binding posts can be mounted on metal or insulating panels of a thickness from zero to 5/16 in. A recent design improvement, reducing the diameter of the panel insulators slightly, now provides 1/16-in. clearance between insulators when the binding posts are mounted on standard ¾-in. centers. Mechanical details and methods of connection are shown below.

The binding post has the same height above panel as the nonlocking GR874® coaxial connector, whose center contact will take a Type 274 Plug, so that a grounded binding post can be mounted adjacent to the coaxial connector to fit a Type 274-MB Double Plug.

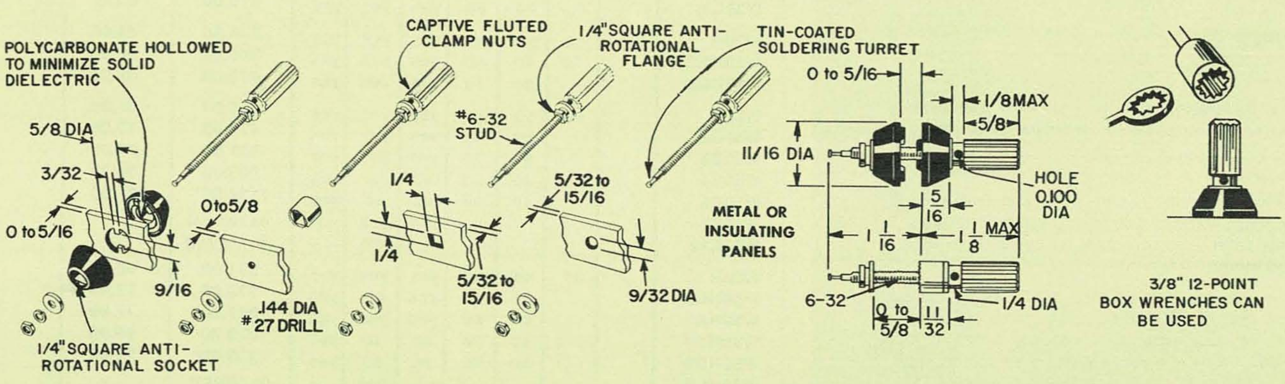
specifications

Rating: 30 A peak, 4 kV peak.
Breakdown: 10 kV peak.
Dissipation Factor: $<$0.0005 at 1 kHz.

METHODS OF CONNECTION

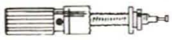
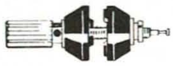
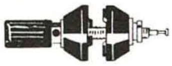
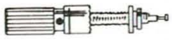
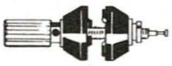
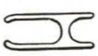


MECHANICAL DETAILS



Locking keys in ⅝-inch mounting holes can be omitted if only moderate resistance to rotation is needed.

BINDING POSTS

TYPE 938 BINDING POSTS	Type	☐ brass, nickel plated / ■ copper, gold plated	Net Weight for 10 oz	Net Weight for 10 g	Catalog Number for Pack	Price in USA	
ASSEMBLIES							
	**938-P**	**Metal Top/Spacers,** brass. Assembly of 938-A, 938-F	5	145	0938-9764	$ 5.50	per pack of 10
	**938-W**	**Metal Top/Black Insulators,** brass. Assembly of 938-A, 938-BB	5	145	0938-9771	5.50	per pack of 10
	938-R	**Metal Top/Red Insulators,** brass. Assembly of 938-A, 938-BR	5	145	0938-9765	5.50	per pack of 10
	938-S	**Metal Top/Gray Insulators,** brass. Assembly of 938-A, 938-BG	5	145	0938-9770	5.50	per pack of 10
	**938-WB**	**Black Top/Black Insulators,** brass. Assembly of 938-C, 938-BB	4	115	0938-9791	6.25	per pack of 10
	938-WR	**Red Top/Red Insulators,** brass. Assembly of 938-D, 938-BR	4	115	0938-9796	6.25	per pack of 10
	938-WG	**Gray Top/Gray Insulators,** brass. Assembly of 938-B, 938-BG	4	115	0938-9797	6.25	per pack of 10
	**938-GM**	**Metal Top/Spacers,** copper. Assembly of 938-G, 938-FG	6½	183	0938-9779	10.00	per pack of 10
	**938-GB**	**Metal Top/Black Insulators,** copper. Assembly of 938-G, 938-BB	6½	183	0938-9782	9.50	per pack of 10
	938-GR	**Metal Top/Red Insulators,** copper. Assembly of 938-G, 938-BR	6½	183	0938-9783	9.50	per pack of 10
	938-GG	**Metal Top/Gray Insulators,** copper. Assembly of 938-G, 938-BG	6½	183	0938-9784	9.50	per pack of 10
	**938-HB**	**Black Top/Black Insulators,** copper. Assembly of 938-H, 938-BB	5	145	0938-9785	9.50	per pack of 10
	938-KR	**Red Top/Red Insulators,** copper. Assembly of 938-K, 938-BR	5	145	0938-9786	9.50	per pack of 10
	938-EG	**Gray Top/Gray Insulators,** copper. Assembly of 938-E, 938-BG	5	145	0938-9787	9.50	per pack of 10
BINDING POSTS 	**938-A**	**Metal-Top Binding Post,** brass	4	115	0938-9766	44.00	per pack of 100
	**938-C**	**Black-Top Binding Post,** brass	3	85	0938-9767	50.00	per pack of 100
	938-D	**Red-Top Binding Post,** brass	3	85	0938-9768	50.00	per pack of 100
	938-B	**Gray-Top Binding Post,** brass	3	85	0938-9769	50.00	per pack of 100
	**938-G**	**Metal-Top Binding Post,** copper	5½	158	0938-9755	77.00	per pack of 100
	**938-H**	**Black-Top Binding Post,** copper	4	115	0938-9756	77.00	per pack of 100
	938-K	**Red-Top Binding Post,** copper	4	115	0938-9759	77.00	per pack of 100
	938-E	**Gray-Top Binding Post,** copper	4	115	0938-9757	77.00	per pack of 100
INSULATORS 	**938-BB**	**Black Insulators,** pair	1	30	0938-9775	5.50	per pack of 100
	938-BR	**Red Insulators,** pair	1	30	0938-9776	5.50	per pack of 100
	938-BG	**Gray Insulators,** pair	1	30	0938-9774	5.50	per pack of 100
	**938-YB**	**Double Insulators.** Interlocking bosses permit mounting on very thin panels	2	60	0938-9792	11.00	per pack of 100
ACCESSORIES 	**938-F**	**Spacer,** nickel-plated brass. Square anti-rotational socket and anti-rotational teeth	1	30	0938-9754	5.50	per pack of 100
	938-FG	**Spacer,** gold-plated brass. Square anti-rotational socket and anti-rotational teeth	1	30	0938-9777	11.00	per pack of 100
	**938-L**	**Shorting Link,** nickel-plated brass. For two binding posts mounted on ¾-in. centers	1	30	0938-9760	5.50	per pack of 100
	938-LG	**Shorting Link,** gold-plated brass. For two binding posts mounted on ¾-in. centers	1	30	0938-9751	17.00	per pack of 10

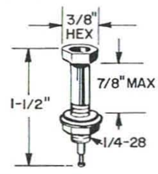
Prices for binding-post assemblies are for shipment unassembled. When assembly and/or individual packaging before shipment is required, add 10¢ per binding post for assembly, 8¢ for packaging.

JACKS AND PLUGS

	Dimensions in Inches	Catalog Number per pack	Price in USA

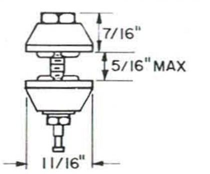
JACKS

The Type 938 Jacks also fit Type 274 Plugs. The Type 938-J Jack has a longer shank than the Type 274 Jack. The Type 938-X Jack Assembly consists of the Type 938-J Jack and Type 938-B Insulators. Both the 938 Jacks and 274 Jack are rated at 15 amperes.



938-J JACK. Fits Type 274 Plugs, has long unthreaded shank that makes it suitable for mounting in Types 938-BB, 938-BR, and 938-BG Insulators or Type 938-F Spacers. Net Weight per pack: 30 oz (850 g).

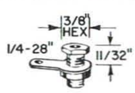
0938-9758 — **$39.00** per pack of 100



938-XB JACK ASSEMBLY, black. Net Weight per pack: 4 oz (115 g).
0938-9793 — **$5.50** per pack of 10

938-XR JACK ASSEMBLY, red.
0938-9794 — **$5.50** per pack of 10

938-XG JACK ASSEMBLY, gray.
0938-9795 — **$5.50** per pack of 10

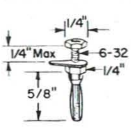


274-J JACK. Nickel-plated brass, fits Type 274 Plugs. Net Weight per pack: 15 oz (425 g).

0274-9735 — **$11.00** per pack of 100

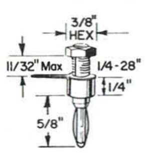
PLUGS

Type 274 Plugs are rated at 15 amperes and are designed for positive and reliable contact, typically 1 milliohm. The plug seats firmly in a jack so that the plug springs are not depended upon for mechanical stability.



274-P PLUG. Nickel-plated brass stud and beryllium copper springs, fits Type 274 and Type 938 Jacks. Net Weight per pack: 10 oz (300 g).

0274-9736 — **$17.00** per pack of 100



274-U PLUG. Nickel-plated brass stud and beryllium copper springs, fits Type 274 and Type 938 Jacks. Net Weight per pack: 30 oz (850 g).

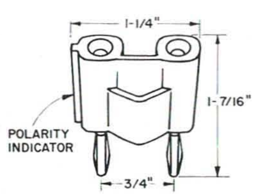
0274-9737 — **$39.00** per pack of 100

The Type 274-DB Insulated Single Plug is a styrene-insulated plug with a jack top. A set-screw clamp is provided on the plug end.

274-DB1 INSULATED SINGLE PLUG, black. Net Weight per pack: 40 oz (120 g).
0274-9730 — **$5.50** per pack of 10

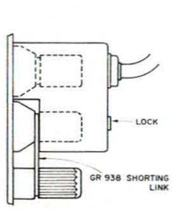
274-DB2 INSULATED SINGLE PLUG, red.
0274-9731 — **$5.50** per pack of 10

Rating:
15 A, peak;
4 kV, peak.
Breakdown:
10 kV, peak.
Dissipation Factor:
<0.0005 at 1 kHz.

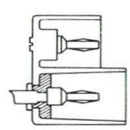


274-MB INSULATED DOUBLE PLUG. Molded styrene double-plug assembly, which fits Type 938 Binding Posts or Type 274 Jacks on standard ¾-inch spacing. Jack top permits stacking for multiple connections. A formed side strap provides strain relief for attached cables up to 0.2-inch diameter. The plug is completely insulated; for safety, all metal parts are effectively enclosed.

0274-9746 — **$7.75** per pack of 10



Rating:
15 A, peak;
1 kV, peak.
Breakdown:
2 kV, peak.
Dissipation Factor:
<0.0005 at 1 kHz.

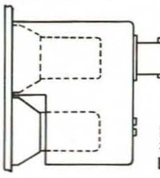


274-NK SHIELDED DOUBLE PLUG. Double plug in an aluminum case for completely shielded connections to 938 Binding Posts. Accepts cables with 0.2-inch OD. Stepped case permits a 938-L(G) Shorting Link to be used between low-terminal binding post and a ground binding post without interfering with proper shielding. High terminal of double plug remains fully shielded. The 274-NK can be locked to binding posts; turning a screw expands one pin inside body of the binding post. This plug terminates the Type 274-NL, 776-A, and 874-R34 Patch Cords. Net Weight per pack: 30 oz (850 g).

0274-9747 — **$22.00** per pack of 10

ADAPTORS AND CORDS

ADAPTORS

	Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
  Fits standard ¾-in.-spaced binding posts	274-QBJ	**Adaptor** — Shielded banana plugs in the Type 274-QBJ Adaptor provide connection from standard ¾-inch-spaced binding posts to a type BNC Plug. The adaptor will lock onto the binding posts providing semipermanent adaptation to BNC.	—	—	3	90	0274-9751	$33.00
 Fits Type 274 Double-Plug Patch Cords	874-Q2	**Adaptor** — This adaptor provides connection from GR874® coaxial connectors to binding posts.	—	—	2	60	0874-9864	53.00
	777-Q1	**Adaptor** — The 777-Q1 contains a phone plug and two jacks with ¾-inch spacing to accept double or individual GR 274 plugs.	—	—	1	30	0777-9710	28.00
	777-Q2	**Adaptor** — The 777-Q2 combines, in a molded assembly, a phone jack and two GR 274 plugs with ¾-inch spacing. It thus adapts a phone plug to GR 938 Binding Posts.	—	—	1	30	0777-9711	31.00
	777-Q3	**Adaptor** — This adaptor provides fully shielded connection from GR874 coaxial connectors to Type 938 Binding Posts with ¾-inch spacing. Constructed like a GR 274-NK, the adaptor shares many of its features; it can be locked to binding posts by a turn of a screw for semipermanent conversion to GR874.	—	—	2	60	0777-9712	66.00
NEW 	777-Q4	**Adaptor** — This adaptor converts a phone jack to a BNC connector.	—	—	2	60	0777-9713	33.00

ADAPTOR CABLES

	Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
	776-A	**Patch Cord** — This 3-ft shielded cable will connect between a BNC jack, often found on instrument panels, and binding posts ¾-inch spaced. The 50-Ω cable is fitted with a BNC plug (male) and a GR 274-NK Shielded Double Plug.	36	920	3	90	0776-9710	66.00
	776-B	**Patch Cord** — The 776-B consists of a 3-ft shielded 50-Ω cable fitted with a BNC plug (male) and a GR874® coaxial connector. It is convenient for interconnecting instruments with differing connectors, i.e. GR874 and a BNC jack. A right-angle cable access to the GR874 conserves space.	36	920	3	90	0776-9711	83.00

CORDS (continued)

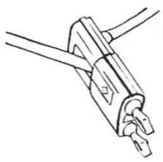
PATCH CORDS

This 3-ft 50-Ω shielded cable has a BNC plug (male) on each end for interconnecting devices fitted with panel-mounted BNC jacks.

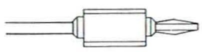
Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
776-C	Patch Cord	36	920	2	60	0776-9712	$66.00

The 776-D Patch Cord is a 50-Ω shielded cable with GR874 connectors at each end. For convenience around instrument front-panel controls and space-saving rear-panel connections, the cable enters the molded GR874 connector body from the side. Not intended for high-frequency use where SWR is a consideration.

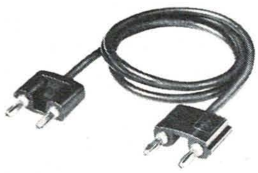
Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
776-D	Patch Cord	36	920	2	60	0776-9713	99.00

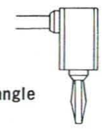


Stackable



In-line

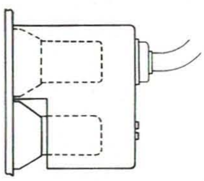




Right-angle

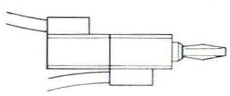
The connector bodies are encapsulated first in polystyrene for its electrical properties and then in cellulose-acetate butyrate for its high-impact properties. The configuration of the connectors is such that any double plug can be connected to any other — whether in-line or right-angle.

Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
274-NQ	Double-Plug Patch Cord, in-line cord	36	920	3	85	0274-9743	44.00
274-NQM	Double-Plug Patch Cord, in-line cord	24	610	2	60	0274-9753	44.00
274-NQS	Double-Plug Patch Cord, in-line cord	12	305	1½	45	0274-9744	44.00
274-NP	Double-Plug Patch Cord, right-angle cord	36	920	3	85	0274-9748	44.00
274-NPM	Double-Plug Patch Cord, right-angle cord	24	610	2	60	0274-9752	44.00
274-NPS	Double-Plug Patch Cord, right-angle cord	12	305	1½	45	0274-9742	44.00



The Type 274-NK Shielded Double Plugs used on these cords are made of aluminum and provide strain relief for the cable.

Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
274-NL	Shielded Double-Plug Patch Cord	36	920	6	170	0274-9750	66.00
274-NLM	Shielded Double-Plug Patch Cord	24	610	5	145	0274-9749	66.00
274-NLS	Shielded Double-Plug Patch Cord	12	305	4	115	0274-9745	66.00

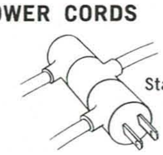


Stackable

The connector bodies are encapsulated in cellulose-acetate butyrate. They include a jack for stacking, and the plugs seat firmly in jacks so that plug springs are not depended on for mechanical stability. Contact resistance is in the order of one milliohm.

Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
274-LLB	Single-Plug Patch Cord, black	36	920	1½	45	0274-9732	17.00
274-LLR	Single-Plug Patch Cord, red	36	920	1½	45	0274-9734	17.00
274-LMB	Single-Plug Patch Cord, black	18	460	1	30	0274-9738	17.00
274-LMR	Single-Plug Patch Cord, red	18	460	1	30	0274-9739	17.00
274-LSB	Single-Plug Patch Cord, black	9	230	1	30	0274-9740	17.00
274-LSR	Single-Plug Patch Cord, red	9	230	1	30	0274-9741	17.00

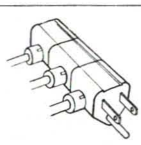
POWER CORDS



Stackable

Made of plastic-covered number 18 conductor. Plug and connector bodies are molded integrally with the cord, and the hammerhead design permits stacking. Type SVT cord rated by Underwriters Laboratories at 7 amperes and 300 volts, rms. Female connector fits either 2-wire or 3-wire plug.

Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
CAP-35	2-Wire Power Cord	7 feet	2.14 meters	7	200	4200-9636	25.00



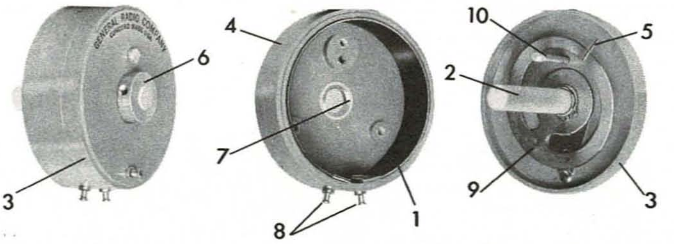
Stackable

Made of plastic-covered number 18 conductor. Plug and connector bodies are molded integrally with the cord, and the hammerhead design permits stacking. Type SVT cord rated at 7 amperes and 230 volts. The connectors, designed for 125-volt operation, conform to the Standard for Grounding Type Attachment Plug Caps and Receptacles, ANSI C73.11-1963.

Type		Length in.	Length mm	Net Weight oz	Net Weight g	Catalog Number per pack of 10	Price in USA
CAP-22	3-Wire Power Cord	7 feet	2.14 meters	9	255	4200-9623	25.00

970-Series POTENTIOMETERS

These potentiometers are moderately priced controls with high-quality performance. They can be used at dc, throughout the audio- and ultrasonic-frequency ranges, and, in many applications, at low radio frequencies. When ganged, the 970-Series Potentiometers retain their low-capacitance characteristics. Units are designed to be nested with molded spacing rings, stacked on a long shaft, and held together with thin metal clamping rings and tie rods. This assembly allows units to be set in any desired phase relationship.



SIMPLE MECHANICAL ADJUSTMENT
EXCELLENT MECHANICAL STABILITY
EXCELLENT REPEATABILITY

6 Projecting hub permits adjustment of shaft with respect to contact brush while case is closed. Hub rotates in a recessed brass insert molded into cover to form a metal-to-metal bearing close to plane of brush.

7 A second bearing is provided by a nylon-graphite insert to guide shaft into base.

EXCELLENT LINEARITY
LOW TEMPERATURE COEFFICIENT
LOW INDUCTANCE

1 Uniformly wound, low-temperature coefficient resistance element on a thin, phenolic-laminate mandrel firmly cemented into body molding.

LOW NOISE

1 Firm clean track
5 Precious-metal contact
9 Uniform contact pressure

HIGH LEAKAGE RESISTANCE
LOW CAPACITANCE TO GROUND

2 Glass-reinforced-polyester shaft
3 New diallyl-phthalate dust-proof cover
4 New diallyl-phthalate body

HIGH RESOLUTION

5 Small-diameter brush of precious-metal alloy

HIGH RELIABILITY

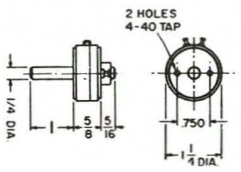
8 Turret terminals are both riveted to end of clamps and soldered to ends of winding and to silver-plated, spring-bronze contact take-off in cover so that none of the fixed internal connections depends on pressure alone.

9 Brush arm and spring are combined into a single stamping of spring-temper phosphor-bronze.

10 Screw that holds cover to base passes through a horseshoe-shaped slot in brush arm to serve as a rotational stop that exerts no force on brush.

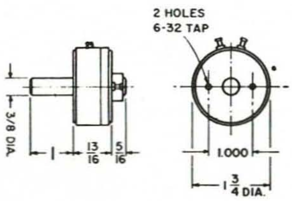
(All dimensions in inches)

971



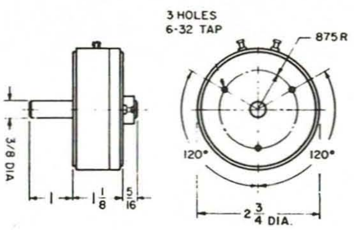
Wt: Approx ½ oz

973



Wt: Approx 1 oz

975



Wt: Approx 3 oz

Type	Nominal Resistance Ohms	Temperature Coefficient of Resistance %	Resolution %	Catalog Number	Price in USA
971-B	2	±0.07	<1	0971-9702	$9.50
971-C	5	±0.07	<1	0971-9703	9.50
971-D	10	±0.002	<1	0971-9704	9.50
971-E	20	±0.002	<1	0971-9705	9.50
971-F	50	±0.002	<0.5	0971-9706	9.50
971-G	100	±0.002	<0.5	0971-9707	9.50
971-H	200	±0.002	<0.5	0971-9708	9.50
971-J	500	±0.002	<0.5	0971-9710	9.50
971-K	1000	±0.002	<0.5	0971-9711	9.50
971-L	2000	±0.002	<0.5	0971-9712	9.50
971-M	5000	±0.002	<0.2	0971-9713	9.50
971-N	10,000	±0.002	<0.2	0971-9714	9.50
971-P	20,000	±0.002	<0.2	0971-9716	9.50
973-C	5	±0.07	<0.5	0973-9703	11.00
973-D	10	±0.07	<0.5	0973-9704	11.00
973-E	20	±0.002	<0.5	0973-9705	11.00
973-F	50	±0.002	<0.5	0973-9706	11.00
973-G	100	±0.002	<0.5	0973-9707	11.00
973-H	200	±0.002	<0.5	0973-9708	11.00
973-J	500	±0.002	<0.2	0973-9710	11.00
973-K	1000	±0.002	<0.2	0973-9711	11.00
973-L	2000	±0.002	<0.2	0973-9712	11.00
973-M	5000	±0.002	<0.2	0973-9713	11.00
973-N	10,000	±0.002	<0.1	0973-9714	11.00
973-P	20,000	±0.002	<0.1	0973-9716	11.00
973-Q	50,000	±0.002	<0.1	0973-9717	11.00
975-J	500	±0.002	<0.2	0975-9710	13.00
975-K	1000	±0.002	<0.2	0975-9711	13.00
975-L	2000	±0.002	<0.2	0975-9712	13.00
975-M	5000	±0.002	<0.2	0975-9713	13.00
975-N	10,000	±0.002	<0.1	0975-9714	13.00
975-P	20,000	±0.002	<0.1	0975-9716	13.00
975-Q	50,000	±0.002	<0.05	0975-9717	14.00
975-R	100,000	±0.002	<0.05	0975-9718	14.00

Type	Effective Electrical Rotation	Total Mechanical Rotation	Standard Resistance Tolerance	Average Torque oz/in.	Independent Linearity %	Power Rating at 0°C ambient temp* Mounted on Alum Panel	Power Rating at 0°C ambient temp* Suspended in Air
971	315° ± 5°	330° ± 5°	±5%	1¾	±2	5.6	3.5
973	320° ± 5°	330° ± 5°	±5%	2½	±1	8.4	5.9
975	320° ± 2°	330° ± 5°	±2%	4	±0.5	13.4	10.7

* Power rating in watts decreases linearly with rising ambient temperature to zero at 100°C.

RACK ADAPTORS AND SETS

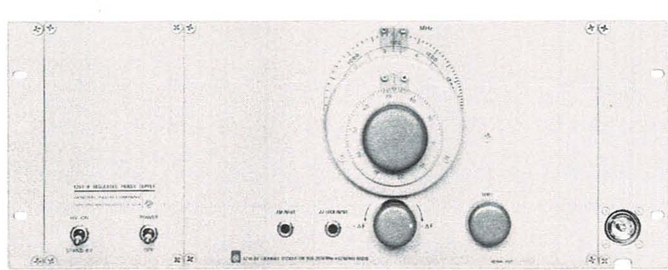
Listed below are the instrument-panel extensions and hardware, supplied in complete sets, for converting bench-model instruments for mounting in standard 19-inch relay racks. In many cases, these instruments are offered in a choice of rack or bench mountings and should be ordered initially according to mounting requirements, as complete cabinets and hardware are included. When retrofitting is necessary the adaptors below should be ordered.

Instruments missing from this list may require more extensive changes than can be done by simple kits or may be unavailable for rack mounting other than by special order. In these cases, a General Radio district office or representative should be consulted.

Instrument	Height (in.)	Catalog Number	Price in USA
1157-B	3½	0480-9722	$26.00
1192	3½	0480-9722	26.00
1192-Z	3½	0480-9702	13.00
1192 + 1157-B	3½	0480-9702	13.00
1210 + 1201 or 1203	7	0480-9986*	14.00
1211-C	7	0480-9848	19.00
1211-C + 1263 or 1264	7	0481-9846	29.00
1211-C + 1267 or 1269	7	0481-9842	30.00
1215-C	7	same as 1211's	
1218-BV	7	0481-9842	30.00
1218-BV + 1263 or 1264	14	0482-9842	44.00
1218-BV + 1267 or 1269	7	0481-9846	29.00
1232-A	5¼	0480-9838	11.00
1232-A + 1311	5¼	0480-9836	6.75
1232-A + 1232-P1 + 1311	5¼	0480-9837	6.75
1236	7	0480-9848	19.00
1236 with oscillator		see 1241's	
1240-A	5¼	0480-9836	6.75
1240-AP	5¼	0480-9837	6.75
1241-9701, 1241-9703	7	0480-9670	16.00
1241-9705	14	0480-9671 and -9848	35.00

* Charcoal panel; all others light gray.

Instrument	Height (in.)	Catalog Number	Price in USA
1263	7	0480-9848	19.00
1264	7	0480-9848	19.00
1309-A	5¼	0480-9838	11.00
1310-B	5¼	0480-9838	11.00
1311	5¼	0480-9838	11.00
1311 + 1232-A	5¼	0480-9836	6.75
1311 + 1232-A + 1232-P1	5¼	0480-9837	6.75
1340	5¼	0480-9723	25.00
1361-A	7	same as 1211's	
1362	7	same as 1211's	
1363	7	same as 1211's	
1381	3½	0480-9722	26.00
1382	3½	0480-9722	26.00
1390-B	7	0480-9842	11.00
1396-B	5¼	0480-9723	25.00
1433 4-dial	3½	0480-2080	9.00
5-dial	3½	0480-2060	9.50
6-dial	3½	0480-2020	7.00
7-dial	5¼	0480-2091	9.00
1436	3½	0480-9722	26.00
1455 4-dial	3½	0480-2060	9.50
5-dial	3½	0480-2020	7.00
1491-A, -B, -C	8¾	0480-9715	17.00
-D, -F, -G	8¾	0480-9705	22.00
1808	5¼	0480-9723	25.00
1840-A	3½	0480-9822	11.00



Types 1218-BV and 1267 shown rack-mounted with 0481-9846 Rack-Adaptor Set.

ABBREVIATIONS, SYMBOLS AND PREFIXES

In this catalog, as in other General Radio publications, our use of symbols, prefixes, and abbreviations follows the recommendations of the International Electrotechnical Commission, the American National Standards Institute, Inc., the Institute of Electrical and Electronics Engineers, and other scientific and engineering organizations. Where there is not agreement among these groups, we generally choose the usage favored by the majority.

ABBREVIATIONS AND SYMBOLS

a	atto (10^{-18})
A	ampere
Å	angstrom
ac	alternating current
afc	automatic frequency control
a-m	amplitude modulation
ANSI	American National Standards Institute, Inc.
APS	American Physical Society
ASA	Acoustical Society of America
ASTM	American Society for Testing and Materials
avc	automatic volume control
avg	average
B	susceptance
bar	bar (10^5N/m^2)
BCD	binary-coded decimal
c	speed of light, centi (10^{-2})
C	capacitance, coulomb
°C	degrees Celsius (Centigrade)
cd	candela
CIF	cost, insurance, freight
CML	current-mode logic
COD	cash on delivery
cw	continuous wave
d	deci (10^{-1})
D	dissipation factor
da	deka (10)
dB	decibel
dBm	decibel referred to one milliwatt
dc	direct current
DCTL	direct-coupled transistor logic
dia	diameter
DTL	diode-transistor logic
e	electronic charge
E	voltage
EIA	Electronic Industries Association
emf	electromotive force
F	farad, Faraday
°F	degrees Fahrenheit
f	frequency, femto (10^{-15})
fm	frequency modulation
FOB	free on board
G	conductance, giga (10^9)
g	gram, gravitational constant
g_m	transconductance
H	henry
h	hour, Planck's constant, hecto (10^2)
hf	high frequency
h_f	forward current-transfer ratio
h_i	short-circuit input impedance
h_o	open-circuit output admittance
h_r	reverse voltage-transfer ratio
Hz	hertz (cycle per second)
I	current
IC	integrated circuit
ID	inside diameter
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
i-f	intermediate frequency
in.	inch
ISA	Instrument Society of America
ISO	International Standards Organization
j	$\sqrt{-1}$
J	joule
k	kilo (10^3)
°K	degrees Kelvin
l	liter (10^{-3} m^3)
L	inductance
lb	pound
LC	inductance-capacitance
lm	lumen
log	logarithm
lx	lux
m	meter, milli (10^{-3})
M	mega (10^6)
max	maximum
mbar	millibar
mil	0.001 inch
min	minimum, minute
n	nano (10^{-9})
N	newton
oz	ounce
p	page, parallel (as L_p), pico (10^{-12})
P	poise (10^{-5}N • s/m^2)
PF	power factor
ppm	parts per million
pps	pulses per second
pk-pk	peak-to-peak
PRF	pulse repetition frequency
Q	quality factor (storage factor)
R	resistance
®	registered trademark
rad	radian
RC	resistance-capacitance
RCTL	resistor-capacitor-transistor logic
re	referred to
rf	radio frequency
RH	relative humidity
rms	root-mean-square
rpm	revolutions per minute
RTL	resistor-transistor logic
s	second, series (as L_s)
shf	super-high frequency
sq	square
sync	synchronous, synchronizing
T	period, Tesla, tera (10^{12})
t	time
TTL	transistor-transistor logic
uhf	ultra-high frequency
v	velocity
V	volt
VA	volt ampere
vhf	very-high frequency
vlf	very-low frequency
W	watt
Wb	Weber
wt	weight
X	reactance
Y	admittance
Z	impedance
α	short-circuit forward current-transfer ratio (common base)
β	short-circuit forward current-transfer ratio (common emitter)
Γ	reflection coefficient
Δ	increment
δ	loss angle
θ	phase angle
λ	wavelength
μ	micro (10^{-6})
Ω	ohm
℧	mho
ω	angular velocity ($2\pi f$)

PREFIXES

Orders of magnitude from 10^{-18} to 10^{12} are designated by the following prefixes:

Order	Prefix	Symbol
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

CABINETS AND MOUNTING

General Radio instrument cabinets are rugged, attractive, and versatile. Heavy-gauge aluminum and tough finishes combine to keep GR instruments operating and looking like new through many years of hard service.

We use four basic cabinet types: (1) rack-bench cabinets, with standard 19-inch rack-width panels and optional bench or rack-mounts, (2) Flip-Tilt cases, for portable instruments, (3) convertible-bench cabinets, for smaller laboratory instruments, and (4) lab-bench cabinets, for laboratory standards, decade boxes, and similar instruments.

PEDESTAL CABINET

RACKABLE CABINET

RACK-BENCH CABINET
For bench use, the rack-bench cabinet is equipped with aluminum end frames.

RACK-BENCH INSTRUMENTS

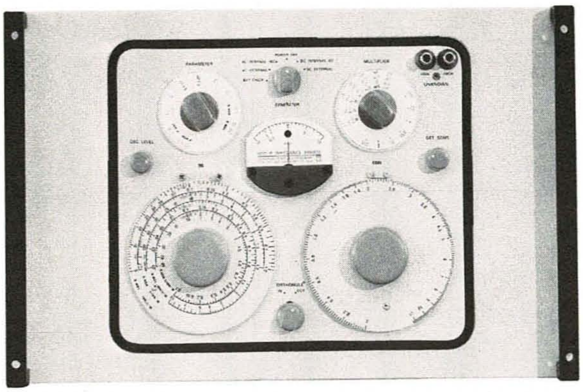
General Radio instruments with 19-inch-wide front panels are supplied in a choice of mounting for either relay-rack installation or for use on a bench where portability counts. All cabinets, whether for rack or bench use, are effective shields preventing mutual interference with other nearby instruments.

Newer instrument models are mounted in either a "pedestal" cabinet for bench use or a "rackable" cabinet, each specifically designed for its particular function. The pedestal cabinet raises the instrument slightly on a recessed pedestal that provides a handhold for lifting. In smaller instruments, the pedestal is the base for a tilting mechanism and, inside, provides storage space for instruction manuals and small accessories. For convenient carrying, larger instruments and assemblies in the pedestal cabinet have hinged heavy-duty handles recessed into the sides near the top of the cabinet. Slides in both pedestal and rackable cabinets permit easy removal for servicing. The rackable cabinet has all the provisions for mounting the instrument in a standard 19-inch relay rack with universal mounting-hole spacing per EIA Standard RS-310 and includes rear-support brackets as well.

Many instruments with 19-inch panels are supplied in the easily converted rack-bench cabinet. For rack mounting, the addition of side-support hardware allows the in-

Locked closed, with accessories and instruction manual inside, the instrument is well protected against damage by the Flip-Tilt case.

Flip-Tilt case in one of its many operating positions. Rubber gasket provides friction to allow almost any tilt angle.

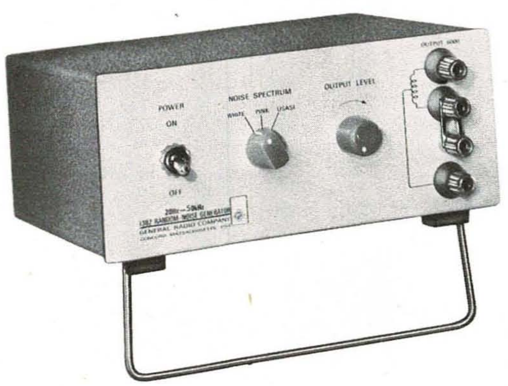


Another of the many faces of the versatile Flip-Tilt, which here has traded cover and handle for a rack adaptor panel.

strument cabinet to be mounted in a rack and act as a drawer slide. The same cabinet becomes the bench version by the substitution of end frames for the side supports. These end frames act as carrying handles and feet and permit several similarly equipped instruments to be stacked and bolted together without additional hardware.

FLIP-TILT CASES

General Radio's exclusive Flip-Tilt case includes three main parts: the instrument cabinet, a captive cover, and a carrying-handle and lever assembly. When the instrument is closed for storage or transit, the cover is locked in place over the front panel by means of slide-buttons and latches on the carrying handle. To open the cabinet, the user slides the buttons out of the latches and pushes down on the carrying handle. The lever action of the handle raises the cabinet from the cover. The cabinet is then easily flipped into position for operation. The operating position may be fully open and locked squarely in the cover or tilted at almost any angle. A rubber seal around the edge of the cover provides friction to hold the cabinet in the tilted position. When the instrument is closed, the same gasket provides a seal for the enclosure. Accessories and instruction manual are conveniently stored in the Flip-Tilt cover.



Convertible-bench instruments with meters tilt on extendible bail for easy viewing of front panel. Panel extensions are used for rack mount.

Certain Flip-Tilt instruments are also available in standard relay-rack cabinets; most other Flip-Tilt instruments are available adapted for rack mounting. In such adaptations, the Flip-Tilt case (minus cover and handle) is neatly and securely mounted in a relay-rack adaptor panel.

CONVERTIBLE-BENCH CABINETS

Small and medium-sized instruments commonly used on the bench are housed in GR's unique convertible-bench cabinet, designed primarily for the bench but offering quick relay-rack adaptability.

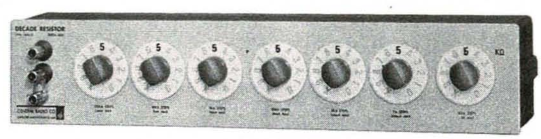
The convertible-bench cabinet is made of sturdy aluminum finished in GR medium gray wrinkle. The dust cover can be readily removed.

Instruments with panel meters can be tilted to the most convenient angle.

Conversion for relay-rack mounting is easy: matching panel extensions are simply attached by means of screws to the instrument and to the relay rack.

LAB-BENCH CABINETS

Lab-bench cabinets are simple enclosures used primarily for laboratory standards and decade boxes. Two U-shaped pieces of ⅛-inch extruded aluminum are strip-locked together to form the sides, and an aluminum bottom plate and $\frac{3}{16}$-inch aluminum panel complete the enclosure. The result is a cabinet well shielded, structurally solid, and efficiently manufactured.



LAB-BENCH CABINET

Two aluminum extrusions are strip-locked together to form the sides, heavy aluminum panel and bottom plate are added, and this precision capacitor is given the excellent shielding and trim appearance of the lab-bench cabinet.

OTHER CABINETS

While most General Radio instruments are housed in the five cabinets described above, several other types of mounting are used to serve the special demands of various instruments. These range from the pocket-sized cases used for certain portable sound-measuring instruments to the specialized structures of a slotted line or an admittance meter.

Accessory mounting hardware, such as end frames, relay-rack supports, and relay-rack adaptor panels, may be ordered separately by those customers wishing to convert from one type of mounting to another. Many of these accessories are listed along with the related instruments. Further information on such hardware, dimensions, etc., is available on request.

DECIBEL CONVERSION TABLES

In communications systems the ratio between any two amounts of electric or acoustic power is usually expressed in units on a logarithmic scale. The decibel (1/10th of the bel) on the briggsian or base-10 scale and the neper on the napierian or base-e scale are in almost universal use for this purpose.

Since voltage and current are related to power by impedance, both the decibel and the neper can be used to express voltage and current ratios, if care is taken to account for the impedances associated with them. In a similar manner the corresponding acoustical quantities can be compared.

From Table I and Table II on the following pages conversions can be made in either direction between the number of decibels and the corresponding power, voltage, and current ratios. Both tables can also be used for nepers by application of a conversion factor.

Decibel — The number of decibels N_{dB} corresponding to the ratio between two amounts of power P_1 and P_2 is

$$N_{dB} = 10 \log_{10} \frac{P_1}{P_2}$$

When two voltages E_1 and E_2 or two currents I_1 and I_2 operate in identical impedances,

$$N_{dB} = 20 \log_{10} \frac{E_1}{E_2} \quad \text{and} \quad N_{dB} = 20 \log_{10} \frac{I_1}{I_2}.$$

If E_1 and E_2 and I_1 and I_2 operate in unequal impedances,

$$N_{dB} = 20 \log_{10} \frac{E_1}{E_2} + 10 \log_{10} \frac{Z_2}{Z_1} + 10 \log_{10} \frac{k_1}{k_2}$$

and $$N_{dB} = 20 \log_{10} \frac{I_1}{I_2} + 10 \log_{10} \frac{Z_1}{Z_2} + 10 \log_{10} \frac{k_1}{k_2},$$

where Z_1 and Z_2 are the absolute magnitudes of the corresponding impedances and k_1 and k_2 are the values of power factor for the impedances. E_1, E_2, I_1, and I_2 are also the absolute magnitudes of the corresponding quantities. Note that Table I and Table II can be used to evaluate the impedance and power factor terms, since both are similar to the expression for power ratio.

Neper — The number of nepers N_{nep} corresponding to a power ratio $\frac{P_1}{P_2}$ is

$$N_{nep} = \frac{1}{2} \log_e \frac{P_1}{P_2}.$$

For voltage ratios $\frac{E_1}{E_2}$ or current ratios $\frac{I_1}{I_2}$ working in identical impedances,

$$N_{nep} = \log_e \frac{E_1}{E_2} \quad \text{and} \quad N_{nep} = \log_e \frac{I_1}{I_2}.$$

Relations Between Decibels and Nepers

Multiply decibels by 0.1151 to find nepers
multiply nepers by 8.686 to find decibels

TO FIND VALUES OUTSIDE THE RANGE OF CONVERSION TABLES

Table I: Decibels to Voltage and Power Ratios

Number of decibels positive (+): Subtract +20 decibels successively from the given number of decibels until the remainder falls within range of Table I. To find the voltage ratio, multiply the corresponding value from the right-hand voltage-ratio column by 10 for each time you subtracted 20 dB. To find the power ratio, multiply the corresponding value from the right-hand power-ratio column by 100 for each time you subtracted 20 dB.

Example — Given: 49.2 dB
49.2 dB − 20 dB − 20 dB = 9.2 dB

Voltage ratio: 9.2 dB ⟶ 2.884
2.884 × 10 × 10 = 288.4

Power ratio: 9.2 dB ⟶ 8.318
8.318 × 100 × 100 = 83180

Number of decibels negative (−): Add +20 decibels successively to the given number of decibels until the sum falls within the range of Table I. For the voltage ratio, divide the value from the left-hand voltage-ratio column by 10 for each time you added 20 dB. For the power ratio, divide the value from the left-hand power-ratio column by 100 for each time you added 20 dB.

Example — Given: −49.2 dB
+49.2 dB + 20 dB + 20 dB = −9.2 dB

Voltage ratio: −9.2 dB ⟶ 0.3467
0.3467 × 1/10 × 1/10 = 0.003467

Power ratio: −9.2 dB ⟶ 0.1202
0.1202 × 1/100 × 1/100 = 0.00001202

Table II: Voltage Ratios to Decibels

For ratios smaller than those in table — Multiply the given ratio by 10 successively until the product can be found in the table. From the number of decibels thus found, subtract +20 decibels for each time you multiplied by 10.

Example — Given: Voltage ratio = 0.0131
0.0131 × 10 × 10 = 1.31

From Table II, 1.31 ⟶ 2.345 dB
2.345 dB − 20 dB − 20 dB = −37.655 dB

For ratios greater than those in table — Divide the given ratio by 10 successively until the remainder can be found in the table. To the number of decibels thus found, add +20 dB for each time you divided by 10.

Example — Given: Voltage ratio = 712
712 × 1/10 × 1/10 = 7.12

From Table II, 7.12 ⟶ 17.050 dB
17.050 dB + 20 dB + 20 dB = 57.050 dB

TABLE I

GIVEN: Decibels **TO FIND: Power and {Voltage / Current} Ratios**

TO ACCOUNT FOR THE SIGN OF THE DECIBEL

For positive (+) values of the decibel — Both voltage and power ratios are greater than unity. Use the two right-hand columns.

For negative (−) values of the decibel — Both voltage and power ratios are less than unity. Use the two left-hand columns.

Example — *Given:* ±9.1 dB; *Find:*

	Power Ratio	*Voltage Ratio*
+9.1 dB	8.128	2.851
−9.1 dB	0.1230	0.3508

Voltage Ratio	*Power Ratio*	*dB* (← − dB + →)	*Voltage Ratio*	*Power Ratio*
1.0000	**1.0000**	**0**	**1.000**	**1.000**
.9886	.9772	.1	1.012	1.023
.9772	.9550	.2	1.023	1.047
.9661	.9333	.3	1.035	1.072
.9550	.9120	.4	1.047	1.096
.9441	.8913	.5	1.059	1.122
.9333	.8710	.6	1.072	1.148
.9226	.8511	.7	1.084	1.175
.9120	.8318	.8	1.096	1.202
.9016	.8128	.9	1.109	1.230
.8913	**.7943**	**1.0**	**1.122**	**1.259**
.8810	.7762	1.1	1.135	1.288
.8710	.7586	1.2	1.148	1.318
.8610	.7413	1.3	1.161	1.349
.8511	.7244	1.4	1.175	1.380
.8414	.7079	1.5	1.189	1.413
.8318	.6918	1.6	1.202	1.445
.8222	.6761	1.7	1.216	1.479
.8128	.6607	1.8	1.230	1.514
.8035	.6457	1.9	1.245	1.549
.7943	**.6310**	**2.0**	**1.259**	**1.585**
.7852	.6166	2.1	1.274	1.622
.7762	.6026	2.2	1.288	1.660
.7674	.5888	2.3	1.303	1.698
.7586	.5754	2.4	1.318	1.738
.7499	.5623	2.5	1.334	1.778
.7413	.5495	2.6	1.349	1.820
.7328	.5370	2.7	1.365	1.862
.7244	.5248	2.8	1.380	1.905
.7161	.5129	2.9	1.396	1.950
.7079	**.5012**	**3.0**	**1.413**	**1.995**
.6998	.4898	3.1	1.429	2.042
.6918	.4786	3.2	1.445	2.089
.6839	.4677	3.3	1.462	2.138
.6761	.4571	3.4	1.479	2.188
.6683	.4467	3.5	1.496	2.239
.6607	.4365	3.6	1.514	2.291
.6531	.4266	3.7	1.531	2.344
.6457	.4169	3.8	1.549	2.399
.6383	.4074	3.9	1.567	2.455
.6310	**.3981**	**4.0**	**1.585**	**2.512**
.6237	.3890	4.1	1.603	2.570
.6166	.3802	4.2	1.622	2.630
.6095	.3715	4.3	1.641	2.692
.6026	.3631	4.4	1.660	2.754
.5957	.3548	4.5	1.679	2.818
.5888	.3467	4.6	1.698	2.884
.5821	.3388	4.7	1.718	2.951
.5754	.3311	4.8	1.738	3.020
.5689	.3236	4.9	1.758	3.090

Voltage Ratio	*Power Ratio*	*dB* (← − dB + →)	*Voltage Ratio*	*Power Ratio*
.5623	**3162**	**5.0**	**1.778**	**3.162**
.5559	.3090	5.1	1.799	3.236
.5495	.3020	5.2	1.820	3.311
.5433	.2951	5.3	1.841	3.388
.5370	.2884	5.4	1.862	3.467
.5309	.2818	5.5	1.884	3.548
.5248	.2754	5.6	1.905	3.631
.5188	.2692	5.7	1.928	3.715
.5129	.2630	5.8	1.950	3.802
.5070	.2570	5.9	1.972	3.890
.5012	**.2512**	**6.0**	**1.995**	**3.981**
.4955	.2455	6.1	2.018	4.074
.4898	.2399	6.2	2.042	4.169
.4842	.2344	6.3	2.065	4.266
.4786	.2291	6.4	2.089	4.365
.4732	.2239	6.5	2.113	4.467
.4677	.2188	6.6	2.138	4.571
.4624	.2138	6.7	2.163	4.677
.4571	.2089	6.8	2.188	4.786
.4519	.2042	6.9	2.213	4.898
.4467	**.1995**	**7.0**	**2.239**	**5.012**
.4416	.1950	7.1	2.265	5.129
.4365	.1905	7.2	2.291	5.248
.4315	.1862	7.3	2.317	5.370
.4266	.1820	7.4	2.344	5.495
.4217	.1778	7.5	2.371	5.623
.4169	.1738	7.6	2.399	5.754
.4121	.1698	7.7	2.427	5.888
.4074	.1660	7.8	2.455	6.026
.4027	.1622	7.9	2.483	6.166
.3981	**.1585**	**8.0**	**2.512**	**6.310**
.3936	.1549	8.1	2.541	6.457
.3890	.1514	8.2	2.570	6.607
.3846	.1479	8.3	2.600	6.761
.3802	.1445	8.4	2.630	6.918
.3758	.1413	8.5	2.661	7.079
.3715	.1380	8.6	2.692	7.244
.3673	.1349	8.7	2.723	7.413
.3631	.1318	8.8	2.754	7.586
.3589	.1288	8.9	2.786	7.762
.3548	**.1259**	**9.0**	**2.818**	**7.943**
.3508	.1230	9.1	2.851	8.128
.3467	.1202	9.2	2.884	8.318
.3428	.1175	9.3	2.917	8.511
.3388	.1148	9.4	2.951	8.710
.3350	.1122	9.5	2.985	8.913
.3311	.1096	9.6	3.020	9.120
.3273	.1072	9.7	3.055	9.333
.3236	.1047	9.8	3.090	9.550
.3199	.1023	9.9	3.126	9.772

TABLE I (continued)

Voltage Ratio (← dB)	Power Ratio (← dB)	dB	Voltage Ratio (dB →)	Power Ratio (dB →)
.3162	**.1000**	**10.0**	**3.162**	**10.000**
.3126	.09772	10.1	3.199	10.23
.3090	.09550	10.2	3.236	10.47
.3055	.09333	10.3	3.273	10.72
.3020	.09120	10.4	3.311	10.96
.2985	.08913	10.5	3.350	11.22
.2951	.08710	10.6	3.388	11.48
.2917	.08511	10.7	3.428	11.75
.2884	.08318	10.8	3.467	12.02
.2851	.08128	10.9	3.508	12.30
.2818	**.07943**	**11.0**	**3.548**	**12.59**
.2786	.07762	11.1	3.589	12.88
.2754	.07586	11.2	3.631	13.18
.2723	.07413	11.3	3.673	13.49
.2692	.07244	11.4	3.715	13.80
.2661	.07079	11.5	3.758	14.13
.2630	.06918	11.6	3.802	14.45
.2600	.06761	11.7	3.846	14.79
.2570	.06607	11.8	3.890	15.14
.2541	.06457	11.9	3.936	15.49
2512	**.06310**	**12.0**	**3.981**	**15.85**
.2483	.06166	12.1	4.027	16.22
.2455	.06026	12.2	4.074	16.60
.2427	.05888	12.3	4.121	16.98
.2399	.05754	12.4	4.169	17.38
.2371	.05623	12.5	4.217	17.78
.2344	.05495	12.6	4.266	18.20
.2317	.05370	12.7	4.315	18.62
.2291	.05248	12.8	4.365	19.05
.2265	.05129	12.9	4.416	19.50
.2239	**.05012**	**13.0**	**4.467**	**19.95**
.2213	.04898	13.1	4.519	20.42
.2188	.04786	13.2	4.571	20.89
.2163	.04677	13.3	4.624	21.38
.2138	.04571	13.4	4.677	21.88
.2113	.04467	13.5	4.732	22.39
.2089	.04365	13.6	4.786	22.91
.2065	.04266	13.7	4.842	23.44
.2042	.04169	13.8	4.898	23.99
.2018	.04074	13.9	4.955	24.55
.1995	**.03981**	**14.0**	**5.012**	**25.12**
.1972	.03890	14.1	5.070	25.70
.1950	.03802	14.2	5.129	26.30
.1928	.03715	14.3	5.188	26.92
.1905	.03631	14.4	5.248	27.54
.1884	.03548	14.5	5.309	28.18
.1862	.03467	14.6	5.370	28.84
.1841	.03388	14.7	5.433	29.51
.1820	.03311	14.8	5.495	30.20
.1799	.03236	14.9	5.559	30.90
.1778	**.03162**	**15.0**	**5.623**	**31.62**
.1758	.03090	15.1	5.689	32.36
.1738	.03020	15.2	5.754	33.11
.1718	.02951	15.3	5.821	33.88
.1698	.02884	15.4	5.888	34.67
.1679	.02818	15.5	5.957	35.48
.1660	.02754	15.6	6.026	36.31
.1641	.02692	15.7	6.095	37.15
.1622	.02630	15.8	6.166	38.02
.1603	.02570	15.9	6.237	38.90

Voltage Ratio (← dB)	Power Ratio (← dB)	dB	Voltage Ratio (dB →)	Power Ratio (dB →)
.1585	**.02512**	**16.0**	**6.310**	**39.81**
.1567	.02455	16.1	6.383	40.74
.1549	.02399	16.2	6.457	41.69
.1531	.02344	16.3	6.531	42.66
.1514	.02291	16.4	6.607	43.65
.1496	.02239	16.5	6.683	44.67
.1479	.02188	16.6	6.761	45.71
.1462	.02138	16.7	6.839	46.77
.1445	.02089	16.8	6.918	47.86
.1429	.02042	16.9	6.998	48.98
.1413	**.01995**	**17.0**	**7.079**	**50.12**
.1396	.01950	17.1	7.161	51.29
.1380	.01905	17.2	7.244	52.48
.1365	.01862	17.3	7.328	53.70
.1349	.01820	17.4	7.413	54.95
.1334	.01778	17.5	7.499	56.23
.1318	.01738	17.6	7.586	57.54
.1303	.01698	17.7	7.674	58.88
.1288	.01660	17.8	7.762	60.26
.1274	.01622	17.9	7.852	61.66
.1259	**.01585**	**18.0**	**7.943**	**63.10**
.1245	.01549	18.1	8.035	64.57
.1230	.01514	18.2	8.128	66.07
.1216	.01479	18.3	8.222	67.61
.1202	.01445	18.4	8.318	69.18
.1189	.01413	18.5	8.414	70.79
.1175	.01380	18.6	8.511	72.44
.1161	.01349	18.7	8.610	74.13
.1148	.01318	18.8	8.710	75.86
.1135	.01288	18.9	8.811	77.62
.1122	**.01259**	**19.0**	**8.913**	**79.43**
.1109	.01230	19.1	9.016	81.28
.1096	.01202	19.2	9.120	83.18
.1084	.01175	19.3	9.226	85.11
.1072	.01148	19.4	9.333	87.10
.1059	.01122	19.5	9.441	89.13
.1047	.01096	19.6	9.550	91.20
.1035	.01072	19.7	9.661	93.33
.1023	.01047	19.8	9.772	95.50
.1012	.01023	19.9	9.886	97.72
.1000	**.01000**	**20.0**	**10.000**	**100.00**

Voltage Ratio (← dB)	Power Ratio (← dB)	dB	Voltage Ratio (dB →)	Power Ratio (dB →)
3.162×10^{-1}	10^{-1}	10	3.162	10
10^{-1}	10^{-2}	20	10	10^{2}
3.162×10^{-2}	10^{-3}	30	3.162×10	10^{3}
10^{-2}	10^{-4}	40	10^{2}	10^{4}
3.162×10^{-3}	10^{-5}	50	3.162×10^{2}	10^{5}
10^{-3}	10^{-6}	60	10^{3}	10^{6}
3.162×10^{-4}	10^{-7}	70	3.162×10^{3}	10^{7}
10^{-4}	10^{-8}	80	10^{4}	10^{8}
3.162×10^{-5}	10^{-9}	90	3.162×10^{4}	10^{9}
10^{-5}	10^{-10}	100	10^{5}	10^{10}

To find decibel values outside the range of this table, see page 299.

TABLE II

GIVEN: $\left\{\begin{matrix}\text{Voltage}\\ \text{Current}\end{matrix}\right\}$ **Ratio**

TO FIND: Decibels

POWER RATIOS

To find the number of decibels corresponding to a given power ratio — Assume the given power ratio to be a voltage ratio and find the corresponding number of decibels from the table. The desired result is exactly one-half of the number of decibels thus found.

Example — *Given:* a power ratio of 3.41.

Find: 3.41 in the table:

3.41 → 10.655 dB (voltage)
10.655 dB × ½ = 5.328 dB (power)

Voltage Ratio	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
1.0	**.000**	**.086**	**.172**	**.257**	**.341**	**.424**	**.506**	**.588**	**.668**	**.749**
1.1	.828	.906	.984	1.062	1.138	1.214	1.289	1.364	1.438	1.511
1.2	1.584	1.656	1.727	1.798	1.868	1.938	2.007	2.076	2.144	2.212
1.3	2.279	2.345	2.411	2.477	2.542	2.607	2.671	2.734	2.798	2.860
1.4	2.923	2.984	3.046	3.107	3.167	3.227	3.287	3.346	3.405	3.464
1.5	3.522	3.580	3.637	3.694	3.750	3.807	3.862	3.918	3.973	4.028
1.6	4.082	4.137	4.190	4.244	4.297	4.350	4.402	4.454	4.506	4.558
1.7	4.609	4.660	4.711	4.761	4.811	4.861	4.910	4.959	5.008	5.057
1.8	5.105	5.154	5.201	5.249	5.296	5.343	5.390	5.437	5.483	5.529
1.9	5.575	5.621	5.666	5.711	5.756	5.801	5.845	5.889	5.933	5.977
2.0	**6.021**	**6.064**	**6.107**	**6.150**	**6.193**	**6.235**	**6.277**	**6.319**	**6.361**	**6.403**
2.1	6.444	6.486	6.527	6.568	6.608	6.649	6.689	6.729	6.769	6.809
2.2	6.848	6.888	6.927	6.966	7.008	7.044	7.082	7.121	7.159	7.197
2.3	7.235	7.272	7.310	7.347	7.384	7.421	7.458	7.495	7.532	7.568
2.4	7.604	7.640	7.676	7.712	7.748	7.783	7.819	7.854	7.889	7.924
2.5	7.959	7.993	8.028	8.062	8.097	8.131	8.165	8.199	8.232	8.266
2.6	8.299	8.333	8.366	8.399	8.432	8.465	8.498	8.530	8.563	8.595
2.7	8.627	8.659	8.691	8.723	8.755	8.787	8.818	8.850	8.881	8.912
2.8	8.943	8.974	9.005	9.036	9.066	9.097	9.127	9.158	9.188	9.218
2.9	9.248	9.278	9.308	9.337	9.367	9.396	9.426	9.455	9.484	9.513
3.0	**9.542**	**9.571**	**9.600**	**9.629**	**9.657**	**9.686**	**9.714**	**9.743**	**9.771**	**9.799**
3.1	9.827	9.855	9.883	9.911	9.939	9.966	9.994	10.021	10.049	10.076
3.2	10.103	10.130	10.157	10.184	10.211	10.238	10.264	10.291	10.317	10.344
3.3	10.370	10.397	10.423	10.449	10.475	10.501	10.527	10.553	10.578	10.604
3.4	10.630	10.655	10.681	10.706	10.731	10.756	10.782	10.807	10.832	10.857
3.5	10.881	10.906	10.931	10.955	10.980	11.005	11.029	11.053	11.078	11.102
3.6	11.126	11.150	11.174	11.198	11.222	11.246	11.270	11.293	11.317	11.341
3.7	11.364	11.387	11.411	11.434	11.457	11.481	11.504	11.527	11.550	11.573
3.8	11.596	11.618	11.641	11.664	11.687	11.709	11.732	11.754	11.777	11.799
3.9	11.821	11.844	11.866	11.888	11.910	11.932	11.954	11.976	11.998	12.019
4.0	**12.041**	**12.063**	**12.085**	**12.106**	**12.128**	**12.149**	**12.171**	**12.192**	**12.213**	**12.234**
4.1	12.256	12.277	12.298	12.319	12.340	12.361	12.382	12.403	12.424	12.444
4.2	12.465	12.486	12.506	12.527	12.547	12.568	12.588	12.609	12.629	12.649
4.3	12.669	12.690	12.710	12.730	12.750	12.770	12.790	12.810	12.829	12.849
4.4	12.869	12.889	12.908	12.928	12.948	12.967	12.987	13.006	13.026	13.045
4.5	13.064	13.084	13.103	13.122	13.141	13.160	13.179	13.198	13.217	13.236
4.6	13.255	13.274	13.293	13.312	13.330	13.349	13.368	13.386	13.405	13.423
4.7	13.442	13.460	13.479	13.497	13.516	13.534	13.552	13.570	13.589	13.607
4.8	13.625	13.643	13.661	13.679	13.697	13.715	13.733	13.751	13.768	13.786
4.9	13.804	13.822	13.839	13.857	13.875	13.892	13.910	13.927	13.945	13.962
5.0	**13.979**	**13.997**	**14.014**	**14.031**	**14.049**	**14.066**	**14.083**	**14.100**	**14.117**	**14.134**
5.1	14.151	14.168	14.185	14.202	14.219	14.236	14.253	14.270	14.287	14.303
5.2	14.320	14.337	14.353	14.370	14.387	14.403	14.420	14.436	14.453	14.469
5.3	14.486	14.502	14.518	14.535	14.551	14.567	14.583	14.599	14.616	14.632
5.4	14.648	14.664	14.680	14.696	14.712	14.728	14.744	14.760	14.776	14.791
5.5	14.807	14.823	14.839	14.855	14.870	14.886	14.902	14.917	14.933	14.948
5.6	14.964	14.979	14.995	15.010	15.026	15.041	15.056	15.072	15.087	15.102
5.7	15.117	15.133	15.148	15.163	15.178	15.193	15.208	15.224	15.239	15.254
5.8	15.269	15.284	15.298	15.313	15.328	15.343	15.358	15.373	15.388	15.402
5.9	15.417	15.432	15.446	15.461	15.476	15.490	15.505	15.519	15.534	15.549

TABLE II (continued)

Voltage Ratio	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
6.0	**15.563**	**15.577**	**15.592**	**15.606**	**15.621**	**15.635**	**15.649**	**15.664**	**15.678**	**15.692**
6.1	15.707	15.721	15.735	15.749	15.763	15.778	15.792	15.806	15.820	15.834
6.2	15.848	15.862	15.876	15.890	15.904	15.918	15.931	15.945	15.959	15.973
6.3	15.987	16.001	16.014	16.028	16.042	16.055	16.069	16.083	16.096	16.110
6.4	16.124	16.137	16.151	16.164	16.178	16.191	16.205	16.218	16.232	16.245
6.5	16.258	16.272	16.285	16.298	16.312	16.325	16.338	16.351	16.365	16.378
6.6	16.391	16.404	16.417	16.430	16.443	16.456	16.469	16.483	16.496	16.509
6.7	16.521	16.534	16.547	16.560	16.573	16.586	16.599	16.612	16.625	16.637
6.8	16.650	16.663	16.676	16.688	16.701	16.714	16.726	16.739	16.752	16.764
6.9	16.777	16.790	16.802	16.815	16.827	16.840	16.852	16.865	16.877	16.890
7.0	**16.902**	**16.914**	**16.927**	**16.939**	**16.951**	**16.964**	**16.976**	**16.988**	**17.001**	**17.013**
7.1	17.025	17.037	17.050	17.062	17.074	17.086	17.098	17.110	17.122	17.135
7.2	17.147	17.159	17.171	17.183	17.195	17.207	17.219	17.231	17.243	17.255
7.3	17.266	17.278	17.290	17.302	17.314	17.326	17.338	17.349	17.361	17.373
7.4	17.385	17.396	17.408	17.420	17.431	17.443	17.455	17.466	17.478	17.490
7.5	17.501	17.513	17.524	17.536	17.547	17.559	17.570	17.582	17.593	17.605
7.6	17.616	17.628	17.639	17.650	17.662	17.673	17.685	17.696	17.707	17.719
7.7	17.730	17.741	17.752	17.764	17.775	17.786	17.797	17.808	17.820	17.831
7.8	17.842	17.853	17.864	17.875	17.886	17.897	17.908	17.919	17.931	17.942
7.9	17.953	17.964	17.975	17.985	17.996	18.007	18.018	18.029	18.040	18.051
8.0	**18.062**	**18.073**	**18.083**	**18.094**	**18.105**	**18.116**	**18.127**	**18.137**	**18.148**	**18.159**
8.1	18.170	18.180	18.191	18.202	18.212	18.223	18.234	18.244	18.255	18.266
8.2	18.276	18.287	18.297	18.308	18.319	18.329	18.340	18.350	18.361	18.371
8.3	18.382	18.392	18.402	18.413	18.423	18.434	18.444	18.455	18.465	18.475
8.4	18.486	18.496	18.506	18.517	18.527	18.537	18.547	18.558	18.568	18.578
8.5	18.588	18.599	18.609	18.619	18.629	18.639	18.649	18.660	18.670	18.680
8.6	18.690	18.700	18.710	18.720	18.730	18.740	18.750	18.760	18.770	18.780
8.7	18.790	18.800	18.810	18.820	18.830	18.840	18.850	18.860	18.870	18.880
8.8	18.890	18.900	18.909	18.919	18.929	18.939	18.949	18.958	18.968	18.978
8.9	18.988	18.998	19.007	19.017	19.027	19.036	19.046	19.056	19.066	19.075
9.0	**19.085**	**19.094**	**19.104**	**19.114**	**19.123**	**19.133**	**19.143**	**19.152**	**19.162**	**19.171**
9.1	19.181	19.190	19.200	19.209	19.219	19.228	19.238	19.247	19.257	19.226
9.2	19.276	19.285	19.295	19.304	19.313	19.323	19.332	19.342	19.351	19.360
9.3	19.370	19.379	19.388	19.398	19.407	19.416	19.426	19.435	19.444	19.453
9.4	19.463	19.472	19.481	19.490	19.499	19.509	19.518	19.527	19.536	19.545
9.5	19.554	19.564	19.573	19.582	19.591	19.600	19.609	19.618	19.627	19.636
9.6	19.645	19.654	19.664	19.673	19.682	19.691	19.700	19.709	19.718	19.726
9.7	19.735	19.744	19.753	19.762	19.771	19.780	19.789	19.798	19.807	19.816
9.8	19.825	19.833	19.842	19.851	19.860	19.869	19.878	19.886	19.895	19.904
9.9	19.913	19.921	19.930	19.939	19.948	19.956	19.965	19.974	19.983	19.991

Voltage Ratio	0	1	2	3	4	5	6	7	8	9
10	**20.000**	**20.828**	**21.584**	**22.279**	**22.923**	**23.522**	**24.082**	**24.609**	**25.105**	**25.575**
20	26.021	26.444	26.848	27.235	27.604	27.959	28.299	28.627	28.943	29.248
30	29.542	29.827	30.103	30.370	30.630	30.881	31.126	31.364	31.596	31.821
40	32.041	32.256	32.465	32.669	32.869	33.064	33.255	33.442	33.625	33.804
50	33.979	34.151	34.320	34.486	34.648	34.807	34.964	35.117	35.269	35.417
60	35.563	35.707	35.848	35.987	36.124	36.258	36.391	36.521	36.650	36.777
70	36.902	37.025	37.147	37.266	37.385	37.501	37.616	37.730	37.842	37.953
80	38.062	38.170	38.276	38.382	38.486	38.588	38.690	38.790	38.890	38.988
90	39.085	39.181	39.276	39.370	39.463	39.554	39.645	39.735	39.825	39.913
100	**40.000**	—	—	—	—	—	—	—	—	—

To find decibel values outside the range of this table, see page 299.

REACTANCE CHART

Always use corresponding scales

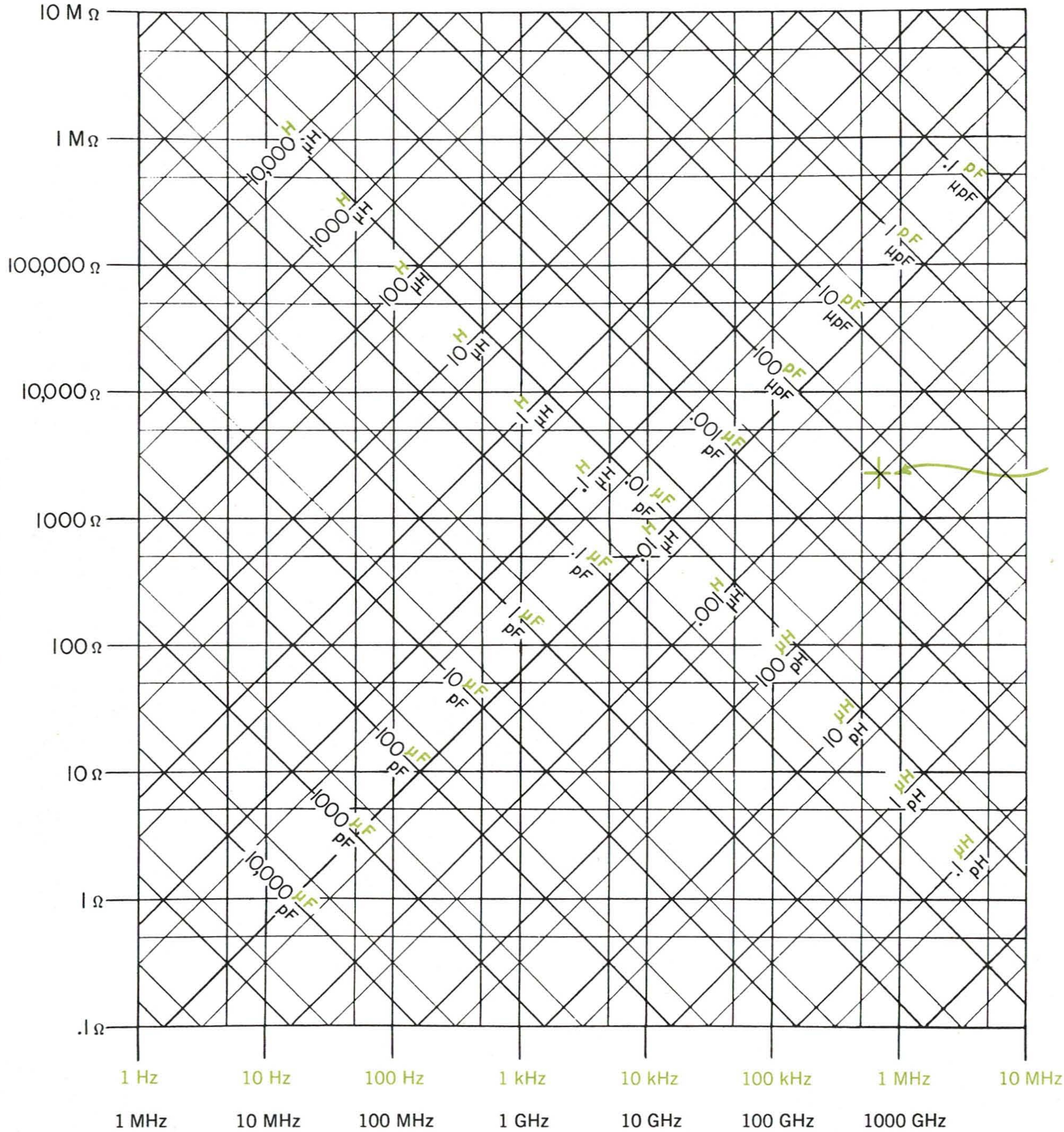


FIGURE 1

Figure 1 is the complete chart, used for rough calculations. Figure 2, which is a single decade of Figure 1 enlarged approximately 7 times, is used where two or three significant figures are to be determined.

TO FIND REACTANCE

Enter the charts vertically from the bottom (frequency) and along the lines slanting upward to the left (capacitance) or to the right (inductance). Corresponding scales (green or black) must be used throughout. Project horizontally to the left from the intersection and read reactance.

TO FIND RESONANT FREQUENCY

Enter the slanting lines for the given inductance and capacitance. Project downward and read resonant frequency from the bottom scale. **Corresponding scales (green or black) must be used throughout.**

REACTANCE CHART

Always obtain approximate value from Figure 1 before using Figure 2

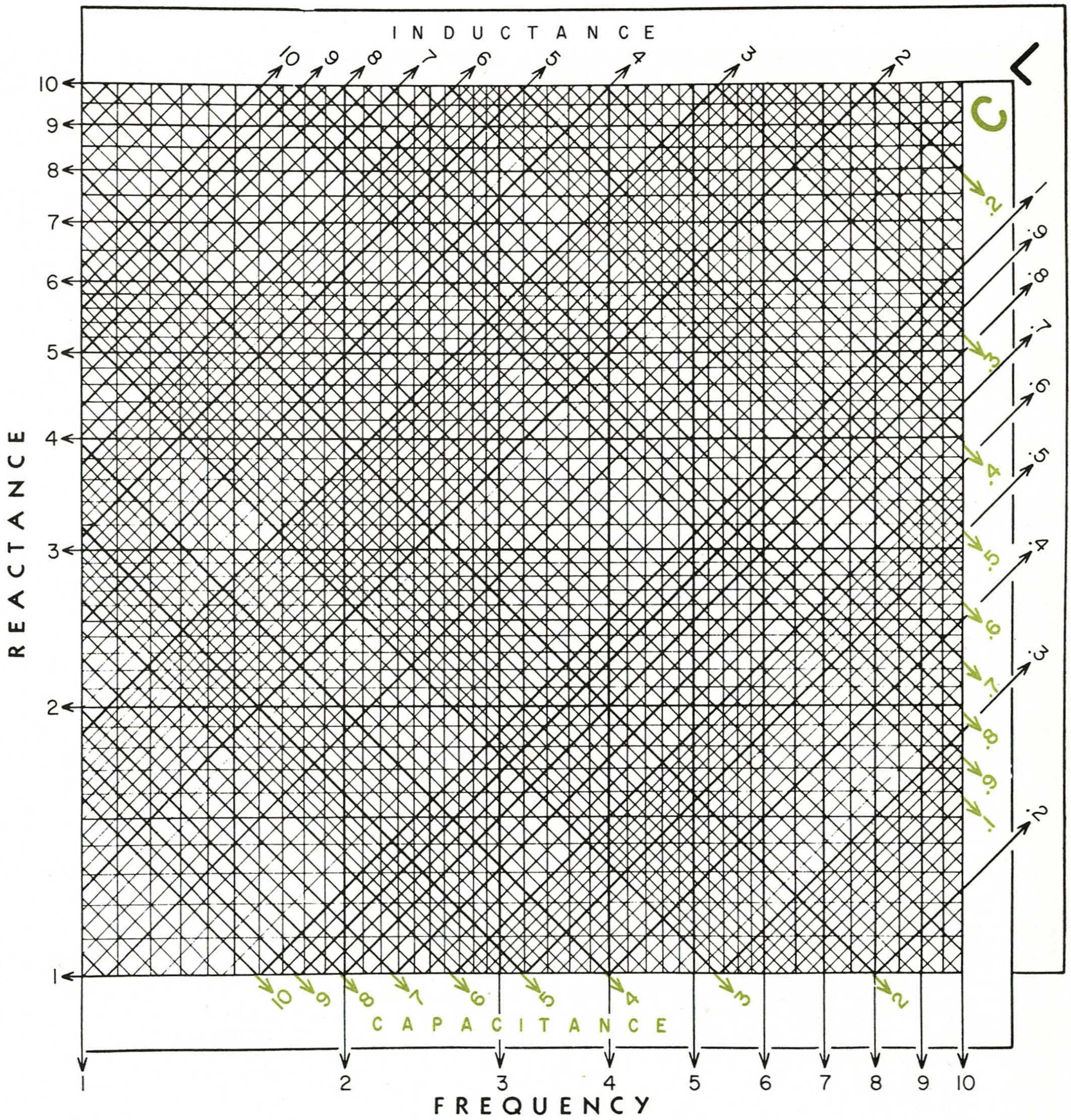


FIGURE 2

Example: The point indicated in Figure 1 corresponds to a frequency of about 700 kHz and an inductance of 500 μH, or a capacitance of 100 pF, giving in either case a reactance of about 2000 ohms. The resonant frequency of a circuit containing these values of inductance and capacitance is, of course, 700 kHz, approximately.

USE OF FIGURE 2

Figure 2 gives additional precision but does not place the decimal point, which must be located from a preliminary entry on Figure 1. Since the chart necessarily requires two logarithmic decades for inductance and capacitance for every single decade of frequency and reactance, unless the correct decade for L and C is chosen, the calculated values of reactance and frequency will be in error by a factor of 3.16. In Figure 2, the capacitance scale is green; inductance scale is black.

Example: (Continued) The reactance corresponding to 500 μH or 100 pF is 2230 ohms at 712 kHz, their resonant frequency.

Index By Type Number

Index By Type Number

(cont'd)

Index By Type Number

(cont'd)

Index By Subject and Title

Index By Subject and Title

(cont'd)

Index By Subject and Title

(cont'd)

Index By Subject and Title

(cont'd)

Index By Subject and Title

(cont'd)

Federal Stock Numbers for GR Instruments

GR Type No.	Fed. Stock No.
M2	5950-121-5326
M2G2	5950-577-6989
M2G3	5950-557-6988
M5	5950-615-0209
M5G3	5950-521-8076
M5G3BB	6120-023-3819
M5HG2	5950-859-1151
M10	6120-812-7681
M10G2	5950-755-9349
M10G3	5950-504-9047
M20	6120-824-7393
M20G3	6120-725-4226
M20G3M	6120-810-3761
W2	5950-606-8682
W2M	5950-683-3641
W2G2	5950-082-8153
W2G3	6120-837-7133
W2G3 (MFP)	5950-556-1724
W2MT	5950-866-5221
W5	5950-951-9647
W5M	5950-553-6657
W5MT	5950-823-1051
W5MT3	5950-617-9242
W5G2	6120-884-1441
W5G3	6120-681-6930
W5G3M	6120-879-3698
W5MT3A	5950-937-5601
W5MT3W	4931-777-1385
W5MT3VM	5950-112-3440
W5H	5950-809-5379
W5HM	5950-835-4462
W5HMT	5950-681-7431
W5L	6120-845-1176
W5LG3	5820-756-5566
W8L	6120-105-6108
W10	6120-849-2588
W10M	6120-816-1517
W10MT	6120-772-7917
W10MT3	5950-682-2557
W10MT3A	6120-054-7794
W10G3	6120-805-0745
W10H	6120-660-9211
W10HM	6120-828-1490
W10HMT	5950-686-2153
W10HMT3	6625-073-2226
W20	6120-800-2482
W20M	6120-834-2923
W20MT3	6120-833-0904
W20G3	6120-669-8565
W20BB	6120-987-5874
W20MBB	5950-927-7805
W20G2BB	5950-067-4294
W20G2MBB	5950-927-7803
W20G3BB	5950-068-5180
W20H	6120-710-5747
W20HM	5950-877-7923
W20HMT3A	5950-926-0742
W30	5950-078-1445
W30HM	6120-849-8928
W50	6120-681-6862
W50M	6120-769-1140
W50G2	6120-911-9777
W50MBB	6120-894-1826
W50HG2M	6120-927-7826
W50HG3	6120-811-0505
VB1	5977-536-3287
VB2	5977-504-7048
VBT-2	5977-964-8075
VBT-4	5977-542-7940
VBT-5	5977-533-8036

GR Type No.	Fed. Stock No.
VBT-6	5977-775-6799
VBT-8	5977-727-9061
VBT-10	5977-880-1553
VBT-11	5977-033-8550
VBT-12	5977-877-6844
VBT-13	5977-841-5878
107-J	6625-669-0342
107-K	6625-669-0343
107-L	6625-310-8813
107-M	6625-448-0307
107-N	6625-989-5438
500-T	6625-585-6119
510-P4L	5930-499-1999
510-P4	5930-499-2000
510-A	6625-553-8082
510-B	6625-311-6104
510-C	6625-993-1190
510-D	6625-864-6074
510-E	6625-709-0308
510-F	6625-709-0310
510-G	6625-708-7235
510-H	5905-561-4160
510-AA	6625-690-5156
631-P1	5960-193-5124
716-C	6625-649-2961
716-P4	4931-522-1487
874-D20L	5985-912-1544
874-D50L	6625-623-0067
874-EL	5935-627-0622
874-EL-L	5935-933-8153
874-F500L	5915-786-9168
874-F1000L	5915-937-5404
874-F2000L	5915-907-8721
874-F4000L	5915-907-8722
874-G3	5985-525-3010
874-G6	5905-812-9250
874-G10	5905-755-2378
874-G10L	5985-087-4715
874-G20	5985-080-2122
874-GAL	5950-752-3144
874-K	6625-887-7753
874-L10	6625-713-2108
874-L20	6625-713-2109
874-L30	6625-715-5578
874-LAL	5985-911-0540
874-LTL	4920-922-6219
874-LR	6625-059-7768
874-MB	6625-020-9712
874-R20A	6625-789-4723
874-R22A	5995-754-8178
874-R22LA	5995-933-6852
874-R33	6625-793-1351
874-R34	6625-729-4629
874-QBJA	5935-765-5481
874-QBJL	5935-961-5498
874-QCJA	5985-707-2830
874-QHJA	6625-706-6269
874-QLJA	5935-053-0040
874-QLTJ	5935-983-9825
874-QNJA	5935-833-7247
874-QNJL	5935-905-5335
874-QTNJ	5935-758-9529
874-QTNJL	5935-904-8557
874-QUJ	5935-502-8354
874-QAP7L	5935-420-3645
874-QBPA	5935-671-8326
874-QCP	5935-706-2827
874-QHPA	5935-921-8789
874-QLPA	5935-733-5911
874-QLTP	5935-983-9824

GR Type No.	Fed. Stock No.
874-QNP	5935-225-8768
874-QTNP	5935-761-0408
874-QUP	5935-666-4873
874-QMDP	5935-887-6008
874-C8A	5935-916-0791
874-CL8A	5935-789-6031
874-C58A	5935-981-7264
874-CL58A	5935-914-8878
874-PBA	5935-840-7284
874-PB8A	5935-965-6178
874-PB58A	5935-944-3687
874-PFL	5935-925-6261
874-PRL58A	5935-925-6262
874-Q2	5935-555-1885
874-Q9	5935-949-8608
874-T	5935-864-9958
874-UB	6625-713-2110
874-VI	6625-864-1551
874-VQ	6625-793-1352
874-VR	5985-778-2146
874-MR	6625-624-7149
874-W50B	5985-992-2109
874-WN3	6625-706-2829
874-WO	5935-888-4296
874-WO3	5935-707-2931
874-X	5935-669-5817
900-BT	5935-000-0202
900-QNJ	5935-838-2722
900-QNP	5935-838-2723
900-WN	5985-083-4708
916-AL	6625-649-3054
940-E	6625-842-4869
940-F	6625-842-4871
940-G	6625-842-4868
940-H	6625-842-4872
1001-A	6625-866-0168
1115-B	6625-538-9694
1142-A	6625-988-2524
1162-A7C	6625-333-9860
1191-B	6625-926-7641
1201-C	6625-902-9745
1203-B	6625-777-6438
1208-C	6625-935-1343
1210-C	4920-925-7490
1211-C	4931-777-1384
1212-A	6625-472-9585
1215-C	6625-965-8235
1216-A	6625-783-9002
1217-C	6625-903-5469
1218-B	6625-920-1006
1230-A	6625-975-4005
1232-A	6625-873-6684
1235-9607	6625-575-6669
1262-B	4931-891-3070
1263-C	6625-061-0214
1269-A	6625-871-8018
1304-B	6625-585-9736
1310-A	6625-054-3476
1311-A	6625-930-3449
1330-A	6625-553-0969
1390-B	6625-799-8999
1401-A	6625-585-3990
1401-B	6625-585-3992
1401-C	6625-585-3989
1403-A	6625-730-8565
1403-D	6625-804-7402
1403-G	6625-804-7401
1403-K	6625-804-9059
1403-N	6625-804-9053
1404-A	4931-916-5949

Federal Stock Numbers for GR Instruments

(cont'd)

GR Type No.	Fed. Stock No.
1409-F	6625-629-1983
1409-G	6625-804-9058
1409-K	6625-585-4052
1409-L	6625-585-4053
1409-M	6625-583-0038
1409-R	6625-557-0876
1409-T	6625-585-4051
1409-U	6625-585-4050
1409-X	6625-653-1565
1409-Y	6625-629-1980
1419-A	6625-953-7537
1419-K	6625-585-1670
1422-D	6625-987-9060
1422-CC	6625-846-4429
1422-CD	6625-779-3602
1422-ME	6625-060-1818
1422-CB	6625-891-5939
1423-A	6625-775-1753
1424-A	6625-731-7404
1432-J	6625-649-5057
1433-U	6625-892-4783
1433-K	6625-649-4037
1433-N	6625-649-0034
1433-P	6625-228-9918
1433-X	6625-947-7534
1434-G	6625-067-9025
1434-M	6625-229-6642
1440-9601	6625-133-7548
1450-TA	6625-201-8779
1450-TB	6625-612-1837

GR Type No.	Fed. Stock No.
1455-AH	6625-722-1569
1481-C	6625-614-8202
1481-M	6625-820-6185
1482-B	6625-583-0040
1482-C	6625-804-4125
1482-D	6625-806-8627
1482-E	6625-567-2700
1482-F	6625-580-1501
1482-G	6625-580-1502
1482-H	6625-583-0041
1482-J	6625-993-9456
1482-K	6625-556-8585
1482-L	6625-556-8584
1482-M	6625-804-4129
1482-N	6625-804-4130
1482-P	6625-583-0044
1482-Q	6625-993-9458
1482-R	6625-993-9459
1482-T	6625-583-0043
1521-9428	6625-864-0631
1521-9463	6625-862-0632
1521-P1	5905-448-5331
1521-P2	5905-448-5335
1521-P3	5905-448-5334
1521-P4	5905-448-5712
1531-AB	6680-880-1844
1531-P1	5960-844-5968
1538-P1	5960-781-1466
1551-C	6625-969-4136
1553-A	6625-103-3117

GR Type No.	Fed. Stock No.
1556-B	6625-994-9424
1557-A	6625-879-5114
1560-P5	5965-971-5635
1560-P21B	6625-086-9982
1564-A	6625-883-8858
1565-A	6625-912-6149
1568-A	6625-974-3558
1571-AL	6610-087-4771
1602-B	6625-511-0512
1603-A	6625-976-7969
1605-AH	6625-993-5608
1606-A	6625-553-8473
1606-B incl P2	6625-103-2040
1608-A	6625-902-8687
1609-A	6625-106-0643
1610-B	6625-059-6562
1620-A	4931-916-5952
1632-A	6625-476-0593
1644-A	6625-867-6628
1650-B	6625-444-6084
1652-A	6625-802-5040
1750-A	6625-087-0632
1806-A	6625-832-8956
1840-A	6625-937-6156
1862-C	6625-880-9446
1863-9700	6625-456-7442
1911-AS2	6625-930-6313
2990-9201	4931-178-1108
2990-9159	6625-411-4538

GENERAL RADIO COMPANY

MAIN OFFICE AND PLANT: WEST CONCORD, MASSACHUSETTS 01781

FOR SALES DEPARTMENT:

See below for most convenient office

FOR GENERAL BUSINESS:

Telephone: (From Metropolitan Boston) 646-7400
(From all other locations) 617 369-4400

TWX NO. 710 347-1051
Cable Address: GENRADCO CONCORD (MASS)

SALES ENGINEERING OFFICES IN NORTH AMERICA

OFFICE		SALES AREA	TELEPHONE AND TWX
ATLANTA	1711 Tullie Circle, N.E. Suite 113 Atlanta, Georgia 30329	Georgia Florida (Panhandle Only) Tenn. (Knoxville East Only) South Mississippi	Local: 404 633-6183 Toll Free: 800 241-5122 TWX: 810 751-3118
Cocoa Beach		Florida (Less Panhandle)	Toll Free: 800 241-5122
Huntsville		Alabama North Mississippi Tenn. (Knoxville West)	Toll Free: 800 241-5122
BOSTON	Bolton, Massachusetts 01740	Maine, Massachusetts, New Hampshire, Vermont, Rhode Island	Bolton: 617 779-5562 Boston: 617 646-0550 TWX: 710 347-1051
Hartford		Western Massachusetts, Upper Connecticut	203 658-2496
***CHICAGO**	9440 West Foster Avenue Chicago, Illinois 60656	Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Wisconsin	312 992-0800 TWX: 910 221-5486
Detroit		Michigan	313 261-1750
Indianapolis		Indiana	317 636-3907
***CLEVELAND**	5579 Pearl Road Cleveland, Ohio 44129	Northern Ohio, Western Pennsylvania	216 886-0150 TWX: 810 421-8320
Dayton		Southern Ohio, Kentucky	513 434-6979
***DALLAS**	2600 Stemmons Freeway Suite 210 Dallas, Texas 75207	Texas, Arkansas, Louisiana, Oklahoma	214 637-2240 TWX: 910 861-4229
Houston		Austin, San Antonio, Houston Area	713 464-5112
***LOS ANGELES**	17361 Armstrong Avenue Irvine Industrial Complex Santa Ana, California 92705	Arizona, Southern California, New Mexico, Hawaii	714 540-9830 TWX: 910 595-1762
Albuquerque		New Mexico, Colorado, Wyoming	505 265-1097
Burbank		Kern, Ventura, Santa Barbara, San Luis Obispo, Northern half of Los Angeles	714 540-9830
Denver			303 447-9225
San Diego		San Juan Capistrano, Orange, Riverside	714 540-9830
***METROPOLITAN NEW YORK**	845 Broad Avenue Ridgefield, New Jersey 07657	New York City and vicinity Long Island, Northern New Jersey	(N.Y.) 212 964-2722 (N.J.) 201 943-3140 TWX: 710 992-8960
Bridgeport			203 377-0165
Groton		Lower Connecticut	203 445-8445
Long Island		Long Island	201 943-3140
PHILADELPHIA	Fort Washington Industrial Park Fort Washington, Pennsylvania 19034	Delaware, Eastern Pennsyl- vania, Southern New Jersey	215 646-8030 TWX: 510 661-2920
***SAN FRANCISCO**	P. O. Box 1389 626 San Antonio Road Mountain View, California 94040	Northern California, Idaho, Nevada, Utah	415 948-8233 TWX: 910 370-7459
Anchorage	Harry J. Lang & Associates 1406 West 47th Avenue Anchorage, Alaska 99503	Alaska	907 279-5741
Seattle		Oregon, Washington, Montana	206 747-9190
SYRACUSE	Pickard Building East Molloy Road Syracuse, New York 13211	Upstate New York (East)	315 454-9323 TWX: 710 541-0464
Rochester		Upstate New York (West)	315 454-9323
***WASHINGTON & BALTIMORE**	P. O. Box 2205 11420 Rockville Pike Rockville, Maryland 20852	D.C., Maryland, Virginia, West Virginia	301 881-5333 TWX: 710 828-9780
Greensboro		North and South Carolina	919 288-4316
***TORONTO**	307 Evans Avenue Toronto 530, Ontario	Ontario and Western Provinces	416 252-3395 TELEX: 02-29294
Montreal		Maritime and Quebec Provinces	514 737-3673
Ottawa		Ottawa	613 233-4237

*SERVICE, INCLUDING REPAIRS, CALIBRATION, AND SPARE PARTS, AVAILABLE AT THESE OFFICES.

GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS 01781, USA

INTERNATIONAL DIVISION

■ **Telephone:** 369-4400 (Code 617) ■ **Cable Address:** GENRADCO CONCORD (MASS.) ■ **Telex:** 094-594 GENRADCO WCRD

SERVING THE MIDDLE AND EAST ASIA, PACIFIC, AND LATIN AMERICA

DISTRIBUTORS

***ARGENTINA AND PARAGUAY**
Coasin S.A.
Virrey del Pino 4071
Buenos Aires, Argentina
Tel: 52-3185
Cable: COASIN-BUENOS AIRES
Telex: 012-2284

***AUSTRALIA**
Warburton Franki (Adelaide) Pty. Limited
322 Grange Road
Kidman Park, South Australia 5025
(Post Box 683F, G.P.O., Adelaide 5001)
Tel: 56.7333
Cable: ZELEMITE-ADELAIDE
Telex: Warfran AA82579

Warburton Franki (Brisbane) Pty. Limited
13 Chester Street, Fortitude Valley
P. O. Box 345
Queensland 4006, Australia
Tel: 51.5121
Cable: FRIGDEL-BRISBANE

Warburton Franki Industries (Melbourne) Pty. Limited
220 Park Street
P. O. Box 35
South Melbourne, Victoria 3205 Australia
Tel: 69.0151
Cable: IGNITION-MELBOURNE
Telex: Warfran AA31370

Warburton Franki Industries (Sydney) Pty. Limited
307 Kent Street
Box 1523, G.P.O.
Sydney, N.S.W. 2001 Australia
Tel: 29.1111
Cable: BOOSTER-SYDNEY

***BRAZIL**
Ambriex S.A.
Av. Graça Aranha, 226 - 6° and -s/601/609
Rio de Janeiro, Brazil
Tel: 242-7990
Cable: RAIOCARDIO RIODEJANEIRO

Ambriex S.A.
Av. Pacaembú 811
São Paulo, Brazil
Tel: 52-7806
Cable: RAIOCARDIO SAOPAULO

CHILE
Coasin Chile Ltda.
Casilla 14588 — Correo 15
Santiago, Chile
Tel: 39-6713
Cable: COACHIL-SANTIAGO

COLOMBIA
Manuel Trujillo Venegas e Hijo, Ltda.
Carrera 7a, No. 48-71
Apartado Aéreo 20702
Bogota, D.E., Colombia
Tel: 320679
Cable: TRUVEHIJOS-BOGOTA

ECUADOR
Suministros Tecnicos Ltda.
Rumichaca 825
P. O. Box 259-4492
Guayaquil, Ecuador
Tel: 512-419
Cable: SUMITEC-GUAYAQUIL

HONG KONG AND MACAU
Gilman & Co. Ltd.
Alexandra House, 8th Floor
Des Voeux Road, Central
P. O. Box 56
Hong Kong, B.C.C.
Tel: 227011
Cable: GILMAN-HONGKONG
Telex: HX 3358

INDIA
Motwane Private Limited
127 Mahatma Gandhi Road
P. O. Box No. 1312
Bombay 1, India
Tel: 252337
Cable: CHIPHONE-BOMBAY
Telex: (011) 2456
Branches: Bangalore, Calcutta, Kanpur, Lucknow, Madras, New Delhi

***JAPAN**
Midoriya Electric Co., Ltd.
3, 2-chome, Kyobashi, Chuo-ku
Tokyo, 104, Japan
Tel: 561-8851
Cable: MIDRIYAELC-TOKYO
Telex: TK4531

KOREA
M-C International
717 Market Street
San Francisco, California 94103
Tel: (415) 397-1455
Cable: EMCEE SAN FRANCISCO
Telex: (ITT): 470130, (RCA): 27212, (WUI): 67604

M-C International
Room 516, Bando Building
Seoul, Korea
Tel: 22-6891
Cable: EMCEEKOREA SEOUL
Telex: 7872428S

MALAYSIA
Vanguard Company
87, Jalan Ampang
P. O. Box No. 975
Kuala Lumpur, Malaysia
Tel: 88213
Cable: VANCO-KUALA LUMPUR

***MEXICO**
Electronica Fredin, S.A.
Avenida Pedregal 50
Lomas de Chapultepec
México 10, D.F. México
Tel: 20-89-48

***NEW ZEALAND**
W. & K. McLean Limited
103-105 Felton Mathew Avenue
P.O. Box 3097
Auckland 1, New Zealand
Tel: 587-039
Cable: KOSFY-AUCKLAND

W. & K. McLean Limited
181 Upper Willis Street
G.P.O. Box 496
Wellington 1, New Zealand
Tel: 555-869
Cable: KOSFY-WELLINGTON

PAKISTAN
Pak Land Corporation
Central Commercial Area
P.E.C.H. Society
Karachi 29, Pakistan
Tel: 472315
Cable: PAKLAND-KARACHI

PERU
Importaciones y Representaciónes Electronicas S.A.
Avda. Franklin D. Roosevelt 105
Lima 1, Perú
Tel: 272076
Cable: IREING-LIMA

PHILIPPINES
T. J. Wolff & Company
2212 Pasong Tamo Street
Makati, Rizal, Philippines
Tel: 89-34-86
Cable: WOLCO-MANILA

SINGAPORE
Vanguard Company
16, Cecil Street
P. O. Box 983
Singapore 2, Singapore
Tel: 94695

TAIWAN
Heighten Trading Company, Limited
16, Nanking East Road, Section 3
P. O. Box 1408
Taipei, Taiwan, Republic of China
Tel: 518324
Cable: HEIGHTEN-TAIPEI

*REPAIR SERVICES ARE AVAILABLE AT THESE OFFICES

GENERAL RADIO COMPANY INTERNATIONAL DIVISION (continued)

THAILAND
G. Simon Radio Co., Ltd.
30 Patpong Avenue, Suriwong
Bangkok, Thailand
Tel: 30991-3
Cable: SIMONCO-BANGKOK

URUGUAY
Coasin Uruguay S.A.
Cerrito 617-4° Piso
Montevideo, Uruguay
Tel: 9 79 78
Cable: COAUR-MONTEVIDEO

VENEZUELA
Coasin C.A.
Av. Libertador entre Avs. Las Palmas y Las Acacias
Edif. La Linea - Piso 12 - Ofic. 123A
Apartado 50939
Sabana Grande No. 1
Caracas, Venezuela
Tel: 72 96 37
Cable: INSTRUVEN-CARACAS

GENERAL RADIO COMPANY (OVERSEAS)

POSTFACH 124, CH 8034 ZURICH , SWITZERLAND

■ **Telephone:** (051) 47 70 20 ■ **Telex:** 53638 GENRADOVER

SERVING EUROPE, THE NEAR EAST, AND AFRICA

AUSTRIA
Dipl. Ing. Peter Marchetti
Capistrangasse 3
A-1060 Wien, Osterreich
Tel: 57 82 30
Cable: DIGIMETER WIEN

BELGIUM
Groenpol-Belgique S.A.
30, Place Sainctelette
Bruxelles, Belgique
Tel: 02/25 16 36, Telex: 23028

DEMOCRATIC REPUBLIC OF THE CONGO
Desco de Schulthess
Brandschenkestrasse 2
8002 Zürich, Sweiz
Tel: 25 44 50, Telex: 52 547

DENMARK
SEMCO Semler & Co.
1, Aebeløgade
2100 København, Denmark
Tel: (01) 29 03 11, Telex: 9311

EASTERN EUROPE
Please contact:
GENERAL RADIO COMPANY (OVERSEAS)

EIRE
Please contact:
GENERAL RADIO COMPANY (U.K.) LIMITED
or
GENERAL RADIO COMPANY (OVERSEAS)

FINLAND
Into O/Y
P.O. Box 153
Helsinki, Finland
Tel: 11 123
Cable: INTO HELSINKI

***FRANCE**
General Radio France
14, Crespin du Gast
F-75 Paris 11e, France
Tel: 023 5774, Telex: 22991

***GERMANY**
General Radio GmbH
Ampfingstrasse 46
D-8 München 80, BRD
Tel: 40 18 17, Telex: 52 99 17
Hamburg Office:
Isestrasse 3
Hamburg 13, BRD
Tel: 45 06 56

GREECE
Marios Dalleggio Representations
2, Alopekis Street
Athens 139, Greece
Tel: 710 669, Telex: 21 64 35

ISRAEL
Eastronics Ltd.
P.O. Box 21029
Tel Aviv, Israel
Tel: 44 04 66, Telex: 033-638

***ITALY**
General Radio Italia S.p.A.
74/2 Via Valvassori Peroni
I-20133 Milano, Italia
Tel: 29 31 29

NETHERLANDS
Groenpol Industriele Verkoop N.V.
Kabelweg 25
Postbus 1188
Amsterdam-W2, Holland
Tel: 020/64 474, Telex: 11177

NORWAY
Gustav A. Ring A/S
Sørkedalsveien 33
Oslo 3, Norway
Tel: 46 68 90, Telex: 16 234

PORTUGAL
Casa Serras
E. Dias Serras Lda.
Rua Augusta, 228
Lisboa 2, Portugal
Cable: SERRASDOURO

REPUBLIC OF SOUTH AFRICA
G. H. Langler & Co. Ltd.
251 Main Street
P.O. Box 3762
Johannesburg, Republic of South Africa
Tel: 28-2420, 28-4700, Telex: JX 7453

SPAIN
Hispano Electronica S.A.
Commandante Zorita 8
Madrid 20, España
Tel: 233.16.01, Telex: 22404

SWEDEN
Firma Johan Lagercrantz KB
Box 314
S-171 03 Solna 3, Sweden
Tel: 08/83 07 90, Telex: 10 363

SWITZERLAND
Seyffer & Co. A.G.
Badenerstrasse 265
CH-8040 Zürich, Sweiz
Tel: 25 54 11, Telex: 52 540

TURKEY
Mevag Engineering, Trading and Industrial Corporation
Karakoy, Bankalar Caddesi 71-73
P.O. Box 143
Istanbul, Turkey
Tel: 49 83 00
Cable: VASFI-ISTANBUL

***UNITED KINGDOM**
General Radio Company (U.K.) Limited
Bourne End, Buckinghamshire, England
Tel: 22 567, Telex: 84321

YUGOSLAVIA
Please contact:
GENERAL RADIO COMPANY (OVERSEAS)

*REPAIR SERVICES ARE AVAILABLE AT THESE OFFICES

PRINTED IN U.S.A.

FOR FURTHER INFORMATION, QUOTATIONS, DEMONSTRATIONS PLEASE CALL OUR NEAREST OFFICE OR MAIL US ONE OF THE RETURN POSTCARDS

GR Type No.____________________

☐ I would like the following information.____________________

☐ I would like a demonstration.

☐ Please send formal quotation and delivery information.

☐ Other.____________________

Name____________ Title____________

Company Name____________

Room, Bldg., Code or Mail Station____________ Phone____________ Ext.______

Company Address____________
Street City State ZIP

Type of Business____________

CAT U 2 70

GR Type No.____________________

☐ I would like the following information.____________________

☐ I would like a demonstration.

☐ Please send formal quotation and delivery information.

☐ Other.____________________

Name____________ Title____________

Company Name____________

Room, Bldg., Code or Mail Station____________ Phone____________ Ext.______

Company Address____________
Street City State ZIP

Type of Business____________

CAT U 2 70

GR Type No.____________________

☐ I would like the following information.____________________

☐ I would like a demonstration.

☐ Please send formal quotation and delivery information.

☐ Other.____________________

Name____________ Title____________

Company Name____________

Room, Bldg., Code or Mail Station____________ Phone____________ Ext.______

Company Address____________
Street City State ZIP

Type of Business____________

CAT U 2 70

FIRST CLASS
PERMIT NO. 17
WEST CONCORD,
MASSACHUSETTS

BUSINESS REPLY MAIL No Postage Stamp Necessary If Mailed In U.S.A.

Postage will be paid by

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS U.S.A. 01781

Printed in U.S.A.

FIRST CLASS
PERMIT NO. 17
WEST CONCORD,
MASSACHUSETTS

BUSINESS REPLY MAIL No Postage Stamp Necessary If Mailed In U.S.A.

Postage will be paid by

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS U.S.A. 01781

Printed in U.S.A.

FIRST CLASS
PERMIT NO. 17
WEST CONCORD,
MASSACHUSETTS

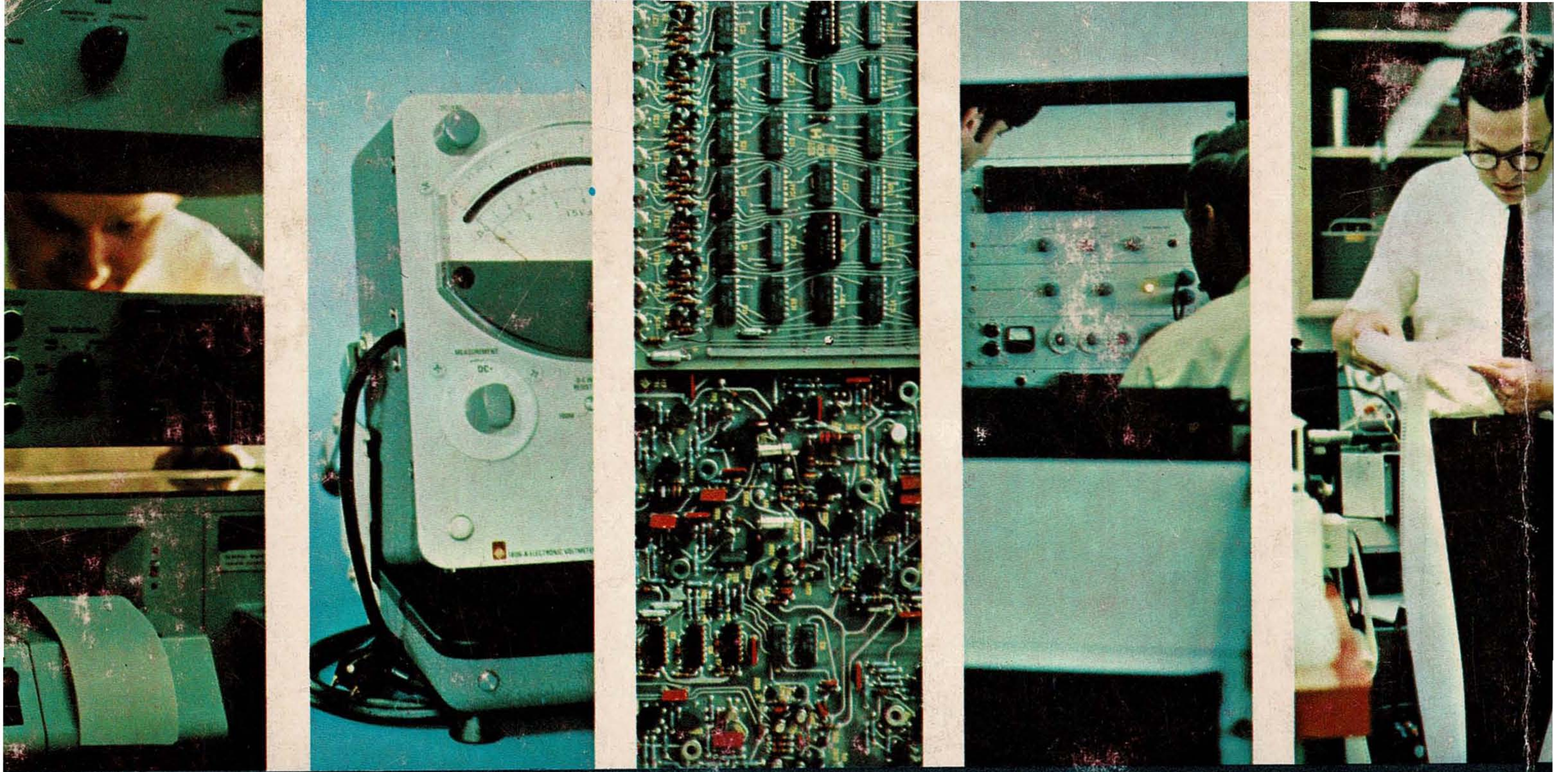
BUSINESS REPLY MAIL No Postage Stamp Necessary If Mailed In U.S.A.

Postage will be paid by

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS U.S.A. 01781

Printed in U.S.A.

FOR FURTHER INFORMATION, QUOTATIONS, DEMONSTRATIONS PLEASE CALL OUR NEAREST OFFICE OR MAIL US ONE OF THE RETURN POSTCARDS



GENERAL RADIO

West Concord, Massachusetts, U S A