AN ANALOG FREQUENCY METER FOR MODERN MEASUREMENTS

The direct-reading frequency meter that displays its response on a direct deflection instrument has been sidetracked of late in favor of the more accurate (and more expensive) digital counter. Previously available frequency meters have had, by today's standards, a rather low accuracy, a few percent at best, and a somewhat limited frequency range. The convenience and reliability of the analog frequency meter, however, make it particularly attractive for many types of measurements. Recognizing this, General Radio Company has developed a new frequency meter, which not only steps up the accuracy by a factor of 10 and greatly increases the range of frequency that can be measured, but also doubles as a highly linear discriminator for fm measurements.

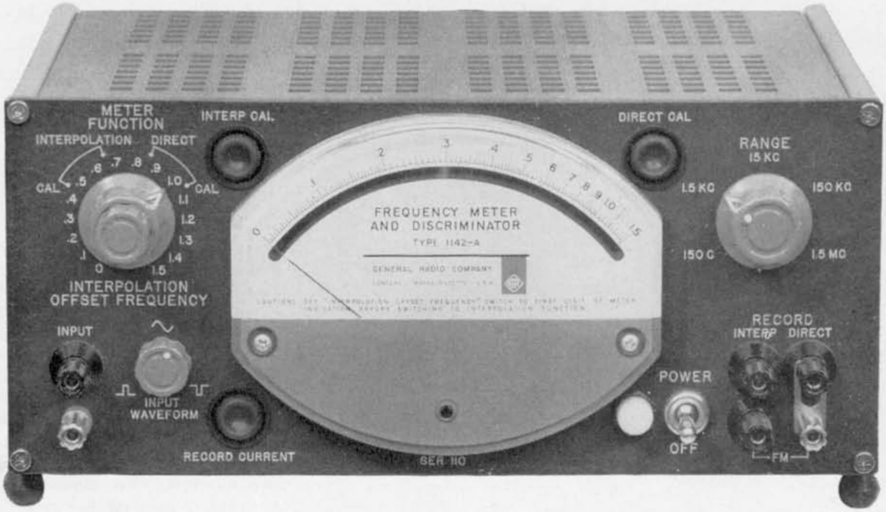
The new TYPE 1142-A Frequency Meter and Discriminator is basically a frequency-to-dc-current converter, operating on the principle of a pulse-count discriminator.[1] Its design features, each tailored to meet definite design objectives, combine to produce an instrument of outstanding performance.

The TYPE 1142-A Frequency Meter and Discriminator will directly measure frequencies between 3 cps and 1.5 Mc. The nominal accuracy is 0.2% of full scale for all but the extremes of its frequency coverage. Input sensitivity, like frequency coverage and accuracy, has been improved by at least an order of magnitude over previous frequency meters. Input signals of 30-millivolt peak amplitude are adequate over most of the frequency range, and the sensitivity is independent of input waveform.

Connection of an external ac voltmeter permits measurements of fm deviation; with a wave analyzer, individual components of incidental fm in oscilla-

[1]U. S. Patent No. 2,362,503.

Figure 1. Panel View of the Type 1142-A Frequency Meter and Discriminator. The instrument is housed in a rack-bench cabinet (see "The Case of the Well-Designed Instrument," *General Radio Experimenter,* March, 1960, page 7).



tors, multipliers, and amplifiers can be measured. Discriminator residual noise level is 100 db below full scale, consisting mainly of the fundamental and second harmonic of the power-line frequency. All other frequencies are down 120 db or more, permitting a resolution of one part in a million for direct measurement.

The usable frequency range, particularly for frequency-drift and incidental-fm measurements, can be extended upward to the thousands of megacycles if the frequency to be measured is heterodyned with a known standard. This gives a proportionate increase in resolution. Examples of drift measurement to one part in 10^{10} and of incidental-fm measurements to one part in 10^9 are described in APPLICATIONS, below.

READ-OUT ACCURACY

To solve the problem of readout to 0.1% accuracy, two features are incorporated. The first is the use of a unique, precision, 6-inch meter, whose scale distribution is linear from 0 to approximately 15% of full scale and logarithmic in the upper 85%. This meter is accurate to *1% of reading down to 10% of full scale,* which is literally an order-of-magnitude greater accuracy at this point than a 1%-of-full-scale meter. The second feature is the use of an interpolation, or *calibrated,* meter-expansion technique, whereby any one of 15 equal portions of any of the five (5) ranges can be expanded precisely 10:1 (see Figure 2). This transfers the first digit of the meter indication to a switch and displays the second and third digits on the meter. This also provides 50% overlaps and eliminates the need for end-of-scale readings.

Provision has been made for driving 1- and 5-ma recorders. Where higher recorder resolution is desired, additional binding posts are provided, which supply the interpolation signal.

EASY TO OPERATE

While no worthwhile feature has been omitted to limit the versatility of this instrument, the requirement of simplicity of operation has not been overlooked. Measurement of an unknown frequency is no more complicated than measurement of a voltage with a voltmeter, as can be seen from the front panel controls. With the METER FUNCTION switch in DIRECT position (Figure 1), simply set the RANGE switch to the appropriate position and read the meter. Adjustment of the INPUT WAVEFORM control is necessary only when optimum sensitivity is required. The measurement accuracy is 1% of reading down to 10% of full scale; 0.1% of full scale at indications below 10% of full scale. In other words, essentially all the error is due to the meter.

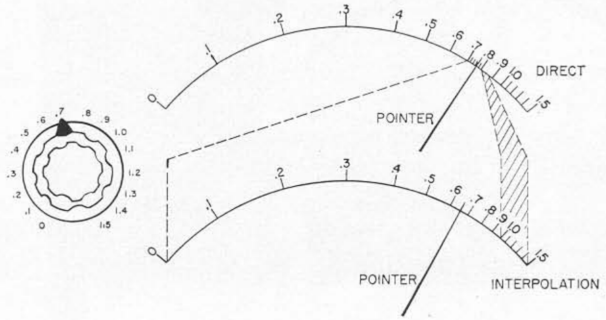
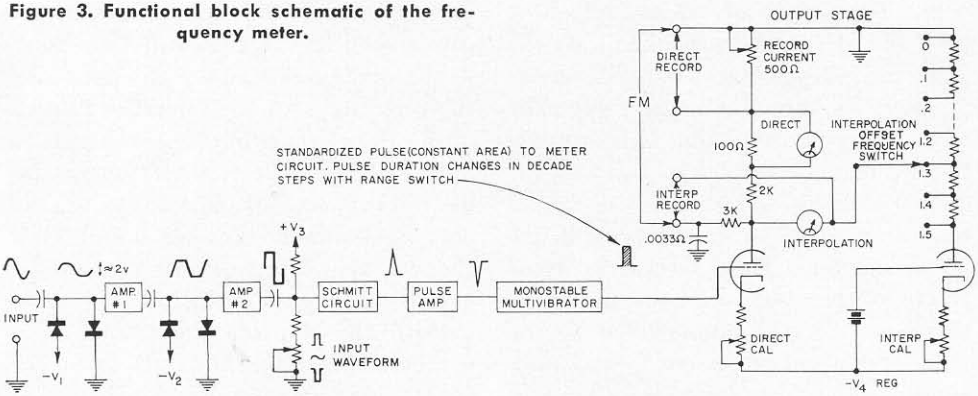


Figure 2. Illustrating meter scale-expansion. With METER FUNCTION switch set on DIRECT, meter indicates 0.77, as shown at top. When set on INTERPOLATION, as shown at bottom, the frequency meter indicates 0.766. The first digit (.7) is set on the INTERPOLATION OFFSET FREQUENCY switch and the interval from .7 to .8 is expanded to cover the scale from 0 to 1.0, so that the second and third digits (66) are easily read on the meter.

Figure 3. Functional block schematic of the frequency meter.



If greater read-out resolution is required, set the INTERPOLATION OFFSET FREQUENCY switch to correspond to the first digit of the meter indication and switch the METER FUNCTION switch to INTERPOLATION. The meter scale will then effectively be expanded by a factor of 10 (see Figure 2), with a read-out accuracy of 0.1%.

CALIBRATION

A calibrating signal, which is the second harmonic of the power-line frequency, provides a quick check for normal operation. Controls for convenient calibration of both the DIRECT and INTERPOLATION modes of operation on the 150-cps range are provided on the front panel. These controls are primarily required for compensation of any long-term drift of the current source, and, therefore, they correct all ranges.

Independent calibration of the other four ranges is rarely required after calibration at the factory, except when the timing or output tubes are replaced, which may necessitate a single adjustment on each of the four top ranges.

PRINCIPLES OF OPERATION

Frequency Meter

Figure 3 is a combined block and elementary schematic diagram. The input signal is clipped or limited, amplified, clipped a second time, and amplified again. The resulting wave-shape approximates a square wave or a series of pulses, depending upon whether the input signal is a sine wave or pulses, respectively.

The pulses trigger a Schmitt circuit, which produces positive pulses of 0.1-μsec duration, coinciding in time with the positive-slope zero crossings of the input signal. These pulses are amplified to trigger the monostable multivibrator, or timing stage. Adjustment of the INPUT WAVEFORM control makes possible a constant Schmitt-circuit sensitivity regardless of the duty ratio and polarity of the pulses.

The monostable multivibrator produces a pulse of constant amplitude and duration for each input pulse. The pulse duration is determined by resistor-capacitor combinations, with accuracy and stability assured by the use of precision, temperature-compensated capacitors and General Radio wire-wound resistors. Range switching changes the timing resistors and capacitors to produce decade changes in pulse duration.

The standardized pulse is then fed to the output stage (to simplify the diagram, two meters are shown in place of one). The left-hand triode, which is normally at cut-off, is turned on by the standardized pulse and remains on for precisely the duration of this pulse. The current flowing at this time is determined by the regulated voltage, V_4, and the cathode resistor — a stable, wire-wound resistor in series with the DIRECT CAL potentiometer. The average current through the plate-load resistors is, therefore, directly proportional to the number of input pulses per second, and, hence, to the input frequency. A meter across a portion of the load resistor indicates this frequency.

The average dc voltage developed between the plate and ground, *i.e.*, at the fm terminals, is precisely 15 volts at full-scale deflection (1.5). A high-impedance recorder or dc voltmeter can be connected to these terminals as an additional readout.

The right-hand triode is a constant-current source with a plate load consisting of 15 equal-value, 0.05%, wire-wound resistors. Its plate current is adjusted so that the total voltage drop across these resistors is a constant 15 volts. When used for interpolation the meter is connected between the plate of the left-hand triode, which is between 0 and −15 volts, dc, depending upon the input frequency and the appropriate "bucking" voltage from the precision voltage divider, and full-scale sensitivity is increased 10:1 by removal of its shunt. End-of-scale readings are eliminated by the provision of a 50% overlap on each of the 15 interpolation ranges; hence, as indicated in Figure 1, any frequency indicated between 1.0 and 1.5 may be read also on the meter between 0 and 0.5 if the INTERPOLATION OFFSET FREQUENCY switch is set one digit higher.

With the shorting link removed, a maximum of 7 ma is available at the DIRECT RECORD terminals, so that most standard 1-ma and 5-ma recorders can be used. The RECORD CURRENT potentiometer is a convenient sensitivity control for these recorders, and has no visible interaction on the DIRECT METER indication.

An additional recorder output at the RECORD INTERPOLATION terminals makes available the interpolation signal from the meter circuit. Full-scale voltage is 0.64 volt behind 4800 ohms. Use of a high-impedance recorder eliminates any interaction on the meter indication.

Discriminator

Operation of the frequency meter circuits requires the generation of a constant-amplitude, constant-duration pulse for each input cycle. These standardized pulses have a fixed-time relation with respect to the input signal and when

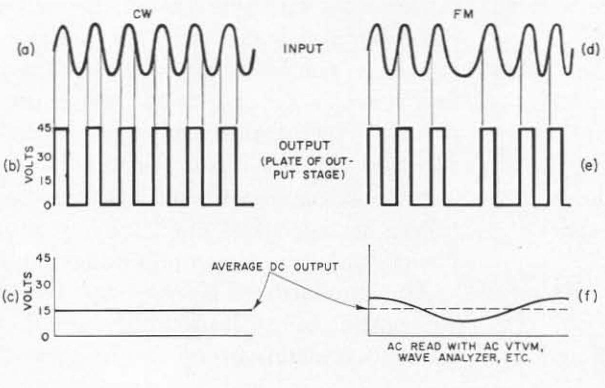


Figure 4. Illustrating the operation of the pulse-count discriminator for (*left*) constant input frequency and (*right*) frequency-modulated input.

suitably filtered provide a precise pulse-count discriminator output.

The output signal at the fm terminals is shown in Figure 4. With a constant-frequency input signal (4a), the standardized pulses are uniformly spaced (4b). A low-pass filter removes all ac components of the pulse train, leaving only the average (dc) component (4c). If the input frequency increases, the average-value component increases also. Thus, if the input frequency varies (4d), *i.e.*, is frequency modulated, the standardized pulses are no longer uniformly spaced (4e), and the average-value component varies correspondingly (4f). This variation is an ac signal identical to the original modulation.

The frequency deviation for an fm signal is readily determined, since full-scale deviation, peak-to-peak, on any range corresponds to 15-volts peak-to-peak output. A change in input frequency of 1 ppm, either peak-to-peak, peak, or rms, results in an ac output voltage of 15 μv, peak-to-peak, peak, or rms, respectively. Since the narrow band noise is more than 120 db down from full output, peak deviations as small as 1.5 cycles on the 1.5-Mc range, or 0.0015 cycle on the 1.5-kc range, can be measured.

It is obvious that the filter must eliminate the ac components of the pulses and still permit the average value component to vary at the modulating frequency. A single-section, RC low-pass filter with a break frequency of 10 kc is used for this purpose, although, in instances when low carrier frequencies are measured, additional filtering may be necessary. If the standard 75-μsec de-emphasis network used in fm broadcasting is desired, an additional capacitance of 0.011 μf should be placed across the fm terminals.

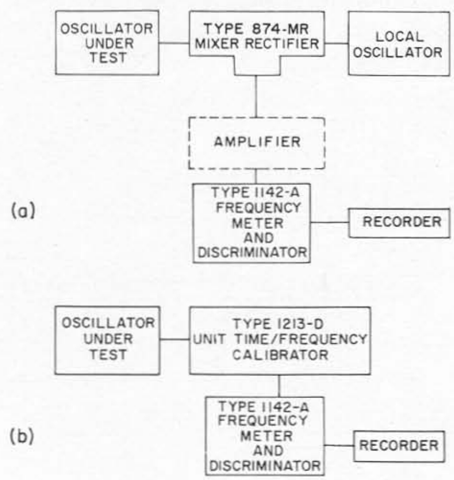
APPLICATIONS

The Type 1142-A Frequency Meter and Discriminator can be used to measure and to record frequency and frequency changes, or used as an extremely linear and low-noise discriminator for fm demodulation and incidental fm measurements. There are, however, many additional applications utilizing this meter as the main element in a measurement system, which greatly extend its range and utility.

Frequency and Drift Measurements

To extend the range of frequencies over which measurements can be made, the signal under measurement is heterodyned with a local oscillator to bring their difference frequency within the range of the frequency meter. Thus, with the arrangement shown in Figure 5a, frequencies can be measured and recorded through the kilomegacycle range. The measurement accuracy is essentially that of the local oscillator. For example, if the local oscillator is a precision standard oscillator, operating at 1000 Mc and the

Figure 5. Block diagrams of arrangements for heterodyning high frequencies down to the range of the frequency meter.



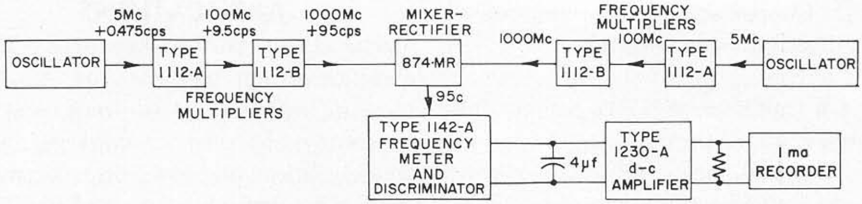


Figure 6. Arrangement of equipment used to measure the relative drift of two 5-Mc oscillators. The 5-Mc frequencies were multiplied up to 1000 Mc to magnify their frequency drift.

frequency of the oscillator under test is within 150 cycles of the local oscillator, then frequency changes of 0.1 cycle or approximately 1 part in 10^{10} can be directly read on the frequency meter. Since a frequency difference as high as 1.5 Mc is also readable on the meter, measurements of warm-up drift on high-frequency oscillators are conveniently made with the same equipment (Figure 5a).

Frequency measurements near integral values of multiples of 100 kc, 1 Mc, and 10 Mc are readily measured using the Unit Time/Frequency Calibrator, Type 1213-D.[2] This instrument includes a crystal-controlled source of these frequencies together with a heterodyne detector and audio-beat amplifier. As shown in Figure 5b, the local oscillator, mixer, and amplifier are replaced by the calibrator unit.

[2] R. W. Frank, "A Time/Frequency Calibrator of Improved Stability," *General Radio Experimenter*, 33, 10, October 1959.

The arrangement shown in Figure 6 was used to obtain the record (Figure 7) of the relative drift of two 5-Mc crystal oscillators. The 4-μf capacitor on the interpolation recorder output provides sufficient filtering to prevent the recorder pen from responding to the pulse frequency in the frequency-meter output. The shunt resistor was used to adjust the full-scale sensitivity of the recorder, in this instance to one part in 10^8.

Measurements with the Discriminator Sources of Error

While the use of the discriminator poses no problems peculiar to this instrument, certain precautions should be taken to insure accurate measurement of low values of fm deviation. Obviously sufficient signal must be available. Operation at the limit of sensitivity will not give the best results. Furthermore, measurements cannot be made in the

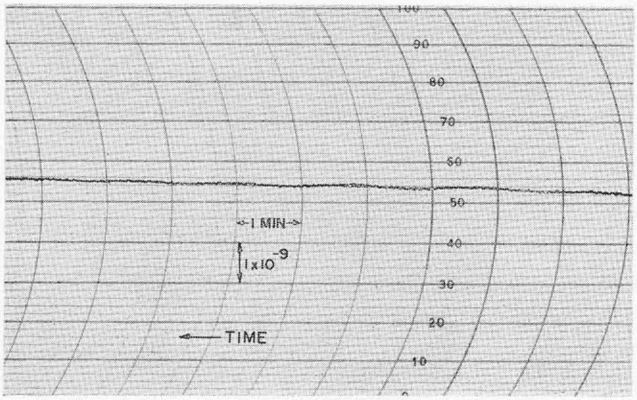


Figure 7. Chart record of the measurement of Figure 6.

presence of noise so great that extraneous zero crossings are generated.

Effects of Additive Noise

A more subtle error in incidental fm measurements can be caused by a low-frequency noise signal superimposed on the input signal. The generated pulse does not start at precisely the zero crossing of the input signal but at a time when the input signal reaches some fixed voltage (usually less than 10 mv). Noise introduced with the signal will result in some variation in the time relationship between the input signal and the output pulses and will be measured as fm. The amount of this generated fm is a function of the frequency of the noise as well as the signal-to-noise ratio. The peak deviation of this extraneous fm is approximately:

$$\triangle f_{cps} = f_{noise} \times \frac{A_{noise}}{A_{signal}}$$

where A = amplitude of noise and input signals

For example, a 1-volt, 100-kc carrier, with a noise signal of 1 mv at 100 cycles, would give an equivalent fm output of 0.1 cycle or 1 ppm deviation. A simple RC high-pass filter can be used to reduce the low-frequency noise signal and usually is adequate to eliminate this problem completely. This filter should always be used to remove the recovered amplitude modulation in the measurement of incidental fm on an amplitude modulated signal that has been heterodyned in a diode mixer such as the Type 874-MR, or to remove 60-cycle hum pickup on the input.

Effects of Amplitude Modulation

The presence of high levels of amplitude modulation on the input signal can also produce errors. Obviously, as the modulation approaches 100%, the input carrier is near zero amplitude during a considerable number of carrier-frequency cycles and the input level may be too low for proper operation. Even with sufficient signal a difficulty exists, as shown graphically in Figure 8. The

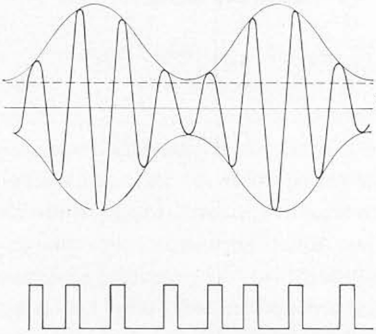


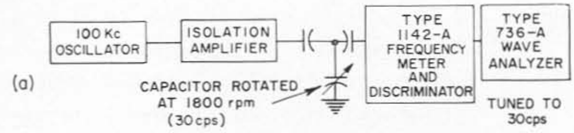
Figure 8. Illustrating the apparent frequency modulation produced by an amplitude-modulated wave.

start time of the output pulses is determined by the time at which the input signal reaches a given instantaneous value; therefore, any change in the slope of the input signal affects the time of these pulses with respect to the zero crossing of the input signal. The fm deviation produced by amplitude modulation is approximately:

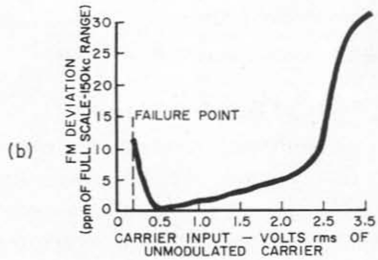
$$\triangle f_{cps} = f_{mod}\, M \,\frac{S}{A_{car}}$$

where f_{mod} = modulation frequency
S = sensitivity of the meter at the carrier frequency (no modulation)
M = modulation index
A_{car} = amplitude of the carrier

The sensitivity is found by reduction of the signal to the failure point. As an example, let us assume that at 100 kc S is found to be 10 mv. A 1-volt, 100-kc carrier, modulated 25% at 400 cycles, will produce an fm output of approximately:



(Above) Figure 9a. Equipment used to determine fm deviation in an amplitude-modulated wave as a function of input level.



(At right) Figure 9b. Plot of results of the measurement shown above.

$$\triangle f_{cps} = 400 \times .25 \times \frac{.01}{1} = 1 \text{ cycle (or 10 ppm)}$$

This a-m-generated fm may be minimized by an increase in the input level or a reduction in the percentage modulation. The input signal cannot be increased indefinitely, however. Because of the nature of limiters, whether they are internal or are added externally to aid in eliminating the a-m, some demodulation of the a-m signal will occur. This demodulated signal reacts upon the input stages in the same manner as additive noise and results in a discriminator output as previously described.

It is difficult, if not impossible to measure this effect with available amplitude-modulated oscillators or signal generators because of the difficulty of separating the fm generated in the source from that of the discriminator.

To measure this effect, a motor-driven capacitive voltage divider, Figure 9a, was used to generate an amplitude-modulated wave relatively free of any fm or phase-modulation effects. A plot of effective fm as a function of input carrier level is shown in Figure 9b. It is apparent that an input level between approximately 0.5 volt and 2.0 volts is optimum. On either side of this range there is an increase in measured fm. At low voltages there is insufficient signal for accurate measurement, and above 2.0 volts the limiters produce some demodulation.

A knowledge of these sources of error in measurements with the discriminator should be helpful in explaining the functions of the various filters used in the measurements of fm, flutter, and wow described below.

Frequency Modulation Measurements

Fm deviation measurements are made by substituting an ac voltmeter for the dc recorder shown in Figure 5a. The use of heterodyne techniques not only extends the frequency range but also increases the resolution.

As an example, incidental-fm measurements of a 50-Mc oscillator were made by using a battery-powered 49.5-Mc local oscillator; battery power was utilized to eliminate incidental-fm components of the ac power supply frequencies from the local oscillator, because these were the primary fm components of interest in the oscillator under measurement. The results, however, showed that, while 60- and 120-cycle fm components of a normal level did exist, even larger peak deviations at 25- and 45-cycle rates were also present. These fm components were finally traced to microphonics in the oscillator under test. The sources of the vibrations were a blower-cooled oscilloscope and power supply resting on the same bench as the 50-Mc oscillator with fan speeds of 1500 and 2700 rpm respectively!

A measurement that demanded the full utilization of the techniques and

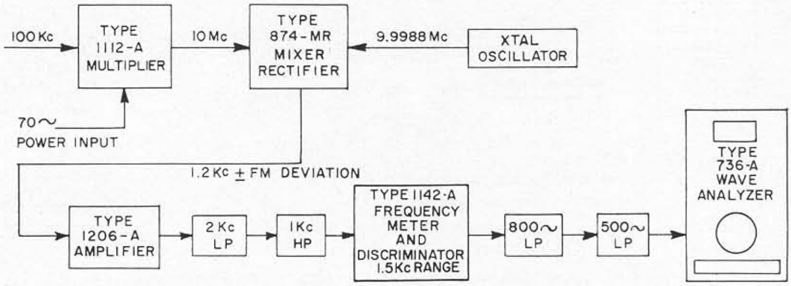


Figure 10. Block diagram of system used for the measurement of fm noise level of the Type 1112-A Standard-Frequency Multiplier.

precautions previously discussed was the determination of the fm noise level of the TYPE 1112-A Standard Frequency Multiplier.[3] A block diagram of the measuring setup is shown in Figure 10. Inasmuch as the predominant fm components were expected to be harmonics of the power-line frequency, the multiplier was powered by a variable frequency power supply set to approximately 70 cycles, so as to permit separation of the multiplier's fm noise level from that of the rest of the system. The low output level of the 9.9988-Mc local oscillator necessitated the use of an amplifier (TYPE 1206-A) to drive the frequency meter. A band-pass filter consisting of a 2-kc, RC, low-pass section together with a 1-kc, RC, high-pass section attenuated extraneous signals (60- and 70-cycle hum as well as high-frequency carrier noise) while passing the 1.2-kc carrier and side bands. The 800-cycle and 500-cycle filters shown in Figure 10 prevent the 45-volt, 1.2-kc pulses from overloading the wave analyzer.

In the above setup, *i.e.*, with a 10-Mc carrier and a 1.2-kc beat, a 7-μv reading on the wave analyzer corresponds to a peak deviation of approximately one part in 10^{10}. The total noise level of the TYPE 1112-A Standard Frequency Multiplier was found to be approximately 5 parts in 10^{10}.

While the previous examples have been primarily concerned with small peak deviations at low modulation rates, there are occasions when the measurement of large frequency deviations or high modulation frequencies is desired. It is apparent that the largest peak deviation measurable with the TYPE 1142-A Frequency Meter and Discriminator is equal to one-half of the range-switch setting in use, or ±750 kc on the 1.5-Mc range. For modulating frequencies above 10 kc, the output is decreased because of the internal 10-kc filter. It is therefore necessary to remove the 0.0033-μf filter capacitor if a higher roll-off frequency is desired. Under this condition, the output impedance is 5.1-kilohms. The roll-off frequency now depends upon the capacitive load of the external voltmeter or filter. It is not possible therefore to state categorically the maximum detectable modulation frequency without a knowledge of the characteristics of the filter and voltmeter being used. However, with a total shunt capacitance 100 $\mu\mu$f, it is possible to maintain the response within 1 db out to a 100-kc modulation frequency.

Flutter and Wow Measurements

The measurement of flutter and wow of tape recorders, both audio and data, or of turntables, is possible with the setup shown in Figure 11. The oscillator frequency is usually an industry standard, *e.g.*, 3 kc for audio recorders. The

[3] F. D. Lewis, "New Standard-Frequency Multipliers," *General Radio Experimenter*, 32, 14, July, 1958.

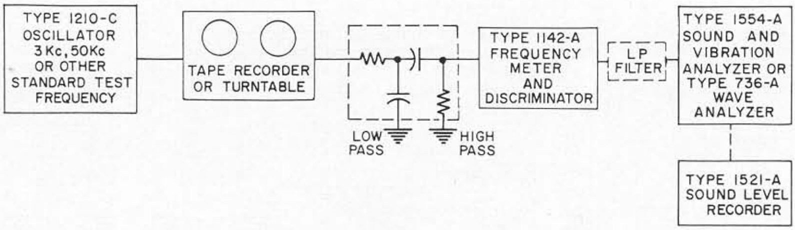


Figure 11. Equipment set-up for the measurement of flutter and wow in recording devices.

high- and low-pass filters preceding the Type 1142-A Frequency Meter and Discriminator may or may not be necessary. The function of the high-pass filter is to attenuate the low-frequency hum components from the recorder amplifiers so that they will not generate any fm in the frequency meter; the low-pass filter is included to attenuate the bias signal often present at the output terminals of a three-head tape recorder when recording and playback are occurring simultaneously. The low-pass filter following the frequency meter may not be necessary when data recorders are being tested, since the internal 10-kc filter of the frequency meter is usually adequate when a carrier of 50 kc or 100 kc is used.

While a wide-band rms voltmeter with the appropriate low-pass filter (300 cycles for audio recorders, 5 kc or 10 kc for data recorders) will give the total flutter and wow level, a wave analyzer indicates specific frequency components allowing one to pinpoint directly the source of the major flutter components. For example, Figure 12 is an automatic plot of flutter of an audio tape recorder made with the use of the Type 1554-A Sound and Vibration Analyzer (tunable from 2.5 cycles to 25 kc) coupled to the Type 1521-A Graphic Level Recorder. Peak flutter components are produced not only at power supply frequencies but also at frequencies directly related to motor speed, capstan speed, idler speed, etc.

Automatic plots like that of Figure 12 can be made over a frequency range of 20 cycles to 25 kc. The response of the Graphic Level Recorder drops off below 20 cycles so that hand-plotting is necessary at lower frequencies.

Other Uses

Since the frequency meter generates a standardized pulse for each input cycle, it follows that it will measure the average of a frequency that is changing even if it is aperiodic or random. This fact is made use of in production testing of the Type 1300-A Beat-Frequency Video Generator. To calibrate the sweep-frequency circuits, the peak deviation with sine wave sweep is set to 1 Mc by measurement of the average output frequency. Since the average of a sine wave is .636 of peak, the frequency is adjusted for a frequency meter indication of 636 kc.

It is also apparent that signals to be counted may be derived from simple photocell devices, tachometers, geiger tubes, magnetic pickups, or any other transducers capable of supplying a 30-mv peak signal.

— Costa G. Chitouras

Note

The development of the Type 1142-A Frequency Meter and Discriminator was carried out by Mr. Chitouras. R. W. Frank contributed to the early design and the project was directed by M. C. Holtje. —Editor

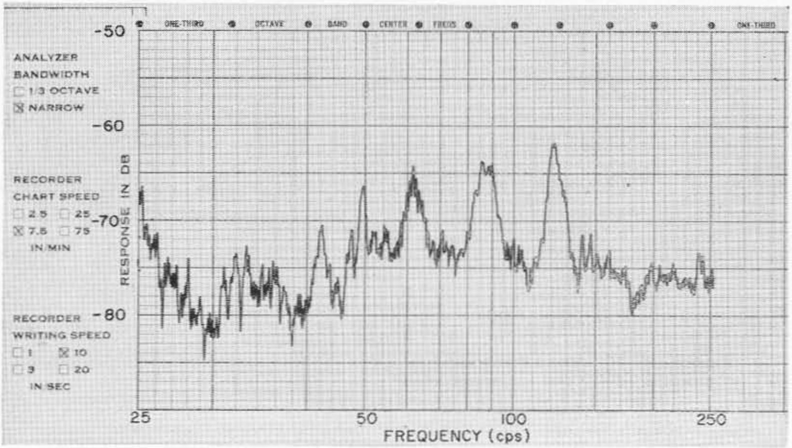


Figure 12. Automatic plot of flutter in an audio tape recorder, made with the equipment shown in Figure 11. A response of −60 db corresponds to a frequency deviation of 0.1% of the test frequency.

SPECIFICATIONS

Range: 3 cps to 1.5 Mc in five decade ranges. Full-scale values are 150 cps, 1.5 kc, 15 kc, 150 kc, and 1.5 Mc. A calibrated interpolation feature effectively expands the meter scale by a factor of 10 so that 1/10 of any of the above ranges covers the full meter scale.

Accuracy:

Recorder Output Current: 0.05% of full scale +.05% of reading, below 15 kc. 0.1% of full scale +0.1% of reading, above 15 kc.

Meter Error:

Direct Reading: 1% of reading above 10% of full scale (0.1% of full scale below 10% of full scale).

Interpolating: 0.1% of full scale (range switch setting).

Line Voltage: Variations of ±10% produce approximately a ±0.15% change in reading below 150 kc and ±1% above 150 kc.

Temperature: Drift after a few minutes is less than 0.2% of reading, substantially complete within 30 minutes.

Over-all accuracy is the sum of the recorder output current error and any of the above applicable errors.

Calibration: Internal calibration at twice line frequency to standardize output current.

Sensitivity: 20 mv, rms, for frequencies between 20 cps and 150 kc, rising to 200 mv at 3 cps and 1.5 Mc. Peak-to-peak voltage requirements for pulse and sine wave inputs are approximately equal, except for extremely short pulses. Input pulse widths of the order of a nanosecond may require as much as 5 volts.

Maximum Input Voltage: 400-v peak.

Input Impedance: 100,000 ohms dropping to a minimum of 10,000 ohms above 150 kc.

Discriminator Characteristics:

Output Voltage: 15 v dc full scale (1.5), all ranges.

Residual fm Noise: More than 100 db below full output (primarily 60 and 120 cps). Measured with a narrow-band wave analyzer, such as the Type 736-A, residual noise at other frequencies is more than 120 db down from full output.

Linearity: 0.05% of full scale (15 v) +0.05% of output voltage, below 15 kc. 0.1% of full scale (15 v) +0.1% of output voltage, above 15 kc.

Recorder Output:

Direct: Output current adjustable to drive recorders from 1-ma (3000 ohms, max) to 5-ma (200 ohms, max).

Interpolate: Full-scale voltage .64 v behind 4800 ohms.

Tubes: One 6AW8, one 5687, one 6AN5, three 5965, one 6AV5GA, one 5651.

Accessories Supplied: Type CAP-22 Power Cord, spare fuses.

Power Supply: 105-125 (or 210-250) volts, 50 to 60 cps. This instrument will also operate at line frequencies up to 400 cps.

Dimensions: Panel, 12 x 5¼ inches (305 x 135 mm); depth behind panel, 10¼ inches (265 mm).

Net Weight: 16 pounds (7.3 kg).

Type		*Code Word*	*Price*
1142-A	**Frequency Meter and Discriminator**	MAGIC	**$495.00**
480-P-312	**Panel Extensions for Relay Rack (pair)**	MERIT	**6.50**

U.S. Patent Nos. 2,362,503 and D187,740.