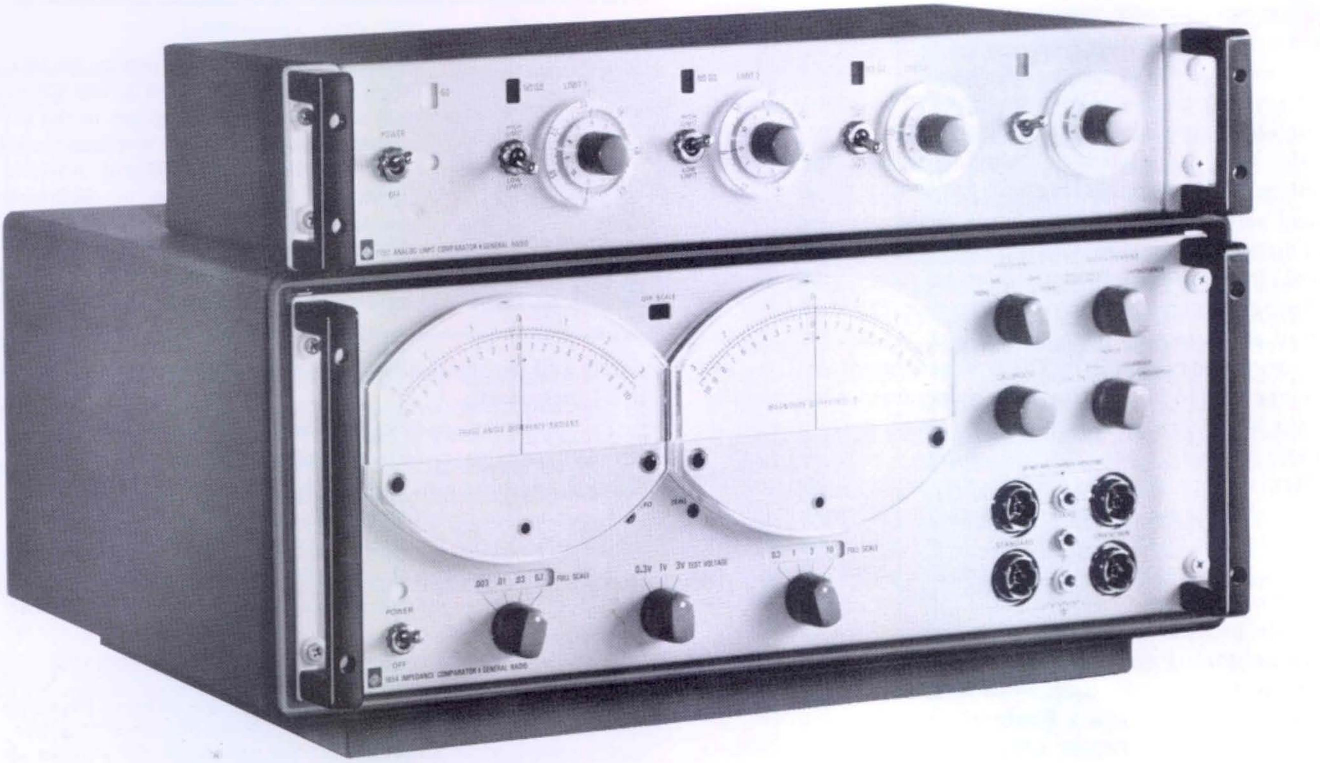


Type 1654 Impedance Comparator with its companion accessory, Type 1782 Analog Limit Comparator.

IMPEDANCE COMPARISON SPRINTS AHEAD

Mobility in measuring impedances, coupled with accuracy, wide range, and ability to control!

The Goal

Over the years, GR has tried to relieve the tedium and monotony of passive component inspection and testing by introducing functional-designed test equipment. For instance, we feel that technicians are able to remain alert for longer periods of time when test data are presented in simple GO/NO GO patterns. Eliminating the time normally required to read panel-meter indications also results in a saving in labor costs. In our estimation, the design of the new GR impedance comparator has successfully joined the concept of complex, programmed testing with the concept of simple, individual component measurements, at no sacrifice in accuracy or reliability.

The first comparison bridge engineered by General Radio for production testing was the manually-operated GR 1604 Comparison Bridge.[1] Several years later, it was followed by the GR 1605 Impedance Comparator,[2] incorporating greater precision and versatility, simultaneously indicating phase-angle and magnitude differences between two external test impedances over an extended frequency range, and requiring no bridge balancing. This bridge was semi-automatic in operation.

In 1964 the GR 1680-A Automatic Capacitance Bridge[3] brought with it a component test rate better than two per second. The inspection-rate bottleneck was broken, and the unit's acceptance by industry encouraged introduction of another digital unit - the GR 1681 Automatic Impedance Comparator System.[4] The customer received digital readout of phase-angle and magnitude differences, higher accuracy and resolution, and greater compatability with automatic component- and data-handling equipment.

Many analog-measurement operations and customers still existed. The need to extend and expand the design of analog comparators was the incentive to develop the latest type of GR comparator, which incorporates automatic features.

The Achievement

The GR 1654 Impedance Comparator supersedes the GR 1605 comparator and, with its companion accessory the GR 1782 Analog Limit Comparator, provides a semi- or fully-automatic system at about one-third the cost of a similar digital system. Measurement features include

- Operating range from 100 Hz to 100 kHz in four steps.

[1] Holtje, M. C., "A New Comparison Bridge for the Rapid Testing of Components," *General Radio Experimenter*, December 1952.

[2] Holtje, M. C., and Hall, H. P. "A High-Precision Impedance Comparator," *General Radio Experimenter*, April 1956.

[3] Fulks, R. G., "The Automatic Capacitance Bridge," *General Radio Experimenter*, April 1965.

[4] Leong, R. K., "The Automatic Impedance Comparator," *General Radio Experimenter*, June-July 1968.

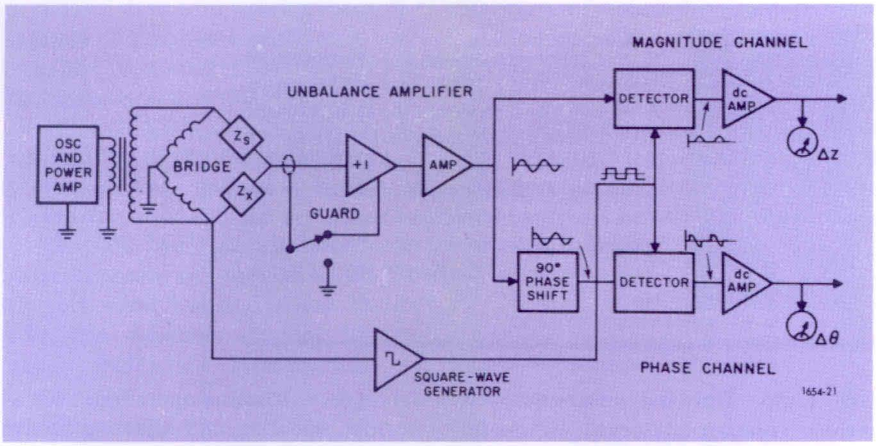


Figure 1. Block diagram of GR 1654 Impedance Comparator.

- Comparison precision to 30 parts per million.
- Impedance range from 2 Ω to 20 MΩ at 100 Hz.
- Capacitance range as low as 0.1 pF direct reading, with a modified substitution method.*
- Six deviation ranges from 0.1% to 30% full scale.
- Test voltages from 0.3 to 3 volts, for easy voltage-coefficient tests.
- Operating rate up to 4 units per second, in the automatic test mode.
- Positive indication of direction of overload.
- Indications on large panel meters.
- Analog output voltages.

*Refer to Circuit Notes at end of article.

The block diagram of the 1654 comparator, Figure 1, illustrates use of a tightly-coupled 1:1 ratio toroidal transformer as two arms of the bridge; the standard and test impedances complete the circuit. The unbalanced-output signal of the bridge is fed through a guarded circuit, which effectively reduces cable capacitance by three orders of magnitude. This permits measurement, with negligible error, of test items as remote as thirty feet. From the amplifier system the signal is passed to the magnitude and phase channels.

Input to the magnitude-channel phase detector is direct. Input to the phase channel first undergoes a 90° phase shift, before connection to the phase detector, in order to bring the test frequency signal in phase with the error voltage component due to any phase difference. The phase detector is fundamentally a switch operated in synchronism with the test frequency. Exact switching is controlled by a square wave derived from the zero phase signal of the bridge.

The rectified voltage is that component of the error voltage which is in phase with the controlling square-wave voltage. The detected output is fed to a stable dc operational amplifier which provides the required analog output voltage that is interpreted as magnitude difference or phase-angle differ-

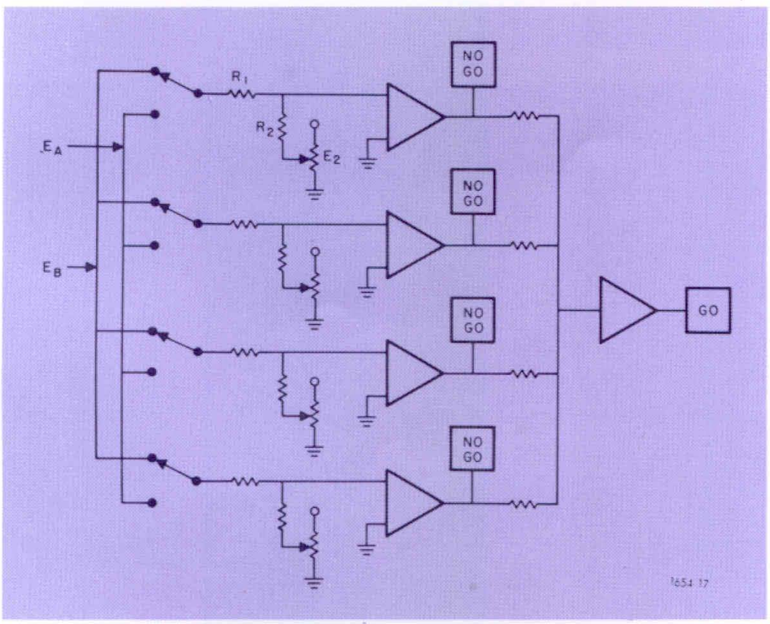


Figure 2. Block diagram of GR 1782 Analog Limit Comparator.

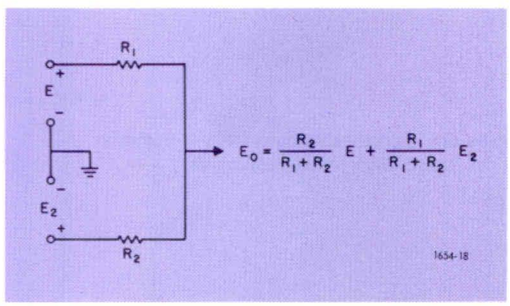


Figure 3. Schematic of limit comparison function.

ence between the test item and the standard.

The 1782 accessory unit (Figure 2) incorporates front-panel lamps to indicate GO or NO GO conditions. Each NO GO lamp indicates a single test limit, established as a preset voltage E_2. The input voltage E, derived from the magnitude or phase channels of the 1654, is compared with E_2, as shown in the schematic diagram, Figure 3. Unbalance voltage E_o, if it exists, is amplified by an operational amplifier with sufficient positive feedback to cause the amplifier to switch off or on. Its output triggers the NO GO lamp drivers; if the comparison is out of established tolerance, the NO GO lamps will light. Within-tolerance conditions for all limits will trigger the GO lamp. Optional relay-equipped models operate external automatic sorting devices.

Applications

On its own, the GR 1654 is a work horse on the inspection line or in the laboratory. Routine operations such as sorting, selecting, and adjusting passive components (R, L, and C), and any complex assembly of these components, are accomplished as quickly as you can make connections to the bridge. The GR 1680-P1 Test Fixture

R. K. Leong holds degrees from Northeastern University (BSEE-1960 and MSEE-1962). After two years' service in the U. S. Army as 1st Lt., coordinating instrumentation for upper atmosphere research, he joined GR in 1964 as a development engineer in the Low-Frequency Impedance Group. He has specialized in bridge and comparator design. He is a member of Tau Beta Pi and Eta Kappa Nu.

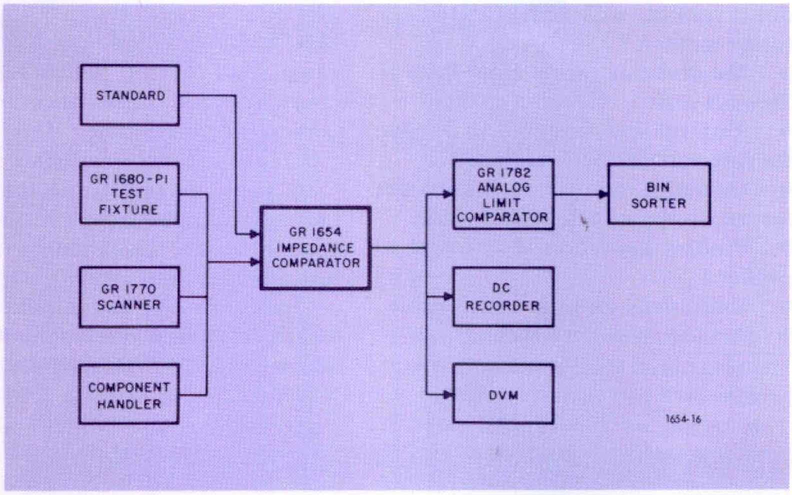


Figure 4a. Typical instruments and devices for automatic component-measurement system.

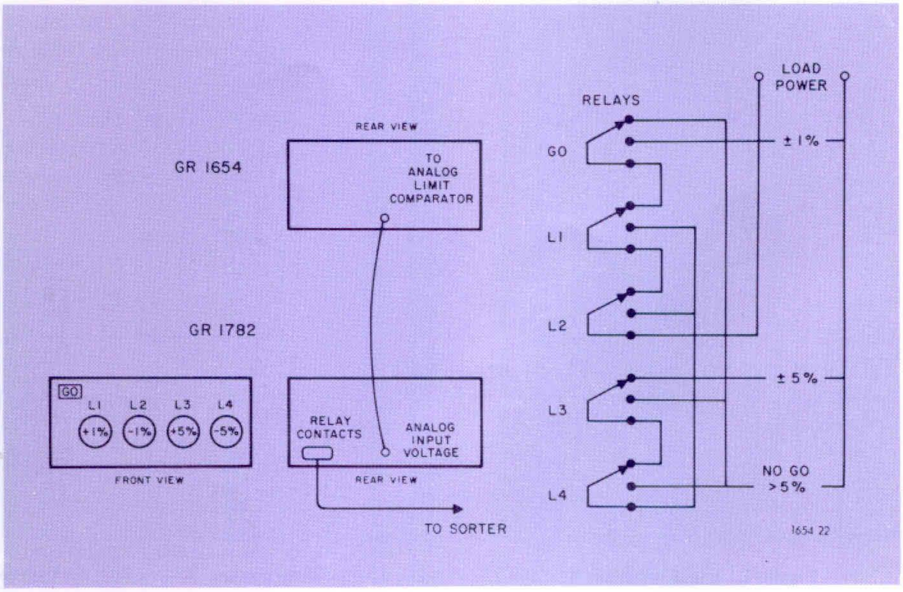


Figure 4b. Typical sorting system - schematic and relay interconnections.

is an ideal device for holding manually-inserted components. For faster sorting, the comparator and supporting instruments and accessories are an efficient automatic component-measuring system, as shown in Figure 4a. A typical sorting system is shown in Figure 4b.

The GR 1654 also is suitable for measurements of capacitors of extremely small values, low-loss capacitors, and dielectric samples; temperature-coefficient measurements of components tested within environmental chambers are a routine matter. Production testing of back-biased diodes and transistor-collector junctions is also routine; testing and adjusting of ganged capacitors and potentiometers for desired tracking within tolerances is another useful application.

—R. K. Leong

Complete specifications for the GR 1654 and 1782 instruments are available in the 1969 supplement to GR Catalog T.

Catalog Number	Description	Price in USA
	1654 Impedance Comparator	
1654-9700	Bench Model	**$1300.00**
1654-9701	Rack Model	**1250.00**
	1782 Analog Limit Comparator	
	Bench Model	
1782-9700	without relays	**550.00**
1782-9702	with relays	**625.00**
	Rack Model	
1782-9701	without relays	**570.00**
1782-9703	with relays	**645.00**

All prices subject to quantity discount.

CIRCUIT NOTES

The GR 1654 bridge circuit (Figure 5) measures impedance difference as a percentage of the average of the standard (Z_s) and unknown (Z_x) impedances. The real part of small phase-angle differences can be derived from the equation

$$\text{Re}\ \frac{E_o}{E} = \frac{|Z_x| - |Z_s|}{|Z_x| + |Z_s|} \quad (\text{When } \theta_x - \theta_s \leqslant 0.1 \text{ radian})$$

Introduction of nonlinear networks into the magnitude channel results in a linear indication of the impedance difference as a percent of the standard

$$\text{Re}\ \frac{E_o}{E} = \frac{|Z_x| - |Z_s|}{|Z_s|} \times 100\%$$

and reduces the number of scales for total measurement range. Measurements of R, L, and C furnish magnitude differences as percentages:

$$\frac{R_x - R_s}{R_s} \times 100\%, \quad \frac{L_x - L_s}{L_s} \times 100\%, \quad \frac{C_x - C_s}{C_s} \times 100\%$$

The imaginary part of small phase-angle differences can be obtained from the equation

$$\text{Im}\ \frac{E_O}{E} = \frac{\theta_x - \theta_s}{2}$$

For measurements of R, L, and C, the phase-angle difference indication is a measure of

ΔD of C and L, or ΔQ of R.

Measurement of low-value capacitances usually is limited by input-terminal capacitance C_{IN}. The capacitance effect is mitigated by the connection of the standard C_A, as shown in Figure 6. If the value of C_A is chosen as approximately $10 \times C_X$, or greater, the magnitude difference readout is proportional to $\frac{2C_X}{C_A + C_{IN}}$. For example, if C_{IN} is typically 1 pF and $C_A + C_{IN} = 200$ pF, for a meter reading of 0.1% the value of $C_X = 0.1$ pF. Note that the bridge is *direct* reading.

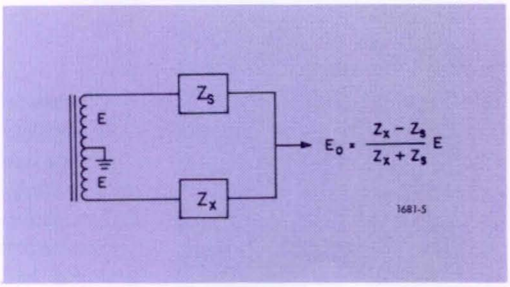
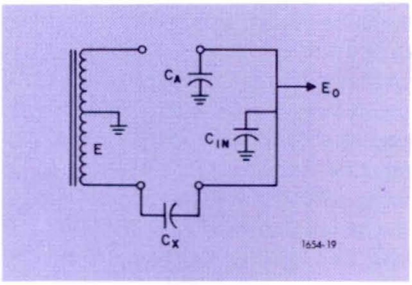


Figure 5. GR 1654 Bridge circuit.

Figure 6. Bridge schematic for small-capacitance measurement.



Information Retrieval

Indexes for Volumes 41 and 42 (1967, 1968) of the *Experimenter* are available upon request to the editor.