the GENERAL RADIO Experimenter

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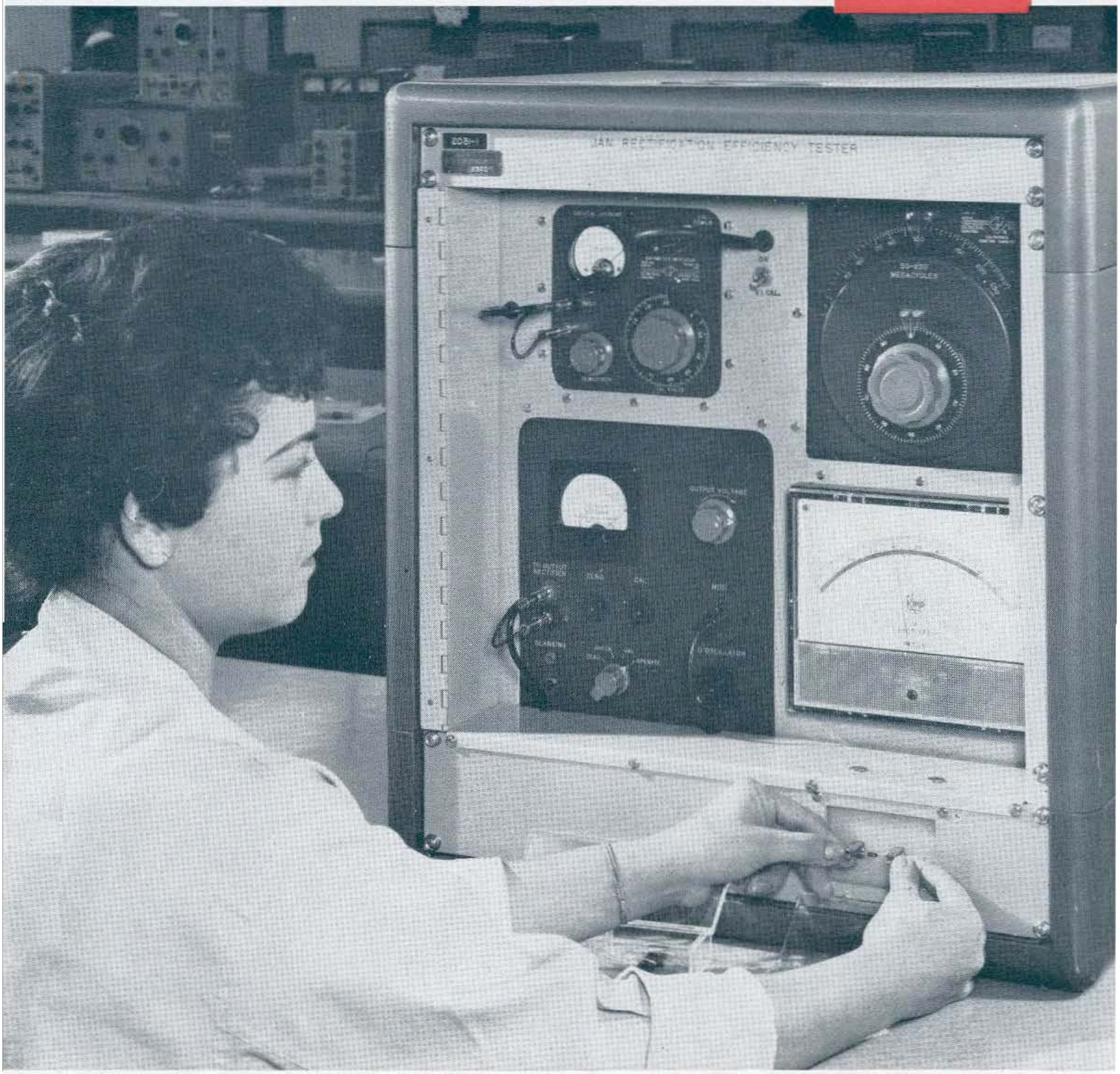

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COVER

General Radio Unit Oscillator, Amplitude-Regulating Power Supply, and coaxial elements are used in testing solid-state diodes at Rheem Semiconductor Corporation (see page 15).

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.

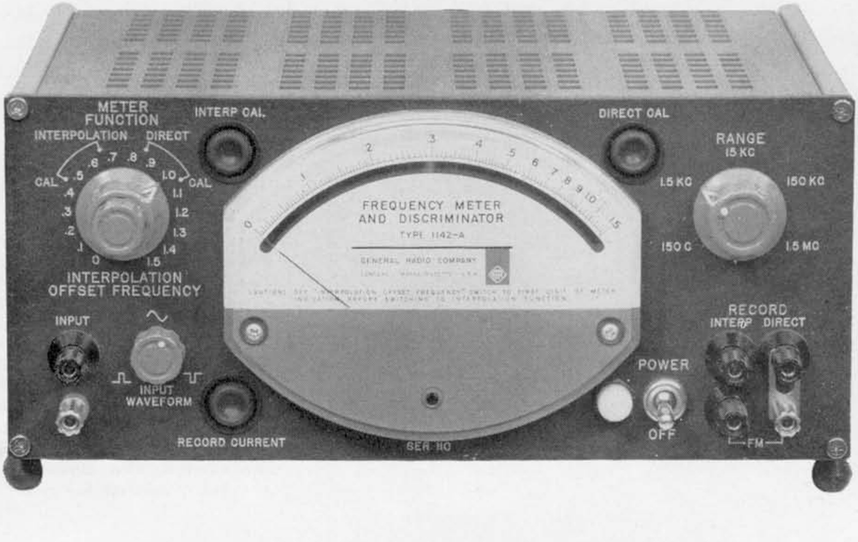
The new Type 1142-A Frequency Meter and Discriminator is basically a frequency-to-dc-current converter, operating on the principle of a pulse-count discriminator.[1] Its design features, each tailored to meet definite design objectives, combine to produce an instrument of outstanding performance.

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.

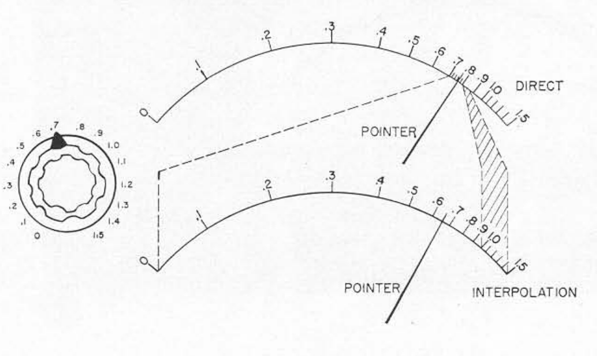
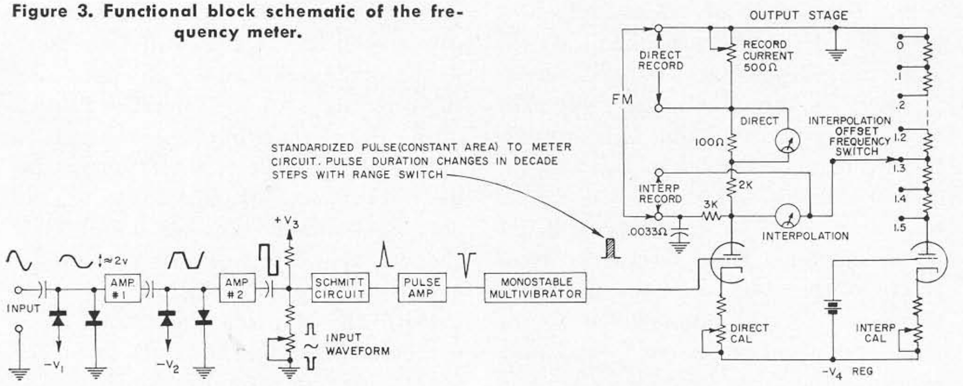


Figure 2. Illustrating meter scale-expansion. With METER FUNCTION switch set on DIRECT, meter indicates 0.77, as shown at top. When set on INTERPOLATION, as shown at bottom, the frequency meter indicates 0.766. The first digit (.7) is set on the INTERPOLATION OFFSET FREQUENCY switch and the interval 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

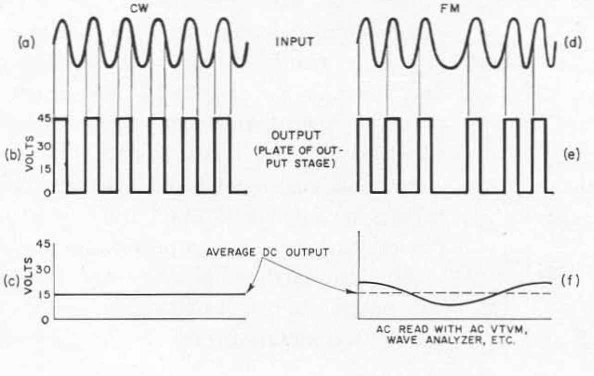


Figure 4. Illustrating the operation of the pulse-count discriminator for (*left*) constant input frequency and (*right*) frequency-modulated input.

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.

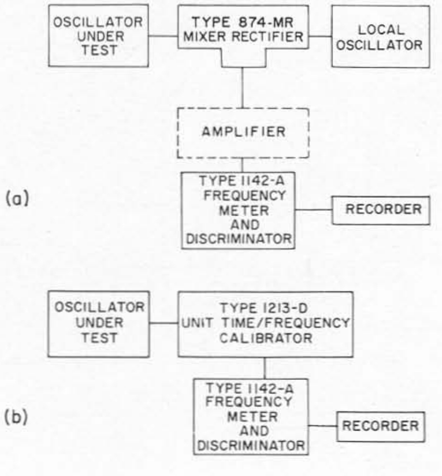
APPLICATIONS

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.



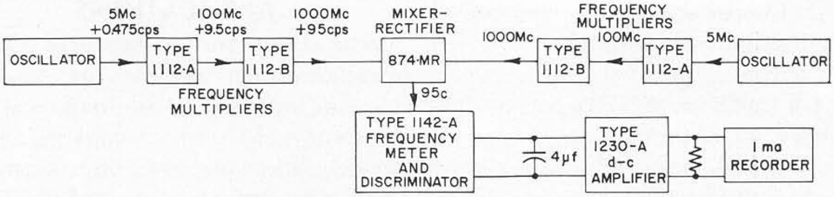


Figure 6. Arrangement of equipment used to measure the relative drift of two 5-Mc oscillators. The 5-Mc frequencies were multiplied up to 1000 Mc to magnify their frequency drift.

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

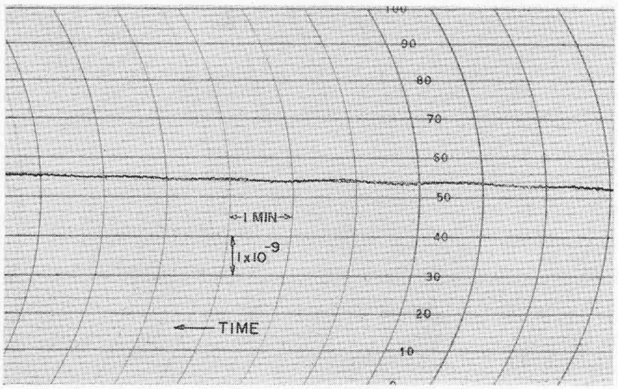


Figure 7. Chart record of the measurement of Figure 6.

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

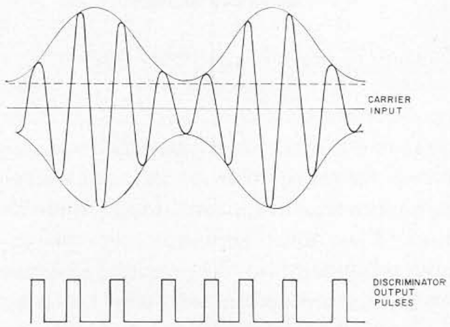


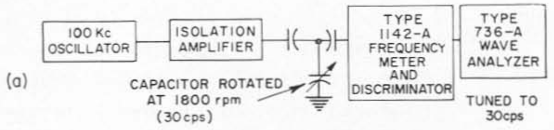
Figure 8. Illustrating the apparent frequency modulation produced by an amplitude-modulated wave.

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:

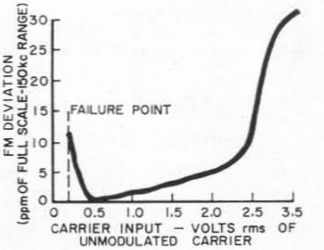
$$\triangle f_{cps} = f_{mod}\, M \frac{S}{A_{car}}$$

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:



(b)



(*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

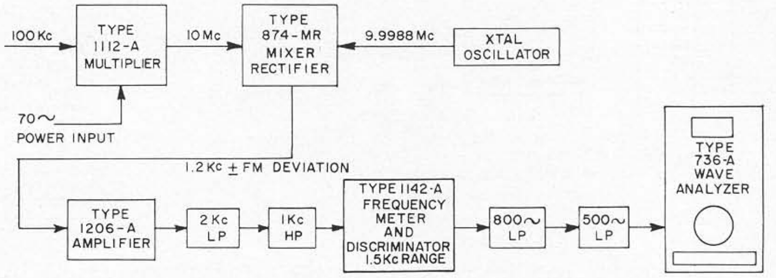


Figure 10. Block diagram of system used for the measurement of fm noise level of the Type 1112-A Standard-Frequency Multiplier.

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 μμf, 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.

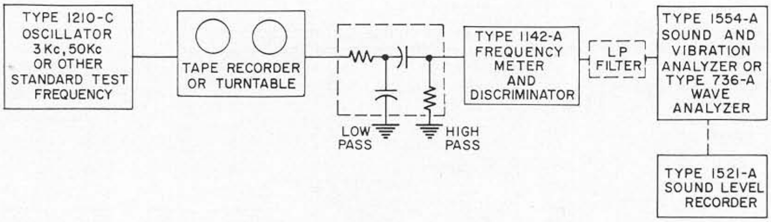


Figure 11. Equipment set-up for the measurement of flutter and wow in recording devices.

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

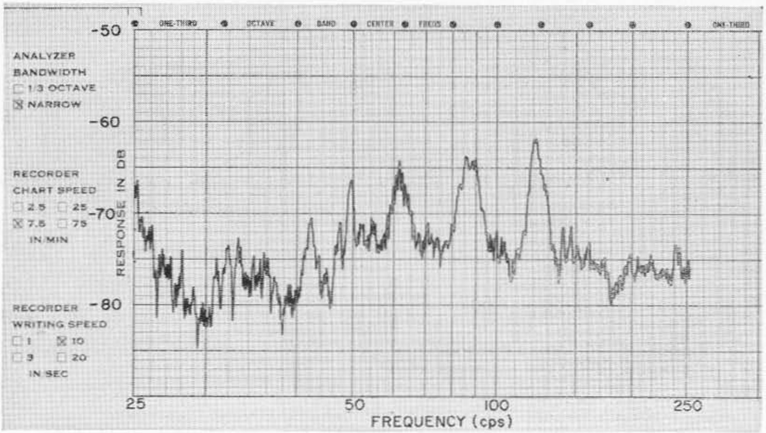


Figure 12. Automatic plot of flutter in an audio tape recorder, made with the equipment shown in Figure 11. A response of −60 db corresponds to a frequency deviation of 0.1% of the test frequency.

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**

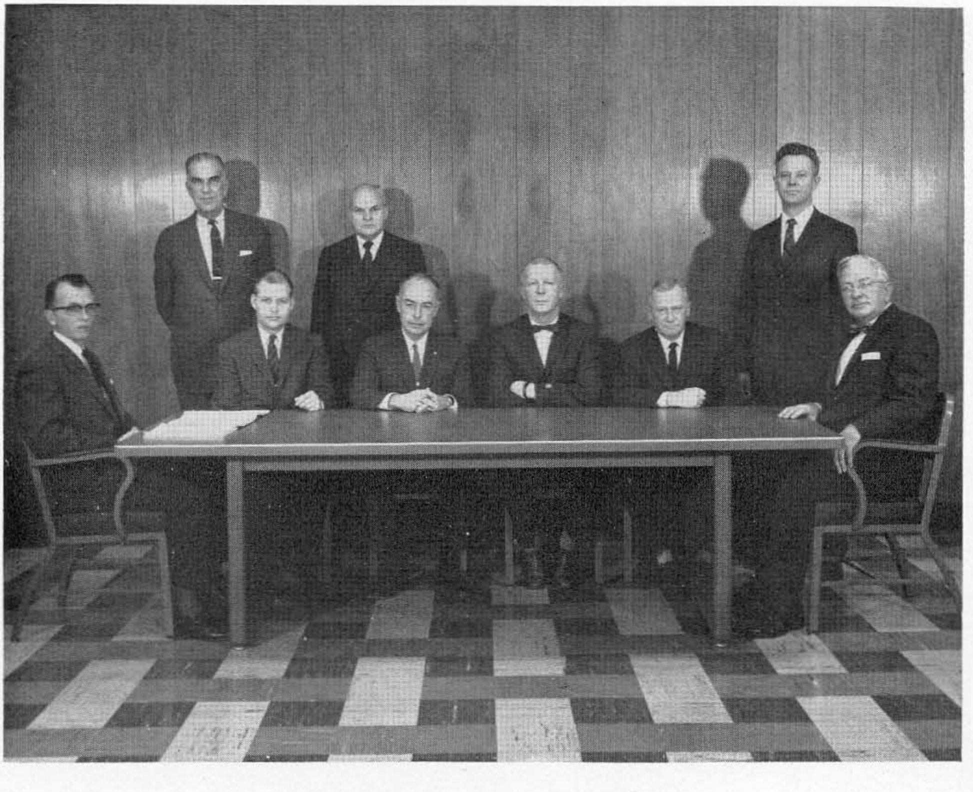
U.S. Patent Nos. 2,362,503 and D187,740.

THE MANAGEMENT COMMITTEE

The operation of the General Radio Company is the responsibility of the Management Committee, whose members are the heads of the functional operating groups of the Company. The committee form of management, which has been in operation at General Radio for well over 20 years, has, we feel, resulted in better decisions being reached and a better-run organization than would be possible for us with any other type of management.

There are, as well, a number of other operating committees each composed of those most directly concerned with the matters indicated by the committee titles. Among these are: *New Products* for determining our program of future developments, *Manufacturing* for coordinating production activities, *Personnel* for administering personnel programs, *Development* for engineering department operations, *Scheduling* for determining production requirements and for price setting, and *Patent* for dealing with patent, license, and trademark matters.

(Left to right) **Lawrence E. Pexton,** ***Treasurer;*** **Arthur E. Thiessen,** ***Chairman of the Board;*** **John D. Quackenbos,** ***Secretary;*** **Charles T. Burke,** ***Director of Planning;*** **Myron T. Smith,** ***Director of Sales;*** **Ivan G. Easton,** ***Vice-President for Engineering;*** **Harold M. Wilson,** ***Vice-President for Manufacturing;*** **Donald B. Sinclair,** ***Executive Vice-President and Technical Director;*** **Charles C. Carey,** ***President and Chairman of the Management Committee.***



TESTING OF SOLID-STATE DIODES AT 100 MEGACYCLES

One of the basic measurements required in the manufacture of solid-state diodes is the determination of the rectification efficiency. JAN specified procedures call for a 100-Mc signal to be fed through the diode into a prescribed RC load. The resulting load voltage is a measure of the rectification efficiency.

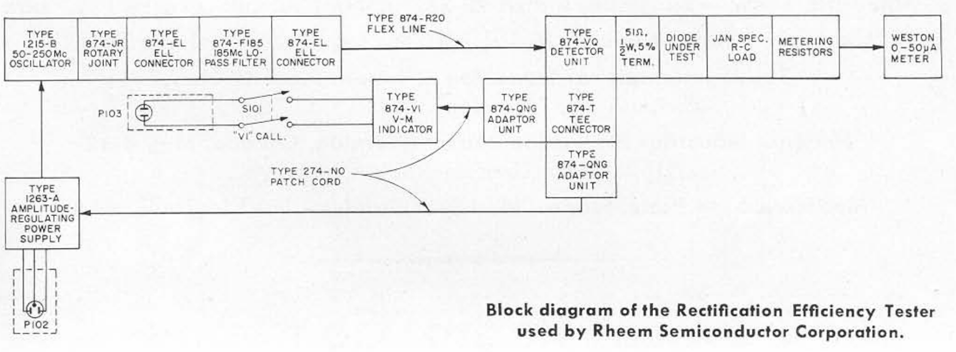
Rheem Semiconductor Corporation, Mountain View, California, thoroughly studied various methods of making the required test and developed an assembly that permits the testing-sorting process to be accomplished at a rate approaching one component per second. The resulting system uses a General Radio Type 1215-B Unit Oscillator as the 100-Mc source, in conjunction with a Type 1263-A Amplitude-Regulating Power Supply. This combination of instruments permits a constant voltage amplitude to be available at the test terminals regardless of any load variations due to individual diode characteristics. The Type 874-VQ Voltmeter Detector and Type 874-VI Voltmeter Indicator are used to make the initial voltage-level setting.

A complete test set comprising these instruments has been designed by Rheem engineers and is shown in operation in the photograph on the front cover of this issue.

Another production-test system incorporating the same types of General Radio equipment measures the transfer current ratio (h_{fe}) of transistors. This assembly makes extensive use of Type 874 Adaptors, Air Lines, and Tees to minimize VSWR. The test jig used is a modified Type 1607–P102 Grounded-Emitter Transistor Mount which permits bias voltages to be applied to the transistor. An rf voltmeter indicates the measured transfer current ratio. As with the rectification efficiency test, speed of this production measurement is based on the rapidity of meter response.

Rheem also performs several tests to determine diode recovery time. In the systems concerned, considerable use is made of Type 874 Coaxial Units due to the ability of the rigid air lines to maintain steep pulse wave fronts.

Since Rheem makes 100% tests of their solid-state devices, the rapid and reliable methods described have enabled lower costs to be assigned to their quality control program.



Block diagram of the Rectification Efficiency Tester used by Rheem Semiconductor Corporation.

INSTRUCTION MANUALS IN OTHER LANGUAGES

To assist our customers with the operation of GR precision measuring instruments, our representatives abroad are preparing technical publications in various languages. The latest additions include an operating manual in French for the TYPE 1650-A Impedance Bridge. The manual is to be used in conjunction with the English-language edition of the operating instructions for this instrument and is available from our exclusive representatives in France, Ets. Radiophon, 148 Avenue Malakoff, Paris 16, France.

Condensed operating instructions in German have been prepared for the TYPE 1551-B Sound-Level Meter for separate use or for use in conjunction with the English-language edition. These are available from our exclusive representatives in Germany, Dr.-Ing. G. Nuesslein, Doernigweg 6, Ettlingen/Karlsruhe, Germany.

We are sure that these translations, as well as the Italian, French, German, and Spanish abstracts of the regular *Experimenter* issues, will be a valuable aid to General Radio's overseas customers.

NEW NAME FOR ISRAELI REPRESENTATIVE

Eastronics, Ltd., is the new name of the General Radio representative in Israel, previously Landseas Eastern Corporation. All inquiries in Israel regarding General Radio products should be addressed to:

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22 Maze Street, P. O. B. 2554
Tel Aviv, Israel

GENERAL RADIO INSTRUMENTS WILL BE DISPLAYED

At the following International Exhibitions during the first six months of 1961

Utrecht Industrial Fair — Holland, March 13-22
Exhibited by: Technische Verkoopkantoor Groenpol

Sydney IRE Show — Australia, March 20-25, *exhibited by:* Instruments Pty., Ltd.

Milan Fair — Italy, April 12-26, *exhibited by:* Ing. S. & Dr. Guido Belotti

Tokyo International Trade Fair — Japan, April 17-May 7
Exhibited by: Midoriya Electric Co., Ltd.

National Industries Production Show — Toronto, Canada, May 8-12
Exhibited by: General Radio Company

Mesucora 61 — Paris, France, May 9-17, *exhibited by:* Ets. Radiophon

General Radio Company

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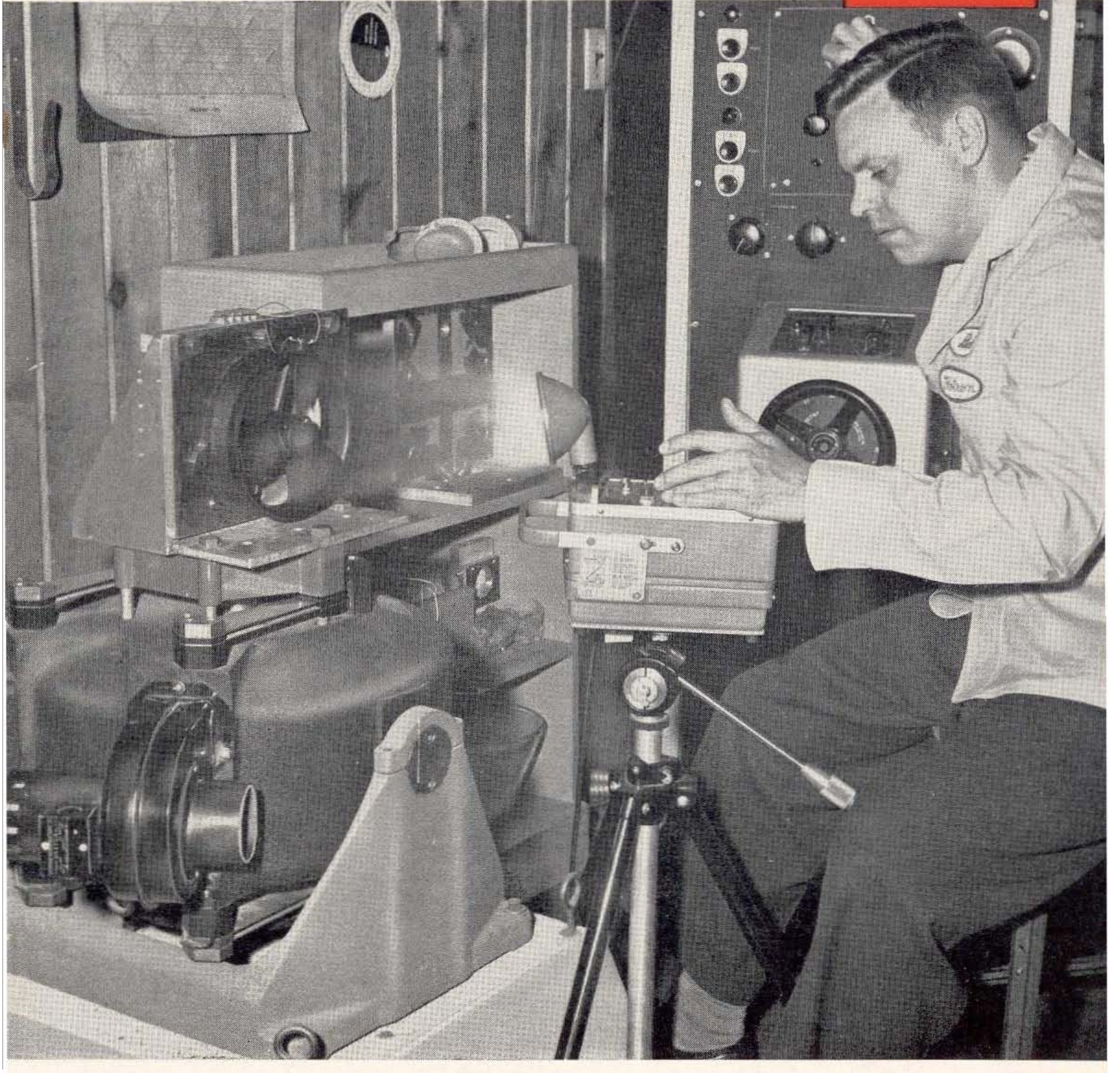

VOLUME 35 No. 3

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IN THIS ISSUE

UHF Oscillator
Modulating Power Supply

THE GENERAL RADIO

EXPERIMENTER

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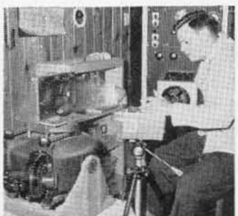
The General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in electronic techniques in measurement. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.



One of the many uses of the new Strobotac® Electronic Stroboscope, Type 1531-A, is in vibration testing. The cover photograph shows a 3300-rpm saucer fan being tested for blade resonance on a shake table at Rotron Manufacturing Company, Woodstock, New York.

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A NEW UHF SIGNAL SOURCE

THE TYPE 1361-A UHF OSCILLATOR

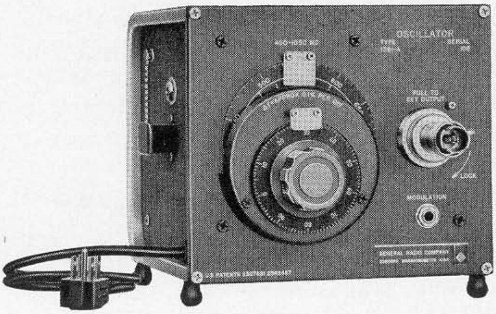

Figure 1. Panel view of the Type 1361-A UHF Oscillator.

Many laboratory and production-line tests require a compact signal source which can deliver more output than the average standard-signal generator, while not requiring an accurate calibration of absolute output level. Measurements with the Type 874-LBA Slotted Line, the Type 1602-B UHF Admittance Meter, the Type 1607-A Transfer-Function and Immittance Bridge, as well as the Type 874-MR Mixer Rectifier in a heterodyne detector system, all require such a source. There is a demand for some features not previously available in the popular General Radio line of Unit Oscillators, such as a readily resettable front-panel output control, and provision for square-wave and pulse modulation. The Type 1361-A UHF Oscillator has been designed with these requirements in mind. It provides a 100-milliwatt output in the 450 to 1050 Mc part of the UHF frequency range. Typical curves of power output *vs.* frequency are shown in Figure 2.

The usefulness of this oscillator for many applications is enhanced by its precision drive with easily repeatable setting. By means of the Type 1750-A Sweep Drive or the Type 908-R Dial Drives, the output frequency can be swept mechanically for oscillographic display or X-Y recording. External power supplies are available to maintain constant amplitude and for amplitude modulation by sine waves, square waves, or pulses.

The oscillator design has been closely coordinated with that of the companion Type 1264-A Modulating Power Supply (see page 6) which provides CW, square-wave, or pulse-modulated operation. Square-wave modulation is generally preferred to sinusoidal modulation be-

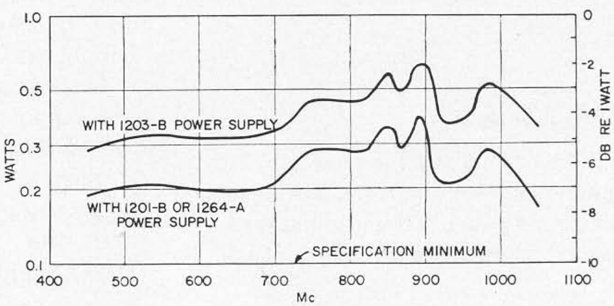

Figure 2. Typical power output characteristic of the Type 1361-A UHF Oscillator.

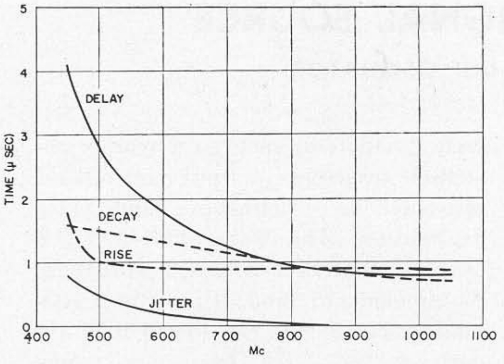

Figure 3. Pulse-modulation characteristics of the Type 1361-A UHF Oscillator used with the Type 1264-A Modulating Power Supply.

cause incidental frequency modulation is much less. Pulse-modulation characteristics are shown in Figure 3.

Frequency Control

A Type 5675 Pencil Tube is used in the oscillator. Frequency is determined by a General Radio butterfly circuit (no sliding contacts) and is controlled by a 4-inch precision dial calibrated to ±1%. The main frequency scale is approximately logarithmic. A vernier dial on the slow-motion drive carries 100 linear divisions, each corresponding to a 0.1% change in frequency. Each full turn of the vernier dial corresponds to a numbered sector on the main dial, so that settings can be recorded and repeated in terms of sector number and vernier divisions.

Output System

The output is adjustable by a waveguide-below-cutoff attenuator located on the front panel. The attenuator is calibrated in relative attenuation over an 80-db range. Additional uncalibrated ranges are provided at the high and low output ends. The output coupling loop slides in and out for output adjustment and can be locked at any point. The output terminal is the new locking Type 874 Coaxial Connector which permits semi-permanent installation of adaptors to virtually any standard military type of connector.

The radiated and conducted fields have been reduced to a very low value by complete shielding, together with the use of ferrite-loaded filters and a ceramic rotor shaft.

Housing

Considerable attention has been paid to providing compatible packages, so that the oscillator can be semi-permanently attached to the Type 1264-A Modulating Power Supply to form a single rigid unit. Each instrument is housed in a rack-bench instrument cabinet* 7 inches high by 8 inches wide. The combination or either individual unit can be readily mounted in a standard relay rack by means of accessory panel extensions.

Power Supply and Modulation

For continuous-wave output the Type 1201-B Unit Regulated Power Supply is recommended to provide maximum stability; where maximum output is required, the Type 1203-B Unit Power Supply can be used.

The Type 1216-A Unit I-F Amplifier will supply adequate power to operate the oscillator in a heterodyne detector.

When square-wave or pulse modulation is required in addition to CW operation, the Type 1264-A Modulating Power Supply should be used.

*H. C. Littlejohn, "The Case of the Well-Designed Instrument," *General Radio Experimenter*, 34, 3, March, 1960.

400-cycle or 1-kc sine-wave modulating voltage from the Type 1214-A Unit Oscillator can be superimposed on the dc plate voltage from any of the above power supplies by way of a panel jack, but the incidental frequency modulation will be appreciable.

The output amplitude can be held constant over the frequency range at a level of approximately 2 volts by use of the Type 1263 Amplitude-Regulating Power Supply. This power supply is recommended for sweep frequency applications in conjunction with a dial drive unit.

Figure 4. Type 1361-A UHF Oscillator relay-rack mounted with Type 480-P408 Panel Extensions.

— G. P. McCouch

SPECIFICATIONS

Frequency
Range: 450 to 1050 Mc.
Calibration: Logarithmic frequency scale; vernier dial calibrated in 0.1% increments.
Accuracy: ±1%.

Stability: Warm-up frequency drift is 0.2%, max.

Attenuator: Range, 80 db with 5-db scale divisions, relative attenuation. Additional uncalibrated range is provided.

Power Supply: Five types of external power supply are available, each designed for a particular purpose:

Tube: One 5675, supplied.

Accessories Supplied: Coaxial patch cord.

Other Accessories Available: Panel Extensions for rack mount (see below), Type 874 Coaxial Elements to fit output connector, adaptors to military connectors.

Cabinet Dimensions: Width 8, height 7⅝, depth 9½ inches (205 by 185 by 240 mm.), over-all.

Net Weight: 7 pounds (3.2 kg).

Type	*Oscillator Modulation Possibilities*[1]	*Oscillator Output*[2] *into 50 ohms*	*Remarks*
1203-B[3]	Sine Wave	125 mw	Gives maximum rf output
1201-B[3]	Sine Wave	100 mw	Gives maximum frequency stability
1263-B	Sine Wave 1-kc square wave	20 mw	Holds oscillator output constant with frequency
1264-A[3]	Sine, pulse, and square waves	100 mw	Power level given is for CW operation
1216-A	Sine Wave	Adequate for heterodyning	

[1] Sine-wave modulation depth is 30% with 40 volts into 6000 ohms. Type 1214-A Unit Oscillator is recommended.
[2] At least as great as stated.
[3] Will operate from 400-cycle line.

Type		*Code Word*	*Price*
1361-A	**UHF Oscillator**	OLIVE	**$285.00**
480-P408	**Panel Extensions (For oscillator only)**	EXPANELJAG	**8.00**
480-P416	**Panel Extensions (For oscillator and Type 1263-B or Type 1264-A Power Supply)**	EXPANELNIT	**6.00**

THE TYPE 1264-A MODULATING POWER SUPPLY

SQUARE-WAVE AND PULSE MODULATION FOR HIGH-FREQUENCY OSCILLATORS

Amplitude modulation of signal sources such as the Type 1361-A UHF Oscillator and the various Unit Oscillators is frequently required, either to simulate the modulation employed in navigation or communication systems, or to permit audio amplification of the detected signal in bridge or slotted-line measurements. At frequencies in the VHF and UHF region, pulse or square-wave modulation is usually employed in preference to sinusoidal modulation, largely because of the difficulty in obtaining amplitude modulation which is linear and free from incidental frequency modulation.

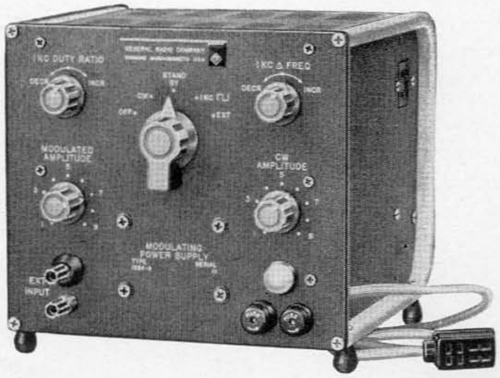

Figure 1. Panel view of the Type 1264-A Modulating Power Supply.

The Type 1264-A Modulating Power Supply produces 100% pulse or square-wave amplitude modulation of high-frequency oscillators as well as permitting continuous-wave operation. While designed especially as a companion to the new Type 1361-A UHF Oscillator, this power supply can also be used with the General Radio Unit Oscillators, Types 1215-B (50-250 Mc), 1209-B (250-920 Mc), 1209-BL (180-600 Mc), and 1218-A (900-2000 Mc).

This power supply (see block diagram, Figure 2) comprises an electronically regulated, adjustable-output, high-voltage, dc supply, a dc-coupled power modulator of the series type driven by a Schmitt trigger circuit, and a 1-kc multivibrator. A function selector switch permits the operator to turn power on, and select CW, stand-by (heaters only energized), 1-kc square wave (internally generated), or external modulation. Independent front panel controls vary the regulated supply voltage for CW operation and the modulator output-pulse amplitude. Controls are also provided to adjust the frequency of the internal 1-kc multivibrator, and the duty ratio of the square wave which it produces.

The modulator stage provides a negative pulse which is applied to the oscillator cathode. Since there is no dc output in the quiescent condition between pulses, the oscillator is completely cut off and modulation is a full 100%. The modulator has high peak current capability in order to charge and discharge rapidly the RF filter capacitances used to control leakage in the associated oscillator. Rise and decay times of less than 1.5 μsec are obtained when feeding the 300-pf shunt capacitance of the filtering employed in the Type 1361-A Oscillator. Inasmuch as these are comparable to the inherent starting and delay characteristics of the oscillator itself, further im-

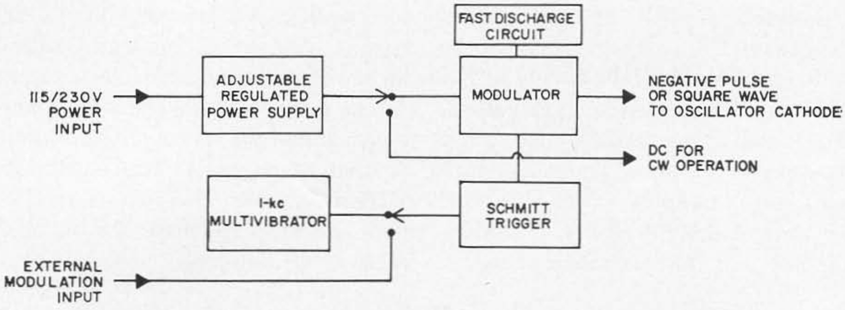

Figure 2. Block diagram of the Type 1264-A Modulating Power Supply.

provement of the modulator video characteristics cannot be justified. Pulse widths from 1.5 μsec to square waves are obtainable with external modulation input. Overshoot of the leading edge of the video pulse is less than 5%, there is no droop, and the output amplitude is independent of pulse width and rate.

The input trigger circuit will accept single or multiple positive pulses or square waves at rates up to 100 kc, or sine waves up to 50 kc, from any source of 20-volt amplitude such as a TYPE 1217-A Unit Pulser or TYPE 1210-C Unit RC Oscillator. No adjustment of triggering is necessary. The built-in stable 1-kc multivibrator of adjustable rate (±15%) and duty cycle provides ideal square-wave modulation for use with sharply selective amplifiers following the signal detector.

In the design of the TYPE 1264-A Modulating Power Supply, several problems of compatibility were considered. It

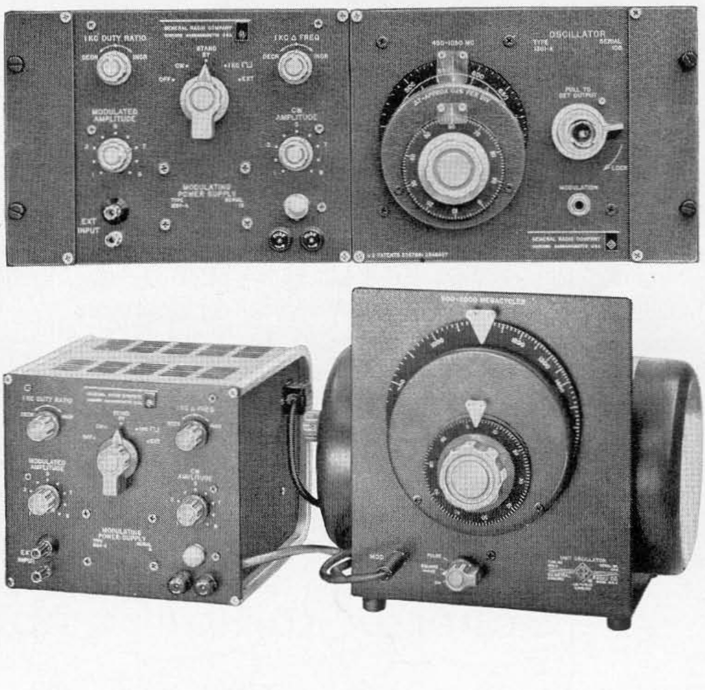

Figure 3. The Type 1264-A Modulating Power Supply is shown (above) relay-rack mounted with the Type 1361-A UHF Oscillator and (below) used on a laboratory bench with the Type 1218-A Unit Oscillator.

was desirable that it be usable with existing Unit Oscillators as well as the new Type 1361-A UHF Oscillator. It was also desirable that the Type 1361-A UHF Oscillator be usable with other existing power supplies. The nearly universal solution adopted works with B+ or B− grounded in the oscillator, and requires only that the cathode be available for pulsing. To use the Type 1264-A with previously existing Unit Oscillators, an accessory adaptor cable is required.

The rack-bench instrument cabinet, 7 inches high by 8 inches wide, is identical to that employed in the Type 1361-A UHF Oscillator. The two may be semipermanently attached for bench or relay-rack mounting.

— G. P. McCouch

SPECIFICATIONS

Output

Regulated dc (unmodulated): Adjustable 200 to 300 v, 50 ma.

Heater Power: 6.3 v ac, 2.1 amps.

Square Waves (internally generated): 850 to 1150 cps, 160 to 210 v (approx.).

Pulses (externally generated): 1.5 μsec to square waves, rise and decay times less than 1.5 μsec each, amplitude 160 to 210 v (approx.), overshoot less than 5%, no ramp off.

Inputs

Power Input: 105 to 125 (or 210 to 250) volts, 50 to 1000 cps, 85 watts.

External Driver: 20 to 50 volts peak positive pulse, or rms sinusoidal; 20 to 100,000 pps for pulses, 20 to 50,000 cps for sine waves.

Accessories Available: Type 1264-P1 Adaptor Cable, used to connect Type 1264-A to Type 1209-B, Type 1209-BL, or Type 1215-B Unit Oscillators. Type 1264-P2 Adaptor Cable, used to connect Type 1264-A to Type 1218-A Unit Oscillator. One pair of Type 480-P408 Panel Extensions is required for individual relay rack mounting, or one pair of Type 480-P416 Panel Extensions for use with the Type 1361-A UHF Oscillator.

Dimensions: Width 8, height 7⅝, depth 9½ inches (205 by 195 by 245 mm.), over-all.

Net Weight: 12 lb (5.5 kg).

Type		*Code Word*	*Price*
1264-A	Modulating Power Supply	MODUL	$285.00
1264-P1	Adaptor Cable for Types 1209-B, 1209-BL, and 1215-B	MODULCABLE	15.00
1264-P2	Adaptor Cable for Type 1218-A	MODULADAPT	8.50
480-P408	Panel Extension (For power supply only)	EXPANELJAG	8.00

ISRAELI REPRESENTATIVES

In the January-February issue of the *Experimenter*, we announced the new name, Eastronics, Ltd., for our representative in Israel. We neglected to mention that our representative in the United States for Israel is the associate organization:

LANDSEAS PRODUCTS CORPORATION
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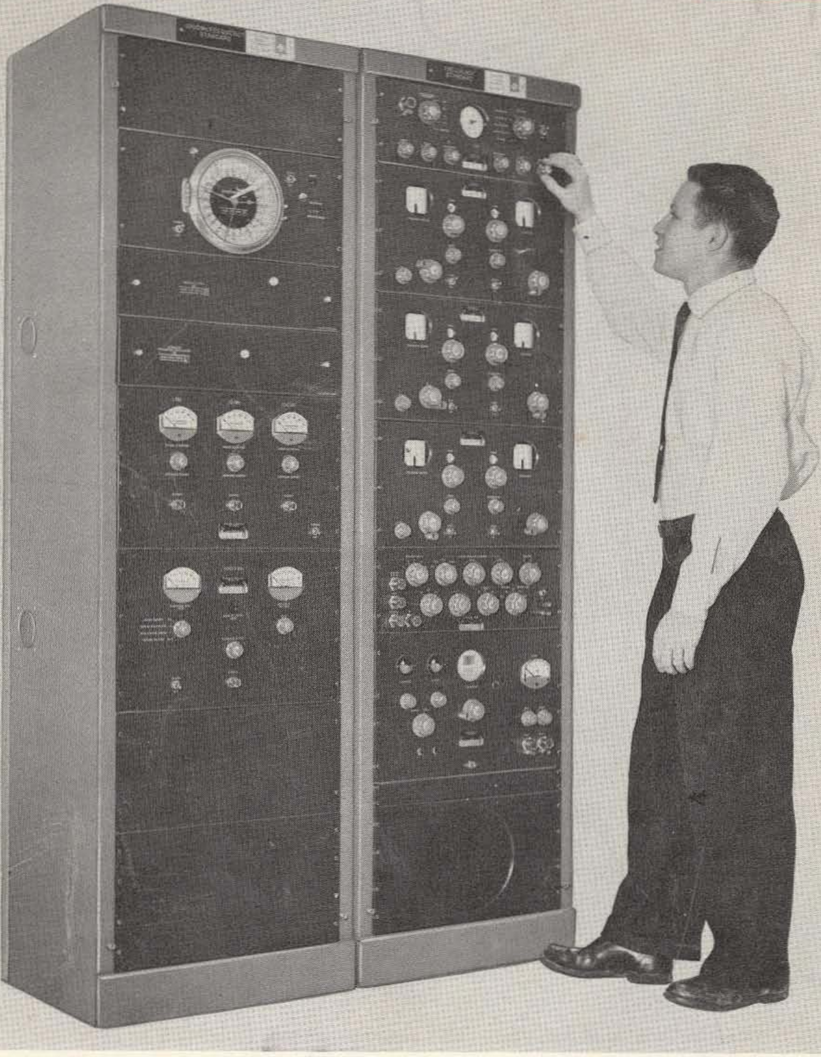
New York 36, New York

General Radio Company

THE GENERAL RADIO EXPERIMENTER



VOLUME 35 No. 4

APRIL, 1961

IN THIS ISSUE

New Frequency Standard

Representative for New Zealand

THE GENERAL RADIO

EXPERIMENTER

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The General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in electronic techniques in measurement. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

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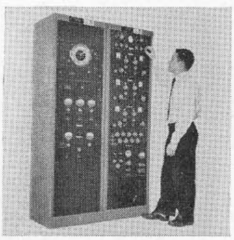

View of the new Type 1120-AH 1000-Mc Frequency Standard (left-hand rack) with the Type 1105-B Frequency Measuring Equipment (right).

THE NEW GR FREQUENCY STANDARD

Like voltage, current, and impedance, frequency is a factor in most electrical measurements. It enters directly into ac measurements, and indirectly into dc measurements, appearing most often as its reciprocal, time. Since time is reciprocally related to frequency, a good frequency standard can become a good time standard for time measurements. In view of the necessity for some sort of frequency standard for even a 1000-cycle impedance measurement, it has become almost routine for an electrical measurement laboratory to possess a stable frequency standard which can be checked against standard-frequency or standard-time signals from appropriate sources.

It would be a mistake to consider that a "frequency standard" consisted solely of an extremely stable oscillator. Frequency dividers and multipliers are necessary to make the frequency standard useful over the range of frequencies covered by electrical measurement techniques, and to permit calibration of the frequency in terms of recognized international standards. The provision of standard output signals over the range from low audio to microwave frequencies insures maximum usefulness for applications ranging from heterodyne-system frequency measurements to service as time-base reference in digital counters for frequency and time-interval measurements.

The frequency standard described in this article makes available, in various combinations, equipment to produce fundamental frequencies from 60 cps to 1000 Mc. It includes completely new instruments for generating the standard frequency, for deriving the desired low-frequency sub-multiples, and for developing harmonic-rich outputs. An improved Syncronometer* integrates the 1000-cycle output to permit time comparisons with standard-time transmissions, and the TYPE 1112-A and TYPE 1112-B Standard-Frequency Multipliers[1] provide high-frequency output up to thousands of megacycles. These several instruments can be used individ-

*Trademark pending.

[1]Frank D. Lewis, "New Standard-Frequency Multipliers," *General Radio Experimenter*, Vol. 32, No. 14, July, 1958.

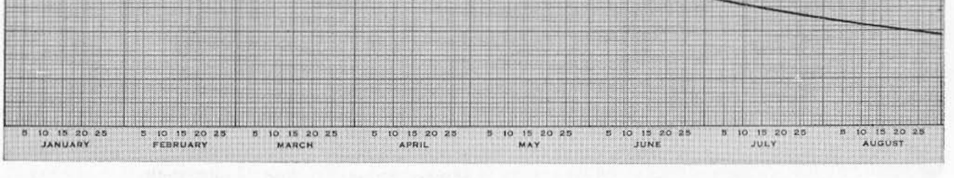

Figure 1. Frequency of Type 1113-A Standard-Frequency Oscillator compared with 18.0-kc standard-frequency transmissions of NBA over a six-month period. The average daily drift at the end of this period is 1.2×10^{-10}. The NBA transmitter is maintained on frequency by comparison with a cesium beam.

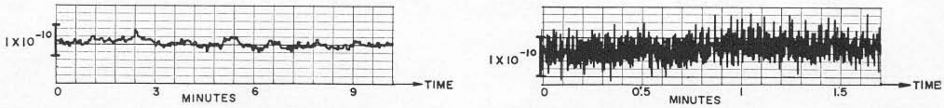

Figure 2. Intercomparison of frequencies of two Type 1113-A Standard-Frequency Oscillators. The short-term frequency instability of one oscillator alone is less than this combined instability by 1: $\sqrt{2}$. The left-hand plot shows frequency variations averaged over 1-second sampling periods; the right-hand plot shows frequency variations averaged over 0.1-second periods.

ually or in various combinations to meet specific needs. They are designed to cooperate with the General Radio Type 1105-B Frequency Measuring Equipment as well as with counter-type frequency-measuring systems.

New techniques, circuits, and components have been used wherever applicable, consistent with conservative design. Practical compromises have been sought throughout to provide performance commensurate with the present state of the art at prices in keeping with equipment for everyday use. Thus, in accord with General Radio practice, the instruments are designed to be rugged, accurate, and dependable for ordinary environments but not (with the considerable added cost necessary) to cope with the stringent requirements of the military services for extreme environmental conditions.

The Type 1120-AH 1000-Mc Frequency Standard illustrated in Figure 1 comprises the Type 1113-A Standard-Frequency Oscillator, the Type 1114-A Frequency Divider, the Type 1103-B Syncronometer, and the Types 1112-A and 1112-B Standard-Frequency Multipliers. Used in conjunction with the Type 1105-B Frequency Measuring Equipment and the new Type 1130-A Digital Time and Frequency Meter[2] this yields a comprehensive line of integrated frequency-measuring equipment.

THE TYPE 1113-A STANDARD-FREQUENCY OSCILLATOR

The heart of the assembly is, of course, the standard-frequency generator. The General Radio Type 1101-B Piezo-Electric Oscillator, last of a long line[3] of distinguished predecessors, added its own contribution to the excellent reputation of General Radio frequency standards for dependability in the field. Today's requirements, however, demand considerably better stability.

[2]To be announced next month.
[3]James K. Clapp, "A New Frequency Standard," *General Radio Experimenter*, Vol. 3, No. 11, April, 1929.

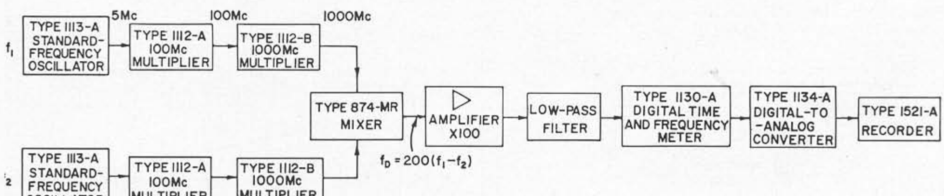

Figure 3. Schematic of equipment used to obtain the data plotted in Figure 2. Two oscillators are compared at 1000 Mc. The difference frequency f_D is made 1 cps for a 1-second sample or 10 cps for a 0.1-second sample. The output from the mixer, about 500-mv peak-to-peak, is amplified to 50 volts peak-to-peak. A low-pass filter eliminates the small amount of 60-cycle and 120-cycle components introduced by the multipliers. Its cut-off frequency is 15 cps, with better than 40 db attenuation at 60 cps. The period of the difference frequency f_D is measured with the Type 1130-A Digital Time and Frequency Meter and its output converted into analog form by the Type 1134-A Digital-to-Analog Converter. The output is plotted by a Type 1521-A Recorder. This recorder has a bandwidth of 10 cps which permits the measurement of stability for 0.1-second samples.

The new Type 1113-A Standard-Frequency Oscillator, which replaces it, uses the Gouriet-Clapp circuit[4], instead of a modified Meacham bridge, and replaces the second-harmonic extensional-mode quartz bar,[5] operating at 100 kc, with a contoured AT-cut quartz plate, operating at 5 Mc. This plate, developed by a group at the Bell Telephone Laboratories[6] under a Signal Corps contract, has a storage factor, Q, in the range of 2 to 3 x 10^6, which makes possible a high degree of decoupling between the frequency-control element and its maintaining circuit. This, in turn, minimizes short-term frequency variations. Care in processing, with particular attention to avoiding contamination,[7] minimizes long-term drift. Over-all stability is therefore excellent, as shown in Figures 1 and 2.

Figure 4 is a schematic of the oscillator, showing the frequency-control system and the delayed AGC, which maintains the drive power to the crystal at approximately 0.5 x 10^{-6} watts, a level carefully chosen to be large enough to be "out of the noise" for short-term fluctuations but small enough so that aging and variations of frequency with drive level, which become significant at high powers, are minimal. Premium quality, long-life tubes are used for oscillator and amplifiers to assure reliability and to increase the time between tube replacements. To minimize effects of cathode-interface impedance[8] the oscillator tube is operated at relatively low transconductance and at reduced heater temperature. Filtered dc heater voltage minimizes 60-cycle frequency modulation, and well-regulated heater and plate supplies make the operation of the instrument substantially independent of line voltage. Ac and dc feedback in the AGC amplifier system keeps the crystal drive level within 10% for 2:1 change in transconductance of the tubes.

The temperature-control for the quartz plate is a two-stage system based upon the vacuum-bottle oven that has given excellent reliability over the years in the Type 1184-A-A Television Transmitter Monitor.[9] The temperature of this oven is determined by a mercury thermostat, which provides an on-off signal to the grid of a thyratron that controls directly the low-power oven heater. Cyclical temperature changes arising from this on-off heating system have

[4] James K. Clapp, "A Broadcast Frequency Monitor for the 20 Cycle Rule," *General Radio Experimenter*, Vol. 14, No. 8, January 1940.
E. P. Felch and J. O. Israel, "A Simple Circuit for Frequency Standards Employing Overtone Crystals," *Proc. IRE*, Vol. 43, No. 5, pp. 596-603, May, 1955.
F. D. Lewis, "Frequency and Time Standards," *Proc. IRE*, Vol. 43, No. 9, p. 1055 and Appendix pp. 1065-1068, September, 1955.

[5] James K. Clapp, "On the Equivalent Circuit and Performance of Plated Quartz Bars," *General Radio Experimenter*, No. 10-11, Vol. 22, March-April, 1948.

[6] A. W. Warner, "High-Frequency Crystal Units for Primary Frequency Standards," *Proc. IRE*, Vol. 40, No. 9, pp. 1030-1033, September, 1952.

[7] A. W. Warner, "Frequency Aging of High-Frequency Plated Crystal Units," *Proc. IRE*, Vol. 43, No. 7, pp. 790-792, July, 1955.

[8] C. T. Kohn, "The Effect of a Cathode Impedance on the Frequency Stability of Linear Oscillators," *Proc. IRE*, Vol. 48, pp. 80-88, January, 1960.

[9] C. A. Cady, "New Television Transmitter Monitor," *General Radio Experimenter*, Vol. 31, No. 4, September, 1956.

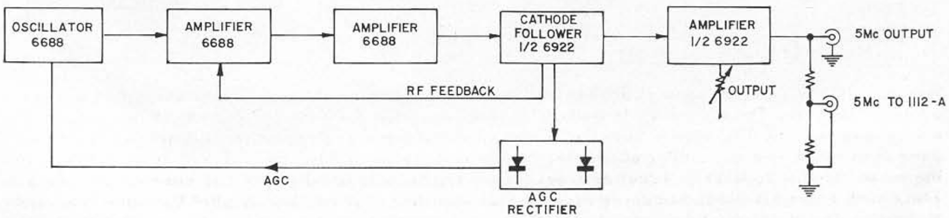

Figure 4. Block schematic of the Type 1113-A Standard-Frequency Oscillator.

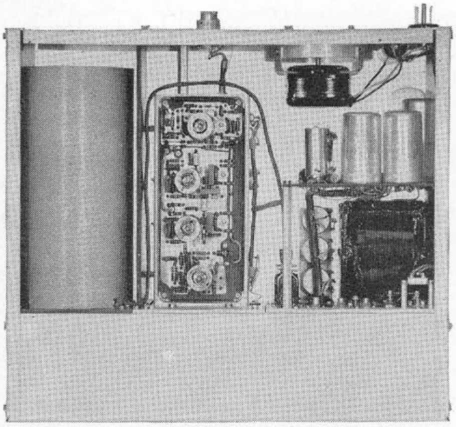

Figure 6. Interior view of the standard-frequency oscillator. Note that all parts are easily accessible. The crystal oven is at the left. The amplifier tubes and other circuit elements are mounted on a Fiberglas etched board in a cast frame. At the rear is a cooling fan with thermal cut-off, which turns off the power if the fan fails.

been reduced to the order of 0.001°C at the quartz plate, and a resultant frequency cycling of less than 10^{-10}. A fan is used to equalize the temperature in the cabinet in order to keep the instrument components cool and to provide a suitable ambient for the outer stage of the temperature-control system. The outer stage, itself, makes it necessary for the inner stage to cope with only a small temperature range. The combination maintains at least a 1500:1 control ratio over an ambient temperature range of 0° to 50°C.

To provide maximum protection against changes in ambient temperature, the oscillator-circuit components that enter into the establishment of frequency are all mounted in the oven with the quartz plate. The coarse frequency adjustment, which covers a range of adjustment of about 5×10^{-7}, is included among these components, and is provided with an ingenious drive mechanism that minimizes heat-leakage problems while assuring precise settability. The fine frequency adjustment, however, covers an adjustment range of only $\pm 5 \times 10^{-9}$ and is not sensitive enough to ambient changes to warrant temperature control. It is individually calibrated to be direct reading, with divisions provided at inter-

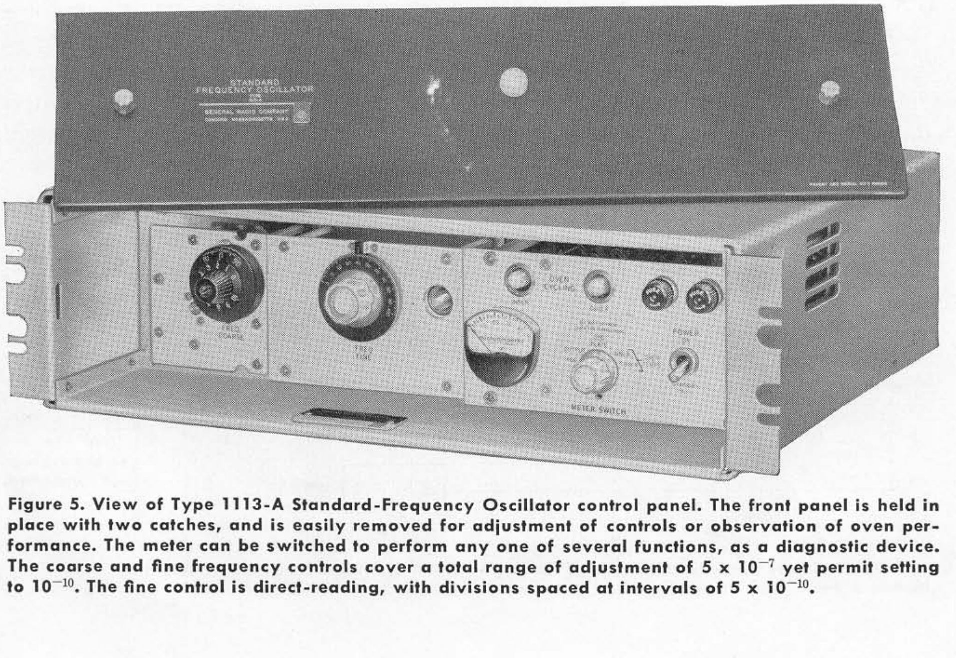

Figure 5. View of Type 1113-A Standard-Frequency Oscillator control panel. The front panel is held in place with two catches, and is easily removed for adjustment of controls or observation of oven performance. The meter can be switched to perform any one of several functions, as a diagnostic device. The coarse and fine frequency controls cover a total range of adjustment of 5×10^{-7} yet permit setting to 10^{-10}. The fine control is direct-reading, with divisions spaced at intervals of 5×10^{-10}.

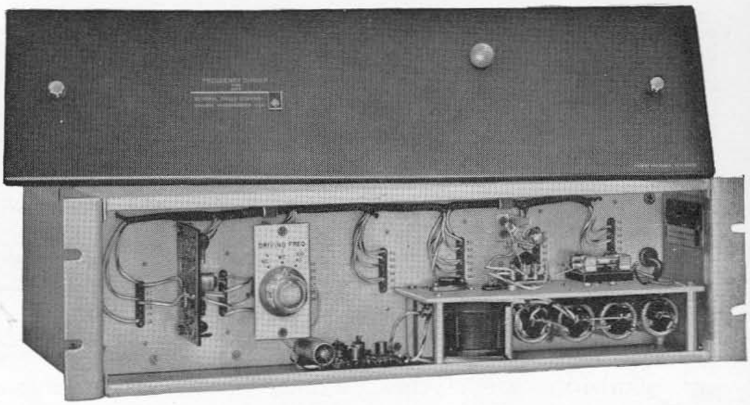

Figure 7. Front view of the Frequency Divider with panel removed.

vals of 5×10^{-10} and is settable to 10^{-10}.

For operational checks, a five-point meter circuit is included. The meter checks oscillator bias, rf output, plate current, inner-oven temperature, and outer-oven temperature.

TYPE 1114-A FREQUENCY DIVIDER

The Frequency Divider produces from the 5-Mc standard signal a series of output frequencies with fundamentals of 1 Mc, 100 kc, 10 kc, 1 kc, and 100 cps. Additional plug-in units are available to furnish outputs at 400 cps and 60 cps. These output frequencies are essentially sine waves. For those applications where harmonic series are needed, the Type 1108-B Coupling Panel[10] provides a harmonic-rich output. One of the important considerations in the design of a frequency standard is that it "fail safe," that is, that there be no possibility that either the output frequencies or the indicated time be in error as a result of failure of the standard-frequency signal. There are two fail-safe conditions in the Type 1120-Frequency Standards. First, the synchronous clock will fall out of synchronism and not restart if the driving signal fails or changes frequency momentarily; and, second, the frequency dividers have no output in the absence of an input signal.

The dividers, however, are designed to restart when the input signal reappears. Thus no valuable data are lost in such applications as automatic frequency-comparison systems in the event of temporary power failure, while the clock stoppage indicates that the timing sequence has been interrupted.

Figures 7 and 8 show the mechanical

[10]See Type 1105-B Frequency-Measuring Equipment, page 12.

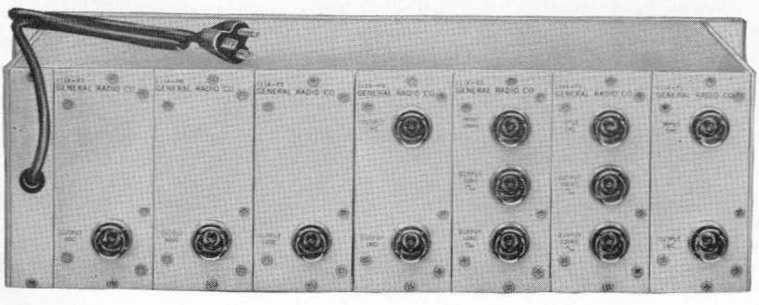

Figure 8. Rear view of the divider with plug-in units installed.

construction of the divider. The front panel can be removed to make test points easily accessible from the front of the relay rack. Plug-in units for the desired output frequencies are inserted from the rear (Figure 8). A typical plug-in unit is shown in Figure 9. Transistors are used throughout for reliability, small size, and low-power consumption. Figure 10 is a block diagram of the divider. The 5:1-Mc divider is regenerative, while the lower-frequency dividers are of the switching type.

The regenerative P1-unit divides the original 5-Mc frequency (or, optionally, 2.5 Mc) to 1 Mc. Each of the following units (P2 to P5) divides by 10. The optional 400-cycle unit selects the second harmonic of a 200-cycle signal, and the optional 60-cycle unit divides 200 by 10 and selects the third harmonic of the 20-cycle signal.

The 5:1-Mc regenerative divider is shown in elementary form in Figure 11. To explain its operation, let us assume the presence of a small 1-Mc voltage in the 1-Mc circuit. This is multiplied to 4-Mc, which is fed back to the mixer and heterodyned with the 5-Mc input, increasing the 1-Mc output.

This regenerative process produces a 1-Mc sine wave. The operating conditions of the circuit are set to obtain

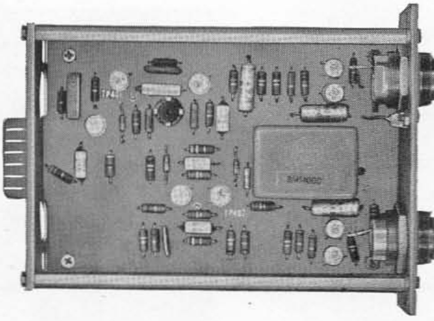

Figure 9. View of a typical plug-in unit.

limiting on a few tenths of a volt input, and the output is essentially constant over 5:1 drive range. For 2.5-Mc input the mixer generates the 5 Mc second harmonic and works as described above, dividing effectively by 2/5.

The lower frequency dividers are of the "switching" type. Figure 12 is a block diagram. The input signal, a square wave, is differentiated. The trigger generator is an amplifier generating short, positive trigger pulses. They are used to drive a monostable multivibrator (one-shot). The time constant of this circuit is chosen to reset at every fifth trigger pulse. Hence, one output pulse is generated for every 5 input pulses. The next stage is a bistable multivibrator (flip-flop). The square wave from this flip-flop is one tenth of the input frequency. A narrow-band filter selects the fundamental component

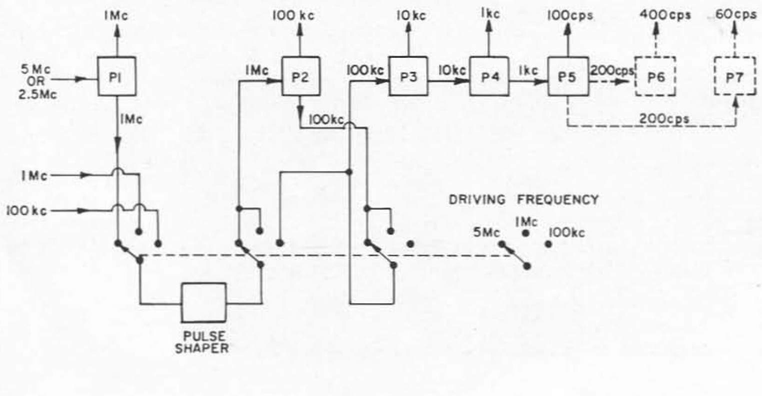

Figure 10. Block diagram of the Frequency Divider.

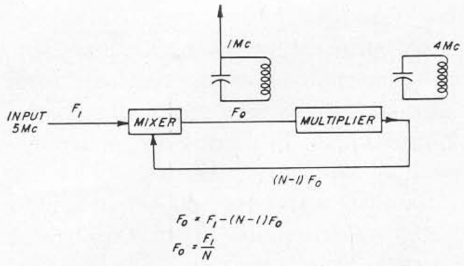

Figure 11. Elementary schematic of the 5:1 regenerative divider.

which is available at the output terminal.

The choice of a regenerative divider from 5 Mc to 1 Mc and switching dividers for the lower frequencies was dictated by two considerations: The use of a regenerative divider above 1 Mc is more economical, while below 1 Mc switching dividers have better phase stability. An important objective of this design has been to obtain high-phase stability so that the output signals can be used for the generation of high-order harmonic spectra with a minimum of phase modulation. For such applications, square-wave outputs are provided at 100 kc and 10 kc in addition to the sine-wave outputs.

The phase stability of a divider may be expressed in two ways: either in degrees phase angle of the output, or in terms of absolute time variation (jitter). In a regenerative divider, the slope of the signal voltage decreases by an order of magnitude for each division by 10. Assuming constant circuit-noise level, the phase-angle jitter will be invariant. This means that the time jitter in absolute units increases by one order of magnitude for each decade of division. Switching dividers on the other hand may be assumed to have constant rise time regardless of fundamental frequency so that the time jitter remains invariant. This means that the phase noise is reduced by an order of magnitude for each 10:1 division. Given an over-all division ratio of 1000, say from 1 Mc to 1 kc, and assuming that for each stage a switching divider contributed 1 nsec, then we will have a total of 3 nsec time jitter at the 1-kc output. If a regenerative divider operating over the same range starts with a 1-Mc slope equal to that of the switching divider, then the 1-Mc to 100-kc stage will contribute 1 nsec as in the pulse system described above. From 100 kc to 10 kc the slope of the sinusoidal waveform has decreased by 10:1, hence, the jitter will be 11 nsec, and at 1-kc output, the jitter will be 111 nsec. This is 30 times more than the switching divider.

While this hypothetical example is for illustrative purposes only, measurements have shown similar relationship between the jitter of such circuits. A typical figure for the circuits of the Type 1114-A is an average of .05 nsec of jitter per decade. The measurement was made with a sampling oscilloscope measuring the total jitter of the 100-c output with respect to the 5-Mc input.

THE TYPE 1103-B SYNCRONOMETER

The reciprocal relationship between frequency and time has been of prime importance from the earliest days of

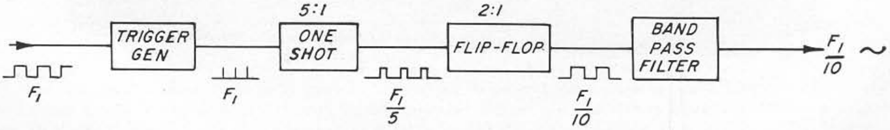

Figure 12. Block diagram of the switching divider.

frequency standards. Time is a fundamental dimension in our physical descriptions of things, and the need for more and more accurate measurements of time has steadily increased over the years. A frequency standard, which generates a series of events at a very constant rate, can be considered as a linear interpolator between measured times that mark the beginning and end of time intervals. To perform this function it is necessary that the events be counted over the interval, and this counting can be nicely done by a synchronous clock.

The events counted are ultimately displayed by the clock as turns of a shaft, or, in finer detail, by the angle of the shaft. A clock designed to run from a frequency standard should therefore run smoothly, at a very constant angular velocity, so that its shaft angle bears a constant relationship to the electrical angle of the sinusoidal driving signal, and it should be provided with a mechanism for accurately determining the shaft angle at any desired point in time.

The General Radio Syncronometers[11] have, over the years, met these requirements admirably, as attested by their use throughout the world. They are based, primarily, upon a 1000-cycle synchronous motor having a 100-tooth rotor fabricated from high-grade silicon-steel laminations. Two driving coils, oppositely disposed with respect to the rotor shaft, carry the 1000-cycle driving signal superimposed upon a dc biasing current. Pulses of torque are therefore exerted upon the teeth at a 1000-cycle rate as they pass the pole pieces, and the rotor shaft turns at 10 revolutions per second. The rotor itself carries a circular well, coaxial with the shaft, which contains radial baffles and which is partially filled with mercury. The mercury, in this configuration, does double duty in serving as a heavy mass to produce flywheel action and as a damping agent to minimize hunting.

The rotor shaft, which is vertical when the instrument is in its normal operating position, drives a horizontal shaft at 1 revolution per second through the combination of a worm and gear. This shaft, in turn, drives the clock mechanism through another right-angle worm-

[11] "The Type 411 Synchronous Motor," *General Radio Experimenter*, Vol. 1, No. 11, May, 1927.
H. S. Wilkins, "Synchronous Motor-Driven Clocks," *General Radio Experimenter*, Vol. 5, No. 5, October, 1930.

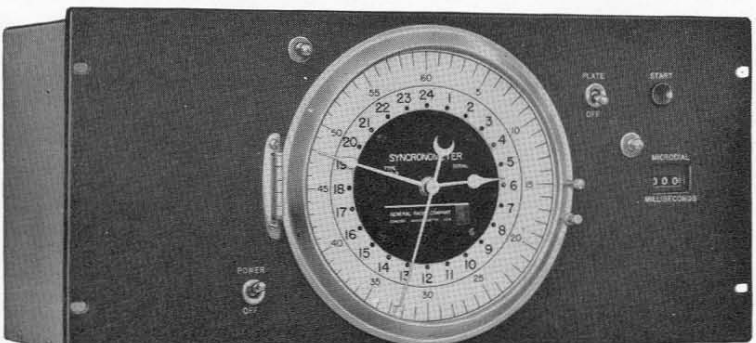

Figure 13. Type 1103-B Syncronometer. The new 24-hour dial face is easier to read than the old. The microdial and second-hand shafts are accessible through the ports to the right and left of the clock face, respectively, and can be set with a crank. The Type 1103-B is completely self-contained, with its own power supply, and can be driven from any one-volt 1000-cycle source.

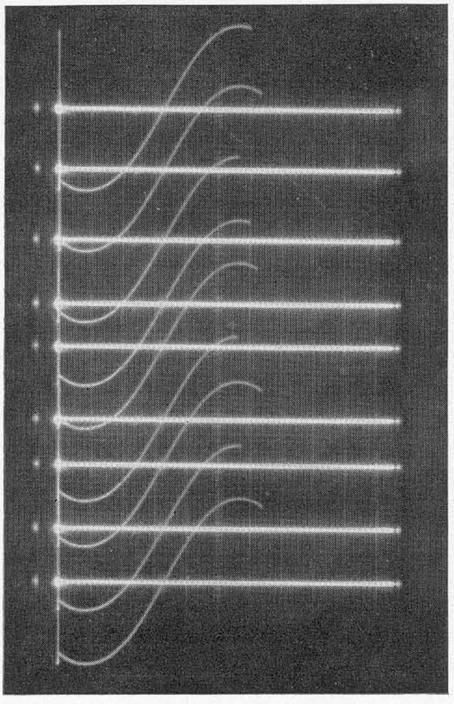

Figure 14. Successive traces, at 2-second intervals, of 1000-cycle signals terminated by closure of the contactor in the Type 1103-B Syncronometer. For comparisons with standard-time signals the Type 1109-B Comparison Oscilloscope is recommended.

and-gear combination, which reduces the speed to 2 revolutions per minute. The second hand of the clock is driven from this shaft through a 2:1 differential gear, which makes possible continuous adjustment of the second-hand position without affecting the operation of the clock motor in any way. The minute-hand and hour-hand shafts are positively driven by the second-hand shaft, so that their relative positions remain correct when adjustments are made. The hands themselves, however, are driven through slip clutches so that they can be individually set, when desired.

The one-revolution-per-second shaft also drives the contactor that is used to determine the value of the shaft angle at a given moment in time. The contactor is mounted on a disc, whose plane is normal to the shaft, on a bearing that is accurately coaxial with the shaft. The contactor is actuated by a cam on the shaft, and the angular position of the disc is adjustable from the front panel through a worm-and-wheel drive. A mechanical counter, driven from the adjusting shaft, provides an in-line digital readout that is direct reading in milliseconds and that can be read to 0.1 millisecond on an interpolating scale having marks at 0.2-millisecond intervals. This choice of scale makes the resolution compatible with the uncertainty in pulse-starting time that arises from propagation anomalies for time signals received over radio paths. This uncertainty, which may be as little as 2 microseconds for ground-wave reception, is generally about 0.1 millisecond for sky-wave reception.[12]

[12]H. F. Hastings, "Precision Frequency Control and Millisecond Timing," Report of NRL Progress, p. 18, August, 1960.

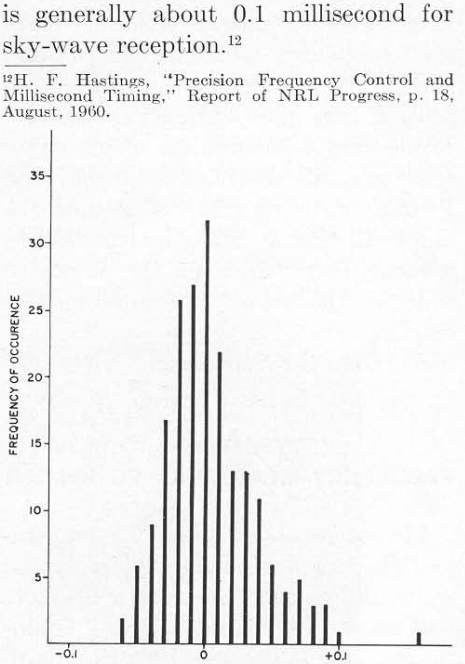

Figure 15. Histogram showing the random nature of variations in closure time of the contactor in the Type 1103-B Syncronometer. The average deviation is less than the average uncertainty in sky-wave reception of time signals.

The Type 1103-B Syncronometer, shown in Figure 13, is improved over its predecessor in several respects. From an operating standpoint, however, the most important are, undoubtedly, the mechanical features discussed above, which make possible more convenient use with an improvement in accuracy of 10:1. An important ingredient in the mechanical system is the contactor, which follows the general design of a contactor worked out by H. F. Hastings of the Naval Research Laboratory. This contactor-mechanism has a very long service life because wear is distributed over a large area, and an accuracy of closure of approximately ±50 to ±80 μsec, without "bounce." Figure 14 shows typical performance for signal display and Figure 15 is a histogram of closing times.[13] The ruggedness of a simple mechanism, refined by improvements based on experience, provides a reliability of operation and ease of maintenance seldom approached by more complex systems incorporating combinations of electrical, optical, and mechanical techniques. Proven operating features include the ability to take a time-of-arrival reading without disturbance of the indicated time on the clock, and provision for starting the 1000-cycle synchronous motor from the front panel.

TYPE 1105-B FREQUENCY-MEASURING EQUIPMENT

Measurements of unknown frequencies in terms of a locally generated standard frequency are being made more and more with digital counting equipment, and the Type 1113-A Standard-Frequency Oscillator and the Type 1130-A Digital Time and Frequency Meter have been designed to combine the high accuracy and stability of a frequency standard with the high resolution and convenience of a counter.

There are, however, limitations to counters that make imperative the use of other types of measuring instrument. In particular, the counter is inherently a broad-band device, wide open to noise and unable to distinguish between a wanted zero-crossing and an unwanted spike. When measurements of frequency must be made in the presence of noise there is therefore a need for devices that make this discrimination. The human ear is excellent for this purpose, and the radio receiver, with human operator, has found considerable use over the years.

The Type 1105-B Frequency-Measuring Equipment comprises, basically, three regenerative radio receivers, or tuned detectors, covering the frequency range from 100 kc to 100 Mc, combined with three high-stability heterodyne-frequency-meter oscillators covering the fundamental frequency ranges 100-200 kc, 1-2 Mc, and 10-20 Mc. The tuned detectors can be operated either oscillating, for initial pickup of the unknown signal, or non-oscillating for detection of the difference frequency between the unknown signal and a standard-frequency signal. This standard-frequency signal can be either a harmonic of the heterodyne-frequency meter, used to locate the frequency within ±0.1%, or a 10-kc harmonic of the Type 1114-A Frequency Divider, used to make the final precise measurement. The final measurement can be made by comparison of the difference frequency with that of the Type 1107-A Interpolation Oscillator. The resolution and stability of this instru-

[13] The closing time is used for reference because of its inherently greater reliability. For a description of use of the Syncronometer see: F. D. Lewis, "Standard Time Signals," *General Radio Experimenter*, Vol. 32, No. 13, June, 1958.

ment are adequate to provide a precision of comparison of ±0.5 cps, and accuracy corresponding can be assured by comparison of the output of the Interpolation Oscillator with the 100-cps output of the TYPE 1114-A Frequency Divider to locate high-accuracy points on the dial. By adjusting the zero of the beat-frequency oscillator used in the Interpolation Oscillator, one can set the dial to read exactly at such points, thereby making the accuracy equal to the resolution. The fractional accuracy then becomes ±5 parts in 10^6 for a frequency of 100 kc, increasing to ±5 parts in 10^9 for a frequency of 100 Mc.

The performance of the TYPE 1105-B Frequency-Measuring Equipment greatly exceeds that of its predecessor at the high-frequency end of its measuring range because the 10-kc and 100-kc harmonics are much stronger. The TYPE 1114-A Frequency Divider does not, in itself, produce a wide range of harmonic frequencies. Avalanche-transistor harmonic generators have therefore been incorporated in the TYPE 1108-B Coupling Panel to perform this specialized function. This approach produces strong, solid harmonic "picket fences" through and beyond the range of the TYPE 1105-B.

The signal produced by the difference frequency between one of these pickets and the unknown frequency is entirely adequate to drive a counter if the unknown signal is greater than about 100μv and "out of the noise." For measurements of this kind a counter can therefore be substituted for the TYPE 1107-A Interpolation Oscillator. For general "off-the-air" measurements, however, the discrimination that can be provided by the oscilloscope comparison with the Interpolation Oscillator is in many cases vital.

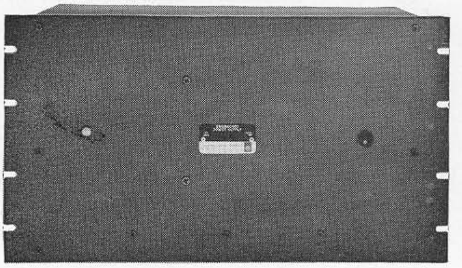

Figure 16. Panel view of the Type 1116-A Emergency Power Supply.

TYPE 1116-A EMERGENCY POWER SUPPLY

An emergency power supply unit is available to maintain continuous operation of a frequency standard comprising an oscillator, frequency-divider, and clock unit. The TYPE 1116-A Emergency Power Supply furnishes ac power from storage batteries, the switch-over being accomplished automatically upon failure of the main ac supply. The transition to battery supply occurs without interruption of the continuous operation of the oscillator and timing system, so that calibration procedure involving time integration can be fully relied upon.

While the design of the TYPE 1113-A Standard-Frequency Oscillator prevents the possibility of permanent damage in the event of power failure, a period of hours or even days may be necessary for the standard to recover equilibrium after a temporary unsettlement caused by power failure.

The emergency power supply is, therefore, a recommended accessory for the frequency standard.

— R. W. FRANK
— F. D. LEWIS
— H. P. STRATEMEYER

Note

The design of the various instruments making up the complete frequency standard and measuring equipment has called upon the talents of many General Radio engineers. The early concept and construction of the Type 1113-A Standard-Frequency Oscillator was worked out by C. A. Cady; the final engineering development was the responsibility of H. P. Stratemeyer, who was also completely responsible for the development and design of the Type 1114-A Frequency Divider. The development of the Type 1112 Frequency Multipliers, which was started by J. K. Clapp, was completed by F. D. Lewis, who, with R. A. Mortenson, was also responsible for the modifications to the Type 1103-B Syncronometer. The avalanche transistor harmonic generators for the Type 1108-B Coupling Panel were designed by J. K. Skilling. The over-all program was under the supervision of R. W. Frank.

— Editor

SPECIFICATIONS

TYPE 1120 FREQUENCY STANDARDS

Each frequency standard assembly is supplied in a floor-type relay rack. The panels and relay rack are finished in General Radio gray crackle lacquer. Space is available in the rack for addition of such auxiliary items as line-voltage regulators, emergency power supply units, radio receiving equipment, and loud speakers.

The performance specifications of these frequency standards are listed under the descriptions of the component units described in the following pages. Two models are available, Type 1120-A and Type 1120-AH.

TYPE 1120-A FREQUENCY STANDARD

Components:

Type 1113-A Standard-Frequency Oscillator
Type 1114-A Frequency Divider
Type 1103-B Syncronometer
Floor-type relay rack
Blank panels to fill rack
Connection cables

Output Frequencies: 5 Mc, 1 Mc, 100 kc, 10 kc, 1 kc, 100 cps. Plug-in units for 400 cps and 60 cps are also available. See Type 1114-A Frequency Divider.

Power Input: 130 watts, maximum, at 105 to 125 (or 210 to 250) volts, 50 to 60 cps.

Dimensions: Height 76⅛, width 22, depth 18½ inches (1950 by 560 by 470 mm), over-all.

Net Weight: 82 pounds (37.5 kg).

TYPE 1120-AH 1000-MEGACYCLE FREQUENCY STANDARD

Components:

Type 1113-A Standard-Frequency Oscillator
Type 1114-A Frequency Divider
Type 1103-B Syncronometer
Type 1112-A Frequency Multiplier
Type 1112-B Frequency Multiplier

Output Frequencies: 1000 Mc, 100 Mc, 10 Mc, 5 Mc, 1 Mc, 100 kc, 10 kc, 1 kc, 100 cps; optionally 60 cps and 400 cps.

Power Input: 330 watts, maximum at 105 to 125 (or 210 to 250) volts, 50 to 60 cps.

Dimensions: Height 76⅛, width 22, depth 18½ inches (1950 by 560 by 470 mm), over-all.

Net Weight: 142 pounds (65 kg).

TYPE 1116-A EMERGENCY POWER SUPPLY

Input: 115 or 230 volts, 50 to 60 cps from power line. 28–32 volts, 7.5–6.5 amp from battery (when operating frequency standard).

Output: 115 volts, nominal, 60 cps, 180 watts continuous. Frequency standard requires 130 watts, max.

Accessories Required: 28-, 30-, or 32-volt battery; battery charging equipment.

Dimensions: Length 19, height 10½ inches (485 by 270 mm), depth behind panel 13 inches (330 mm).

Net Weight: 58½ pounds (26.6 kg).

TYPE 1113-A STANDARD-FREQUENCY OSCILLATOR

Frequency Stability:

Aging: Less than 5×10^{-10} per day, averaged over 10 days, after 60 days of operation. After 1 year of operation typical drift is less than 2×10^{-10} per day.

Short-Term: Better than 1×10^{-10} per minute, as measured with 1-second samples.

Oven Cycling: Less than 1×10^{-10} peak to peak.

Ambient: Less than 1×10^{-10}/°C (5×10^{-9} for 0–50°C).

Line: Less than 1×10^{-10} for 105 to 130 volts.

Loading: Less than $\pm 2 \times 10^{-10}$ for 50 ohms $\pm 20\%$.

Frequency Adjustments:

Coarse: Approximately 500×10^{-9}.

Fine: $\pm 5 \times 10^{-9}$ in divisions of 5×10^{-10}.

Settability: To 1×10^{-10}.

Output: 1 volt rms into 50 ohms at 5 Mc. .4 volt rms for General Radio Type 1112-A Frequency Multiplier.

Power Input: 105 to 125 (or 210 to 250) volts, 50 to 60 cps, 100 watts.

Tube Complement: One each 6AN8, 5AV5GA, 5965, 5727, 5651, 6922/E88CC; three 6688/E180F.

Transistor Complement: One each 2N1138, 2N1372, two 2N445A.

Dimensions: Panel, 19 by 5¼ inches (485 by 135 mm); depth behind panel, 16 inches (410 mm).

Net Weight: 30 pounds (13.6 kg).

TYPE 1114-A FREQUENCY DIVIDER

Transistor Complement: One each 2N645 and 2N1218, two 2N1396, three 2N1372, four 2N520, seven each 2N169A and 2N582, fifteen 2N404, and sixteen 2N1374.

Input: 5 Mc, 1 Mc, 100 kc, 50 ohms. 1 volt ±50%.

Output: (with 5-Mc input): 5 Mc

Sine Waves:

1 Mc 100 kc	1 v	+50% −10%	into 50 ohms
10 kc 1 kc 100 c	1 v	+50% −10%	into 600 ohms
*400 c * 60 c	1 v	+50% −10%	into 600 ohms

*Optional accessories

Square Waves: 100 kc, 10 kc — Approximately 7 volts pp open circuit

Spurious Signals: Better than 34 db down.

Jitter: Less than .5 nsec for 100 c output with respect to 5 Mc input.

Power Input: 105 to 130 (or 210 to 260) volts, 50 to 400 cps, approximately 7 watts.

TYPE 1103-B SYNCRONOMETER

Input: 1000-cycle sine wave, one volt into 50,000 ohms.

Microdial:

Contactor Stability: Maximum contact closing time deviation at any microdial setting is ±0.1 msec.

Calibration Errors: The maximum deviation between the indicated microdial setting and the actual contactor closing time varies sinusoidally from 0 to ±1 msec over the 1000-msec range.

Accuracy of Time Increments: The maximum error over a time interval of 25 msec is ±2% ±0.1 msec.

Power Input: 105 to 125 (or 210 to 250) volts, 50 to 60 cps; 22 watts, continuous; 10 watts for starting motor.

Dimensions: Panel 19 by 8¾ inches (485 by 225 mm); depth behind panel, 11 inches (280 mm).

Net Weight: 35 pounds 16.0(kg).

TYPE 1112-A STANDARD-FREQUENCY MULTIPLIER

Spurious Signals: Unwanted harmonics of the input frequency are at least 100 db below the desired output frequency.

Frequency-Modulation Noise: Less than ±1 x 10^{-9} residual noise.

Locking Range: The input signal can drift ±15 parts in 10^6 before the locked oscillator goes out of control.

Bandwidth: (Expressed as allowable frequency-deviation rate)

Input: 1 volt, 100-kc sine wave from standard-frequency oscillator. Can also be driven at input frequencies of 1, 2.5, and 5 Mc; required input is approximately 5 volts.

Will run free with no input signal, but absolute frequency may be in error by several parts per million.

Output: Four channels; one each of 1 Mc and 10 Mc, and two of 100 Mc; all sine wave; all 50 ohms; 20 milliwatts, max., into 50 ohms.

Open-Circuit Output Voltage: Approximately 2 volts.

Terminals: Type 874 Coaxial Connectors; adaptors are available to fit all commonly used connector types.

Tube Complement: Two each 6AU6, 6C4, 6BC5, 6CY5, 6X8; three 6AN8; one each 6080, 12AX7, 5651.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles, 110 watts.

Accessories Supplied: Type CAP-22 Power Cord, Type 874-R22 Patch Cord, two Type 874-C58 Cable Connectors, spare fuses.

Dimensions: Relay-rack panel, 19 by 12¼ inches (480 by 330 mm); depth, 11½ inches (310 mm).

Net Weight: 25 pounds (11.5 kg).

TYPE 1112-B STANDARD-FREQUENCY MULTIPLIER

Input: 20 milliwatts, 100 Mc, sine wave from Type 1112-A Standard-Frequency Multiplier; 50-ohm input impedance.

Output: 1000-Mc sine wave; 50 mw into 50-ohm load; 50-ohm output impedance.

Locking Range: ±100 kc at the input frequency.

Bandwidth: Allowable frequency deviation rate is 100,000 cycles at the input frequency.

Tube Complement: Three each 6AG5, 6AU5GT, 12AX7, 5651; two 6AK5; one each 6U6, 6AU6, 6BM6, 5876.

Power Input: 125 watts.

Accessoried Supplies: Type CAP-22 Power Cord, Type 874-C58 Cable Connector, two Type 874-R22 Patch Cords, spare fuses.

Net Weight: 35 pounds (16.0 kg).

Other specifications are identical with those for TYPE 1112-A, above.

For a complete description of these instruments, see the *General Radio Experimenter*, 32, 10, July, 1958.

TYPE 1105-B
FREQUENCY-MEASURING EQUIPMENT

Dimensions: Height 76⅛, width 22, depth 20½ inches (1950 by 550 by 500 mm), over-all.
Net Weight: 370 pounds (168 kg).

Type		*Code Word*	*Price*
1120-A	**Frequency Standard**	ENDOW	**$3640.00**
1120-AH	**1000-Megacycle Frequency Standard**	ENJOY	**6450.00**
1116-A	**Emergency Power Supply**	MUMMY	**540.00**
1113-A	**Standard-Frequency Oscillator**	ALLOT	**1550.00**
1114-A	**Frequency Divider**	ADOWN	**950.00**
1114-P6	**400-cycle Plug-in Unit**	CAMEL	**85.00**
1114-P7	**60-cycle Plug-in Unit**	CALIF	**115.00**
1103-B	**Syncronometer**	AUDIT	**900.00**
1112-A	**Frequency Multiplier**	EPOCH	**1450.00**
1112-B	**Frequency Multiplier**	EPODE	**1360.00**
1105-B	**Frequency-Measuring Equipment**	MITER	**5900.00**

U.S. Patent No. 2,548,457
Patent Pending

PRECISION CONDUCTANCE BRIDGE

A precision conductance bridge employing a General Radio TYPE 1605-A Impedance Comparator is described in the March issue of *Journal of the Electrochemical Society*.[1] Designed for use in the electrochemical laboratory, the bridge has been used for studies of the electrical conductances of high-temperature matter, inorganic salt systems (240-1000°C) and solutions of electrolytes in aqueous and organic solvents at temperatures of 0–45°C.

[1]George J. Janz and James D. E. McIntyre, "A Precision Conductance Bridge of New Design," *Journal of the Electrochemical Society*, March, 1961.

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The firm of W. and K. McLean, Limited has been appointed General Radio sales representative for New Zealand. All technical and commercial inquiries regarding General Radio products should now be directed to that firm, P. O. Box 3097, Auckland.

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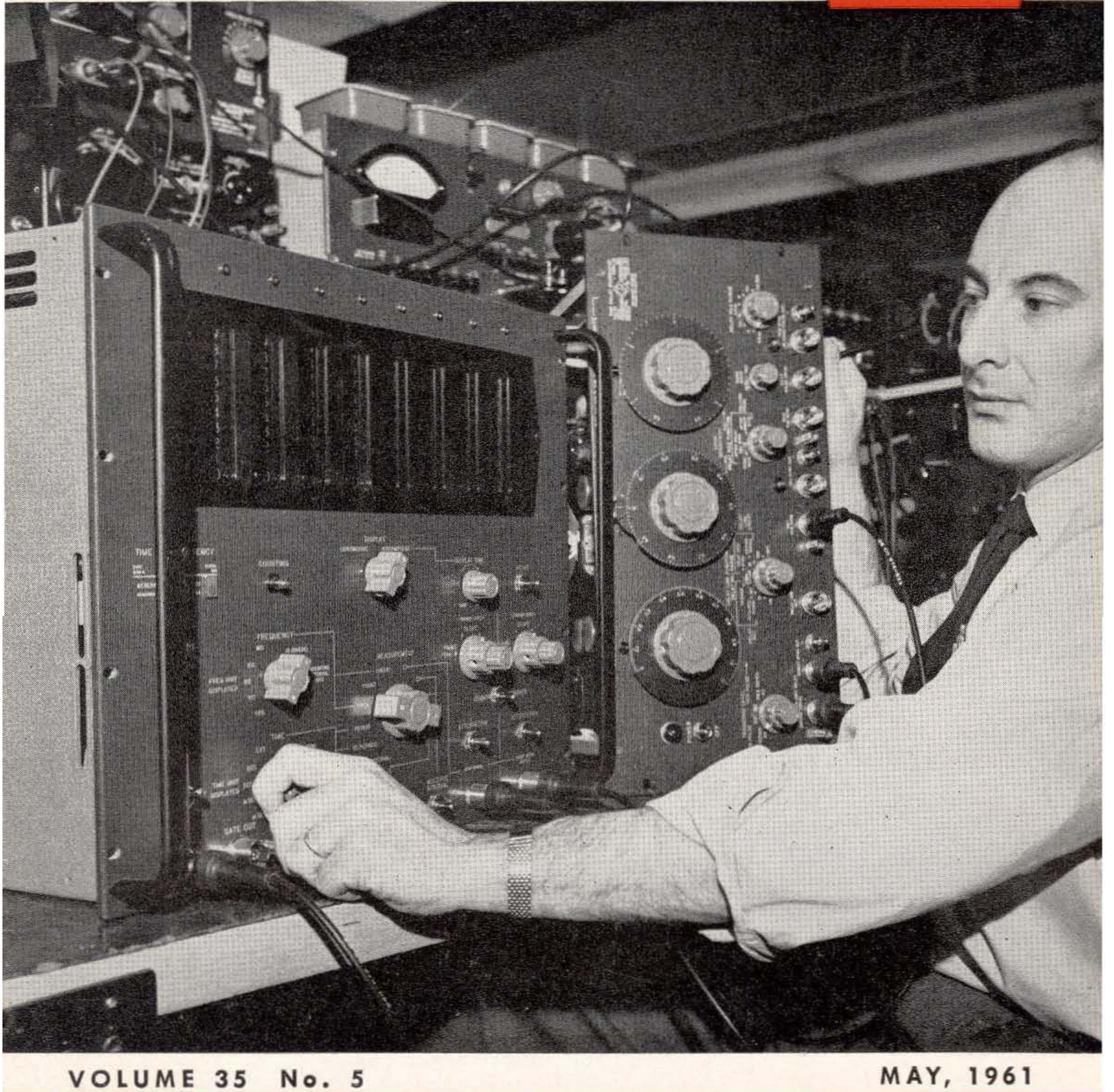

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Digital Time and Frequency Meter

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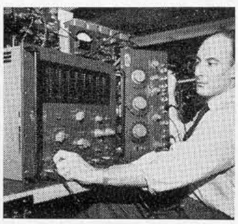


The Type 1130-A Digital Time and Frequency Meter shown in the General Radio Standardizing Laboratory during the calibration of Type 1392-A Time-Delay Generators.

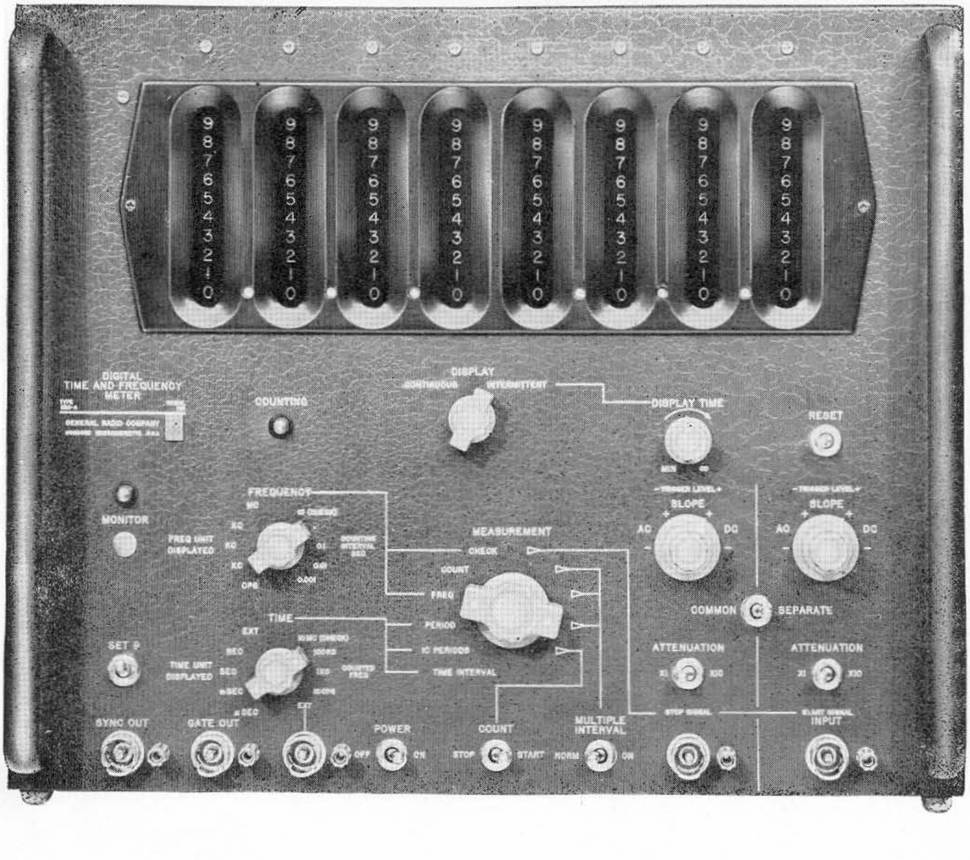
A FREQUENCY COUNTER WITH A MEMORY AND WITH BUILT-IN RELIABILITY

What, another counter? Yes, the Type 1130-A Digital Time and Frequency Meter shown in Figure 1 is a brand-new entry in the field of high-speed counters — new on the scene and new in many important details. Like several others, it is an automatic instrument for the precise measurement of frequency, period, and time intervals. It differs from them, however, in using new circuits and new design ideas to provide unusual features and a very high degree of reliability.

The instrument measures frequencies from dc to 10 Mc with a maximum precision of ± 0.1 cps, periods from 10 μsec to 10^7 sec with a precision of ± 0.1 μsec, and time intervals from 1 μsec to 10^7 sec with a precision of ± 0.1 μsec. It can also be used to count random events, measure frequency ratios, compute phase shift, and measure characteristics of pulse waveforms.

Digital counters have found increasing application during the past ten years, and several commercial versions have come into wide use. The design of still another, having similar basic charac-

Figure 1. Panel view of Type 1130-A Digital Time and Frequency Meter.



teristics, was undertaken only after thorough study indicated that both performance and convenience of use could be substantially improved.

The TYPE 1130-A is *not* "just another counter." From the start of our development work, we decided that we should design and market such an instrument only if we could make some important new engineering contributions that would have substantial value to most users. Studies of several commercial counters have uncovered inherent shortcomings in existing designs, and field experience has shown that malfunctions arising from these occur often enough to be objectionable and to necessitate extensive maintenance programs.

Further inherent disadvantages in previous instruments have resulted from the nature of the measurement sequence, or program used. The process of alternately counting and displaying has led to the familiar "intermittent" type of presentation, which is not only inefficient but tends to cause operator confusion, fatigue, and annoyance.

To overcome the difficulties stemming from these inherent characteristics and, in general, to build a better counter, we had to design circuits that were not based on traditional ideas. So we made a fresh start. Viewing the instrument as the specialized digital computer it is, we designed the operating system, the new basic circuits, the display and controls, and the mechanical assembly from the ground up. The result is an instrument that we believe represents an outstanding combination of performance and reliability.

SPECIFIC GOALS AND ACHIEVEMENTS

Reliability and Ease of Maintenance

It has always been the objective of General Radio to produce reliable equipment, and the standards of quality developed in seeking this objective have formed the basis of the company's reputation. This background has furnished a solid foundation from which to work, but it has been buttressed at all possible points by innovation, as well as by the experience of others.

The computer field, in particular, is a rich source of reliability information and ideas, and the design of the TYPE 1130-A Digital Time and Frequency Meter has drawn extensively upon computer techniques and components. A major decision, obviously, has been the selection of vacuum tubes instead of transistors as active components. Progress in the performance of solid-state devices has been continuous, and often spectacular, in recent years. Reliability, on the other hand, takes time both to be achieved and to be assessed. The wealth of proven components and reliability experience for vacuum tubes has therefore, on balance, been given controlling weight in the decision.

To be most useful, an electronic device should operate for a long time without failure and should be easily put back in service in a short time. The first of these characteristics measures reliability and the second ease of maintenance. The GR Counter has been designed to meet both these requirements. Reliability is assured first of all by thorough system design. The counting units described below, for example, use a feedback system not found elsewhere, and the efficiency of the operating program is unique.

Reliability is further assured by painstaking circuit design. Computer-grade tubes (frame-grid types where suitable) are used throughout the instrument. All components are severely derated and premium-quality connectors are used. Circuits have been designed to operate properly under extensive variations and degradation of tube parameters, and do not require fussy regulated plate and heater power supplies. Only one regulator circuit is used to assure maximum stability of the crystal-controlled time-base oscillator.

Modular construction has been used to simplify maintenance. Every tube circuit is on an etched-circuit board, which can be quickly removed for repair or replacement, and test points are available at marked panels on both sides of the instrument. The etched-circuit boards embody construction techniques that have resulted in a remarkable service record. Since GR began using etched-circuit boards several years ago, we have shipped 14,100 instruments containing 21,300 boards. Among these 21,300 boards only 12 failures have been reported, and the causes for these failures have since been found and corrected.

Display

The problem of data display was the first to be attacked. The operating program used in most counters produces an inefficient and fatiguing intermittent display. While counts are being accumulated by the instrument, no information is presented to the operator. Conversely, while the result is displayed, no new information is entering the counter. We have developed a storage system that holds a count and displays it continuously while a new count is being accumulated. At the end of each counting interval, the new count is transferred to the display in a brief, 100-μsec interval.

Careful attention was also given to the display itself. In-line readouts have been widely adopted for counters but add considerably to expense, complexity, and maintenance. Thermometer-type displays, on the other hand, have a running-up-and-down appearance that has generally been found objectionable. This objection is completely overcome by the use of storage, and it was therefore decided that the simple, reliable neon-lamp columns offered the best solution for both economy and convenience.

Four decades of the GR counter can be used either as storage or as counting units. Depending upon which function is selected, the operator has the choice of either an 8-digit "intermittent" display of conventional type or a 4-digit continuous display. By proper selection of the counting interval the 4 continuously displayed digits can be any 4 consecutive digits in the 8-digit number. When calibrating variable-frequency oscillators, for example, one is usually interested in only the first few digits. These would therefore be chosen for continuous display. Conversely, in the measurement of frequency drift in very stable oscillators, only the last few digits would probably be significant and chosen for continuous display.

A further unique advantage of internal storage is the inherent availability of voltages suitable for analog graphic recording. The simple Type 1134-A Digital-to-Analog Converter accessory, which operates from the storage decades, provides a dc output of 0.1% accuracy and linearity, corresponding to any 3 consecutive digits of the counter display. This output will drive graphic recorders directly without the need of an intermediate, expensive electromechanical storage system. A graphic record is much easier to analyze than a list of numbers, and the results can be just as accurate if the proper digits are selected.

Decimal-Counting Units

The design of the decimal-counting units, or decades, of the GR Counter has incorporated both optimization techniques and novel ideas. A first step was a detailed study of bistable flip-flop circuits and the interrelations of component values and tube characteristics. Design curves[1] were developed from which optimum values could be determined, depending upon desired repetition rates and available tubes. This was followed by an intensive study of decimal-counting systems.

In operation the flip-flops of a decimal-counting unit are complemented.[2] That is, they reverse state at each input pulse and issue an output or carry pulse for every other input pulse. A single flip-flop, therefore, forms a scale-of-two circuit, producing carry pulses at half the repetition rate of the input. Four cascaded flip-flops form a basic scale-of-sixteen assembly as shown in Figure 2.

Early counters displayed their count directly in binary units and it was customary to refer to them as scale-of-64, scale-of-128 counters, etc., depending upon the number of flip-flops used. The modern decimal systems stem from the work of I. E. Grosdoff,[3] who showed how to change the scale-of-sixteen system to a scale-of-ten by means of feedback pulses, and how to light ten neon lamps in the now familiar columnar display. Figure 3 shows the two feedback systems described by Grosdoff.

The double-feedback system is best adapted to lighting ten neon lamps in a decimal display because the plate voltages of the four flip-flops can be properly combined in a simple matrix of resistors. The single-feedback system is best adapted to reliable counting.

Because of the ease of obtaining the display, all previous counters have used the double-feedback system in low-speed decades. Such decades, however, are subject to errors in counting caused by the multiple feedback, and failures from this cause have been a frequent source of trouble.

The first feedback signal in the double-feedback system occurs at the count of four. The 0–1 transition of the third flip-flop resets the second flip-flop to 1. This operation causes no difficulty

FLIP — FLOP ELEMENTS

PULSES TO BE COUNTED → [1st]–[2nd]–[3rd]–[4th]

DECIMAL NUMBER	STATES			
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	0	0	1
9	1	0	0	1
10	0	1	0	1
11	1	1	0	1
12	0	0	1	1
13	1	0	1	1
14	0	1	1	1
15	1	1	1	1
16 = 0	0	0	0	0

Figure 2. Block diagram of four cascaded flip-flops in a scale-of-16 assembly. Each flip-flop is set alternately to states 0 and 1 by its input pulses. On transition from state 1 to state 0, each flip-flop transmits a carry pulse to the following flip-flop, which in turn takes on states 0 and 1 at half the rate of the preceding flip-flop. The flip-flop states corresponding to the number of input pulses are tabulated below the diagram. Note that the listing of the flip-flop states shows the least significant digit at the left — the reverse of the corresponding binary number.

[1] R. W. Stuart, "Vacuum-Tube Flip-Flop Design for Commercial Instrumentation," NEREM Technical Program, November 19, 1958.

[2] From the concept of complementary numbers. In the binary system two numbers, 0 and 1, form the whole. 1 is therefore the complement of 0 and vice versa, and a flip-flop, in taking on both states, has completed the count of all possible numbers.

[3] I. E. Grosdoff, "Electronic Counters," RCA Review, vol. VII, no. 3, Sept., 1946; pp. 438-447.
I. E. Grosdoff, "Electronic Chain with Decimal Indicators," U. S. Patent No. 2,436,963; March 2, 1948.

since the 0–1 transition of the second flip-flop generates no carry pulse. Consider, however, the transition from 5 to 6. The input pulse first sets the flip-flops to states 0001; the 0–1 transition of the fourth flip-flop feeds a pulse back to the third flip-flop to reset it from 0 to 1; this 0–1 transition of the third flip-flop, however, is the same transition previously used to reset the second flip-flop to 1 in the first feedback operation. With new tubes the unwanted feedback does not occur because the transitions from 1 to 0 and 0 to 1 in the third flip-flop follow each other so closely in time that a full-sized feedback pulse to the second flip-flop is not generated. As the tubes age, however, changes in voltage level and delay time can, and do, prevent this sequence from occurring properly, and the count jumps from 5 to 8 instead of from 5 to 6.

The new GR Counter does not use this system anywhere, but uses instead the foolproof single-feedback system. At the same time, by the use of an additional neon lamp[4], the adding matrix for the ten neon lamps is made as simple and economical as the matrix used with the double-feedback system.

Neon lamps are also used in the feedback networks to assure reliable operation[4], and neon lamps and resistors are used to convert a low-speed counting decade into a combination counting and storage decade[4].

The problem of tube aging has been greatly reduced in the GR decades. All circuits will operate with half-dead tubes, that is, tubes with half the g_m or twice the r_p of a design-center tube, or with any combination of new and aged tubes.

The 10-Mc Decade

The cascaded time delays involved in the transition from 7 to 8 in the feedback system described above limit its use to input-pulse repetition rates up to about 1 Mc. For operation at faster

[4]R. W. Stuart, "Electric Switching Circuits," British Patent No. 851,652, U. S. Patent Pending. "Counter and Display System," U. S. Patent Pending. "Counting and Storage Systems," U. S. Patent Pending.

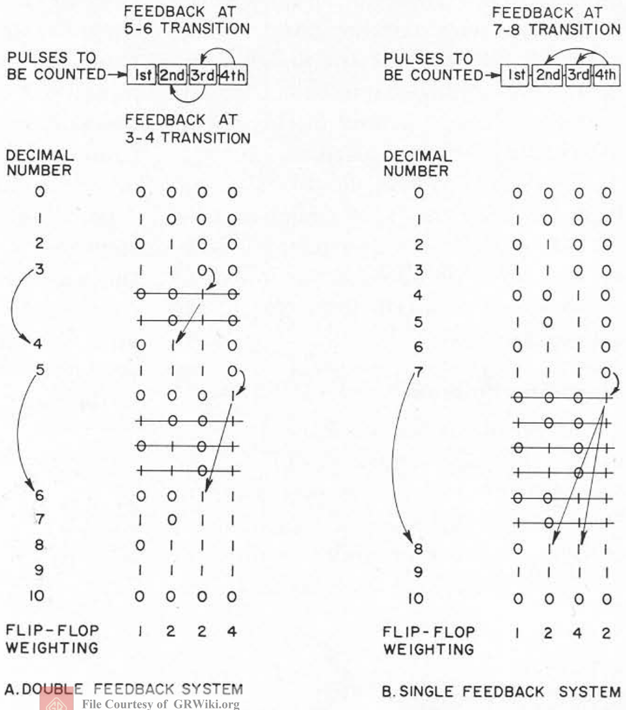


Figure 3. Feedback systems for converting from scale-of-sixteen to scale-of-ten operation. The carry pulses are generated during transitions from state 1 to state 0, the feedback pulses during transitions from state 0 to state 1. The weightings necessary to convert the binary states to a decimal number are listed below the tabulated flip-flop states. The crossed-out binary states do not occur but are bypassed by the feedback reset operations.

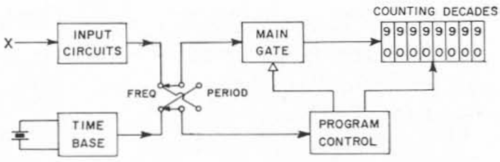


Figure 4. Block diagram of the counter; frequency and period measurement.

rates, high-speed flip-flops and multiple gating systems[5] have been devised to minimize the time delay. In the GR high-speed decade, two novel features have been used that contribute to a degree of reliability comparable to that of the lower speed decades. A block diagram of the gating system used is shown in Figure 6.[6] In this system the 4th flip-flop is a simple set-reset circuit which controls a gate directing the carry pulses from the 1st flip-flop to the 2nd. The count proceeds from 0 to 9 in normal scale-of-sixteen fashion. The transition from 1 to 0 in the 3rd flip-flop at the 8th count sets the 4th flip-flop to the 1 state, closing the gate. The output pulse of the 1st flip-flop at the count of 10 is therefore prevented from triggering the 2nd flip-flop and instead resets the 4th flip-flop to 0, leaving all flip-flops in the 0 state and reopening the gate.

In this system, only the first flip-flop operates at the high-input rate. Current-source coupling[7,8] is used in this circuit to achieve maximum speed.

The decade system described results in a 1-2-4-8 code. This coding is converted to the 1-2-4-2 sequence of the lower speed decades in a four-tube readout unit separate from the 10-Mc counting decade.

Operating Program

The operating sequence, or program, used in previous counters has limited the efficiency of information processing to 50% at best. A 10-second measurement of frequency, for example, requires an annoying dead time of at least an additional 10 seconds for display before a new counting interval begins. In contrast, the program of the GR Counter is 83% efficient. It is therefore necessary to wait only 2 seconds before a new measurement is begun, irrespective of whether 8 digits intermittent or 4 digits continuous are displayed. For a one-second measurement, the waiting interval is only 0.2 second, for a 0.1-second measurement only 0.02 seconds, etc. The efficiency of the continuous display, on the other hand, is essentially 100% since new answers are transferred in only 100 microseconds.

Human Engineering

The positioning and labeling of controls and connectors in previous designs have left much to be desired from the standpoint of the operator. As shown in Figure 1, these components are logically arranged and clearly labeled in the GR counter. The terms used are simple and descriptive. Two-color engraving further simplifies the operation of the instrument. The white engraving indicates information of primary interest to the operator, such as the measurement being made and the units of measurement; the orange engraving indicates secondary or supporting information, such as the counting interval. For example, when the large, centrally located, measurement control is in the Time-Interval position, an orange dot at the rear of the double-bar knob points to an orange line leading to the Start and Stop input connectors.

[5]A. S. Bagley, "A 10 Mc Scaler for Nuclear Counting and Frequency Measurement," HP Journal, vol. 2, no. 2, October, 1950; pp. 1-4.
[6]E. L. Kemp, "Gated Decade Counter Requires No Feedback," *Electronics*, vol. 26, pp. 145-147, February, 1953.
[7]Patent Pending.
[8]R. W. Frank, "An Improved Pulse Generator with 15 ns Rise Time," *General Radio Experimenter*, 33, 2, February, 1959.

TECHNICAL DESCRIPTION

Simplified Block Diagram

The simplified block diagram of Figure 4 shows that the Type 1130-A Digital Time and Frequency Meter contains five basic circuit blocks: the Input Circuits, the Time Base, the Main Gate, the Program Control, and the Decimal-Counting Units. The Input Circuits are used to generate trigger pulses from the input signal. For frequency measurement the trigger pulses are counted for a time interval derived from the time base; for time measurement (period, 10 period, or time interval), the trigger pulses determine the time interval, during which clock pulses from the time base are counted.

The Program Control opens and closes the Main Gate, controls the display, and handles the various resetting operations.

Input Circuits

A prime requirement for digital measuring equipment is that it be as nearly automatic as possible. This requirement is put to its most severe test in the input circuits, where the counter system meets the user's system. Highest reliability can be obtained when the signals counted are pulses of constant amplitude and duration; the more nearly constant, the more reliable the counting. Yet this signal must be derived from the user's signal, in which frequency, waveform, modulation, and noise are all variables. To make the counter useful with the widest variety of input signals we have therefore provided:

1. A means for adjusting the input circuit to produce the triggering pulse at some specified input-voltage level. This permits the rejection of some forms of noise in the input signal and adapts the counter to measure the frequency or period of low-duty-ratio pulsed signals.

2. A means for removing dc so that the frequency of an input signal pedestaled on dc can be measured.

3. An attenuator to help reduce the effects of noise and increase the range of the triggering level control.

4. A means for selecting the slope of the input signal which produces the best trigger pulse. This adjustment is particularly important in period and time-interval measurements where, for maximum accuracy, the most rapidly changing portion of the input signal should be selected.

A simplified schematic diagram of the input circuits of the counter is shown in Figure 5. The two triode sections of the first tube are connected as a push-pull difference-amplifier or "long-tailed pair"[9]. The input signal is applied to one grid of the pair and a variable reference voltage, determined by the Trigger-Level control, is applied to the other grid. This reference voltage determines the point on the input-signal waveform at which a trigger pulse is generated by the Input Circuits. For frequency measurement of clean, sinusoidal signals, it is desirable to generate trigger pulses at the zero-crossings of the input signals to obtain maximum sensitivity. However, for frequency measurement of pulse waveforms in the presence of noise which causes multiple zero-crossings, and for period and time-interval measurements and the counting of random events, it is desirable to adjust the triggering level to the cleanest or most significant portion of the input waveform. The Trigger-Level control is a potentiometer with a grounded center-tap covering a broad region of rotation which allows a quick, noncritical return to ground potential. The range of the reference voltage is ±10 volts which, in conjunction with the 10:1 input attenuator, provides an effective input-triggering range of ±100 volts.

By interchanging the grid connections of the input signal and reference voltage, the Slope Control (not shown in Figure 5) determines whether a trigger pulse is generated at a positive-going or a negative-going crossing of the triggering level. The Slope Control can also connect a capacitor in series with the input signal to block any dc that may be present.

The first amplifier circuit also serves as a stable limiter, since the plate-voltage limits are determined by the plate-supply voltage and the plate and cathode resistors, and are essentially independent of tube characteristics. Because of the symmetrical, balanced nature of

[9] G. E. Valley and H. Wallman, "Vacuum-Tube Amplifier," Radiation Laboratory Series, No. 18, McGraw-Hill Book Company, New York, New York, 1948, p. 441.

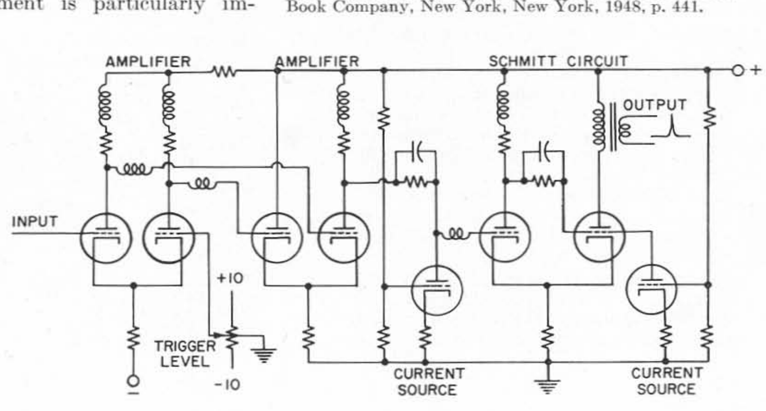


Figure 5. Simplified schematic diagram of the input circuits.

BINARY NUMBERS

DECIMAL NUMBERS	FF1	FF2	FF3	FF4
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	0	0	1
9	1	0	0	1
10	0	1	0	1
11	1	1	0	1
12	0	0	1	1
13	1	0	1	1
14	0	1	1	1
15	1	1	1	1
16	0	0	0	0

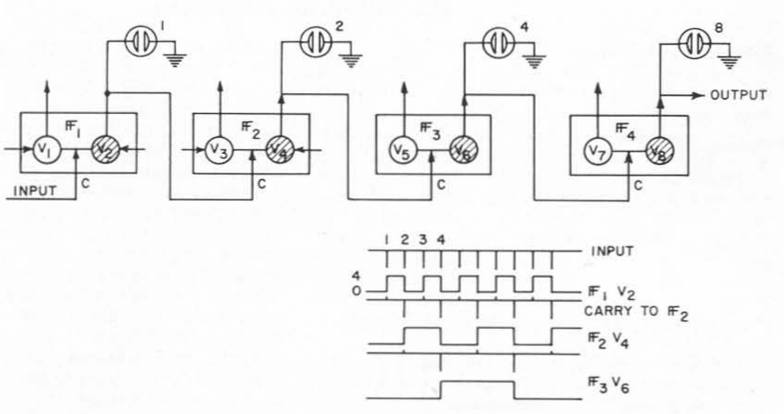


Figure 6. Scale-of-sixteen binary counter and display. The binary numbers represent the states of the flip-flops corresponding to a 1248 weighted code.

the circuit, operation is also essentially independent of plate-supply or filament-voltage variations. Another attribute of this circuit is its very high dynamic range which permits measurement of signals with large amounts of amplitude-modulation or lower frequency noise — since the circuit will not be clamped by the noise or modulation peaks, but will continue to operate at true reference-level crossings.

The output of the first amplifier stage is direct coupled to the second. Both shunt and series-peaking inductors are used to obtain maximum bandwidth. The second stage of amplification is similar to the first except that the push-pull input is converted to a single-ended output. In this connection the circuit is usually referred to as a cathode-coupled clipper.[10]

The output of the second amplifier stage is directly coupled to the following circuit without attenuation by means of a triode connected as a current source.[7,8] Because of the large cathode resistor, the triode draws a constant current through the resistor connected to its plate. With a constant current in the resistor, and therefore a constant voltage across it, any variation in voltage at one terminal of the resistor is transmitted undiminished to the other terminal, but at a different dc level.

The pulse-generating circuit itself is based on the familiar Schmitt circuit[11] with another current-source-connected triode used to couple the left-hand plate to the right-hand grid. Shunt peaking alone is used in this circuit since series peaking would introduce a time delay and decrease the maximum repetition rate of the circuit. The output pulse is generated by a small toroidal transformer, wound on a ferrite core, which is connected to the right-hand plate of the Schmitt circuit.

The sensitivity, (minimum voltage necessary to produce output pulses) of the circuits described is about 100-mv rms from dc to 3 Mc, rising to 250-mv rms at 10 Mc.

Counting Circuits

The general mode of operation of the counting circuits has already been described. The elements of these circuits are "flip-flops," or bistable multivibrators.

Forty of the 87 circuits in the counter are flip-flops. Of these 40 circuits, 36 are used in the Decimal Counting Units, where the binary scale-of-sixteen is permuted to a scale-of-ten for either standard counting or combination counting-storage.

Four cascaded flip-flops forming a scale-of-sixteen are shown in Figure 6.

Let us assume that the circles within the rectangles representing each flip-flop are the two tubes forming the circuit. We define the flip-flop to be in the "0" state with the right-hand tube conducting. Thus, in the figure, the shaded circles represent *on* tubes, and the scale-of-sixteen is in the state 0000. The horizontal line connections represent inputs, say to grids, and a negative pulse placed on the common connection between the tubes will turn off whichever tube is on and will thus complement the state, changing a zero state to a one or a one to a zero. A signal fed to either grid separately will set the flip-flop to the specified state only. If the flip-flop is already in that state, the pulse will have no effect.

Now having established the ground rules, we can begin to count. The first pulse received by flip-flop 1 in Figure 6 will cause it to reverse state (1000). The pulse formed when the right-hand tube goes off will be positive and will not affect FF2. The second pulse will cause FF1 to return to the 0 state and the right-hand tube in turning on will produce a negative pulse causing FF2 to complement (0100). Each 1-to-0 transition will produce a carry pulse and each

[10]Jacob Millman and Herbert Taub, "Pulse and Digital Circuits," McGraw-Hill Book Company, Inc., New York, New York, 1956.

[11]O. H. Schmitt, "A Thermionic Trigger," *Journal of Scientific Instruments*, vol. 15, pp. 24-26, January, 1938.

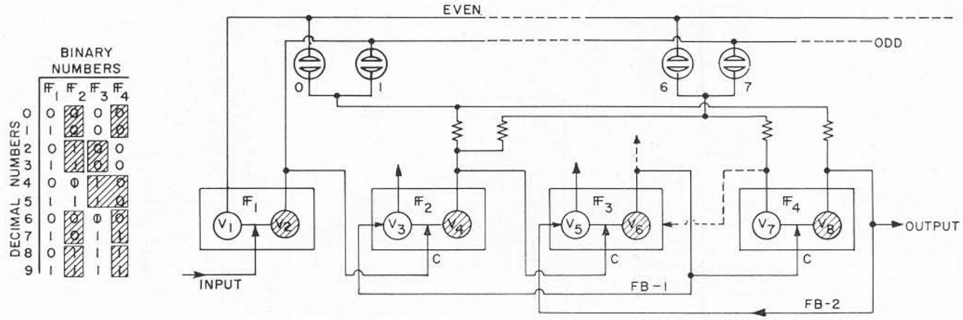


Figure 7. Grosdoff 1224 weighted code showing indicator matrix and feedback paths. The shaded areas designate combinations of flip-flop states that exist uniquely in conjunction with the two states 0 and 1 of FF1 for the allowed states. The neon lamps are connected to the matrix buses.

successive flip-flop will switch at half the rate of the one before it. The simple circuit of Figure 6 therefore produces the conventional scale-of-sixteen sequence.

To make a useful counter, one must add appropriate means to indicate the flip-flop states. This is conveniently done with neon lamps that are operated from combinations of plate voltages in the flip-flop tubes. In Figure 6 four neon lamps are shown, connected to light when the right-hand tube is conducting (state 1). The neon lamps are therefore off for a 0 and on for a 1 in the particular digit (in the binary system) that they represent. These digits are, respectively, 1, 2, 4, and 8, and the flip-flops are said to be weighted 1-2-4-8 for counting. For example, suppose the counter has received 10 pulses. Flip-flops number 2 and 4 will then be *on*, and flip-flops 1 and 3 *off*, yielding a count of $0\ (2^0) + 1\ (2^1) + 0\ (2^2) + 1\ (2^3) = 10$. The first nuclear scalers were constructed in this general fashion, with binary displays.

For convenience and speed of reading in measuring systems it is obviously desirable to count and to display the counted number in the decimal system. I. E. Grosdoff of RCA showed how to construct a decade counter based on

Figure 8a. Plate voltage waveforms at 50 kc of V2, V4, V6, and V8 for 1224 coding. The system operations occurring at pulses 4 and 6 produce the dips in FF2 and FF3 waveforms. These dips, in turn, cause the difficulties inherent in this system. The first feedback is unambiguous; the second, however, requires that the time constant of the feedback path be critically adjusted to be short compared to the time between maximum-rate counts but long compared to the duration of the dips.

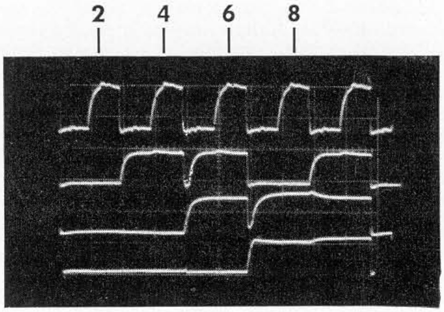
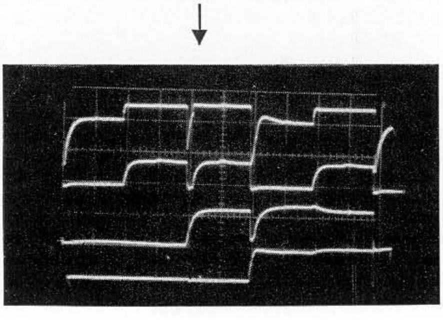


Figure 8b. FF2 grid-voltage waveform. The first feedback shows clearly as an unambiguous signal; the second shows a positive overshoot caused by differentiation of the positive slope of the 0-1 transition in FF3. In this example the grid swings 4 volts above the 10 volts required for cuttoff. When this overshoot becomes too large it will produce the commonly observed decade failure of skipping from an indicated count of 5 to 8.



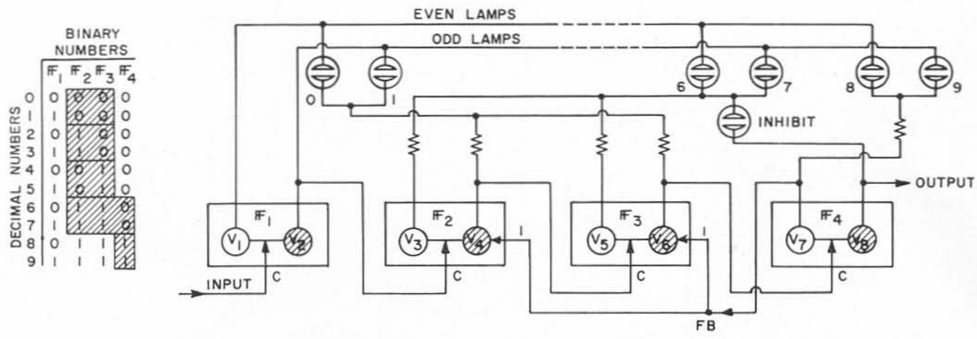


Figure 9. General Radio 1242-weighted code showing feedback and indicator matrix. Shaded areas show neon-lamp matrix connections. For this coding a triple addition must be used. The loss involved in this addition is minimized by the use of INHIBIT lamp instead of a resistor.

permuting the scale-of-sixteen to a scale-of-ten and at the same time connecting ten neon lamps in a simple matrix to display the count as a decimal number.[3]

Figure 7 shows the double-feedback system of Grosdoff. It is the system most commonly used in modern counters *because the ten-lamp matrix is the simplest.* The general sequence of this coding system has already been described, and the weakness analyzed. The possibility of failure is shown clearly in the oscillograms of Figure 8.

The single-feedback system which Grosdoff suggested does not have this built-in hazard. Its operation has been previously described and the system is shown in Figure 9. In this system the count proceeds normally up to the eighth pulse. The 0-1 transition of the fourth flip-flop then resets both the second and third flip-flops simultaneously to 1, eliminating the 6 scale-of-sixteen binary states 8 to 13 without critical timing. The question immediately arises, why hasn't this more reliable code been used rather than the common one? The answer lies in the indicator-lamp matrix which we shall now discuss. See Figure 10, where this coding system is shown in operation at 50 kc.

Refer again to Figure 7. Assume that a given neon lamp in the indicator will ionize only when it is connected from the potential of an off flip-flop plate to that of an on plate. Now, for example, take the decimal number 1. The 1 lamp is connected from the plate of V2, which is off (state 1), via two resistors to plates of V4 and V8 which are on (state 0). Thus the 1 lamp will be on. These states in FF2 and FF4 are unique to the digits 0 and 1 in this coding system. In all other allowed states either one or the other flip-flop is in state 1 and the voltage at the neon lamp is ½ the on-plate voltage, which is not sufficient to light it. Likewise, all shaded state combinations in Figure 7 are unique to corresponding decimal numbers. Note that whether the 0 or the 1 lamp is lighted depends only upon the state of the first flip-flop. The first flip-flop always determines whether the even or odd lamp of a selected pair will light. In this example, therefore, the type of simple resistor matrix shown will unambiguously control the lamps. Now, look at Figure 9. Note that *NO* such combination of two unique states exists for each pair of decimal numbers. In order to get an unambiguous combination, we must combine at least once the states of three of the flip-flops. The General Radio counting decade uses the combinations shown shaded. It would be possible to continue to use a resistor matrix with a three-resistor addition to control the lighting of the six-seven lamp pair, but the loss in such a resistive adder, when coupled with the fixed ionization-deionization voltage-increment requirements of neon lamps, would call for uneconomically large flip-flop plate swings. We have developed a matrix system requiring the *same* plate swings as a normal decade by adding one neon lamp to the matrix to prevent

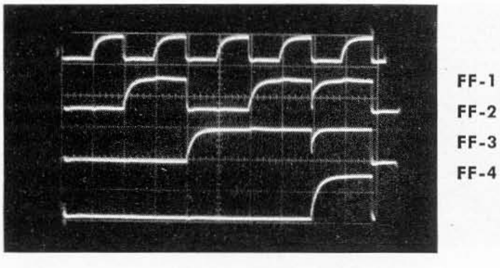


Figure 10. Typical waveforms for the flip-flops in the General Radio 1242 code of plates.

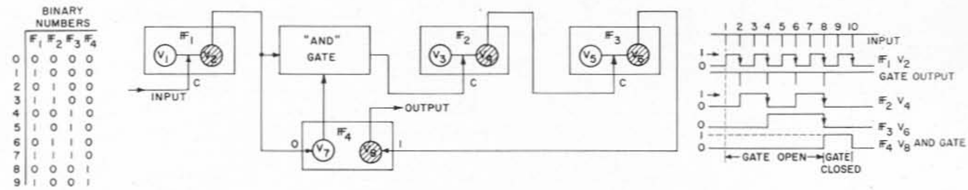


Figure 11. General Radio 10-Mc Decade.

the ionization of the six-seven lamps during the state 8-9.[12] A neon lamp costs little more than a resistor *so we have the reliable code — and at almost no increase in cost.*

Ten-Megacycle Decade

Up to this point we have discussed decade-design principles with no reference to the rate of counting.[13] Beyond a certain maximum input-pulse rate, however, the flip-flops will fail to switch because of insufficient time for capacitances associated with the circuits to charge or discharge.

Practical vacuum-tube counting circuits involving flip-flops whose plate currents operate neon-lamp indicators directly must have plate swings exceeding 100 volts. As the counting rate increases, the flip-flop impedance level must be decreased in order to speed the charge and discharge of circuit capacitance. With fixed voltage requirements, the power input must rise directly with this decreasing impedance. A practical power limit is reached at counting rates of about 1 Mc for the conventional decades of Figures 7 and 9.

In the design of a decade to operate at 10 Mc, a straight reduction of 10 to 1 in circuit impedance levels and plate-voltage swings will not yield a practical, stable, and reliable circuit. With conventional circuits at this frequency, the dc criteria for reliable flip-flop design cannot be met, even with the best frame-grid tubes available today. The reasons are simple. To meet our requirements we must *overdrive* the tubes so that the off tube will remain off under worst tube-aging and component-variation conditions. This overdrive voltage must be available at the grid side of the cross-coupling network which normally has a voltage loss of ⅓ to ½. These design requirements call for larger plate-voltage swings than can be produced within the power ratings of even the best modern tubes.

We have developed a flip-flop, based on the current-source coupling system described in the section on input circuits, in which the cross-coupling loss has been eliminated.[7] Only ½ to ⅓ of the plate swing of a normal circuit is required, with a proportional saving in the power required. With a conventional circuit, the two-to-one tube-rundown criteria can be met at impedance levels appropriate to 5-Mc resolution, with the unity coupling technique the same tube dissipation will yield at 15-Mc circuit.

It is not sufficient, however, to design a flip-flop circuit meeting the fixed dc reliability criteria and switching at a sufficiently fast rate. This circuit must now be designed into a decade.

Reliable flip-flop circuits in which the cutoff tube has a large excess bias voltage require large triggering voltages and, with the finite rise-time of the triggering voltage, accumulate more time delay between the application of the trigger and the actual stage-switching action than the more conventional designs. Various special designs have been suggested for high-speed decades.[10] All of these forms have been analyzed and the configuration shown in Figure 11 was adopted as the optimum structure from the standpoint of time delay.[6]

The decade uses a gate between the first and second flip-flops. This gate is operated at the count of 8 to prevent count No. 10 from setting FF2 to state 1. FF4 is reset to the 0 state by the tenth pulse and issues the carry output.

The time-delay requirements in this system are easily explained. For proper operation the gate must be closed at the count of 10. It is operated by FF4 at the count of 8 and so the total loop delay including the gate rise time to the closed condition must be less than two counts at the maximum input frequency (0.2 μsec at 10 Mc). The gate must again be open and ready to pass a carry pulse for FF2 at count 2. Since the fourth flip-flop is reset directly from FF1, it is clear that the closing time-delay limits. Even with our reliable and "stiff" flip-flops, the total loop delay does not approach the 0.2-μsec failure figure.

Note that the gating system of this decade leaves the second flip-flop in state 0 for the counts 8 and 9. We, therefore, have a pure binary progression with weighting 1-2-4-8. Since any 10-Mc resolution decade must have small plate swings, a set of buffer amplifiers must be used to drive the indicator. These amplifiers are driven by the 10-Mc decade plates through a resistor matrix which changes the code to 1-2-4-2 weighting so that the buffer output is identical with the output of the lower-speed decades.

---

[12]French patent 1,240,360, U. S. Patent pending.

[13]Z. Bay and N. T. Grisamore, "High Speed Flip-Flops for the Millimicrosecond Region," *IRE Transactions on Electronic Computers*, EC-5, 3, September, 1956, p. 121.

An excellent survey of the problems can be found in E. M. William, D. F. Aldrich, and J. B. Woodford, "Speed of Electronic Switching Circuits," *Proc. of IRE*, vol. 38, pp. 65-69, January, 1950.

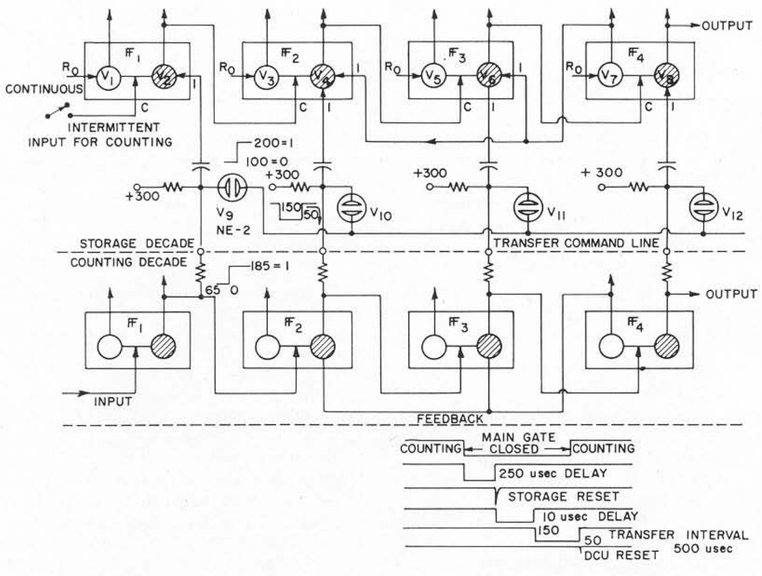


Figure 12. Counting and storage decades for the Type 1130-A.

Combination Counting-Storage Decade and Storage System

A decimal counting unit entirely unique[14] to the TYPE 1130-A Digital Time and Frequency Meter is shown in Figure 12. The unit is a combination decade which can either count in the normal fashion at frequencies in excess of 20 kc; or, alternatively, which can store binary data and present it as a decimal number when these data are read in from other General Radio standard 1-2-4-2 coded decimal counting units.

When the counter is used for continuous display of information, the eight dcu's are broken into two groups of four each. This is done by interrupting the carry pulse between the fourth and the fifth dcu's. (This fifth dcu is the first combination unit.) The timing diagram of Figure 12 shows the sequence of events after a counting interval. This sequence is initiated by the closing of the main gate and ended 1000 μsec later when the decimal counting units are reset to zero.

During this time interval:

1. The storage units are set to zero, erasing the old data from the last counting interval.

2. After a 100-μsec interval to insure that the storage units are at equilibrium,

3. A transfer command pulse is generated on the "transfer" bus lasting for 500 μsec. During this interval, any binary 1 in a counting decade will cause the transfer lamp (V9 through V12) to ionize. The resulting pulse will set the equivalent storage flip-flop to the 1 state.

4. 150 μsec after the termination of the transfer command, the dcu's are reset to zero and the new counting cycle can be started.

When they ionize, the neon lamps themselves provide pulses which transfer data to the storage units, so that the isolating resistors between the counting and storage units can have very high values. Since the neon lamps, when not ionized, have very small capacitance, the counting and storage units operate independently and no complex switching is required.

At the neon-lamp junctions, the logical 0 and 1 levels from the counting decade provide ± 50 volts across the bulb which is *not* to ionize and 150 volts across the lamp which must ionize for a 1 transfer. These levels insure that unselected neon lamps can be used with no danger of false transfer or failure to transfer. We have provided a complex, and heretofore unobtainable, function in the combination counting storage decade, by using only four inexpensive neon lamps, eight resistors, and eight capacitors.

Program

Figure 13 is a block diagram of the program-control system used in the GR Counter.

Let us assume that the sequence begins with a reset pulse from the Reset Generator. The reset pulse sets all the Decimal-Counting Units and the Program-Control Decade to zero and sets the Main Gate Flip-Flop and the Program Gate Flip-Flop to zero, closing the Main Gate, the Program Gate, the Diode Gate, and the Time Gate. Since the Time Gate is closed, clock pulses from the Time Base cannot activate the Main Gate Flip-Flop and the trigger pulses from the Input Circuits cannot enter the Decimal Counting Units.

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[14]Patent Pending.

The reset pulse also triggers the Reset Delay Generator, which produces a pulse 400 μsec later and sets the Program Gate Flip-Flop to the "1" state, opening the Program Gate and partially completing the Diode Gate. The Time Gate is still closed, but pulses from the Time base can pass to the Program-Control Decade. The first Time-Base pulse advances the state of the decade to "1", which completes the Diode Gate and causes the Time Gate to open. The next Time-Base pulse, the second, passes through the Time Gate and complements the Main Gate Flip-Flop to "1", which opens the Main Gate and allows pulses from the Input Circuits to enter the Decimal-Counting Units. The second Time-Base pulse also advances the state of the Program-Control Decade to "2," which disables the Diode Gates and closes the Time Gate so that the following Time-Base pulses cannot close the Main Gate. The Main Gate remains open while the Time-Base pulses continue to advance the state of the Program-Control Decade. When the decade reaches "1" again, the Diode Gate is again enabled and the Time Gate is opened, allowing the next Time-Base pulse, the eleventh, to pass through and complement the Main Gate Flip-Flop to "0," closing the Main Gate. Pulses from the Input Circuit have been allowed to pass through the Main Gate into the Decimal Counting Units for exactly ten Time-Base pulse intervals.

The closing of the Main Gate at the end of the measurement interval sets the Program Gate Flip-Flop to "0" and locks out the Program Gate, Diode Gate, and Time Gate so that the Decimal-Counting Units can display their accumulated count. If the Intermittent display mode is used, the Main Gate closing also triggers the Display-Interval Generator. At the end of the desired 0.1- to 10-second display time the Reset Generator is triggered, producing a reset pulse which begins the cycle again.

If the Continuous display mode is used, the Display Interval is disabled and the Main Gate closing triggers the Transfer Unit. This unit causes the count accumulated in the four counting decades to be transferred to the four storage decades. After a 1-msec interval, generated by the Transfer Delay, the Reset Generator is triggered and the cycle begins again. The measurement cycle can be stopped and started again at any point by the Manual Reset, which is controlled by the front-panel Reset switch.

For 10-Period measurements, the roles of the Input Circuits and Time Base are reversed so that the Main Gate remains open for ten input intervals while Time-Base pulses are registered in the Decimal-Counting Units.

The use of the Program-Control Decade in the system provides three advantages:

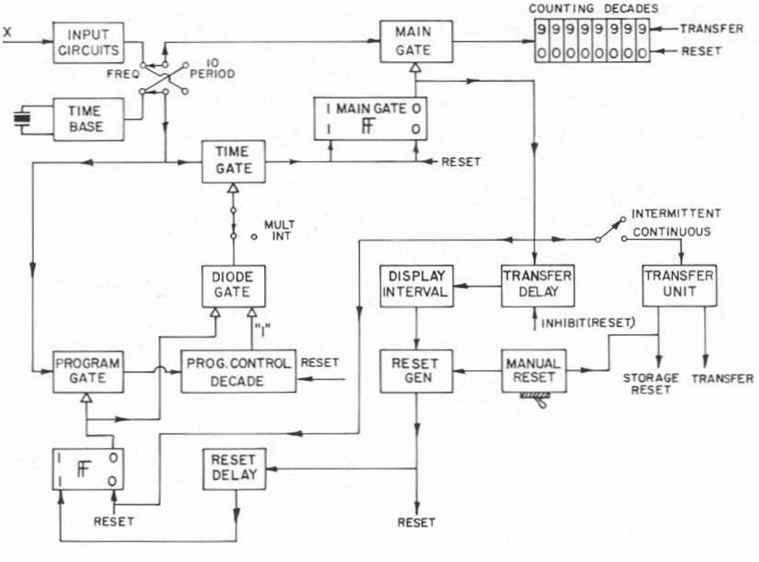
1. To obtain a 10-second measurement interval the lowest speed Time-Base divider operates at 1 cps rather than 0.1 cps.

2. Ten-Period measurements are easily made.

3. The dead time between measurements is decreased to two-tenths of a measurement interval.

For single-period and time-interval measurements, the Program Gate, Program-Control Decade, and Diode Gate are removed from the system, and the Time Gate operates under the direct control of the Program Gate Flip-Flop or the Input Circuits. The system efficiency is then reduced to 50%, a measurement being made during every other interval at best.

Figure 13. Block diagram of the Digital Time and Frequency Meter for frequency and 10-period measurement.



TIME BASE

Drive Sources

The time base of the TYPE 1130-A Counter is designed to operate from a 5-Mc source. To suit a wide variety of requirements, several drive sources are available as optional units which can be plugged into the rear of the counter. The TYPE 1130-P2 Oscillator/Multiplier allows operation from external sources of 100 kc, 1 Mc, or 5 Mc, or from an internal 5-Mc oscillator. The internal-oscillator circuit uses a room-temperature quartz crystal of exceptional characteristics[15] with a short-term stability of about $1/10^8$ per minute and an aging rate of about $2/10^7$ per week. The multiplier circuit uses novel techniques developed especially for this application.[16]

The TYPE 1130-P3 Oscillator contains the oscillator portion of the TYPE 1130-P2 Oscillator/Multiplier and is recommended for those applications where part-per-million accuracy is sufficient.

The TYPE 1130-P4 Precision Oscillator is a solid-state device containing a 5-Mc fundamental-mode crystal. The crystal and the oscillator circuit are enclosed in a proportional-control oven. This oscillator displays a short-term stability of about $1/10^9$ per minute and an aging rate of about $5/10^8$ per week. The time-base drive sources mentioned will be described in further detail in a forthcoming issue of the *Experimenter*.

If extreme precision is required, the counter can be operated from a standard frequency oscillator such as the TYPE 1113-A,[17] using a TYPE 1130-P1 Time-Base Unit or any of the ones mentioned above.

[15]R. W. Frank, H. P. Stratemeyer, "A Time/Frequency Calibrator of Improved Stability," *General Radio Experimenter*, October, 1959.

Time-Base Dividers

The divider circuits are of the proven multivibrator type. The low-frequency dividers use high-valued, plate-load resistors to insure "hard bottoming" and minimize the effect of variations in tube characteristics.[18] The high-frequency, 5-Mc to 1-Mc multivibrator uses a frame-grid double triode in a circuit well stabilized by current feedback.[15] A 100% increase in the plate resistance causes only a 5% change in the free-running frequency of the multivibrators. Because of the exceptional stability of these circuits, no periodic adjustments are required.

Time-Base Monitor

If the 5-Mc time-base drive signal is absent, the divider chain will operate at a frequency error of about 5%. Similarly, if a failure should occur anywhere in the time base, the 1-cps multivibrator, the last divider in the chain, will be in error. Such an error, of course, will become obvious if the counter is set for self-check operation. In addition to this, however, a monitor circuit has been provided to indicate any irregularity in the time base. The 0.5-second half period of the 1-cps divider is continuously compared with a 0.5-second interval, which is independently generated by a free-running multivibrator of design similar to the divider circuits. If the 0.5-second intervals differ by more than 1%, a panel light flashes to warn the operator. Thus the time base is *continuously monitored even when the counter is making measurements.*

[16]H. T. McAleer, "A Novel Method for Frequency Multiplication," *Electronic Industries*, August, 1959.
[17]"New Frequency Standard," *General Radio Experimenter*, April, 1961.
[18]R. W. Frank, F. D. Lewis, "The Type 1213-C Unit Time/Frequency Calibrator," *General Radio Experimenter*, June, 1956.

MECHANICAL DESCRIPTION

The TYPE 1130-A Digital Time and Frequency Meter has been designed to facilitate both the construction of the instrument and the occasional maintenance required. As mentioned above, every vacuum-tube circuit is on an easily removable etched-circuit board plugged into the main structure. The main structure is a rugged framework of cast and machined aluminum, containing the power transformer, some of the power-supply rectifiers and filter capacitors, interconnection cables, plugs, and sockets, some component terminal boards, and the front panel with its switches and switch circuits. Front-panel switches couple automatically to switches on the etched boards without set-screws or critical alignment. Each etched board is securely fastened in the instrument by means of a single screw. Time-Base drive units plug into the rear of the instrument and are held by two panel screws.

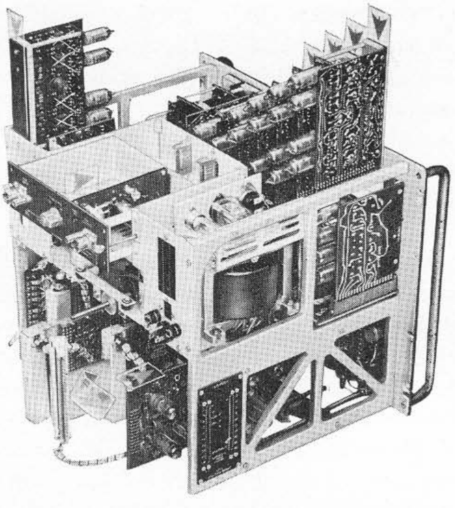


Figure 14. Interior view of the Type 1130-A Digital Time and Frequency Meter. Note that the etched-circuit boards (some shown partially withdrawn) are readily accessible.

Quiet forced-air cooling is used to hold the internal temperature rise to about 15 C above the external ambient temperature. The air filter snaps out easily for cleaning.

A view of the instrument with cabinet removed is shown in Figure 14.

TESTING TECHNIQUES

Because of the modular construction of the Counter, it is possible to test each etched board thoroughly as a unit before installation in the instrument; and the structure itself with its power supply, switches, and components can be tested alone. In addition to subassembly testing, of course, the completed instrument is subjected to over-all testing.

A possible difficulty caused by the wide tolerance of the circuits to tube and component variation is an increase in the probability that a wrong-valued component or a weak tube may go unnoticed, since the circuit may still function properly. To combat this possibility, the circuits are subjected to marginal testing in which the supply and signal voltages are varied over wide ranges. The Decimal-Counting Units, for example, must operate properly for a plate-supply voltage variation of ±120 volts about the nominal value of +300 volts, and the Time-Base unit must operate at half its nominal plate-supply voltage. In addition, every instrument must operate properly to 11.5 Mc.

ACCESSORY EQUIPMENT

To increase the range of application of the Type 1130-A Digital Time and Frequency Meter the following instruments are available:

Type 1132-A Data Printer

Manufactured and serviced by the Clary Corporation of San Gabriel, California, and sold by GR, the Type 1132-A Data Printer provides a permanent printed record of the results of measurement on adding-machine tape and allows unattended measurements. The instrument automatically prints rows of twelve-digit numbers at a rate adjustable from one print every twenty seconds to three prints per second. Eight of the twelve digits are obtained directly from the Counter, and the other four digits may be obtained from external sources. A keyboard and print-command bar at the top of the instrument allow numbers to be typed manually between automatic prints. An output for driving an IBM summary punch is available as a special option. The printer is mounted in a bench-type case with the adding-machine tape issuing from the top.

Type 1134-A Digital-To-Analog Converter

Because of the internal storage capability of the continuous display of the Type 1130-A Digital Time and Frequency Meter, the task of graphical recording is vastly simplified. The Type 1134-A Digital-to-Analog Converter accepts the four-line, 1-2-4-2, binary-coded-decimal outputs of the four storage decades of the Counter and produces a dc analog output of 0.1% accuracy. This accuracy specification includes the effect of nonlinearity, repeatability, ±10% line-voltage variations, long-term stability, and ambient temperatures from 0 to 50C. The Thevenin equivalent of the output circuit of the instrument is a voltage source varying from 0 to —30 volts behind a resistance of 30 kilohms. This output will drive 1-ma graphical recorders with input impedances up to 2 kilohms. An internal 100-ohm resistor can be connected in shunt with the output terminals to provide a 100-millivolt signal to drive most voltage recorders, or external resistors can be connected to produce other voltages. The instrument can be switched to operate from any three, or the last two, consecutive digits of the Counter display, allowing a precision of recording as great as that of the Counter itself. The availability of this instrumentation should increase the popularity of graphical recording of frequency stability, drift, etc., because of the ease of interpretation of a graphical record compared with that of a list of printed numbers.

Type 1133-A Frequency Converter and Video Amplifier *(under development)*

This instrument increases the sensitivity of the Type 1130-A, *and increases the frequency range to 500 Mc. The instrument provides a digital display and can be operated either as a wide-band heterodyne converter for clean signals or as a selective converter for noisy signals. The heterodyne-reference signals are derived from the crystal-controlled Time-Base drive source of the Counter and are just as accurate.*

— R. W. Frank

— H. T. McAleer

ACKNOWLEDGMENT

The design and development of the Type 1130-A Digital Time and Frequency Meter was the work of a development team composed of R. W. Frank, H. T. McAleer, and R. W. Stuart under the leadership of Mr. Frank. The decimal-counting units and the program-control unit were designed by R. W. Stuart, the input amplifiers and time-base unit by H. T. McAleer, and the 10-Mc decade, main-gate system, stop-channel comparator and power supply by R. W. Frank. The modular concept was developed by R. W. Frank and worked out cooperatively with H. T. McAleer and H. G. Stirling. P. K. Bodge consulted on mechanical-engineering problems, and testing and calibration procedures were devised by W. P. Buuck. G. E. Pilkington was responsible for production engineering.

—Editor

SPECIFICATIONS

FREQUENCY MEASUREMENT

Range: Dc to 10 Mc.

Sensitivity: 0.25 volt rms for sine waves, more sensitive at low frequencies; 0.4 volt peak-to-peak for typical pulse waveforms.

Counting Interval: 1 msec to 10 sec, extendible by MULTIPLE INTERVAL switch or external connections.

Accuracy: ±1 count ±time-base-oscillator accuracy.

PERIOD MEASUREMENT

Range: 10μsec to 10^7 sec — (dc to 100 kc) — for single-period measurement. 330 μsec to 10^7 sec — (dc to 30 kc) — for ten-period measurement.

Sensitivity: 0.1 volt rms for sine waves; 0.3 volt peak-to-peak for typical pulse waveforms.

Counting Interval: 1 period, 10 periods, extendible by MULTIPLE INTERVAL switch or external connections.

Counted Frequency: 10 Mc, 100 kc, 1 kc, 10 cps, or external (6 volts rms sine waves, or +10 volts peak pulses, 100 cps to 10 Mc).

Accuracy: ±0.1% at 1 volt rms for single-period measurement; better for higher voltage level and good signal-to-noise ratio. ±0.01% at 1 volt rms for 10-period measurement; better for higher voltage level and good signal-to-noise ratio.

TIME-INTERVAL MEASUREMENT

Range: 1μsec to 10^7 sec.

Sensitivity: 0.3 volt peak-to-peak.

Counted Frequency: 10 Mc, 100 kc, 1 kc, 10 cps, or external (6 volts rms sine waves, or +10 volts peak pulses, 100 cps to 10 Mc).

Accuracy: Dependent on slope of input signals at instants of triggering. For steep slopes (e.g., pulses): ±1 period of frequency counted ± accuracy of frequency counted.

COUNT MEASUREMENT

Rate: Dc to 10 Mc.

Sensitivity: 0.25 volt rms for sine waves, more sensitive at low frequencies; 0.4 volt peak-to-peak for typical pulse waveforms.

Capacity: 10^8 counts.

TIME-BASE OSCILLATOR STABILITIES

Type	*Short-Term*	*Long-Term*
1130-P2	less than $1/10^8$ per minute	less than $2/10^7$ per week
1130-P3 1130-P4	less than $1/10^9$ per minute	less than $5/10^8$ per week
1113-A (with 1130-P1)	less than $1/10^{10}$ per minute measured with 1 sec sample	less than $5/10^{10}$ per day (10-day average after 60 days' operation)

GENERAL

Display: Neon-lamp columns — 8 digits intermittent, 4 digits continuous.

Display Time: Variable, 0.1 to 10 sec, infinite, or continuous display.

Input Impedance: 1 megohm shunted by 40 pf.

Input Attenuator: x 1 or x 10.

Check: 10 cps, 1 kc, 100 kc, or 10 Mc can be counted for 1 msec to 10 sec.

Monitor: Flashing lamp indicates lack of time-base drive signal or improper operation of frequency dividers.

Input Triggering Level: Variable ±10 volts.

Input Triggering Slope: Positive-going or negative-going, ac or dc coupling.

External Outputs — Front Panel: GATE signal (coincides with counting interval).

SYNC pulses (at start of internal program cycle).

10 cps to 10 Mc (except 1 Mc) standard frequencies from EXT connector, depending on settings of MEASUREMENT, FREQUENCY, and TIME controls.

External Outputs — At Rear: MULTIPLE-INTERVAL connections (terminals of MULTIPLE INTERVAL panel switch; "carry" pulse of program-control decade to be counted down by external interval-multiplier circuit for CHECK, FREQUENCY, and 10-PERIOD measurements).

8, four-line, binary-coded-decimal digits (1,2,4,2) ("0" = 185 volts, "1" = 65 volts — 0.5 megohm source impedance — minimum load impedance 1.8 megohm).

Time-Base Drive Required: 5 Mc, 1 volt rms into 50 ohms (supplied by 1130-P2, -P3, -P4, 1113-A).

Power Input: 115/230 volts, 50-60 cps, 400 watts.

Dimensions: Width 19, height 15¾, depth 19 inches (485 by 400 by 485 mm), over-all.

Weight: 85 lb. (39 kg).

ACCESSORY INSTRUMENTS

Time-Base Units (see page 16 and above for description and stability figures).

Type 1130-P2 Time-Base Oscillator/Multiplier (rear plug-in) for operation from 100 kc, 1 Mc, 5 Mc or internal 5 Mc.

Type 1130-P3 5-Mc Time-Base Oscillator (rear plug-in).

Type 1130-P4 5-Mc Precision Time-Base Oscillator (rear plug-in).

Type 1130-P1 Coupling Unit for use with external time base, such as TYPE 1113-A Standard-Frequency Oscillator.

Type 1132-A Data Printer

Type 1134-A Digital-to-Analog Converter for driving graphic recorder.

Type 1130-P5 Servicing Accessory — permits operation of any of 11 printed-circuit boards clear of rest of instrument for operational trouble shooting.

Type		*Code Word*	*Price*
1130-AM1	(Including Type 1130-P1 Time-Base Unit) Bench Mount	LABOR	$2585.00
1130-AR1	(Including Type 1130-P1 Time-Base Unit) Rack Mount	MINIM	2585.00
1130-AM2	(Including Type 1130-P2 Time-Base Oscillator/Multiplier) Bench Mount	LAPEL	2750.00
1130-AR2	(Including Type 1130-P2 Time-Base Oscillator/Multiplier) Rack Mount	MOCHA	2750.00
1130-AM3	(Including Type 1130-P3 Time-Base Oscillator) Bench Mount	LASSO	2670.00
1130-AR3	(Including Type 1130-P3 Time-Base Oscillator) Rack Mount	MOGUL	2670.00
1130-AM4	(Including Type 1130-P4 Precision Time-Base Oscillator) Bench Mount	LUNER	2950.00
1130-AR4	(Including Type 1130-P4 Precision Time-Base Oscillator) Rack Mount	METAL	2950.00
1132-A	Data Printer	LILAC	1450.00
1134-AM	Digital-to-Analog Converter (Bench Mount)	MINOR	595.00
1134-AR	Digital-to-Analog Converter (Rack Mount)	MOTTO	595.00
1130-P5	Servicing Accessory	MOLAR	30.00

U.S. Patents 2,548,457; 2,977,540; and Patents Pending.

CORRECTION

The TYPE 1112-A Standard-Frequency Multiplier input specifications given in the April, 1961 *EXPERIMENTER* should be corrected to read as follows:

Input: 1 volt, 100-kc sine wave from standard-frequency oscillator. Can also be driven at input frequencies of 1 Mc (1.5 volts), 2.5 Mc (0.4 volt), or 5 Mc (0.4 volt). Will run free with no input signal, but absolute frequency may be in error by several parts per million.

General Radio Company

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EXPERIMENTER

VOLUME 35 No. 6 JUNE, 1961

IN THIS ISSUE

Three New Capacitors

THE GENERAL RADIO

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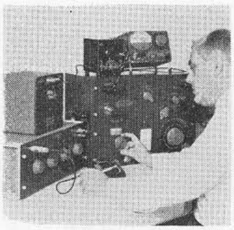
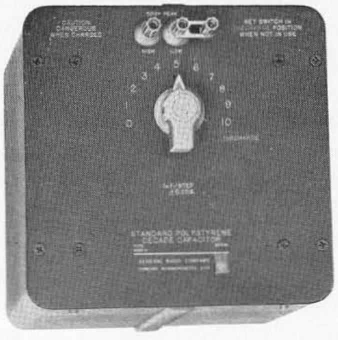


Calibrating Type 1423-A Precision Decade Capacitors in the General Radio Standardizing Laboratory using the Type 716-C Capacitance Bridge.

A NEW 10-MICROFARAD CAPACITANCE STANDARD



Type 1424-A
Standard Polystyrene Decade Capacitor.

General Radio fixed capacitance standards are available from stock, in relative magnitudes of 1-2-5, from 0.01 pf to 1 μf. Type 1401 and Type 1403 Air-Dielectric Models cover the range from 0.01 pf to 1000 pf, while the Type 1409, with silvered-mica dielectric, is available in values from 1000 pf to 1 μf. There has for some time been a demand for capacitance standards having values well above 1 μf. Carrying the silvered-mica standards above 1 μf, however, is not very practical, since the resulting capacitor would be heavy, bulky, and very expensive. For these higher capacitance values, polystyrene dielectric offers many advantages.

Since a large polystyrene capacitor must for production reasons be built up of many smaller capacitors paralleled, it is very little extra trouble to switch the capacitors in one by one instead of connecting them all solidly together. In the new Type 1424-A Standard Polystyrene Decade Capacitor, ten 1-μf capacitors are switched in this manner to provide not one but ten standards, one at each integral microfarad from 1 to 10. Each of the 1-μf capacitors is accurate to 0.25%. When all ten of these have been switched in parallel to make a 10-μf unit, the laws of probability will make the majority of units as close as 0.1% to the nominal 10 microfarads.

Residual Impedances

The most important problems in the design are not so much those of packaging as of minimizing the unwanted residual impedances. Inductance must be minimized to keep the natural frequency of the shorted capacitor low, in order that the capacitor may be used with accuracy over a broad frequency range. If the capacitor is used at 1/20 of its natural frequency, the frequency error will be 0.25%, equal to the adjustment accuracy of the unit. To appreciate the importance of resistance, consider that the reactance of 10 microfarads at 10 kc is 1.6 ohms. Since the dissipation factor of good polystyrene capacitors rarely exceeds 0.0001, a series resistance of 0.16 milliohm would double the dissipation factor. Naturally it is desirable that both L and R be kept so low that their effects will be small, compared to adjustment accuracy and to dissipation factor, respectively.

In this new polystyrene decade, the range of natural frequencies with the terminals shorted is from 525 kc at 1 μf to 235 kc at 10 μf, corresponding to a series-inductance range of 91 to 46 mμh.

The series resistance, R, difficult to measure directly, is low enough not to affect dissipation factor adversely at 1 kc. The desirable reductions of L and R have been accomplished by generous use of current-sheet conductors, ribbon leads, switch-terminal replication, etc. The residual series inductances will be found to be comparable to those of other GR fixed standard capacitors as well as to those of the air-dielectric precision capacitors, even though the TYPE 1424-A is much larger and the conducting leads consequently longer. The paralleling of paths that helps to reduce the inductance is still more effective in reducing the resistance.

Charge Storage

One of the most important considerations in any application involving dc is the large amount of stored energy. With all capacitors switched in (10 microfarads) and charged up to the rated 500 volts dc, the stored energy is 1.25 watt-seconds. This is not only a great deal of energy at a comparatively high voltage, but it will stay in the capacitor a long, long time, because the leakage resistance is of the order of 100,000 megohms, signifying a time constant of 10^6 seconds, or *12 days*. Caution notices are prominently engraved in red on the panel, and the clockwise position of the switch discharges the capacitor through a 100-kilohm resistor. The switch should be kept at the DISCHARGE position except when the capacitor is actually in use. This will assure that a minimum of residual absorbed energy will remain in the capacitor. Should it, through oversight, be left elsewhere after discharge, the low dielectric absorption of polystyrene assures that the residual voltage later acquired, as the absorbed charge comes out of the dielectric, will be small and not hazardous, although it will not be negligible in a dc storage application such as an analog computer.

Sudden charge or discharge is potentially damaging to the capacitor. In the DISCHARGE switch position, the discharge current is limited, with a nominal time constant of one second. Limitation of charging current is accomplished by the charging of each section through a series resistor of 1000 ohms, which is not in series with the capacitor at any detented switch position. This kind of switching is done through the agency of a second switch wafer which inserts the resistor between the sections already charged (if any) and the section about to be charged, during the time of traverse between switch positions. This resistor limits the peak current to 0.5 ampere at full rated voltage in a circuit having a time constant of 1 millisecond, which is fast enough to control charging current reliably, even with fast rotation of the switch.

Construction

The TYPE 1424-A Standard Polystyrene Decade Capacitor uses twenty 0.5-μf capacitors, paired to get ten 1-μf $\pm 0.25\%$ sections. These are housed in two solder-sealed brass cases with Teflon-insulated high terminals, the case being common. These two cases and the switch are mounted to a subpanel, which is itself insulated from the main panel. Thus the capacitor may be used in either a 2- or a 3-terminal connection, with no significant difference in capacitance values. A calibration chart is provided giving the actual capacitance at each of the ten switch positions. Dissipation factor typically is 0.0002, and insulation resistance 10^6 ohm-farads.

Much care was required in the design

of the instrument to keep series L and R at manageable levels. The excellence of the TYPE 1424-A in these respects can be fully exploited only if in application the inductance and resistance of the connecting means employed by the user are as carefully controlled.

— P. K. McELROY

SPECIFICATIONS

Nominal Value: 0 to 10 microfarads, in steps of 1 microfarad.

Adjustment Accuracy: $\pm 0.25\%$ at 1 kc.

Certificate: A certificate is supplied giving measured values, obtained by comparison to a precision better than $\pm .01\%$ with working standards maintained to an accuracy of $\pm .03\%$ in terms of NBS-certified reference standards.

Stability: Change is less than $\pm .05\%$ per year.

Frequency: Calibrated at 1 kc. Variation with frequency down to 60 cps is typically less than $+.02\%$. At higher frequencies, terminal capacitance rises as resonant frequency is approached (see curves). The increase can be calculated from $\frac{\Delta C}{C} = \left(\frac{f}{f_o}\right)^2$. Typical values of f_o are given in the calibration certificate.

Voltage Recovery: Less than 0.1%, 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.

Dissipation Factor: Less than .0003 at 1 kc. (See curves for variation with frequency.)

Temperature Coefficient: Approximately −140 ppm per degree C.

Maximum Operating Temperature: 65 C.

Insulation Resistance: Approximately one million ohm-farads.

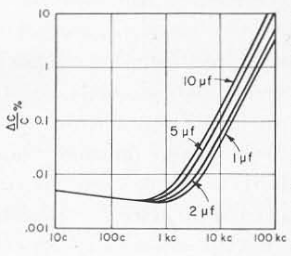
Maximum Voltage: 500 volts peak, up to 10 kc.

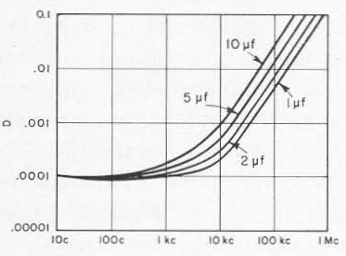
Mounting: Aluminum cabinet and panel, finished in gray.

Terminals: A separate ground terminal is provided, permitting 2- or 3-terminal use.

Dimensions: Width 8, height 7¾, depth 9½ inches (205 by 195 by 240 mm), over-all.

Net Weight: 16½ pounds (7.5 kg).





Typical curves for Type 1424-A Capacitors. (left) Change in capacitance as a function of frequency. These changes are referred to the values which the capacitors would have if there were neither interfacial polarization nor series inductance. The 1-kc value on the plot should be used as a basis of reference in estimating frequency errors. (right) Dissipation factor as a function of frequency.

Type		*Code Word*	*Price*
1424-A	**Standard Polystyrene Decade Capacitor**	BAIRN	**$325.00**

A NEW FOUR-DIAL PRECISION CAPACITOR

Fixed-value impedance standards are generally used for maximum accuracy and stability, while adjustable standards ordinarily provide convenience and flexibility at some sacrifice in stability and accuracy. The new TYPE 1423-A Precision Decade Capacitor, however, combines the high accuracy normally associated only with fixed, reference-type standards with convenient decade construction, which makes available any desired value within the range of the capacitor. Four individual decade capacitors within the cabinet provide 11,110 discrete values of capacitance, each known to an accuracy of $\pm .05\%$. Any value of capacitance be-

Type 1423-A Precision Decade Capacitor.

tween 100 pf and 1.111 μf in steps of 100 pf can be established quickly and easily by straightforward dial settings.

The new decade capacitor is packaged in a standard relay-rack-type cabinet with aluminum end frames for bench use. A new, in-line readout displays the selected value in large, bold numbers for maximum readability.

The decade switches and associated capacitors 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 difference of about one picofarad; see below).

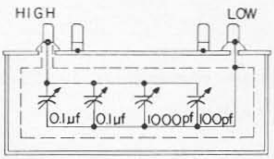
The constituent capacitors are high-quality silvered-mica units, similar in design and construction to those used in the Type 1409 Standard Capacitors, but individually adjusted to values slightly below nominal. Precise final adjustment to nominal value is made by means of small "trimming" or "padding" capacitors within the instrument. On the two lowest decades (100 pf per step and 1000 pf per step), an air trimmer capacitor is provided for each of the 10 positions of the switch. Theoretically, then, each position can be adjusted precisely to nominal value. For the two higher decades (.01 μf per step and 0.1 μf per step), individual point adjustment is neither practical nor necessary, since the variations in switch capacitance, which may be significant on the lower decades, is negligible here. Small fixed-value padding capacitors, individually selected, are used to adjust each of the four capacitors of each decade to the desired tolerance. The air trimmers are readily accessible for subsequent re-adjustment if necessary, and the terminals for the fixed padders are also accessible, although somewhat less readily. Thus this instrument is capable of readjustment, an important feature for those laboratories having facilities and reference standards accurate enough to detect shifts of value. Readjustment should rarely, if ever, be necessary, since many years' experience with such capacitors indicates a typical stability of better than ±.01% per year.

The actual adjustment accuracy of the capacitor as shipped is limited only by the accuracy of our own working standards and measurement, and by the finite patience of the technician who makes the final adjustment. To allow for these factors and for any possible drift within the warranty period, the adjustment accuracy[1] is conservatively rated as ±0.05%, which value is engraved on the panel.

[1] I. G. Easton, "Standards and Accuracy," *General Radio Experimenter*, 34, 6, June, 1960.

Terminal Arrangement

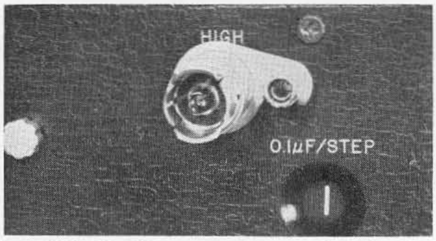
The terminals have been arranged to facilitate connection in a variety of ways. The HIGH and LOW terminals are widely separated on the panel so that ordinary unshielded leads may be used, provided the circuit to which the capacitor is connected will tolerate such a method of connection. A pair of grounded binding posts, each ¾ inch from an insulated binding post, allows use of cables terminated in TYPE 274 Double Plugs. Complete shielding of binding posts as well as of leads can be accomplished by the use of a TYPE 274-NK Shielded Plug Connector. A fifth binding post, connected to the panel, facilitates connection to external ground when the TYPE 274-NK Connector is used.



Schematic diagram of the Type 1423-A Precision Decade Capacitor

The above comments apply, of course, to the three-terminal connection. For two-terminal use, the LOW terminal must be connected to the case by the grounding link provided, and the capacitor connected by the HIGH terminal and any one of the other four binding posts, all now connected to the case.

The new TYPE 874-Q9 Adaptor has been designed to provide a completely shielded transition from the standard ¾-inch-spaced binding posts to a TYPE 874 Coaxial Connector. This adaptor serves not only as the transition to



Type 874-Q9 Adaptor on the panel of the Type 1423 Capacitor.

coaxial systems, but also provides the fixed geometry[2] upon which the two-terminal calibration is based. Although the internal shielding of the capacitor is complete, the HIGH binding post external to the panel has a small capacitance to ground. The capacitance as a two-terminal device differs from the three-terminal capacitance by approximately this capacitance, about one picofarad.

This new instrument is a very flexible and versatile tool for calibration laboratories and for production-line measurements. With the TYPE 1605-A Impedance Comparator, for instance, it forms a complete capacitance measuring assembly, capable of rapid, highly accurate comparisons.

With the new TYPE 1424-A Standard Decade Capacitor extending the range to 10 µf, and the new TYPE 1422[3] Precision Adjustable Capacitors available in the range below 100 pf, the GR line of capacitance standards can provide very accurately and conveniently any value of capacitance from a fraction of a picofarad to 10 µf.

— I. G. EASTON

[2] J. F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," *General Radio Experimenter*, 33, 7, July, 1959.

[3] To be described in a forthcoming issue of the *Experimenter* (also in Catalog Q).

SPECIFICATIONS

Nominal Values: 100 pf to 1.111 µf in steps of 100 pf.

Accuracy of Adjustment: ±.05% at 1 kc, calibrated in the three-terminal connection using TYPE 874-Q9 Adaptors (supplied). Two-terminal connection (made by inserting the capacitor into TYPE 874-Q9 Adaptor) adds about 1.3 pf to reading.

Certificate: A certificate is supplied certifying that each component capacitor was adjusted by comparison to a precision better than ±.01% with working standards maintained to an accuracy of ±.02% in terms of NBS-certified reference standards.

Dissipation Factor

D not greater than	*C range*
.001	100 pf to 1000 pf
.0005	1100 pf to 2000 pf
.0003	2100 pf to 1.1110 μf

Temperature Coefficient of Capacitance: Approximately +35 ppm per degree Centigrade between 10 and 50 degrees C.

Insulation Resistance: Greater than 50,000 MΩ to 0.1 μf and greater than 5,000 MΩ from 0.1 μf to 1.111 μf.

Calibration Frequency: 1 kc.

Frequency Characteristic: The behavior of each individual capacitor is similar to that of a TYPE 1409 Capacitor.

Maximum Voltage: 500 volts peak, up to 10 kc.

Accessories Supplied: Two TYPE 874-Q9 Adaptors.

Mounting: Aluminum relay-rack-style cabinet in gray, supplied with metal end frames for bench mounting.

Dimensions: Width 19, height 7, depth 9¾ inches (485 by 180 by 250 mm), over-all.

Net Weight: 26 pounds (11.8 kg).

Type		*Code Word*	*Price*
1423-A	**Precision Decade Capacitor**	LEVEL	$695.00

A FOUR-DIAL POLYSTYRENE DECADE CAPACITOR

In addition to the two decade capacitance standards already described in this issue, a new four-dial polystyrene decade capacitor, TYPE 1419-B, has been added to our listing and is now available from stock. The new decade is similar to the popular TYPE 1419-A, a three-dial decade announced about five years ago, except for the addition of a 100-pf-per-step decade, TYPE 980-D.

SPECIFICATIONS

Capacitance: 1.1110 μf maximum, in steps of .0001 μf.

Dielectric: Polystyrene (TYPE 980-A, -B, -C, and -D Decade Capacitor Units).

Zero Capacitance: 50 pf, two-terminal; 20 pf, three-terminal.

Accuracy: Capacitance increments from zero position are within the following percentages of the indicated value for any setting: (2-terminal) ±1% on three highest decades and ±(1% +2 pf) on the smallest decade; (3-terminal) ±1% on two highest decades, ±1.5% on the .001-μf-per-step decade, and +1%, −(2% + 4 pf) on the smallest decade.

Dissipation Factor: Less than .0002 at 1 kc.

Insulation Resistance: 10^{12} ohms at 100 v, 23 C, 50% RH.

Temperature Coefficient of Capacitance: −140 ppm per degree Centigrade, nominal.

Maximum Operating Temperature: 65 C.

Maximum Operating Voltage: 500 volts, dc or peak, up to 10 kc.

Frequency Characteristic: Similar to those for the TYPE 980 Decade Capacitor Units (see catalog), modified by the additional inductance and resistance of the box terminals and wiring.

Ratio of DC Capacitance to 1-kc Capacitance: Less than 1.001.

Voltage Recovery: Less than 0.1%, 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.

Terminals: Three TYPE 938 Binding Posts with grounding link.

Mounting: Aluminum panel and cabinet.

Dimensions: Width 4¼, length 16¼, height 5 inches (110 by 415 by 130 mm), over-all.

Net Weight: 8⅜ pounds (3.8 kg).

Type		*Code Word*	*Price*
1419-B	**Decade Capacitor**	BEFIT	$262.00

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VOLUME 35 No. 7

JULY, 1961

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Tuned Amplifier and Null Detector
RC Null Circuits
30-Ampere Variac® Autotransformer
Overseas Seminar

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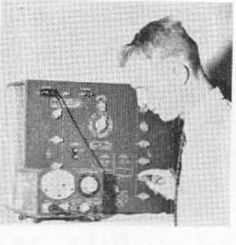


High sensitivity and low noise are features of the new Type 1232-A Tuned Amplifier and Null Detector, shown here with the Type 1632-A Inductance Bridge.

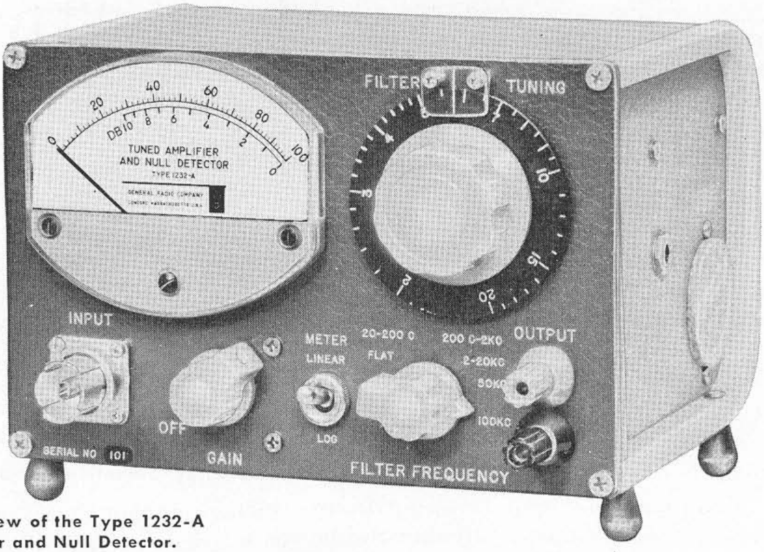


Figure 1. Panel view of the Type 1232-A Tuned Amplifier and Null Detector.

A TUNED AMPLIFIER AND NULL DETECTOR WITH ONE-MICROVOLT SENSITIVITY

The Type 1232-A Tuned Amplifier and Null Detector is a sensitive, low-noise, transistor amplifier, which tunes continuously from 20 cps to 20 kc, with additional fixed-tuned frequencies of 50-kc and 100-kc. It is intended primarily as a bridge detector but has many other important uses, among them the detection of high-frequency modulated signals (with a crystal demodulator), approximate wave analysis at audio frequencies, and as a preamplifier for transducers.

The outstanding characteristics of this instrument — one-microvolt sensitivity, low noise level, and continuous tuning — result from unusual features of circuit design.

CIRCUIT

Preamplifier

Of the elements shown in the block diagram of Figure 2, the preamplifier is one of the most important, because the minimum detectable signal is determined by the preamplifier noise level. The type of transistor for the first stage was chosen to minimize noise, not only from low impedance sources such as inductance bridges at low frequencies, but also from high impedance sources such as capacity bridges at low frequencies. In the light of simplified noise theory[1], this means a transistor with a low open-circuit noise generator, i_n, as well as low short-circuit noise generator, e_n. After noise diagrams were plotted for many transistors, it was discovered that the 2N169A transistor when operated at very low collector current had a noise figure of 3 to 5 db at an optimum source impedance of 50 kilo-ohms, which is unusually high for a

[1] A. E. Sanderson and R. G. Fulks, "A Simplified Noise Theory, and its Application to the Design of Low-Noise Amplifiers," *IRE Transactions on Audio*, July-August, 1961.

transistor. By use of negative feedback the input impedance of the preamplifier is also made 50 kilohms, and the noise level as read on the output meter is relatively constant and independent of the source impedance. This eliminates the inconvenience of having the output meter bang off scale whenever the input circuit is open circuited, as often happens with vacuum-tube amplifiers. In addition, any large difference between the short-circuit and open-circuit noise levels would require increased range on the gain control, since it is always necessary to operate with the noise level well below full-scale output on the meter.

To protect the input transistor from possible damage due to large overloads at the input, it is preceded by a limiter consisting of a series capacitor and two shunt silicon rectifier diodes. This circuit effectively prevents signals greater than 1 volt, peak-to-peak, from reaching the input transistor and does not contribute noise or distortion to low-level signals. With the gain control set for 1 μv full scale, it is possible to connect the input to a 115-volt ac line without damage to the input transistor.

Maximum gain of the preamplifier is about 40 db, which is adequate to swamp the noise of succeeding stages. The total range of the volume control is 120 db, which reduces the full-scale sensitivity to 1 volt full scale, and attenuation in db is roughly proportional to the rotation angle of the gain control.

Series and Shunt Filters

After preamplification, the signal passes through a set of series and shunt filters, which are designed to reject frequencies above and below the selected tuning range. For example, on the 200-cps-to-2-kc tuning range, a series capacitor rejects all frequencies below 200 cps, while a shunt capacitor rejects all frequencies above 2 kc. On all switch positions except FLAT and 20-200 cps, another rejection filter reduces the response at 60 cps to greater than 60 db below peak response.

Frequency-Selective Amplifier

This amplifier consists of three stages with negative feedback through a null network, which has its null at the desired operating frequency. Since there is negative feedback at all frequencies but the desired one, the over-all response peaks at this frequency and is roughly equivalent to that of a tuned circuit with a Q of about 20 (5% bandwidth). The unique feature of this null network is its one-pot tuning[2]. Many null networks require three variable elements, either ganged capacitors or ganged potentiometers. This leads to many problems in alignment and tracking the three elements to maintain a good null. The Hall null network[2] has a perfect null in theory for any position of the tuning potentiometer, and it is possible to cover a 10:1

[2]Henry P. Hall, *IRE Transactions on Circuit Theory*, September 1955, Vol. CT-2, No. 3, p 283. See also the article on page 8 of this issue.

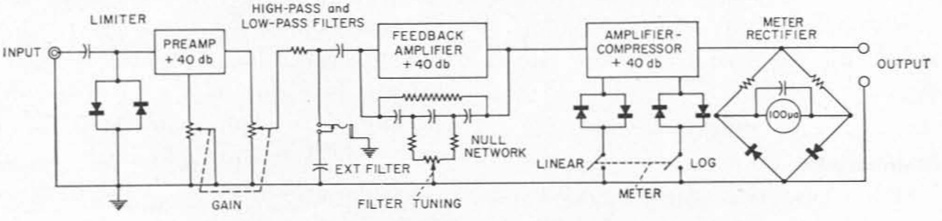


Figure 2. Block schematic of the null detector.

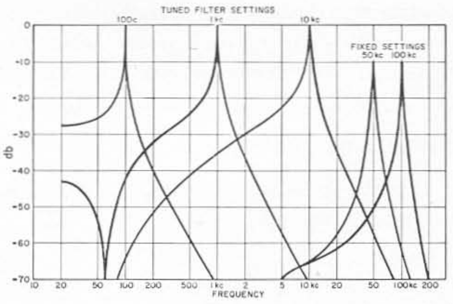


Figure 3. Typical filter characteristics.

tuning range with a 40-db exponential potentiometer. Tuning capacitors are switched to change ranges, which has the advantage of maintaining the impedance level of the null network approximately constant for the three tuning ranges.

Since the 50-kc and 100-kc null networks are not required to be tunable, conventional twin-T null networks are used.

On the FLAT position of the range switch, all filters are switched out and the frequency response is flat to within ±3 db from 20 cps to 100 kc. The overall gain of the amplifier is reduced by 26 db to keep the noise level on the output meter equal to about 10% of full scale at maximum gain.

Amplifier-Compressor

The gain of the frequency selective amplifier is about 40 db, and another 40 db of gain is supplied by the amplifier-compressor, making the total gain of the amplifier about 120 db. With the METER switch set to the LINEAR position, the amplifier-compressor functions as a linear amplifier, driving the meter rectifier circuit as well as supplying the output terminals with about 1.4 volts for full-scale deflection of the meter. The dc supplied to the last transistor is sufficient to drive the output meter to full scale, but very little more, so that it is impossible to damage the meter by overdriving the amplifier. For null detector use, the meter switch is thrown to LOG and the upper part of the meter scale is compressed. Two pairs of silicon diodes are switched in shunt with the collector resistors of two transistors to provide a nonlinear collector impedance. Due to the voltage offset of the silicon diodes, the bottom 20% of the meter scale is virtually unaffected. A signal level corresponding to 100% deflection for linear response will drop to 50% for logarithmic response. An increase of 20 db increases the reading to 80%, and another 20 db raises the reading to 100%. Thus the dynamic range of the instrument for logarithmic operation is about 40 db greater than it is for linear, although the minimum detectable signal is the same.

Meter Circuit

The meter circuit uses a full-wave rectifier in order to double the ripple frequency that passes through the meter and thus to prevent the needle from vibrating visibly at 20 cps. Resistors are used in place of two of the rectifiers in the conventional full-wave bridge in order to linearize the relation between meter indication and signal level, and to minimize distortion. No dc amplification was incorporated into the meter circuit, so that there is no need for a dc zero adjustment on the front panel and no possibility of dc zero instability. High-impedance, crystal-type earphones can be connected to the output terminals.

External Filter

External filters can be connected at the EXT FILTER jack. When a telephone plug is inserted in this jack, the built-in shunt filter is disconnected. The external filter may be either a series tuned circuit to trap out an undesired frequency, or an antiresonant parallel tuned circuit to enhance the selectivity at the desired frequency. For the purpose of calculating the Q of the external filter, the source impedance is about 700 ohms. Since the external filter is plugged into the circuit at a point beyond the 60-cycle rejection filter and where there is 80 db gain to the meter circuit, it is important that the external filter be shielded and preferably that it use a toroidal inductor for minimum sensitivity to hum pickup.

USES

The high sensitivity, low noise level, and continuous-tuning features of this instrument foster a wide variety of uses.

Figures 3, 4, 5, and 6 show the selectivity, response and noise characteristics as functions of frequency.

Bridge Balancing

The above combination of features makes possible extremely precise bridge settings, even with very low-power generators, at any frequency in the audio range. Provision for logarithmic response makes adjustments of generator level unnecessary. The new General Radio meter case, with open, easily read scale, further facilitates the bridge balance.

With the Type 1632-A Inductance Bridge, this null detector makes possible inductance balances to a resolution of 1 part in 10^6. An equivalent precision for capacitance balance can be obtained with the Type 716-C Capacitance Bridge.

Detector-Demodulator

For the detection of modulated high-frequency signals, the Type 1232-A Amplifier and Null Detector can be used with the Type 874-VQ Voltmeter-Dectector. Sensitivity is approximately 200 μv full scale up to about 2000 Mc.

Amplifier or Preamplifier

The high sensitivity of this instrument permits its use as a preamplifier for transducer outputs or oscilloscope input. As a general-purpose laboratory amplifier, it offers both selective and flat characteristics.

Audio Spectrum Analysis

The tuned amplifier can be used as an audio-frequency wave analyzer with a sensitivity of one microvolt and a bandwidth of about 5%. For approximate measurements, the gain can be assumed to be constant with frequency, but excellent accuracy can be obtained if the amplifier is first calibrated with a constant-amplitude, variable-frequency signal.

Since the range of the db scale on the output meter is limited to 10 db, a calibrated attenuator is necessary for greater ranges. With the Type 546-C

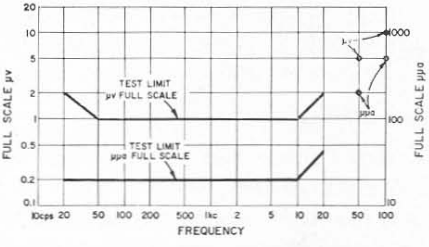


Figure 4. Test limits for both voltage and current as functions of frequency.

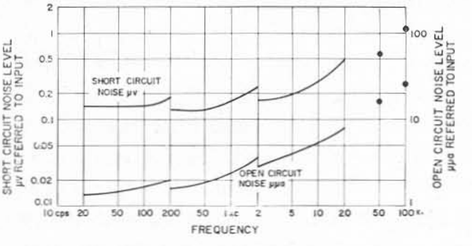


Figure 5. Typical noise levels as a function of frequency.

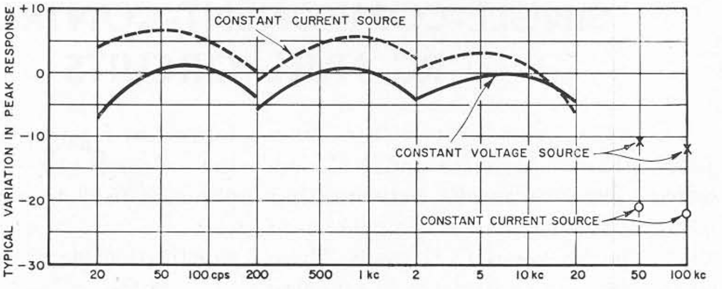


Figure 6. Typical variation in peak response with frequency for constant gain-control setting.

Microvolter, the input to the amplifier can be increased in known steps to cover a measurement range of 120 db.

The author has also found this amplifier with a microphone and a pair of earphones, a valuable aid in tuning his piano. — A. E. SANDERSON

CREDITS

The development of the TYPE 1232-A Tuned Amplifier and Null Detector was carried out by Albert E. Sanderson, author of the foregoing article. The design of the tuned null network was contributed by Henry P. Hall, author of the article starting on page 8. The project was under the direction of R. A. Soderman. — EDITOR

SPECIFICATIONS

Frequency Response:

Tunable Filters: 20 cps to 20 kc in 3 ranges; 6% bandwidth; 2nd harmonic at least 34 db down from peak, 3rd at least 40 db down; rejection filter on two highest ranges reduces 60-cycle level to at least 60 db below peak. Frequency dial accuracy is ±3%.

50 kc and 100-kc Filters: 2nd harmonic at least 60 db down.

Flat Response: ±3 db 20 cps to 100 kc.

Sensitivity: One microvolt, full scale, or better, over most of the frequency range. See Figure 4 for test limits.

Noise Level: Independent of source impedance; see Figure 5.

Input Impedance: Approximately 50 kilohms to one megohm, depending on gain-control setting.

Max Input Voltage: 200 volts ac or 400 volts dc, without damage.

Gain: 120 db on the tunable ranges; 100 db, flat range; 106 db at 50 kc; 100 db at 100 kc position.

Output: 1 volt into 10,000 ohms. Internal impedance is 3000 ohms.

Meter Linearity: Db differences on scale are accurate to ±5% for inputs of less than 0.3 volt.

External Filter: Source impedance, 700 ohms.

Compression: Reduces full-scale sensitivity by 40 db. Does not affect bottom 20% of scale.

Distortion: (In flat position) less than 5%, practically all attributable to the meter rectifiers.

Power Supply: 12 volts dc, from 9 mercury (M72) cells in series. Estimated battery life is 1500 hours. Cost is about 0.4 cent per hour.

Transistor Complement: Six 2N169A, two 2N1395.

Accessories Supplied: TYPE 874-R34 Patch Cord.

Dimensions: Width 8, height 6, depth 7½ inches (205 by 150 by 190 mm) over-all.

Net Weight: 5¾ pounds (2.6 kg).

Type		*Code Word*	*Price*
1232-A	Tuned Amplifier and Null Detector	VOCAL	$360.00
480-P308	Relay-Rack Panel Extensions (Pair)	EXPANELDOG	7.00 Pair

U.S Patents 2,548,457 and D187,740.

VACATION CLOSING

During the weeks of July 24 and 31, our Manufacturing Departments will be closed for vacation.

There will be business as usual in the Sales Engineering and Commercial Departments. Inquiries, including requests for technical and commercial information, will receive our usual prompt attention. Our Service Department requests that, because of absences in the manufacturing and repair groups, shipments of equipment to be repaired at our plant be scheduled to reach us after the vacation period.

SINGLE-COMPONENT-CONTROLLED RC NULL CIRCUITS

The null circuit used in the TYPE 1232-A Tuned Amplifier and Null Detector is one of several RC networks that use only one variable component to adjust the frequency of the null. These circuits have the advantage of avoiding the use of ganged, variable components which must track closely to maintain stability when used in highly selective feedback amplifiers.

The only single-control-element RC null circuits known for many years were those discovered by Sacerdote[1] shown in Figures 1 and 2. These four-terminal bridge networks give a true null at a frequency ω_0 and have tuning laws of:

$$\omega_0 = \frac{1}{RC}\sqrt{\frac{\alpha-1}{\alpha}} \text{ and } \omega_0 = \frac{1}{RC\sqrt{1-\alpha}},$$ respectively, where α is the normalized value of the variable component. These functions do not give as wide a frequency change for a given change in α as do the Wien bridge and the twin-T with ganged components, for which $\omega_0 \sim \frac{1}{\alpha}$. The first bridge is particularly interesting, however, because it gives a zero-frequency null using components of finite value.

Clothier[2] and Doyle[3] showed that the "duals" of these circuits, Figures 3 and 4, also null and have the same frequency characteristics. These are not duals in the usual sense, but are topological duals with R's and C's interchanged. Each pair of dual circuits has the same tuning law, and the two other circuits, formed by interchanging R's and C's in the original two, have a tuning law obtained from that of the first two by substitution of $\frac{1}{1-\alpha}$ for α. Similar sets of four circuits can be formed from the circuits of Figures 5 and 6. These circuits have the same tuning laws.

These frequency bridges all have three complex bridge arms. A simpler arrangement for use in feedback circuits is to have two arms of the bridge consist of a fixed voltage divider. The other two arms of the bridge are formed by a three-terminal network whose output voltage is equal to that of the divider at some frequency, as in the familiar

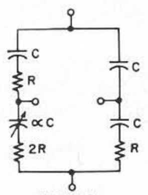


FIGURE 1

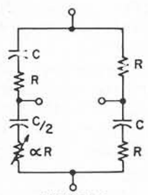


FIGURE 2

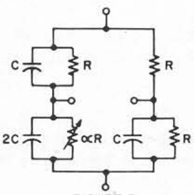


FIGURE 3

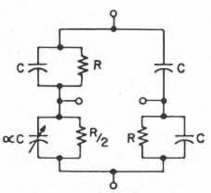


FIGURE 4

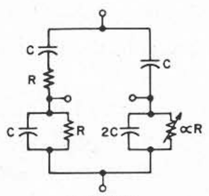


FIGURE 5

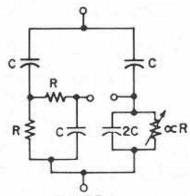


FIGURE 6

[1]Sacerdote, *Alta Frequenza*, August 1934, p. 437.

[2]Clothier, W. K., *IRE Transactions on Circuit Theory*, March 1955, p 97.

[3]Doyle, E. D., See Hague, *AC Bridge Methods*, 5th Edition, page 611.

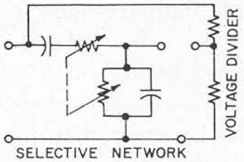


FIGURE 7

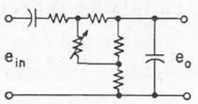


FIGURE 8

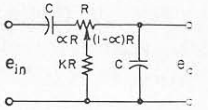


FIGURE 9

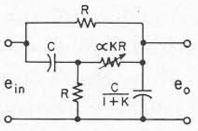


FIGURE 10

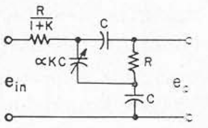


FIGURE 11

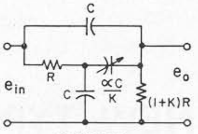


FIGURE 12

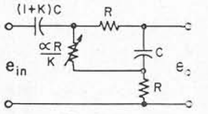


FIGURE 13

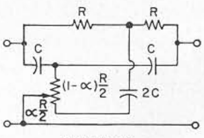


FIGURE 14

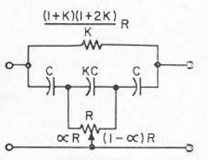


FIGURE 15

Wien bridge[4,5] which is shown in Figure 7. Wigan[6] presents single-control circuits of this type, and his simplest circuit is shown in Figure 8. This one has a very narrow tuning range, but, by making it slightly more complicated, he derives a circuit that has a frequency range from a fixed value to infinity. The circuit of Figure 9 is related to Wigan's circuit by a Y-Δ transformation of the resistors but requires a potentiometer for obtaining a variable-frequency null. It has a tuning law of $\omega_0 = \dfrac{1}{RC\sqrt{K + \alpha - \alpha^2}}$, and there is a dual of this circuit using a differential capacitor.

A new network, shown in Figure 10 (with its derivative networks in Figures 11, 12, and 13), has the interesting tuning law, $\omega_0 = \dfrac{1}{RC}\sqrt{\dfrac{1-\alpha}{\alpha}}$, which theoretically balances for any frequency from 0 to ∞ as α is varied from 1 to 0. This suggests its use in a wide-range oscillator or tuned amplifier. Also, for a 10-to-1 frequency range, it gives a frequency scale very close to the usually desired logarithmic scale.

Another class of network, which often is still easier to use in selective circuits consists of three-terminal RC circuits that give a complete null without being balanced against a voltage divider. The twin-T[7] is the most familiar of this group but is only one of innumerable possible networks. Andreyev[8] discovered a variation on the twin-T (Figure 14) that gives frequency adjustment with a single potentiometer. The tuning law for this circuit is $\omega_0 = \dfrac{1}{RC\sqrt{1-\alpha^2}}$. The only other known circuits of this type are the one used in the Type 1232-A Tuned Amplifier and Null Detector and its dual[9]. This circuit, shown in Figure 15, has a tuning law of $\omega_0 = \dfrac{1}{RC\sqrt{\alpha(1-\alpha)}}$.

In order to span a 10-to-1 logarithmic frequency range, the potentiometer must have an exponential characteristic of over 100-to-1.

[4] Wien, M., *Wied. Ann.*, 1891, 44, 689.

[5] Field, R. F., "A Bridge-Type Frequency Meter", *General Radio Experimenter*, 6, 6, November 1931.

[6] Wigan, E. R., *Electronic Technology*, June, 1960, p. 223.

[7] W. N. Tuttle, "Bridged-T and Parallel-T Null Circuits for Measurements at Radio Frequencies", *Proc IRE*, January, 1940.

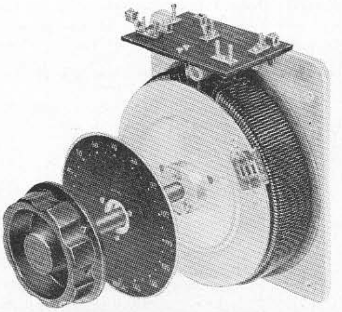
[8] Andreyev, *Telecommunications* No. 2, 1960, p. 195 (Pergamon Press Translation).

[9] Hall, H. P., *IRE Transactions on Circuit Theory*, September 1955, p 283.

For all the circuits discussed here, the selectivity of the transfer voltage ratio, E_0/E_{in}, is not constant as the null frequency is adjusted. This means that a conventional selective amplifier using this characteristic will not have constant selectivity over its range. However, for the circuit used in the TYPE 1232-A Tuned Amplifier and Null Detector, the selectivity of the transfer admittance, I_0/E_{in} (or y_{21}), is quite constant as the null frequency is changed. In order to use this characteristic, the network must be driven by and loaded by low impedances. Therefore, it is used in a feedback circuit with an amplifier having low input and output impedances and a transfer resistance, E_0/I_{in}, (or a real Z_{12}) that is chosen to give the desired selectivity. This combination provides a second harmonic rejection of 34 db over each 10-to-1 frequency range.

— H. P. HALL

THE NEW TYPE W30 VARIAC® AUTOTRANSFORMERS

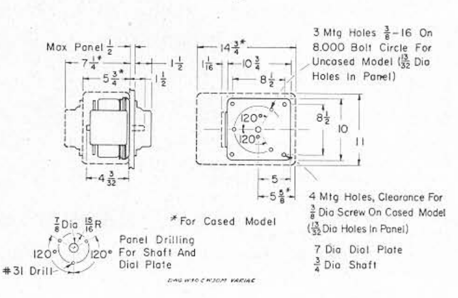


For some time we have felt that the gap between the 20-ampere, TYPE W20, and the 50-ampere, TYPE W50, Variac® Autotransformers was too great. The user contemplating the control of loads in the 30-ampere region was given no alternative but to use either a 50-ampere unit or two 20-ampere units in parallel. Both of these methods being costly and inefficient, we have developed the new 30-ampere models, TYPES W30 and W30H. Their high-power ratings conveniently bridge the gap between those of the TYPES W20 and W50 models.

Sharing the family resemblance common to all Series-W units, the TYPE W30 models incorporate the quality components and proven design features now included in all General Radio Variac autotransformers. These features include an overvoltage connection, to provide an output voltage range from zero to 17% above line voltage, and the patented DURATRAK coating process, for longer brush-track life.

TYPE W30 models are available in open, cased, ganged, and motor-driven assemblies, with or without ball bearings.

The ratings for the TYPES W30 and W30H single-unit models are given in the table below. Complete descriptions and ratings for the TYPE W30 ganged assemblies may be found in the current General Radio catalog.



SPECIFICATIONS

Core loss at 60 cycles: 35 watts, all models.

Driving Torque: 50-100 ounce-inches, all models.

Turns on Winding:
Types W30 and W30M 184
Types W30H and W30HM 367

Angle of Rotation: 320°.

DC Resistance of Winding:
Types W30 and W30M 0.14 ohm.
Types W30H and W30HM 1.17 ohms.

Dial: Reversible dial, line-voltage scale on one side, overvoltage scale on reverse side; calibrated for rated input voltage applied.

Type	Input Voltage (50-60 cycles)	OUTPUT: Line-Voltage Connection: KVA Load Rating (See Note A)	Voltage Range	Rated Current, Amperes	Maximum Current, Amperes (See Note A)	Overvoltage Connection: Voltage Range	Rated Current, Amperes (See Note B)	Replacement Brush	Net Weight, Pounds	Code Word	Price
W30 (Uncased)	120	4.32	0–120	30	36	0–140	30	VBT–13 $4.00	36	KALAL	$75.00
W30M (Cased)	120	3.84	0–120	28	32	0–140	28	VBT–13 $4.00	46	KALER	97.00
W30H (Uncased)	240 120	3.74 —	0–240 —	12 —	15.6 —	0–280 0–280	12 6	VBT–14 $4.00	29	ZABAL	75.00
W30HM (Cased)	240 120	3.74 —	0–240 —	12 —	15.6 —	0–280 0–280	12 6	VBT–14 $4.00	36	ZABER	97.00

Notes

A. Maximum current can be drawn at maximum voltage for the line-voltage connection only. Kva as listed = normal input line voltage times maximum current.

B. Rated current should not be exceeded for the overvoltage connection. Output kva for overvoltage connection = output voltage times rated current.

GENERAL RADIO DEMONSTRATES TRAVELING EXHIBIT AT PARIS SEMINAR

At the second biennial General Radio overseas sales and engineering seminar, a new traveling exhibit of General Radio products was demonstrated to more than 40 engineers and export sales representatives from 16 countries.

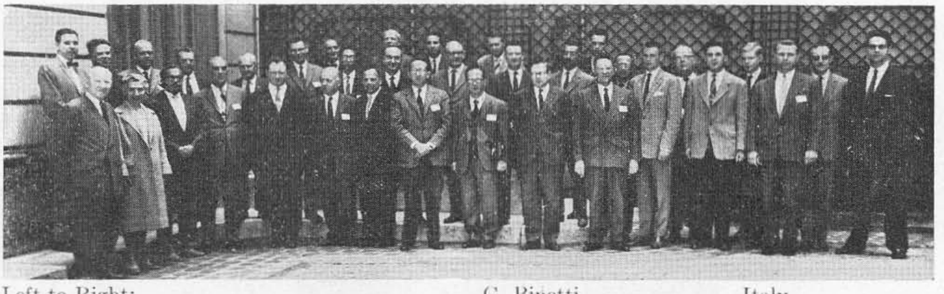
Held in Paris at the offices and laboratory of Etablissements Radiophon, General Radio representatives for France and the French colonies, the seminar included both

The General Radio traveling exhibit is demonstrated to export sales representatives by Peter J. Macalka, of General Radio Company.

lectures and laboratory workshops to acquaint the representatives with new GR products and their applications.

The traveling exhibit will be handled by General Radio's new technical and commercial organization, General Radio Company Overseas, with headquarters at Zurich. The exhibit is housed in a specially equipped Mercedes Benz station wagon. The instruments are mounted on ten custom-built tables, which stow snugly into the wagon for transportation, but are quickly and easily removed and set up in customers' plants or other locations. This ingeniously designed traveling show will house over 100 instruments, as much equipment as can be shown in a standard 40-foot display booth at a conventional exhibit. The over-all design follows the general pattern of the station-wagon shows that have been used successfully by General Radio for several years in the United States.

Interior of the station wagon, showing the tables securely installed for transporting.



Left to Right:

M. C. Holtje	General Radio
Paul Fabricant	France
D. B. Sinclair (rear)	General Radio
Mlle. Claude Naichouler	France
A. Bergholtz	Sweden
B. Archer	England
T. T. Joseph	India
A. E. Thiessen	General Radio
H. C. Parish	Australia
L. Kohn	France
U. Clementz	Sweden
M. Berlin	France
C. E. Worthen (rear)	General Radio
H. Nagakura	Japan
R. Danziger	Israel
I. G. Easton (rear)	General Radio
G. Belotti	Italy
A. Lara Saenz	Spain
G. Molac (rear)	France
G. Nusslein	Germany
G. Binetti	Italy
P. van Gent	Holland
P. Cornet	France
K. Teir	Finland
L. Goett	France
K. Lindenmann (rear)	Switzerland
R. Peel	Belgium
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A. R. Buys	Holland
K. L. Nyman	Finland
E. Lyons	England
P. Nyman	Finland
H. A. Molinari	Switzerland
J.-L. Robert	France
P. J. Macalka	General Radio

Also present, but not in picture, were:

I. Myrseth	Norway
H. Klip	Holland
T. Kenny	Israel
K. Karayannis	Greece
J. Keller	Switzerland

PRINTED IN U.S.A.

THE GENERAL RADIO EXPERIMENTER

VOLUME 35 No. 8 AUGUST, 1961

IN THIS ISSUE

New Sound-Level Meter
New Precision Capacitors

THE GENERAL RADIO

EXPERIMENTER

Published Monthly by the General Radio Company

VOLUME 35 · NUMBER 8 AUGUST, 1961

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The General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in electronic techniques in measurement. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

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COVER

Rotor and stator plates of the Type 1422 Precision Capacitors are individually aligned during assembly.

New Model Meets Both American and International Standards

TYPE 1551-C SOUND-LEVEL METER

The change in type number (Type 1551-B to Type 1551-C) designates two significant changes in the performance of the General Radio Sound-Level Meter.[1] A new and superior microphone is now supplied, and the frequency weighting characteristics have been modified to conform to the new American Standard Specifications for General-Purpose Sound-Level Meters. (ASA S1.4-1961.) Neither change is obvious at a glance, since the appearance of the instrument, except for a shift from B to C in the engraved type number on the panel, is unchanged.

[1]E. E. Gross, "Improved Performance Plus a New Look for the Sound-Level Meter," *General Radio Experimenter*, Vol. 32, No. 17, October 1958.

NEW MICROPHONE

The Type 1560-P3 Microphone* supplied with the Type 1551-C Sound-Level Meter is a PZT piezoelectric ceramic type developed expressly for sound-level meters. It replaces and is interchangeable with the older Type 1560-P1** Rochelle-salt crystal microphone. Its characteristics approach those of condenser microphones classed as laboratory standards. Unlike condenser microphones, however, the ceramic unit does not require a special preamplifier with a high dc polarizing-voltage sup-

*Identified by red insigne on face of microphone and Shure Brothers model no. 98108 on nameplate.

**Identified by blue insigne on face of microphone and Shure Brothers model no. 98B99 on nameplate.

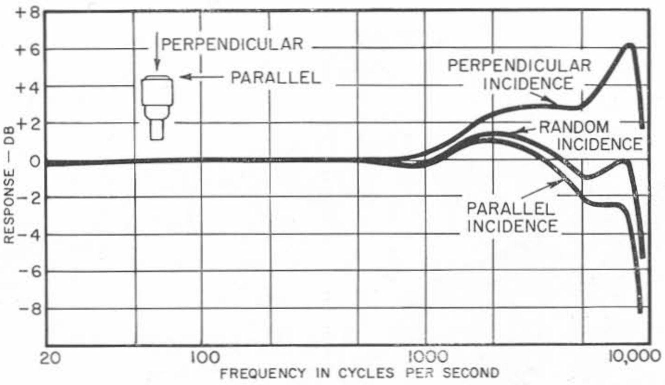


Figure 1. Response of the Type 1560-P3 Ceramic Microphone.

ply, and its impedance is an order of magnitude lower, so that leakage due to high humidity is less of a problem, and it can be used more readily at the end of a cable.

Several other features of this new microphone make it highly desirable for sound-level meter use:

1. Frequency Response. As shown in Figure 1, the microphone has a flat response to sounds of random incidence. Of the several hundred microphones we have measured to date, all match the curve shown to within ±.3 db from 20 cps to above 1000 cps, and most of the microphones match the curve to within ±1 db up to 8000 cps.

2. Sensitivity. The nominal sensitivity is the same (−60 db re 1 volt per microbar) as for TYPE 1560-P1 Rochelle-salt crystal microphone, which is unusually high for a small ceramic unit.

3. Temperature Coefficient of Sensitivity. The output voltage is practically constant with temperature. Our measurements indicate that the temperature coefficient of sensitivity is approximately −.01 db per degree Centigrade. This compares very favorably with that of laboratory standard microphones, such as the Western Electric Co. TYPE 640-AA.

4. Internal Impedance. The internal impedance of the new microphone is capacitive, and, although it is of the same order of magnitude as that of the

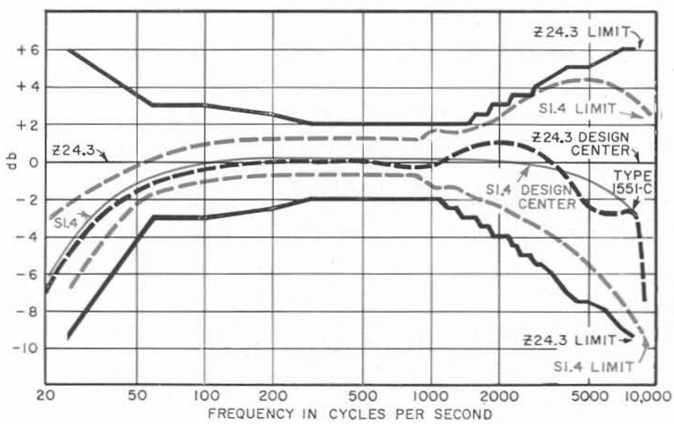


Figure 2. Design centers and limits for C-weighting characteristics, as specified by Z24.3 and S1.4 (red) standards together with acoustical response of the Type 1551-C Sound-Level Meter for C-weighting.

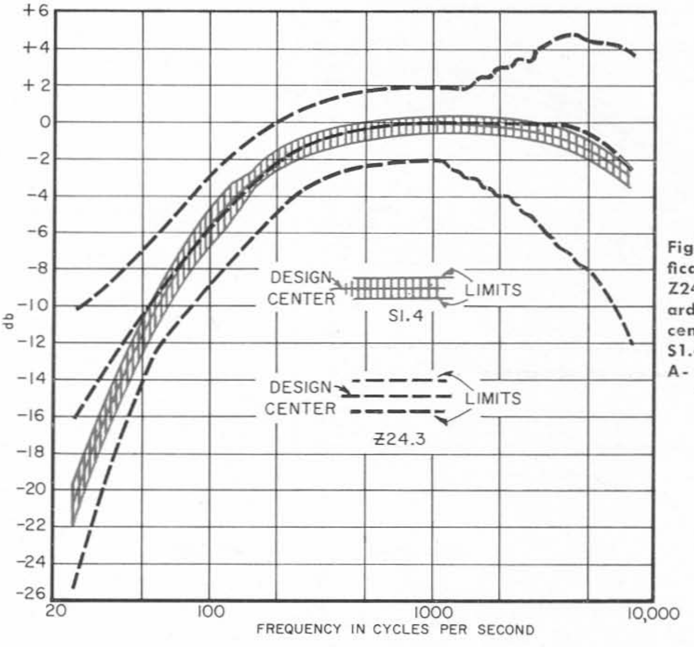


Figure 3. B-weighting specifications of S1.4 (red) and old Z24.3 standards. S1.4 standard shown assumes design-center, C-weighting, since S1.4 characteristic for both A- and B-weighting is specified with respect to C.

Rochelle-salt crystal, it is much more nearly constant. The capacitance is 475 pf at 25C and varies from 445 pf to 510 pf over a temperature range of 0 to 50C. The Rochelle-salt unit, for comparison, has a nominal capacitance of 1100 pf, at 25C, which drops to 650 pf at 10 and 30C.

This high stability of internal impedance results in greatly improved operation when the microphone is used with a long extension cable; the cable loss no longer varies widely as a function of the temperature at the microphone.

5. Directivity. The new microphone, since it is the same physical size and is similar in construction, maintains the good directional characteristics of the Type 1560-P1. Up to 1000 cps the variation in output with angle of sound incidence is very small. Above 1000 cps diffraction causes the microphone to respond more to sounds arriving normal to the diaphragm axis (0-degrees or perpendicular incidence) than to sounds from other directions. Figure 1 shows the extent of the variation in sensitivity as a function of the direction of sound incidence.

6. Ruggedness. Designed to be durable and dependable, this microphone will withstand, without damage, temperatures of −30 to +95C and relative humidities of 0 to 100%.

CIRCUIT CHANGES

New ASA Standard

The older Type 1551-B Sound-Level Meter[1] was designed to meet the requirements of the then current standard, ASA-Z24.3-1944.

The new Type 1551-C has been modified to conform to the weighting requirements of the newly announced standard (ASA S1.4 1961). The changes in response are not large, but an instrument matching the design center curves of ASA Z24.3 1944 will not fall within the tolerance allowed in ASA S1.4 1961.

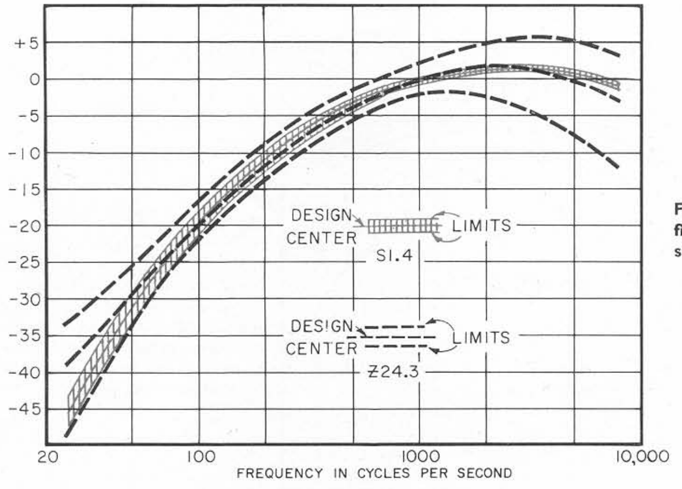


Figure 4. A-weighting specifications of S1.4 and old Z24.3 standards, assuming design-center C-weighting.

Figure 2 shows the design center, C-weighting, and tolerances allowed by both standards, plus the actual response of the new TYPE 1551-C Sound-Level Meter to sounds of random incidence. Design center curves differ only at high and low frequencies, while the new tolerances reduce the possible differences between sound-level meters of different manufacture, particularly at low frequencies.

Figures 3 and 4 compare the new and old B and A weighting characteristics respectively. The old weighting curves are specified as drawn. The new weighting curves (ASA S1.4 1961) are specified with respect to the C weighting characteristics. They are shown here as they would be in an instrument that matches the C-weighting design center. Here again the aim is to insure that instruments of different manufacture will have very similar characteristics.

In addition to the new weighting characteristics, the TYPE 1551-C has a flat response (20 kc position of the weighting switch) from 20 cps to 20 kc for sound-pressure measurements with wide range microphones. The output signal is unweighted and suitable for spectrum analysis.

International Standard

This sound-level meter also conforms to the new international standards. The requirements of the International Recommendation for Sound-Level Meters (IEC Publication 123, 1961) are, in most respects, similar to those of ASA S1.4 1961. The TYPE 1551-C readily meets all of the electrical requirements. The free-field acoustical response requirement is met when the microphone post is set at an angle of 55° with respect to the panel of the instrument. The swivel microphone post can be supplied with a detent at this preferred angle. In the near future all TYPE 1551-C Sound-Level Meters will be supplied with a properly detented microphone post for this application.

This new sound-level meter, with its stable, high-performance ceramic microphone and its conformance to both American and International Standards represents a significant advance in the accuracy and reliability of sound measurement devices.

— E. E. GROSS

SPECIFICATIONS

Sound-Level Range: From 24 to 150 db (re .0002 microbar).

Frequency Characteristics: Any one of four response characteristics, A, B, C, or 20 kc, can be selected by a panel switch.

The A, B, and C weighting positions are in accordance with American Standard Association specifications on sound-level meters.

The 20-kc position allows the use of the complete frequency response of the sound-level meter's amplifier, which is flat from 20 cps to 20 kc, so that complete use can be made of wide-range microphones such as the General Radio Type 1551-P1 Condenser Microphone Systems.

Microphone: The microphone is a highly stable PZT ceramic type. Condenser and dynamic microphones are available as accessories.

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 the standard reference level.

Output: An output of 1 volt across 20,000 ohms (when the panel meter is at full scale) is available at an output jack. The output can be used to drive frequency analyzers, recorders, and oscilloscopes. A phone-plug-to-Type 274 connecting cable (Type 1560-P95) is available.

Input Impedance: 25 megohms in parallel with 50 pf.

Output Impedance: 7000 ohms.

Meter Damping: The panel meter has two different damping characteristics, either FAST or SLOW response being selected by a panel switch. The meter ballistics agree with current ASA standards.

Calibration: Built-in calibration circuit standardizes the sensitivity of the electrical circuits in the sound-level meter.

Calibration Accuracy: After standardization, sound-level measurements are within ±1 db at 400 cps, as specified in ASA standards. The Type 1552-B Sound-Level Calibrator is available for making periodic acoustic checks on the over-all calibration, including microphone.

Temperature and Humidity Effects: Readings are independent (within 1 db) of temperature and humidity over normal ranges of room conditions.

Power Supply: Two 1½-volt size D flashlight cells (Rayovac 2LP or equivalent) and one 67½-volt battery (Burgess XX-45 or equivalent) are supplied. A 115-volt ac power supply, the Type 1262-B, is available.

Tube and Transistor Complement: Four CK512-AX, two CK6418, one 2N1372 transistor.

Accessories Supplied: Telephone plug.

Accessories Available: Type 1551-P2 Leather Case, which permits operation of the instrument without taking it from the case. Type 1560-P95 Connecting Cable, for connecting output to Type 1521-A Graphic Level Recorder.

Cabinet: Aluminum, finished in gray crackle.

Dimensions: Height 9¼, width 7¼, depth 6⅛ inches (235 by 185 by 160 mm), over-all.

Net Weight: 7¾ lb (3.5 kg) with batteries; 9¾ lb (4.4 kg) including leather case.

Type		*Code Word*	*Price*
1551-C	**Sound-Level Meter**	MIMIC	**$415.00**
1262-B	**Power Supply**	MAYOR	**95.00**
	Set of Replacement Batteries	MIMICADBAT	**3.90**
1551-P2	**Leather Carrying Case**	CALYX	**24.50**
1560-P95	**Connecting Cable**	CONEC	**3.00**

NEW DYNAMIC MICROPHONE SYSTEM

The Type 1560-P12 Dynamic Microphone System replaces the older Type 759-P25 Dynamic Microphone and Accessories[1] as a high-quality acoustic pickup system for sound-level meters, analyzers, graphic level recorders or tape recorders. This new microphone system, illustrated in Figure 1, includes the Type 1560-P2 Dynamic Microphone, the Type 1560-P22 Microphone Transformer, the Type 1560-P72 25-foot cable and the Type 1560-P32 Tripod.

Microphone Characteristics

The older Type 759-P25 Dynamic Microphone was a special Altec Lansing Type 633-A. The Type 1560-P2 Dynamic Microphone is also manufactured by Altec Lansing and is a special version

[1] "A Dynamic Microphone for the Sound-Level Meter," *General Radio Experimenter*, Vol. XXV, No. 11, April 1951.

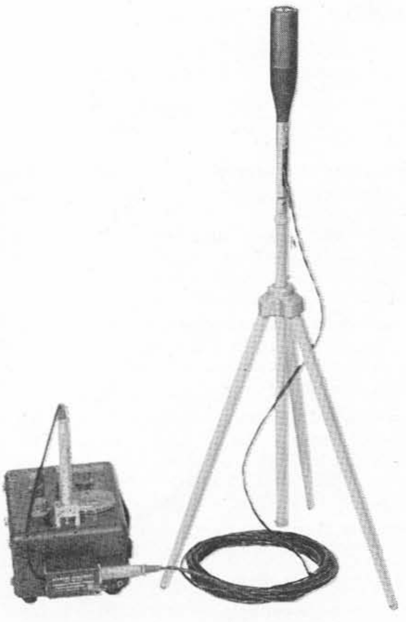


Figure 1. View of the Dynamic Microphone System with the Sound-Level Meter.

of their TYPE 661-A Microphone modified to meet the requirements of the American Standard Specifications for General-Purpose Sound-Level Meters (ASA S1.4-1961). The TYPE 661-A uses the same basic moving coil system of the TYPE 633-A, but it is housed in a smaller diameter shell which decreases diffraction effects at high frequencies. It has a sintered bronze face plate, in place of a silk cloth screen, which provides excellent protection from dust and other particles, a very worthwhile feature when the microphone is used in industrial areas and subjected to atmospheres containing tiny iron particles resulting from machining and grinding operations.

The low-frequency response, as illustrated in Figure 2, remains essentially flat down to 25 cps. In addition to the Microphone System response to sound of perpendicular incidence (0°) and sounds of random incidence, Figure 2 shows the over-all response of the TYPE 1551-C Sound-Level Meter (C weighting) and the TYPE 1560-P12 Dynamic Microphone System to sounds of random incidence. (See Figure 3 in accompanying article on TYPE 1551-C Sound-Level Meter for ASA S1.4 1961 requirements for C-weighting specifications.)

Use with Acoustic Calibrator

As shown in Figure 3, a step has been machined in the face of the microphone so that it can be readily calibrated with the TYPE 1552-B Sound-Level Calibrator. With 2.0 volts at 400 cps applied to the calibrator and the calibrator mounted as shown, the sound pressure level developed at the TYPE 1560-P2 Microphone is 119 db re 0.0002 microbar.

Transformer

The response curves shown in Figure 2 are for the complete dynamic micro-

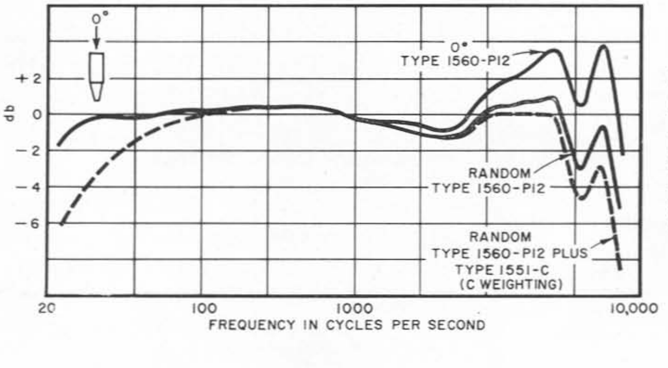


Figure 2. Free-field response characteristics of the Type 1560-P12 Dynamic Microphone System for 0° and random incidence, and for the Dynamic Microphone System plus the Type 1551-C Sound-Level Meter for random incidence.

phone system and include the Type 1560-P22 Dynamic Microphone Transformer, which has a very small effect on the frequency response of the system between 25 cps and 10 kc. This transformer steps up the output of the microphone from −90 db to −60 db re 1 volt per μbar so that the Type 1551-C Sound-Level Meter still reads directly in db re 0.0002 microbar when connected to the dynamic microphone system. The transformer is very well shielded to minimize the effects of stray magnetic fields. As shown in Figure 1, a strap that is part of the transformer case provides a convenient means to attach the transformer to the sound-level meter cabinet.

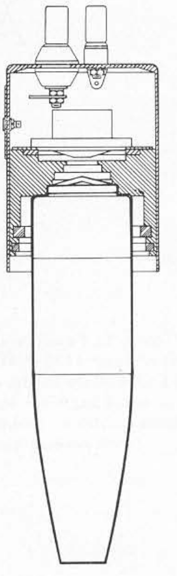


Figure 3. Sketch showing how the GR acoustic Calibrator fits firmly on the dynamic microphone to assure definite and reproducible calibration conditions.

Use

A number of noise-measurement codes require the use of a dynamic microphone, and noise-control situations continually arise where the dynamic microphone is required or where its use simplifies the measurement problem as when measurements must be made at the end of a long cable. Because of its low internal impedance, the dynamic microphone can drive very long cables with no loss in output voltage and consequently requires no cable corrections.

The combination of the dynamic microphone system and the Type 1551-C Sound-Level Meter meets the requirements of ASA S1.4 1961.

SPECIFICATIONS

Sensitivity: Open-circuit output of typical microphone is 90 db below one volt per microbar, and of microphone plus transformer is 60 db below one volt per microbar. The sensitivity is satisfactory for direct reading of sound-pressure level by the Type 1551-C, Type 1551-B, Type 1551-A,* and Type 759-B* Sound-Level Meters.

Direct Use with Analyzers: Microphone output can be supplied directly to the Type 1550-A† Octave-Band Noise Analyzer provided the level of the measured components is above 70 db (re 0.0002 microbar) or to the Type 1554-A† Sound and Vibration Analyzer, provided the level of measured components is above 50 db. (A Type 1552-B Sound-Level Calibrator is necessary to obtain absolute level.)

Maximum Safe Sound-Pressure Level: Sound-pressure levels above 140 db can damage the microphone.

Calibration: Output level is checked in our laboratories at several frequencies against a standard microphone that is calibrated periodically. The level at 400 cps is stated.

Cable Correction: No correction is necessary for the 25-foot cable supplied or the Type 1560-P72B 100-foot cable.

Components: Type 1560-P2 Dynamic Microphone, Type 1560-P22 Transformer Assembly, Type 1560-P72 Cable, Type 1560-P32 Tripod.

Net Weight: 5¼ pounds (2.4 kg); microphone only, 8½ oz (250 g).

*Type 1560-P92 Adaptor required.
†Type 1560-P93 Adaptor required.

Type		*Code Word*	*Price*
1560-P12	**Dynamic Microphone System**	DYNAM	**$210.00**
1560-P72B	**Extra 100-foot cable**	ADAPTORWAY	**30.00**
1560-P92	**Adaptor Assembly**	ADAPTORBUG	**12.50**
1560-P93	**Adaptor Assembly**	ADAPTORCOP	**12.50**

A NEW AND IMPROVED PRECISION CAPACITOR

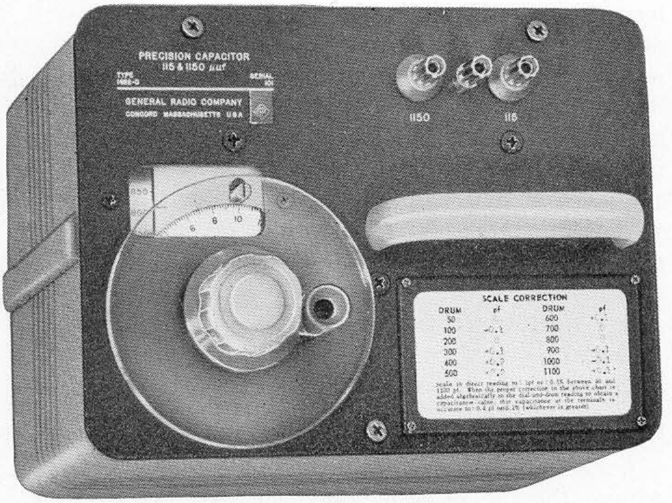


Figure 1. Panel view of the new Type 1422 Precision Capacitor. Note the large, transparent flange on the control knob, which greatly facilitates precise setting.

There are many readers of the *Experimenter* who will have no difficulty in recalling, in a nostalgic moment, the consistent proud contention of the makers of the Dodge automobile in the 1920's that they made "no yearly models, only continuous improvements." Such a description might with equal truth be applied to the history of precision worm-driven capacitors at General Radio. Until the appearance of the new Type 1422 Capacitor in our current catalog, there had been only two distinctively different catalogued designs in forty years of continuous manufacture, the Types 222 and 722. Yet, these two designs throughout their useful lives were being constantly improved as new methods or materials became available, or when field reports indicated the desirability of modifications. Eventually, of course, the improvements that seemed desirable got beyond the capabilities of the existing design, and then a fresh start had to be made. A review of precision-capacitor manufacture and design (including some specialized designs never catalogued) will help to make more significant the improved features that have been incorporated into the new Type 1422.

Type 222 First Design

When the writer arrived at General Radio in the summer of 1921, the Type 222 Capacitor, then known as a condenser, was already a well-established product of the six-year-old firm (Figure 2).

It was massively and heavily constructed, using cast brass end plates spaced apart by three hexagonal brass posts. Bearings were conical, steel shaft against bronze insert. Only the rotor and stator plates were aluminum. The worm and wheel were stock articles of commerce made available to all and sundry through the commercial foresight of the Boston Gear Works.

To illustrate the care exerted to reduce backlash, from the very beginning the worm, taper-pinned to its shaft, was spring-pressed into engagement with the worm wheel to control backlash as much as could then be done. The worm shaft was journaled in a long hinged brass casting, as can be clearly seen in Figure 2. After assembly and before calibration, each capacitor was subjected to a running-in period to make the worm and wheel fit more closely to one another. At the same time a similar effect was produced on the conical bearings at the two ends of the main shaft.

The insulation at first was laminated phenolic, at that time the novel material called Bakelite. Even though its losses were appreciably higher than those of hard rubber (the popular good insulation of the day), it was preferred because it was much more stable mechanically.

Improvements

Almost immediately began a long series of changes and improvements.

Stator insulation progressed from phenolic to porcelain and then to steatite. The floating, spring-pressed, worm and wheel arrangement went through at least four successive designs, each an advance over its predecessors.

Direct-reading scales first appeared on the TYPE 222-M, a capacitor designed for parallel substitution measurements, direct reading in "capacitance removed."

Throughout this process of improvement the deficiencies in the 222 design were being recognized, and, when in 1936 the TYPE 722 was introduced,[1] a number of basic improvements were made. The composite structure of end

[1]"A New Precision Condenser," *General Radio Experimenter*, 10, 8, January 1936.

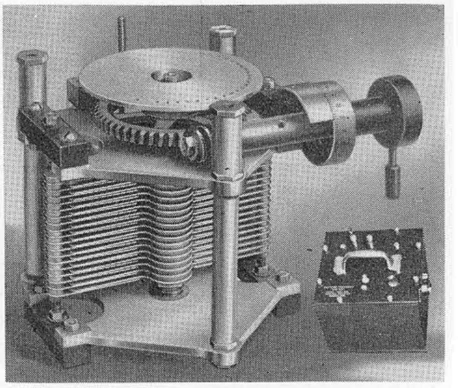


Figure 2. Interior view of an early Type 222 Precision Capacitor, grandfather of all present types. Inset shows cabinet.

plates and spacer rods was replaced by an aluminum frame cast in one piece, with a consequent increase in rigidity and mechanical stability. The conical bearings on the main shaft gave way to ball bearings, and the worm drive was again improved, still further reducing the backlash. Finally, all metal parts directly affecting the capacitance were made of aluminum or aluminum alloy to give a low and uniform temperature coefficient of capacitance. Additional capacitance-removed (double-section), high-frequency, and low-capacitance models were listed, and direct-reading scales were used throughout. Linearity over 21, rather than 20, worm turns was achieved, providing small overlap beyond nominal decimal maximum ΔC's.

Three-Terminal Types

Meanwhile, by the early 1950's, a number of developments in both military and commercial measuring techniques, and demands for high measurement accuracy made it apparent that three-terminal (or insulated-rotor) capacitors should be made available on a catalog basis. Although these were available at first only in high-capacitance models (50-to-1100 pf), the need for

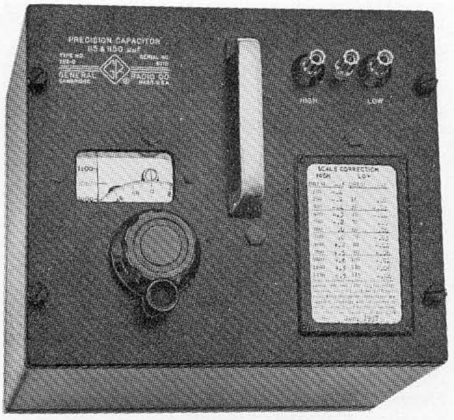
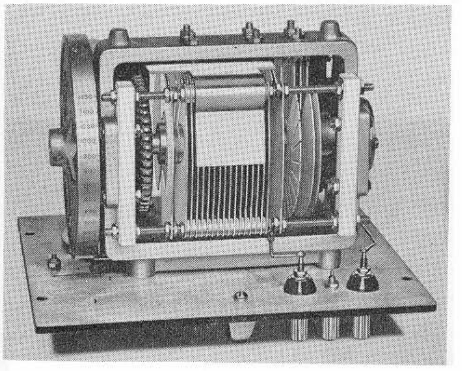



Figure 3. Panel and interior views of the Type 722-D Precision Capacitor, successor to the Type 222.

standardization at lower capacitance magnitudes, where three-terminal construction is mandatory, dictated the design of units with capacitance (ΔC) as low as 1.1 pf.

Special Types of Precision Capacitors

Although it was planned to keep in stock versions of the Type 722 for which there was a solid continuing demand, some 150 special variations have been made in the 25 years of its life, a few of them eventually becoming stock items (e.g., Type 722-CB).[2] As an example of special designs, several Type 722-CE's have been made having two linear capacitance ranges, respectively 0.05 to 1.1 and 0.005 to 0.11 pf.

However, requirements have arisen with which the Type 722 structure was unable to cope.

Figure 4 illustrates a Type 622 Capacitor having many special features. The rugged 5-sided casting was made to secure rigidity because of the very high frequency-stability requirements for the oscillator which this capacitor tuned. It was used in an instrument for the Navy which at sea would be subject to violent tilting as the ship pitched and rolled in bad weather. The rotor plates yielded an end-corrected narrow-range straight-line frequency performance. The extra shaft near the assembler's thumb in Figure 4 actuates a simple computer which averages two readings without calculation.

Figure 5 illustrates small precision worm-driven capacitors, Type 779, which fulfill a requirement for a capacitor of only 210 pf ΔC to occupy appreciably smaller volume than does the Type 722 and are used in an aircraft fuel-gage calibrator.

Type 1422 Introduced

While the Type 722 was far from obsolete, its design *was* 25 years old. Most of the improvements that could be made within the framework of the original design had been made. If further progress was to be realized, it would require starting afresh, but retaining the many demonstrated sound features of both the Type 722 and the Type 222, and borrowing from other of the mentioned designs. This has been done in the new Type 1422. Seven dif-

[2]Ivan G. Easton, "A Three-Terminal Precision Condenser," *General Radio Experimenter*, 23, 4, October 1958.

ferent models are listed, the analogues of the TYPE 722's previously offered. Figures 1 and 6 illustrate external views respectively of typical two-terminal and three-terminal models, while Figures 7 through 11 are internal views. A number of new features and improvements will be enumerated and described in connection with the illustrations:

1. The cases have been changed to aluminum instead of wood. This gives ¾ inch more stack room on the shaft with the same case length and a narrower box than the TYPE 722. The sides of the case are made from a heavy aluminum extrusion embodying decorative flutings (Figures 1 and 6).

2. For many years users have requested a slow-motion drive for greater ease in fine setting of the worm dial, not that accuracy of reading may be improved but that bridge balancing may be facilitated. Providing the speed reduction is very difficult to do with the spring-pressed worm arrangement. However, the large transparent skirt for the spinner knob (shown in Figures 1 and 6) gives about a 3-to-1 increase in diameter versus the fluted portion of the knob. There is even greater improvement in setting ease since one can rest a thumb against both the panel and the edge of the skirt and roll the thumb for fine control.

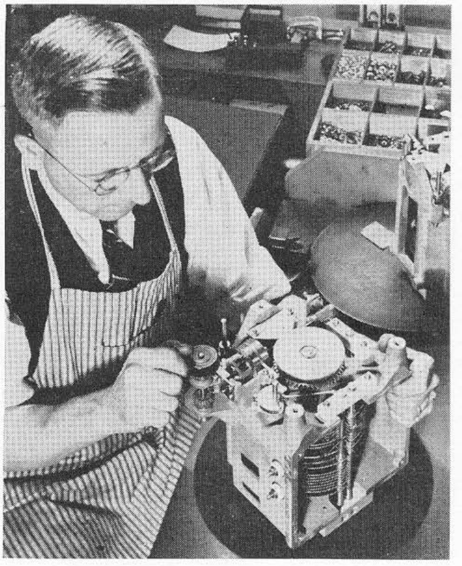


Figure 4. Final adjustments on a Type 622 "bathtub" capacitor, a special model designed for mechanical stability under extreme conditions.

3. Figure 6 illustrates the use of the new locking TYPE 874 Connectors on three-terminal capacitors. This feature makes it possible to lock connecting cables in place or to fit the capacitor semipermanently and inexpensively with other types of common coaxial connectors. The customer need merely purchase and attach two locking adaptors to have a capacitor with rigidly fastened coaxial connectors of the type desired.

4. Although there were no obvious places of entry, dust in the cabinet has occasionally been a problem in the past. To control this, the hole in the cabinet for the worm shaft has a minimal clearance, the transparent skirt catches the dust when the panel is in the usual horizontal operating position, and the window through which the scales are read has been changed to gasketed triplex safety glass.

5. To improve the rigidity and stability with time of the small section of a

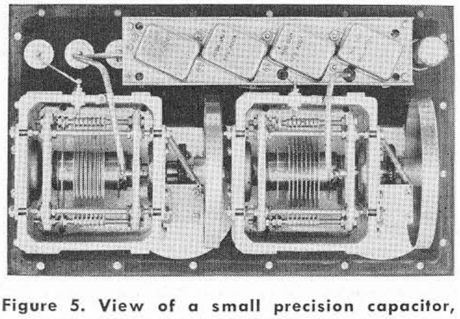


Figure 5. View of a small precision capacitor, designed for use in fuel gauge calibrator.

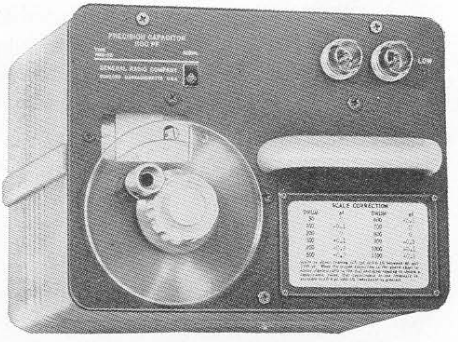


Figure 6. Panel view of the new Type 1422-CB Precision Capacitor, an insulated rotor, 3-terminal model, with a capacitance range of 50 to 110 pf.

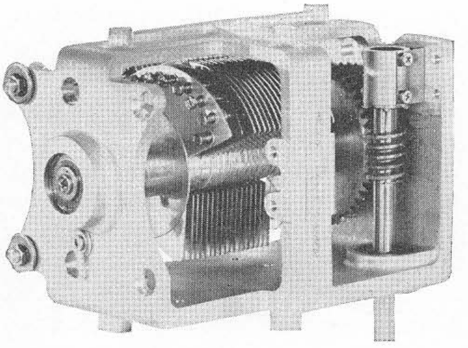


Figure 7. Interior view of the CB-model. Note the shielding washers at the extreme left, which prevent the direct electrostatic flux from traversing the solid insulation.

two-section capacitor, an additional support for each stator rod is provided by the crescent-shaped aluminum piece, shown in Figure 8, and mounted from an added bridge which is part of the main casting.

6. Once the small section is no longer cantilever supported, its weight may be safely increased. Thus, more plates more widely spaced are used for the small section common to the TYPES 1422-D and -MD.

7. The bridge which supports the small section also serves to make the main casting more rigid. This rigidity is further improved by adding the ribbing on the bottom and filleting the inside corners of the casting.

8. Stator rods have been increased from 3/16 to 1/4 inch in diameter to stiffen the structure and to reduce the difference in capacitance between horizontal and vertical panel positions.

9. The adding of the bridge gives the opportunity for a third foot on the bottom, so that the capacitor, when out of its cabinet during manufacture, may be set stably on a flat surface without abrasion of the drum dial.

10. Improvement in the ball-bearing arrangements was desirable to improve the backlash situation and stability with time. When the ball-bearing manufacturers recently made available oppositely disposed pairs of ball bearings with any desired preload, the answer to both problems was at hand. The main shaft has a pair of these at each end. At the drum-dial end the outer races are firmly clamped to the main casting and the inner races to a shoulder on the shaft. At the rear end (visible in Figures 8 and 9) the inner races of the two bearings are clamped tightly to a shaft shoulder by the 1/4-28 Philips head screw to be seen there. The outer races float in the close-fitting, precision-bored hole through the boss at the end of the main casting. This arrangement prevents the "climbing" which occurs even in a ball bearing, smaller than that which occurs with a cone bearing, but still observable. Backlash now, if it is detectable, is generally no larger than the width of the engraved line on the dial.

11. It is just as important to give the worm shaft similar preferred treatment to reduce backlash and eliminate non-uniformities of motion that would disturb the linearity of capacitance change. Note that any axial shake in the

worm shaft can appear as backlash. To reduce this the new design incorporates a smaller preloaded ball-bearing pair, the outer races of which are tightly clamped within the round housing to be seen in Figures 7 and 10. The inner races are tightly clamped by a nut to a shoulder on the worm shaft. The round housing is supported with sidewise flexibility, but longitudinal integrity by a thin U-shaped beryllium copper member fastened to the housing by four screws and clamped to the main casting. This structure locates the shaft axially. The U-shaped beryllium copper piece provides free parallelogram-type floating motion for the worm shaft. The spring pressure to produce this motion is exerted by a spring-loaded bearing ball contained within the hex-headed housing going through the solid bracket just to the right of the ball-bearing mount. The self-aligning bearing at the dial end of the worm shaft fits nicely over a shaft shoulder and floats without shake within the precision-bored hole in the main casting. The shake inherent in the bearing is taken up by a partially compressed six-fingered Z-washer often used with ball bearings, which bears only against the outer race.

12. The nature and disposition of the insulators are greatly different from those of the Type 722. The insulators, instead of being long bars, are short buttons or washers having one face flat and the other spherical in contour. They mate with spherically counterbored holes in the casting or in an aluminum bar. One obvious advantage is that these insulators are self-aligning. Another is that they offer a minimum of disturbance to the "all-aluminum" nature of the structure. In the Type 722 the stator plates would, with an increase in capacitor temperature, push the stator rods farther apart than would the steatite insulators (see Figure 3), thus putting a bow in the rods. Thermal behavior with the present design is much more predictable.

13. Since the insulators are made of Rexolite 1422 (the identity of the numbers is pure coincidence), many advantages accrue. Rexolite 1422 is a cross-linked, thermo-setting, modified polystyrene which acquires heat stability as a result of chemical modification without the serious impairment of dielectric

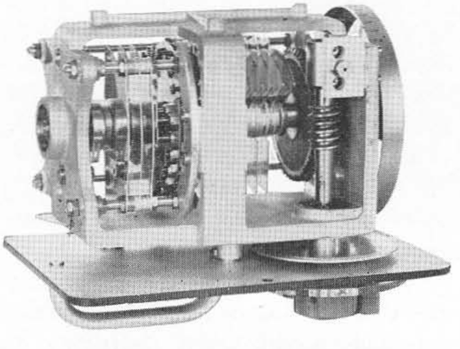


Figure 8. Interior view of the Type 1422-ME, a dual-range unit, calibrated in capacitance removed, 0 to 10.5 and 0 to 105 pf.

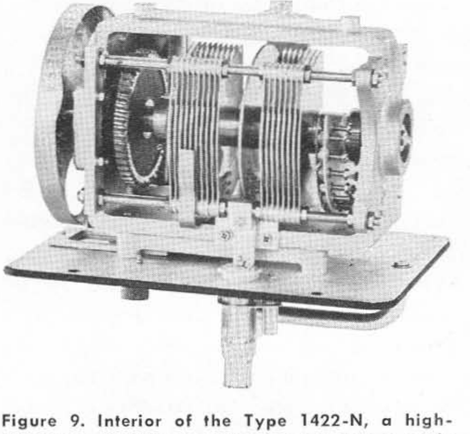


Figure 9. Interior of the Type 1422-N, a high-frequency model whose rotor connection is made through brushes bearing on a disk at the center of the stack in order to reduce residual inductance. Note the low-inductance lead to the terminal.

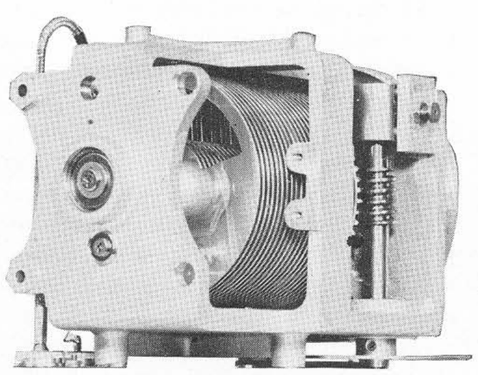


Figure 10. Interior of the 3-terminal Type 1422-CC Precision Capacitor, in which a window in the rotor plate is rotated between two oppositely poled stator plates to give a range of 5 to 110 pf.

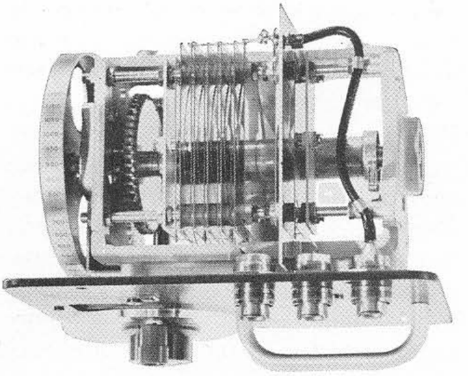


Figure 11. Interior view of the 3-terminal Type 1422-CD, another window type with two ranges, 0.5 to 11 and 0.05 to 1.1 pf.

properties usually accompanying such tampering. The dielectric loss of Rexolite 1422 is essentially comparable to that of fused quartz and along toward one order of magnitude better than that of steatite. Further, its surface is comparably hydrophobic to that of silicone-coated fused quartz. That is, it is moisture resistant and maintains high leakage resistance without the hazard of the possible disappearance of the silicone. Therefore, there is no need any longer to provide quartz-insulated capacitors for either ac or dc uses.

14. As usual, an advantage has its cost. A small price has been paid for the use of Rexolite 1422 insulating buttons. The zero capacitance of each capacitor section is somewhat larger in the Type 1422 than in the Type 722. This difference causes no trouble except in the case of the small section of the Type 1422-D, which is now linear down to only 35 pf versus the 25 pf of the Type 722.

15. Adjustment of the serrated plates for linearizing the capacitance-rotation curve is accomplished by advancing or retracting hex-head screws against the serrations of a spring-tempered phosphor-bronze plate. This method yields many advantages over the prior use of hand-bending serrated aluminum plates with pliers. Access to the adjusting screws is through large clearance holes in the ends of the casting.

16. Level-adjusting plates have been moved from the rear to the front cross-bar of the main casting so that their adjusting screws may be made accessible through the front panel. This facilitates making that adjustment with the capacitor inside rather than outside its case.

17. In the design of the Type 1422-CB Capacitor, extra shielding has been provided (either cups or washers or both) to keep stray rotor-to-stator field from traversing any of the solid insulation, despite its excellence. Thus the dielectric losses in the Type 1422-CB, as well as in the -CC and -CD, between the two hot electrodes should be only those losses in air and at the air-plate interfaces.

18. An examination of the accuracy specifications for the Type 1422 Capacitors will reveal major differences in format, philosophy, and the specification numbers actually used. Better control of

dimensions achieved through changes in mechanical design and improved tooling yield better linearity or initial adjustment figures in some cases. Better Bureau of Standards certifications and more certainty of the precision of our own measurements enable us to give better accuracy figures for calibrations given on the panel charts and on the special 106-point calibrations, which are more significant and useful successors to what used to be called worm-correction calibrations.

Thus the TYPE 1422 Precision Variable Capacitors are ready to give the user improved service over the fine record of the predecessor TYPE 722's. They represent significant improvements in a number of important areas. There is no intention to suggest that they represent the ultimate in precision capacitors, and work is still under way to the end that this latest design of precision capacitor shall be the beneficiary of the "continuous improvements" that have made its predecessors the standard of the industry.

— P. K. McElroy

SPECIFICATIONS

Accuracy: See table. The errors tabulated are possible errors, i.e., the sum of error contributions from setting, stability, adjustment, calibration, interpolation, and standards. The probable errors are almost always smaller. The accuracy is increased when the readings are corrected using the 10 or more calibrated values of capacitance given on the correction chart on the capacitor panel and interpolating linearly between calibrated points. The highest 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 listed below. A mounted certificate of calibration is supplied, giving corrections to one more figure than the tabulated accuracy.

Calibration: The measured values are obtained by comparison, to a precision better than $\pm(.01\% + .00001$ pf), with working standards whose absolute values are known to an accuracy typically $\pm.02\%$, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards.

The measured values of total capacitance of the two-terminal capacitors are the capacitances added when the TYPE 1422 Capacitor is plugged into a TYPE 874-Q9 Adaptor. The uncertainty of this method of connection is approximately $\pm.03$ pf. Calibration of total capacitance with the fine-wire connection method* used for the TYPE 722 Capacitors results in measured values approximately 0.45 pf lower than those obtained with the TYPE 874-Q9 Adaptor.

Resolution: The dial can be read and set without difficulty to 1/5 division.

The backlash is less than one-fifth division, corresponding to .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.

Insulation Resistance: Under standard conditions (23 C, less than 50% RH), greater than 10^{12} ohms.

Maximum Voltage: All models, 1000 volts, peak.

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 TYPE 874 Coaxial Connectors are used on 3-terminal models.

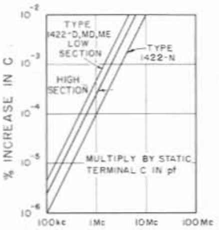
Accessories Supplied: 2 TYPE 874-C58 Cable Connectors with all three-terminal models.

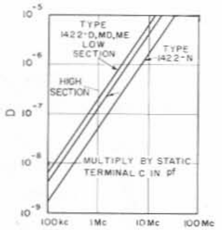
Accessories Available: TYPE 874-Q9 Adaptor.

Mounting: The capacitor is mounted on an aluminum panel finished in crackle and enclosed in a dust-tight ⅛-inch-thick aluminum case.

Dimensions: Panel, 7 by 9½ inches; depth 8⅛ inches, (180 by 240 by 205 mm) over-all.

*John F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," *General Radio Experimenter*, 33, 7, July 1959.





Variation with frequency of effective capacitance and D per pf of capacitance for Type 1422 two-terminal Precision Capacitors.

Temperature Coefficient: Approximately ±.002% per degree Centigrade, for small temperature changes.

Residual Parameters: See table. The series resistance varies as the square root of the frequency above 100 kc. Its effect is negligible below this frequency.

Frequency Characteristic: See plots above, for two-terminal models. The resonance frequency for the -CB and -CC models is approximately 20 Mc; for the -CD model, 60 Mc for each section.

Dissipation Factor: The losses in the two-terminal capacitors are primarily in the stator supports, which are of low-loss polystyrene ($DC = .01 - 10^{-12}$).

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, 10×10^{-6} for -CC, -CD.

TYPE 1422	TWO-TERMINAL							THREE-TERMINAL			
			RF	READS CAPACITANCE REMOVED							
	-D		-N	-MD		-ME		-CB	-CC	-CD	
CAPACITANCE RANGE, pf: Min	100	35	100	0	0	0	0	50	5	0.5	.05
Max	1150	115	1150	1050	105	105	10.5	1100	110	11	1.1
SCALE, pf/Division:	0.2	.02	0.2	0.2	.02	.02	.002	0.2	0.02	.002	.0002
ACCURACY: ± Picofarads listed below or ± .03%, whichever is greater											
Direct-Reading (Adjustment):											
Total Capacitance	0.6†	0.1†	0.6†	Differences from Zero				0.6	0.15	.04	.008
Capacitance Difference	1.2	0.2	1.2	1	0.2	0.2	.05	1.2	0.3	.08	.061
With Corrections from Calibration Chart (supplied):											
Total Capacitance	0.3†	.04†	0.3†					0.3	.04	.01	.002
Capacitance Difference‡	0.6	.08	0.6	0.6	.08	.08	.02	0.6	.08	.02	.004
With Corrections from Precision Calibration (extra charge):											
Total Capacitance	0.1†	.01†	0.1†					0.1	.01	.001	.0002
Capacitance Difference‡	0.2	.02	0.2	0.2	.02	.02	.004	0.2	.02	.002	.0004
STABILITY: Capacitance change per year not greater than 1 scale division											
RESIDUALS (typical values):											
Series Inductance, μh	.06	0.10	.024	.06	0.10	.06	0.10	0.14	0.17	0.17	0.17
Series Resistance, ohms at 1 Mc	.02	.03	.008	.02	.03	.02	.03	0.1			
Terminal Capacitances, pf:		high terminal to case				min scale		20	560	74	23
						max scale		20	850	98	25
		low terminal to case				min scale		33	600	92	93
						max scale		36	920	117	115
Capacitance at Zero Scale Setting, pf:				1140	135	145	35				

†Total capacitance is the capacitance added when the capacitor is plugged into a TYPE 874-Q9 Adaptor.

‡Divide error by 2 when one setting is made at a calibrated point.

Type		*Net Weight Pounds*	*Net Weight KG*	*Code Word*	*Price*	*Additional Price for Precision Calibration†*
1422-D	**Precision Capacitor**	11¼	5.1	RAPID	**$265.00**	**$ 90.00**
1422-MD	**Precision Capacitor**	11	5	RAVEL	**265.00**	**90.00**
1422-ME	**Precision Capacitor**	10½	4.8	RAZOR	**255.00**	**110.00**
1422-N	**Precision Capacitor**	10¾	4.9	READY	**250.00**	**50.00**
1422-CB	**Precision Capacitor**	10¾	4.9	REBUS	**250.00**	**55.00**
1422-CC	**Precision Capacitor**	12½	5.7	RECUR	**280.00**	**55.00**
1422-CD	**Precision Capacitor**	11	5	REDAN	**280.00**	**165.00**

†When ordering capacitor with precision calibration, add P to the type number, and add WORMY to capacitor code word.

IMPROVEMENTS IN THE VACUUM-TUBE BRIDGE

The TYPE 1661 Vacuum-Tube Bridge is used primarily for highly accurate measurements of the low-frequency dynamic coefficients of vacuum tubes. It can also measure directly the short-circuit conductance parameters and the hybrid parameters of transistors.

The TYPE 1661-B now supersedes the TYPE 1661-A. This latest model permits greater flexibility in the measurement of two-section tubes, such as triode-pentodes.

These can now be measured sequentially without the necessity of reconnecting the patch cords. While the dynamic coefficients of one section are being measured, the grid, cathode, screen-grid, and plate of the other section may be grounded, open, or connected directly to their individual power supplies, as determined by the selector switch setting. This last position permits measurement of static tube characteristics with no voltage drops because of bridge transformers. A central switch position permits measurement of the static characteristics of both sections simultaneously. There is also provision for measuring the dc voltage at the "plate" of the section whose dynamic coefficient is being measured. This feature is particularly useful in the measurement of transistors or high-plate-current tubes where the voltage drop across the 34-ohm primary of the output transformer may be significant.

The terminal arrangement for connecting power supplies now provides for two grid, two screen-grid, and two plate supplies. Two pairs of terminals permit connecting individual cathode resistors for the two tube sections. Panel plugs are provided for paralleling heater leads when the tube is designed for both 12.6- and 6.3-volt heater operation.

A Nuvistor socket is now supplied to permit testing this new line of tubes.

The price remains unchanged at $1100.00.

LOCAL EXHIBITS — SYRACUSE TO WASHINGTON, D. C.

Convenient, comprehensive, competent, and concise. These words describe the second annual Electronic Instrument Manufacturers Exhibit (EIME), cosponsored by seven leading instrument manufacturers. If you are between Syracuse and Washington, you can reach an exhibit location easily. Many new instruments to solve your measurement problems will be demonstrated by factory engineers. You can discuss your interests in unhurried detail.

The sponsors are General Radio Company, Lambda Electronics Inc., Non-Linear Systems Inc., Panoramic Electronics Inc., Sensitive Research Inc., Tektronix Inc., and Trio Laboratories Inc. The schedule of exhibits is:

Syracuse, New York, Sheraton Inn, September 21, Thursday, 12:00 – 7:00 P.M.

Norwalk, Connecticut, Norwalk Motor Inn, September 25, Monday, 12:00 – 7:00 P.M.

Roosevelt Field, L. I., New York, Sagamore Room, September 27 and 28, Wednesday and Thursday, 12:00 – 8:00 P.M.

Cedar Grove, New Jersey, The Towers, October 2, Monday, 12:00 – 7:00 P.M.

Philadelphia, Pennsylvania, Bellevue Stratford Hotel, October 3 and 4, Tuesday and Wednesday, 12:00 – 8:00 P.M.

Watchung, New Jersey, Wally's, October 9, Monday, 12:00 – 7:00 P.M.

Washington, D. C., Marriott Motel, October 11, Wednesday, 2:00 – 9:00 P.M.

General Radio will be operating its newest frequency instruments: the TYPE 1130 series of digital counting instruments, the TYPE 1142-A Frequency Meter and F-M Discriminator, and the TYPE 1120-A Frequency Standard. Among other new instruments, see the TYPE 1232-A Tuned Amplifier and Null Detector, the TYPE 1553-A Vibration Meter, and the TYPE 1264-A Modulating Power Supply.

BARGAIN SALE

TYPE 650-P1 OSCILLATOR-AMPLIFIER

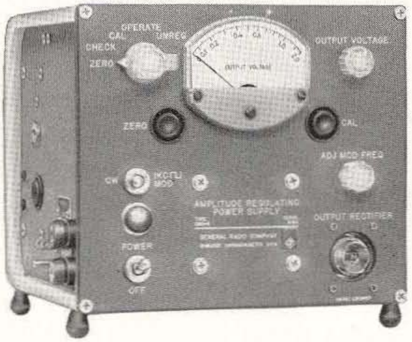
Experimenter readers who are still using TYPE 650-A Impedance Bridge (which has now been replaced by the TYPE 1650-A) may be interested in acquiring a TYPE 650-P1 Oscillator-Amplifier which converts the bridge to an ac-operated instrument, provides a 1000 cycle generator and a dc supply for resistance measurements, and includes an amplifier tuned to 1000 cycles for the detector circuit. This instrument, originally priced at $155, is now available at $87.50, while they last.

TYPE 1262-A POWER SUPPLY

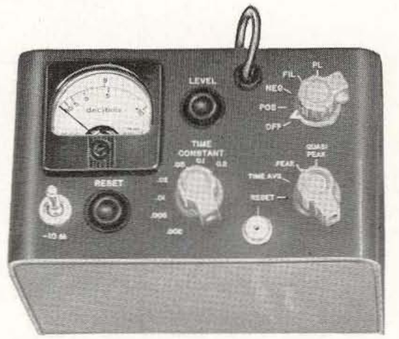
This power supply is an ac power pack, which converts the discontinued TYPE 1551-A Sound-Level Meter to ac operation. Originally priced at $70 for the 115 volt model and $85 for the 230 volt model, it is now available to those interested at the reduced price of $25. For 115 volt supply order TYPE 1262-A; for 230 volt supply order TYPE 1262-AQ18. Both models operate from power line frequencies of 50-60 cps.

THE GENERAL RADIO EXPERIMENTER

Type 1263–B
Amplitude-Regulating Power Supply



Type 1556–B
Impact Noise Analyzer



Type 1432–X
Decade Resistor

Type 1590–A Remote Control

VOLUME 35 No. 9

SEPTEMBER, 1961

THE GENERAL RADIO

EXPERIMENTER

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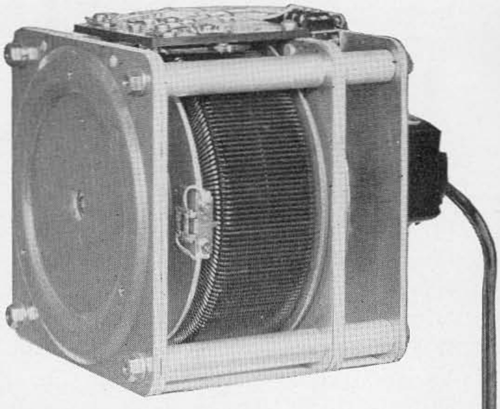
A REMOTE CONTROL FOR VARIAC® AUTOTRANSFORMERS



Motor-driven Variac® autotransformers are often positioned from a push-button control. The push buttons operate a two-phase motor to change the Variac setting and a voltmeter is used to indicate the output voltage. While this system provides the utmost in simplicity and reliability, the meter ballistics and the reaction time of the operator require that the motor drive be slow. Otherwise, considerable difficulty is experienced in adjusting to the desired output voltage.

A new device, the Type 1590-A Remote Control (shown in Figure 1), eliminates the requirement for slow-speed operation. The complete system is a simple, closed-loop servomechanism, as shown in Figure 2. This system automatically compensates for load regulation and if a low power regulated line is available to operate the remote control line-voltage fluctuations can also be corrected. By suitable switching many circuits can be sequentially adjusted from a single control. The system maintains the basic simplicity and reliability of the push-button control while offering the possibility of higher speed operation and greater flexibility. The correction rate depends upon the size of the driven Variac autotransformer and can be as high as 60 volts per second for small units.

Figure 1. The Remote Control makes possible precise voltage settings on voltage transformers from a remote point.

The control Variac can be set to any desired voltage. If the remote Variac is not at the same voltage, the difference voltage will appear across the two-phase motor winding and cause the motor to rotate. The phase of this error voltage, and therefore the direction of rotation of the two-phase motor, depends upon whether the remote Variac output voltage is greater or less than that of the control Variac.

Since 10 volts or more is required to overcome friction and start the motor,

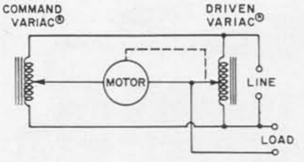


Figure 2. Elementary schematic of the servo system.

the remote Variac setting might differ by as much as ±10 volts from that of the control Variac if the difference voltage were used directly. To decrease this error, a step-up transformer is used (Figure 3) between the brushes of the Variacs and the motor winding. Thus, with a 10-to-1 step-up ratio, a 1-volt error can cause the motor to operate.

While the use of a 10-to-1 step-up transformer decreases the required voltage difference between the Variacs by 10-to-1, it also creates the possibility of applying ten times the full line voltage or 1200 volts across the motor winding if the Variacs are momentarily set at opposite ends. For example, this high voltage could occur if the Variacs were set at opposite positions before power was applied or if the control unit is set very rapidly from zero to full output. To avoid this temporary high voltage the transformer is designed to saturate at 13 volts on the primary, limiting the motor voltage to about 130 volts.

The magnetizing current in the transformer increases rapidly as the core approaches saturation and means for limiting this current must be provided. A series resistor is not suitable since a

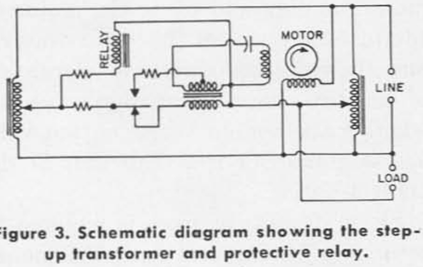


Figure 3. Schematic diagram showing the step-up transformer and protective relay.

value large enough to protect the Variac also contributes significant voltage drop and phase shift in the applied motor voltage, and therefore decreases the motor torque and increases the minimum error voltage to several volts. The use of a nonlinear resistor can provide adequate protection for momentary large error voltage and still contribute negligible voltage drop and phase shift as balance is approached. This technique has been used successfully in high-speed control units.

Since the Remote Control Unit must be a general-purpose device suitable for both slow- and high-speed applications, the peak power of 200 watts may have to be dissipated for considerable time, and, hence, the use of any resistive current-limiting device is not attractive. For this reason a protective relay is used to limit current. Whenever the error voltage is large enough to result in a transformer current greater than 2 amperes, the relay switches to a transformer primary winding with more turns. This maintains the motor voltage at a safe value and limits the transformer current without dissipating too much power.

To limit the surge current before the relay has time to operate, a 2 2-ohm resistor is used in series with the transformer. This resistor, combined with the transformer winding impedance at saturation, limits the surge current to 20 amperes under the worst possible condition. This surge current flows for one-half cycle only. If for some reason the protective relay should fail to operate, a Klixon breaker will shut off the control unit before excessive temperatures result. The breaker is operated both by the heating of the current-limiting resistors that dissipate most of the power and by the Variac brush current.

Voltage Correction

The voltage fluctuations arising from load changes are automatically compensated, since at balance there can be no appreciable difference of voltage between the control and driven Variacs. If a regulated line is available to supply the small amount of power needed to operate the command Variac, corrections can also be automatically obtained for fluctuations in line voltage at the remote autotransformer. The regulated line must have low impedance at 60 cps and must have the same phase angle as the unregulated line to the remote unit. Such a combination can provide large amounts of power at a regulated voltage which is adjustable from zero to 140 volts. The addition of a buck-boost transformer, to limit the correction range to ±10% about the normal line voltage, will result in an increase of 5:1 in the power rating.

— M. C. Holtje
— C. A. Tashjian

Ordering

To order the proper motor-driven Variac autotransformer, use the same type-numbering system as for our standard motor-driven units. The motor capacitor and microswitches, specified by C and K in the type numbers for standard units, are not used with the Type 1590-A, except on 64-second models. For all others these letters should be omitted from the type numbers. Thus, for 2% positioning accuracy with a Type W10G2 Variac autotransformer, order Type W10G2D8.

SPECIFICATIONS

Tracking Accuracy: ±2% of input line voltage, when used with motor speed listed in the table.

Power: 105 to 125 volts, 50 to 60 cps.

Accessories Required: Standard motor-driven Variac autotransformer less capacitor and microswitches.

Connections: Knockouts and a terminal strip are provided in the case for the four leads necessary to connect the control unit to the remote Variac autotransformer.

Dimensions: Width 4⅞, height 6⅝, depth 5⅞ inches (124 by 169 by 149 mm) over-all.

Net Weight: 6½ pounds (3 kg).

TRAVERSE TIME AND CORRECTION RATE FOR 2% POSITIONING ERROR:

DRIVEN VARIAC AUTO-TRANSFORMER MODEL	SINGLE UNIT		TWO-GANG (G2)		THREE-GANG (G3)	
	Traverse Time* (Seconds)	Approximate Correction Rate (Volts/sec)	Traverse Time* (Seconds)	Approximate Correction Rate (Volts/sec)	Traverse Time* (Seconds)	Approximate Correction Rate (Volts/sec)
W2	2	60	2	60	4	30
W5	2	60	4	30	8	15
W10	4	30	8	15	16	8
W20	8	15	16	8	32	4
W30	16	8	32	4	32†	4
W50	32	4	64‡	2	64†‡	2

*If half the positioning error is desired, the traverse time can be doubled, giving half the correction rate. Traverse time greater than 64 seconds should not be used.

†3% positioning error.

‡Exception: microswitches necessary on 64-second models.

Type		*Code Word*	*Price*
1590-A	**Remote Control**	REMCO	**$95.00**

THE IMPACT NOISE ANALYZER

Measures Both Electrical and Acoustical Noise Peaks

Figure 1. The Type 1556-B Impact Noise Analyzer with the Type 1551-C Sound-Level Meter.

The revolution in business communication, brought about by the transmission of data over private wire circuits to and from computers and other business machines, has made necessary new methods of evaluating telephone-line noise to permit better rating of a line for its adequacy in this application. The noise on a line can introduce errors in the data transmitted. Since the transmitted signal is usually a series of pulses, a simple measurement of the rms value of the noise is not adequate. The measurement of noise peaks is a better approach, and the Type 1556-A Impact Noise Analyzer[1] has been extensively used for this purpose. In such tests many readings are taken, and the operations required can become tiresome. In order to make the instrument more convenient for this use, as well as for the measurement of acoustic impact noise, a new model, the Type 1556-B, shown in Figure 1, is now available.

The new model has all the features of the earlier one. For instance it can measure the peak value of an impact or electrical pulse and store this value so that an indicating meter can be used to show this peak, even for a single pulse that has a duration of only tens of microseconds. Ordinarily, the stored signal must be erased before another pulse is measured, and one can do this by setting the rotary switch in a "Reset" position. This resetting, however, must be done many times in a short period when noise on data transmission lines is measured, and a more convenient means is desirable.

In the new model, at the suggestion of the Bell Telephone Laboratories, an auxiliary button that can be pressed to reset the circuits more easily and quickly has been added. This button can also be operated by a camera cable release. Since one length and type of cable release is unlikely to satisfy most customers and since cable releases are

[1]Arnold Peterson, "The Measurement of Impact Noise," *General Radio Experimenter*, 30, 9, February, 1956.

readily available, they are not furnished with the instrument.

Field experience with the analyzer in the measurement of acoustic noise has also indicated the desirability of this change. Although the original problem that led to the development of the impact noise analyzer was that of measuring the high-level sound from impacts in heavy machinery, the instrument has been widely applied to the measurement of relatively quiet impacts. Here, the impact noise from the detenting action while switching out of the "RESET" position could interfere with the desired measurements. In the new model it is possible to reset and release more quietly.

— ARNOLD PETERSON

SPECIFICATIONS

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

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

Frequency Range: 5 cps to 20 kc.

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 microseconds for a value within 1 db of peak value (for rectangular pulses). Storage time at normal room temperature is greater than 10 seconds for a 1-db change in value.

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

Time-Average Reading: Charge time of rectifier circuit selected by seven-position switch, having times of .002, .005, .01, .02, .05, 0.1, and 0.2 second for the resistance-capacitance time constant. Storage time at normal room temperature is greater than 1 minute for a 1-db change in value.

Accessories Required: A sound-level meter or frequency analyzer to supply the analyzer input if it is to be used for acoustic measurements.

Input Terminals: Cord with phone plug at one end.

Batteries: One 1½-volt size D flashlight cell (Rayovac 2LP or equivalent) and one 45-volt B battery (Burgess XX30 or equivalent) are supplied. Typical battery life is 100 hours.

Transistors: Two 2N1372 and one 2N1374.

Tube Complement: One TYPE CK6418.

Cabinet: Aluminum; carrying case supplied. Case fastens directly to one end of TYPE 1551 Sound-Level Meter.

Dimensions: Height 4¼, width 7½, depth 6½ inches (110 by 195 by 165 mm).

Net Weight: 4½ lb (2.1 kg); carrying case, 1 lb (0.5 kg).

Type		*Code Word*	*Price*
1556-B	**Impact Noise Analyzer**	MEDAL	**$220.00**

TYPE 1263-B AMPLITUDE-REGULATING POWER SUPPLY

For most measurements it is desirable that the generator output amplitude be constant with frequency. The TYPE 1263-A Amplitude-Regulating Power Supply[1] has provided a convenient means of accomplishing this with General Radio Unit Oscillators and has been particularly useful in conjunction with the TYPE 1750-A Sweep Drive for sweep-frequency measurement techniques.

A new model is now available, TYPE 1263-B, which has similar characteristics to its predecessor. It can be used with the Sweep Drive as well in circuits where the oscillator frequency is changed manually or by means of the TYPE 907-R and 908-R Dial Drives.

A feature of the new model is provision

[1]W. F. Byers, "The Type 1263-A Amplitude-Regulating Power Supply," *General Radio Experimenter*, 29, 11, April, 1955.

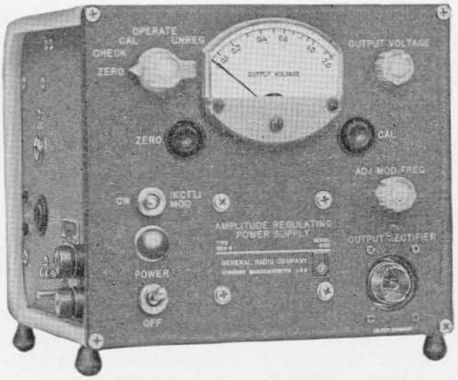


Figure 1. Panel view of the Type 1263-B Amplitude-Regulating Power Supply.

for square-wave modulation of the oscillator at 1,000 cps. This feature is particularly useful in frequency-response measurements because it permits the use of a tuned audio amplifier following the detector, thus achieving high sensitivity with simple equipment. The TYPE 1232-A Tuned Amplifier and Null Detector[2] is an excellent amplifier for this purpose. The square-wave modulation feature provides modulation free from incidental fm, a necessary condition for frequency-sensitive measurements.

The housing has been changed to the rack-bench type,[3] compatible with the TYPE 1361-A UHF Oscillator.[4] The two units can be attached to each other to form a rigid assembly.

Circuit

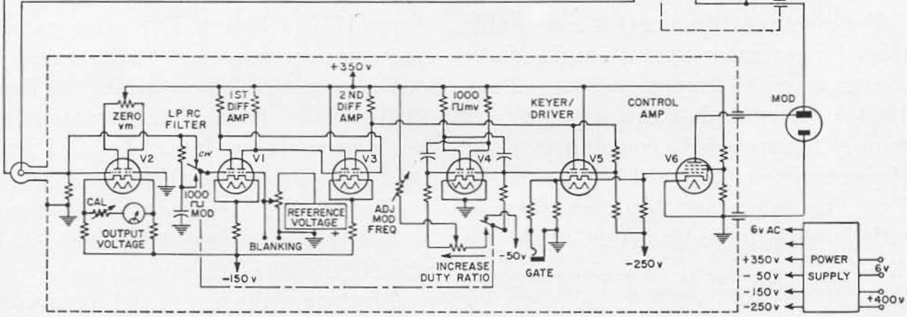
Figure 2 is a schematic of the power supply. With the controlled oscillator unmodulated, the dc potential developed by the oscillator output rectifier is compared with a dc reference potential, and the difference is brought to a minimum by a change in the oscillator plate voltage. When the oscillator is modulated by the internal 1-kc square-wave source, the average carrier level is controlled, which corresponds to one-half the maximum amplitude. Maximum oscillator output that can be controlled is 2 volts unmodulated and 1 volt modulated, corresponding to 2 volts at modulation peaks.

[2]A. E. Sanderson, "A Tuned Amplifier and Null Detector," *General Radio Experimenter*, 35, 7, July, 1961.

[3]H. C. Littlejohn, "The Case of the Well-Designed Instrument," *General Radio Experimenter*, 34, 3, March, 1960.

[4]G. P. McCouch, "A New UHF Signal Source," *General Radio Experimenter*, 35, 3, March, 1961.

Figure 2. Elementary schematic of the Amplitude-Regulating Power Supply with rectifier and rf oscillator.



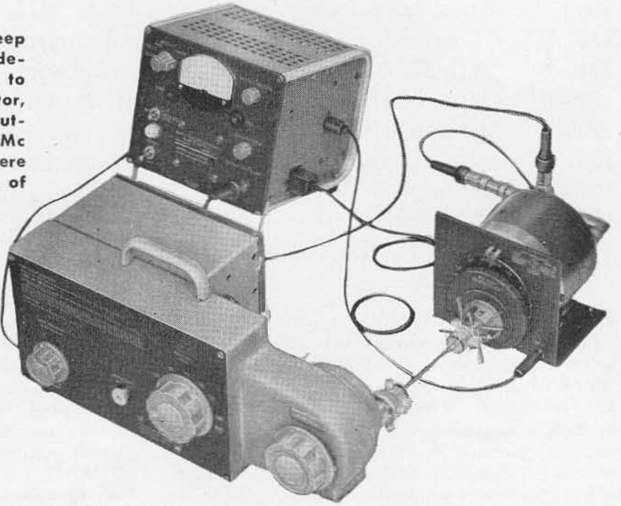


Figure 3. The Type 1750-A Sweep Drive and the Type 1263-B Amplitude-Regulating Power Supply set up to sweep a Type 1208-B Unit Oscillator, thus providing a constant sweep output over a frequency span of 250 Mc to 920 Mc. The equipment shown here is listed below, with the exception of the oscillator and sweep drive.

Since users may prefer to provide their own rectifier for the oscillator output, this is not supplied. The Type 874-VR Rectifier is recommended, however, and plugs directly into the coaxial output connectors of General Radio oscillators and is readily connected to the connector on the panel by a Type 874-R22 Patch Cord. The panel meter indicates the oscillator output voltage and, when a Type 874-VR Voltmeter Rectifier is used, indicates the equivalent zero-impedance generator voltage in series with 50 ohms.

Applications

For automatic sweep operation of the oscillator, as, for instance, in the display of amplitude-frequency characteristics on an oscilloscope, the Type 1750-A Sweep Drive is recommended. The complete assembly is shown in Figure 3. For this application, a blanking contact is provided in the sweep drive.

For slower-speed plotting, as with an X-Y plotter, Type 907-R and 908-R Dial Drives can be used. Figure 4 is a block diagram of a typical assembly.

Oscillator

The Type 1263-B Amplitude-Regulating Power Supply can be used with the following General Radio Oscillators:

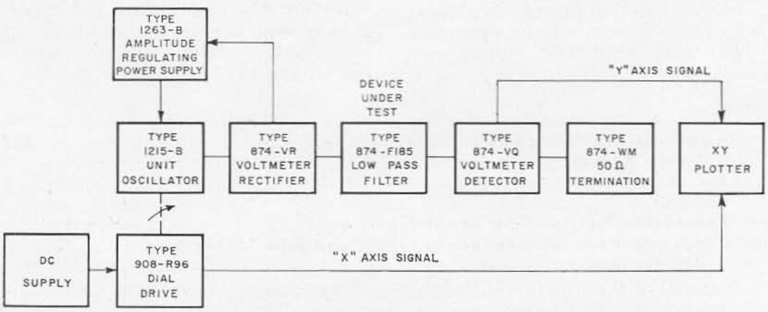


Figure 4. A typical setup for plotting frequency characteristics.

Type	Frequency Range
1211-B*	0.5 to 5 Mc and 5 to 50 Mc
1215-B	50 to 250 Mc
1209-BL	180 to 600 Mc
1209-B	250 to 920 Mc
1361-A	450 to 1050 Mc
1218-A	900 to 2000 Mc

*Not recommended for modulated operation

The earlier, A-models, of the Types 1211, 1215, and 1209 Unit Oscillators will operate satisfactorily with this power supply after a slight modification of the terminal connections. Other oscillators with compatible power requirements can be operated if a dc connection can be made to the cathode circuit to apply plate current control.

— W. F. Byers

SPECIFICATIONS

Rf Output Voltage: 0.2 to 2.0 volts behind 50 ohms for any recommended oscillator (see below), and a Type 874-VR Voltmeter Rectifier. With 1-kc square-wave modulation, 0.2 to 1.0 volt behind 50 ohms (average).

Rf Output Regulation: Below 500 Mc, rf output of recommended Unit Oscillators is held to within ±5% including the effects of harmonics. This regulation can be attained up to 2000 Mc if proper low-pass rf filters are used and a correction applied for the output-rectifier frequency characteristic.

Modulation

Frequency: 1-kc square-wave, adjustable ±5%, stable to within 5 cps 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 μsec each.

Overshoot: None.

Ramp-off: Less than 0.5%.

Gate Voltage: Synchronized with "off" interval of modulation, exceeds 1 volt into the recommended load of 30 kΩ shunted by 300 pf. Rise and decay times are less than 50 μsec each. Gate output during "on" interval of modulation is less than .01 volt.

Plate Supply Output: 0 to 300 volts at 30 ma.

Heater Supply Output: 6 v ±10% at 0.5 amp, 5.4 v ±10% at 0.7 amp.

Response Time: For a 2-to-1 step variation in oscillator output, correction is completed within 0.5 msec with cw operation, 50 msec with 1-kc modulation. Recovery time after blanking is less than 2 msec with cw operation, less than 200 msec with 1-kc square-wave modulation.

Hum and Noise: Peak residual hum and noise modulation is less than ±0.3% on cw; less than ±3% with 1-kc square-wave modulation.

Output Voltmeter: 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.

Tube Complement: Four 12AX7, one each 5963, 6V6GT, 0A2.

Power Input: 105 to 125 (or 210 to 250) volts, 50 to 60 cps, 55 watts maximum, at full load.

Accessories Supplied: Type CAP-22 Three-Wire Power Cord, connector cable for modulation jack on oscillator, spare fuses.

Other Accessories Required: Type 874-VR Voltmeter Rectifier, Type 874-R22 Patch Cord for connecting output rectifier, and Type 874-T Tee for monitoring oscilloscope connection in sweeping applications.

Recommended Oscillators: Type 1215-B (50 to 250 Mc), Type 1209-BL (180 to 600 Mc), Type 1209-B (250 to 920 Mc), Type 1361-A (450 to 1050 Mc), Type 1218-A (900 to 2000 Mc), and for cw operation only, Type 1211-B (0.5 to 50 Mc).

Other Accessories Available: The Type 1750-A Sweep Drive is recommended for automatic operation; coaxial cables, connectors, attenuators, filters, and adaptors; Type 480-P408 Panel Extensions for relay-rack mounting; Type 480-P416 Panel Extensions for rack mounting with the Type 1361-A UHF Oscillator.

Mounting: Aluminum panel and cabinet.

Dimensions: Width 8, height 7, depth 9¼ inches (205 by 180 by 235 mm), over-all.

Net Weight: 14½ pounds (6.6 kg).

Type		*Code Word*	*Price*
1263-B	Amplitude-Regulating Power Supply	GAVOT	$355.00
874-VR	Voltmeter Rectifier	COAXRECTOR	30.00
874-T	Tee	COAXTOGGER	11.00
874-R22	Patch Cord	COAXTANNER	7.60
480-P408	Panel Extensions (pair, for power supply only)	EXPANELJAG	8.00 Pair
480-P416	Panel Extensions (pair, for power supply and Type 1361-A UHF Oscillator)	EXPANELNIT	6.00 Pair

The previous model of the Amplitude-Regulating Power Supply, Type 1263-A, is still available. This model does not provide 1-kc square-wave modulation. The Type 1263-A is priced at $305.00; code word is SALON.

SIX-DIAL DECADE RESISTOR

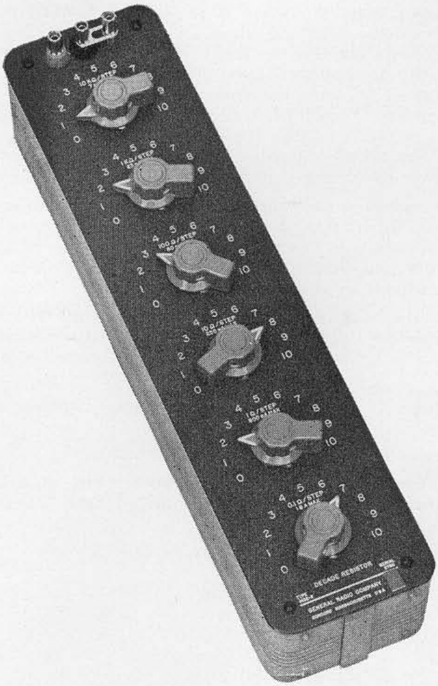


Figure 1. View of the Type 1432-X Decade Resistor.

General Radio decade resistors are stable, accurate units designed for use at audio and radio frequencies as well as at dc. Available in single decades or in multi-dial boxes, they have been manufactured continuously since 1915. The design and construction of the resistors are constantly being improved, as new materials and production methods become available, and new combinations of decade units in the TYPE 1432 assemblies are made available as demand becomes evident. The latest is the TYPE 1432-X Decade Resistor, shown in Figure 1, a six-dial box with a total resistance of 111,111 ohms, adjustable in steps of 0.1 ohm.

Mechanical protection, as well as electrical shielding, is provided by the aluminum cabinet and panel, which completely enclose both the resistors and the switch contacts. The resistance elements have no electrical connection to the cabinet, for which a separate shield terminal is provided.

SPECIFICATIONS

Accuracy of Adjustment: All resistors are adjusted at dc within ±0.05% of the stated value at their terminals, except the 1-ohm units, which are adjusted within ±0.15%, and the 0.1-ohm units, which are adjusted within ±0.5%.

Total Resistance at Terminals: Sum of dial settings plus the zero resistance given below.

Frequency Characteristics: Similar to those of individual decade resistance units, modified by the increased series inductance, L_0, and shunt capacitance, C, due to the wiring and the presence of more than one decade in the assembly. At total resistance settings of approximately 1000 ohms or less, the frequency characteristic is substantially the same as those shown in Figure 2. At higher settings, shunt capacitance

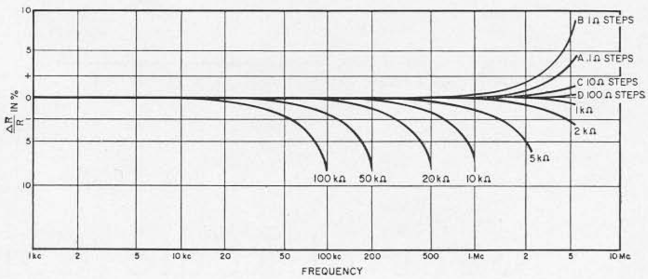


Figure 2. Maximum percentage change in series resistance as a function of frequency for decade-resistance units in Type 1432-X Decade Resistor.

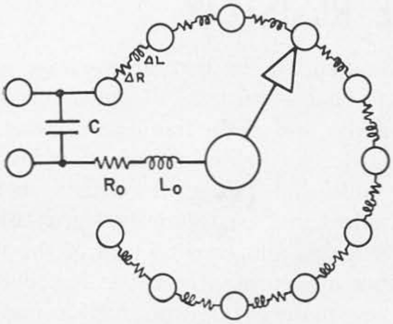


Figure 3. Equivalent circuit of a resistance decade, showing location and nature of residual impedances.

becomes the controlling factor, and the effective value of this capacitance depends upon the settings of the individual decades. See Residual Impedances below, and Figure 3.

Residual Impedances:

Zero Resistance (R_0): .001 ohm or less per dial at dc; 0.04 ohm per dial at 1 Mc; proportional to square root of frequency at all frequencies above 100 kc.

Zero Inductance (L_0): 0.10 μh per dial.

Effective Shunt Capacitance (C): This value is determined largely by the highest decade in use. With the LOW terminal connected to shield, a value of 15 to 10 pf per decade may be 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 ±0.002% per degree Centigrade at room temperatures, except for the 0.1-ohm decade, where the box wiring will increase the over-all temperature coefficient.

Maximum Current: See Table. Values for 40°C rise are engraved on panels directly above switch knobs.

Terminals: Jack-top binding posts set on General Radio standard ¾-inch spacing. Shield terminal is provided.

Mounting: Aluminum panel and cabinet.

Dimensions: Width 4⁵⁄₁₆ inches (110 mm); height 4¾ inches (120 mm); length 18¼ inches (470 mm).

Net Weight: 7 pounds, 8 ounces (3.4 kg).

TABLE I

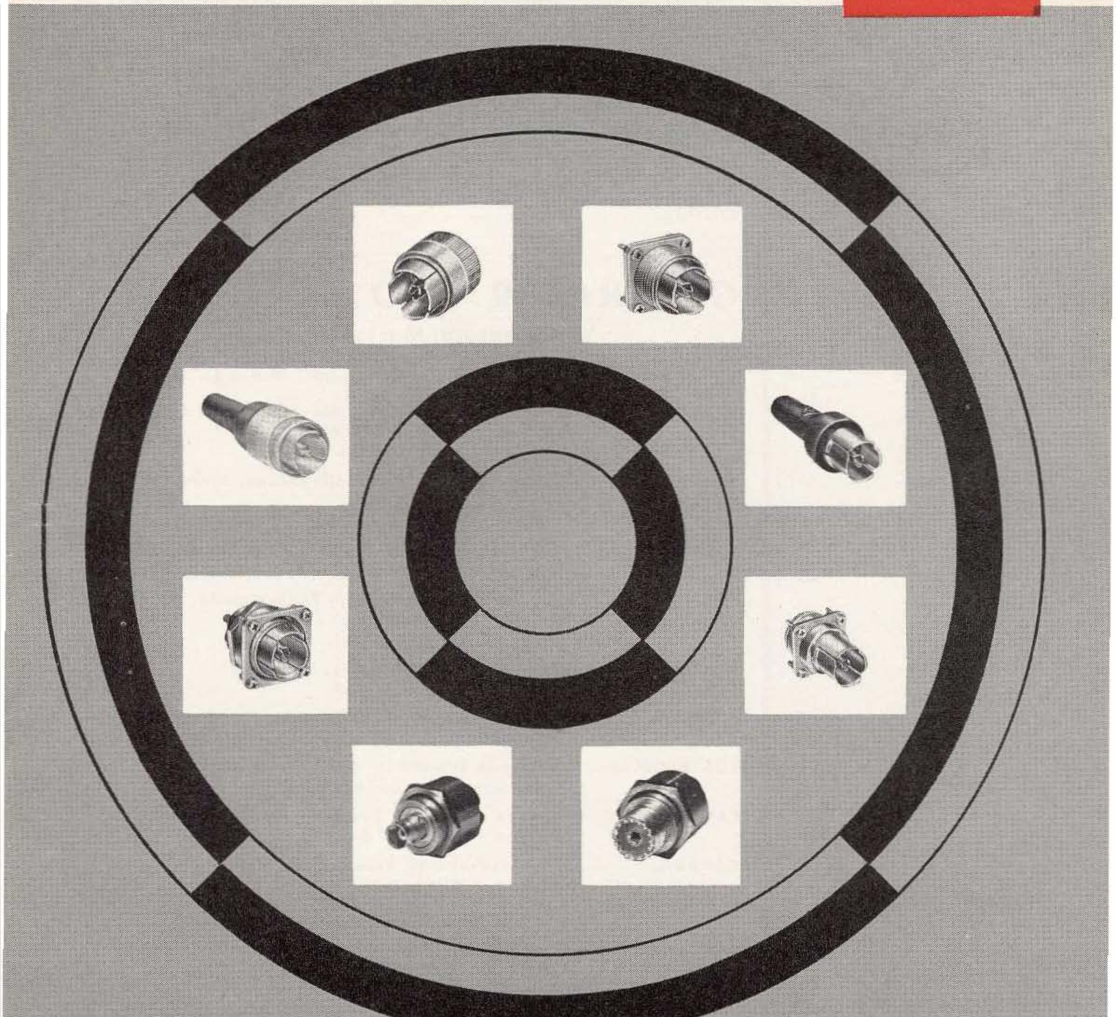
RESISTANCE PER STEP (ΔR) OHMS	ACCURACY OF RESISTANCE INCREMENTS	MAXIMUM CURRENT 40°C RISE	POWER PER STEP WATTS	ΔL μh
0.1	±0.5%	1.6 amp	.25	0.014
1	±0.15%	800 ma	.6	0.056
10	±0.05%	250 ma	.6	0.11
100	±0.05%	80 ma	.6	0.29
1,000	±0.05%	23 ma	.5	3.3
10,000	±0.05%	7 ma	.5	9.5

TYPE		RESISTANCE TOTAL	RESISTANCE MULTIPLE OF	NO. OF DIALS	CODE WORD	PRICE
1432-X	Decade Resistor	111,111	0.1	6	DOGMA	$160.00

General Radio Company

THE GENERAL RADIO

EXPERIMENTER



VOLUME 35 No. 10 OCTOBER, 1961

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Delay Line
New District Offices

THE GENERAL RADIO

EXPERIMENTER

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NEW AND IMPROVED COAXIAL CONNECTORS

LOWER VSWR — NEW LOCKING TYPES — LOWER LEAKAGE

The TYPE 874 Coaxial Connector* has found increasingly wide acceptance each year since its introduction in 1948. It is a unique device, designed primarily for use in measurement systems and compatible, through a comprehensive line of low-reflection adaptors, with all other commonly used coaxial connectors.

Its hermaphroditic feature — all connectors are identical and any one plugs directly into any other — and its excellent VSWR have made it the basis of an extensive line of measuring instruments and accessories for use at frequencies up to about 5000 Mc. Because the original design of the connector contemplated its manifold applications, these instruments have provided outstanding performance and versatility both in the electronics industry and in educational institutions.

To the instrument manufacturer, the problem of what type of coaxial connector to supply on his product has been a difficult one, for different customers want different types of connectors. The TYPE 874, with its associated line of adaptors, has provided the solution for a growing list of instrument manufacturers. New connector and adaptor designs, described in this article, make this solution much more attractive and more satisfactory than ever before.

The use of several millions of these connectors in a wide variety of applications at frequencies ranging from dc to several thousand megacycles per second has clearly demonstrated the versatility and soundness of the basic concept and design. Not surprisingly, however, such widespread usage has also indicated where improved performance would further enhance the utility of the connector and has generated requests for additional features. The improvements most frequently requested have centered in four areas.

*U. S. Patent No. 2,548,457.

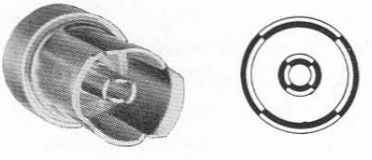


Figure 1. (Left) Type 874 Coaxial Connector. (Right) Cross section of two connectors plugged together.

1. The desire for a permanent connection is obviously in conflict with the desire for quick-connect/disconnect feature of the TYPE 874. Nevertheless, many users have expressed a desire for a permanent locking feature while still retaining all the other desirable characteristics of the connector.

2. Although rf leakage is of the same order as that found in other widely used connectors, the usefulness of the connectors in certain critical applications would be increased if the leakage were reduced.

3. Although VSWR for these connectors has been lower than that of most other basic connectors up to frequencies of the order of 4000 or 5000 Mc, a reduction in the VSWR and an even wider frequency range would naturally be welcomed. The VSWR should also be closely reproducible, regardless of how

many times a pair of connectors is plugged together and unplugged.

4. In the original design, some loosening of the connector assembly could occur with prolonged use as a result of cold flow of the insulating support bead. A design in which the secureness of the connector assembly does not depend upon the bead compression would provide more rigid and permanent mechanical assemblies.

An active and continuous development program in design, manufacturing technique, and quality control has been carried on for several years, with particular emphasis on the areas mentioned above. The results of this program to date are detailed below, wherein the new locking version of the connector is described, as well as the improved performance and reliability of both the locking and the non-locking versions. Included in the expanded line are also locking adaptors to other types of connectors.

GENERAL IMPROVEMENTS

Minor revisions in dimensions, closer tolerances, improved tooling, and a particularly rigorous program of statistical quality control have extended the range of satisfactory operation to about 7000 Mc, improved reliability, reduced VSWR variation from unit to unit, and improved the mechanical feel and ease of use of the connector. The most significant design change, however, provides a secure metal-to-metal joint in the outer conductor assembly, eliminating dependence on compression of the polystyrene bead which now serves only to support the inner conductor. Although the bead is still put under compression when the connector is assembled, this is merely to ensure that the bead stays in place. Figure 2 shows this construction.

Needless to say, one of the important criteria for any design change was that the improved connector be compatible electrically and mechanically with connectors already in use. Any Type 874 connector, regardless of vintage, will connect satisfactorily to any other Type 874 connector.*

THE NEW LOCKING CONNECTOR

The new locking version of the Type 874 complements the non-locking, quick-

*The only exception is that a new locking connector will not mate with a Type 874-P Panel Connector because of its long shroud. This type of connector is now replaced by the Type 874-PB and -PL Panel Connectors.

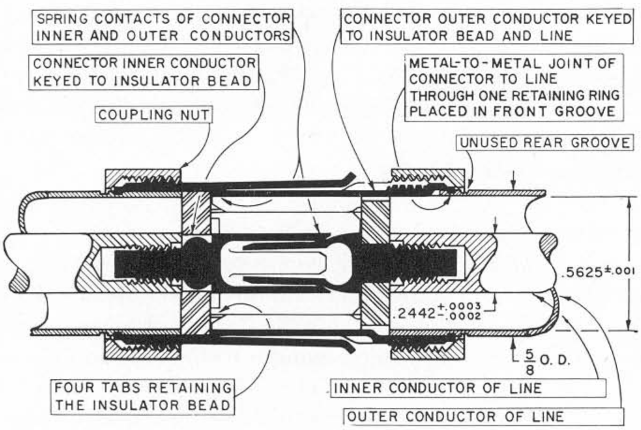


Figure 2. Sectional view of improved non-locking connector. The back edge of the connector outer conductor is drawn up against the retaining ring when the coupling nut is fully tightened. The beveled inside surface of the coupling nut forces the split retaining ring solidly against the bottom of the groove in the outer conductor of the line, and thus a solid metal-to-metal joint is obtained between the outer conductors of the connector and line. The insulating bead is held securely in place by four small tabs which sink into the insulator as the coupling nut is tightened.

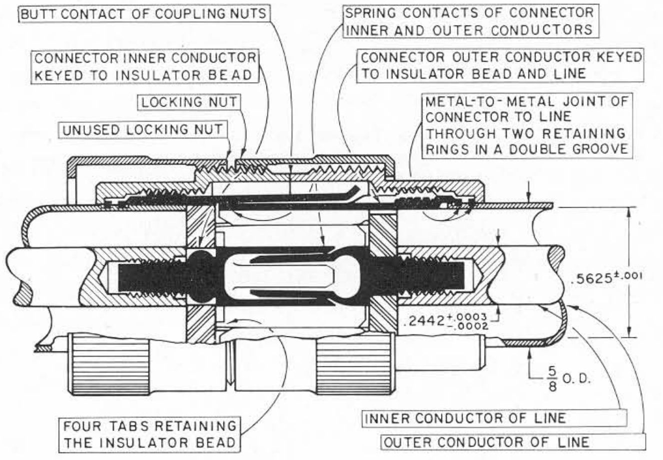


Figure 3. Sectional view of the new locking connector. The solid metal-to-metal joint between the connector and the line on which it is mounted is obtained by clamping a pair of retaining rings against a ridge between two grooves in the outer conductor of the line. As the coupling nut is tightened, the two rings are forced against the ridge by the back edge of the connector outer conductor and a shoulder inside the coupling nut.

connect/disconnect type by providing a rigid connection for semi-permanent installations. These are now in production, and they offer the following features:

1. Provision for rigid mechanical coupling (at the user's option, connectors will mate without locking).

2. Ease of use.

3. Retention of the hermaphroditic feature so that any two connectors will mate and lock together.

4. Compatibility with existing non-locking Type 874 connectors.

5. Retention of the quick-connect/disconnect feature when the locking feature is not wanted.

The last two items are particularly significant. The ability to connect together a non-locking and a locking type (and to use the lock or not to use it as one chooses) results in a coaxial connector system of extraordinary flexibility and versatility.

Figure 3 shows in detail how the above results have been achieved. The coupling nut, which fastens the outer connector to the coaxial line, has been modified and a locking nut added. When two locking Type 874's are plugged together, the locking nut of either can be screwed onto the coupling nut of the other to lock the connection. The locking nut on the second connector is backed off to a storage position. When the two connectors are mated and locked, the coupling nuts are butted together and provide a stop, eliminating the possibility of damage to the inner or outer conductor through overtightening.

The solid metal-to-metal joint mentioned previously is an integral and, in fact, essential part of the design of the locking connector.

The new locking connectors are available for use on air lines, cables, and panels. Locking cable connectors are available in five sizes to accommodate various popular coaxial cables. Locking panel connectors are available in both recessed and nonrecessed versions, each having four cable sizes and one wire-lead type.

ELECTRICAL PERFORMANCE

Standing-Wave Ratio

VSWR characteristics of typical Type 874-BL Locking Connectors and Type 874-B Connectors taken from a current production run are shown in Figure 4.

The slight difference between the

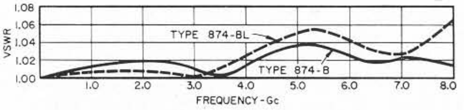


Figure 4. Typical VSWR of Type 874-B and -BL Connectors. Each curve shows the VSWR that a *pair* of connectors introduces into a line.

VSWR of the locking and non-locking versions is the result of a design feature whereby the connectors are normally disengaged very slightly when the locking nut is fully tightened, thereby preventing forced bottoming, which might cause distortion of the connector contacts. The VSWR characteristic plotted corresponds to the statistically maximum disengagement of the connectors.

In addition to the improved mechanical features of the locking connector, the rf leakage has been greatly reduced, owing to the additional shielding provided by the coupling and locking nuts. The leakage from typical sets of the Type 874-BL Locking Connectors is shown as a function of frequency in Figure 5. The leakage characteristics of the non-locking Type 874 Connector and Types BNC and N connectors are shown for comparison. An improvement of approximately 50 db over the non-locking version is shown.

For these measurements, the connectors tested were inserted in a coaxial line, which was terminated in 50 ohms. This line was in turn made the center conductor of a larger, terminated, 50-ohm coaxial line, and the power leaking into the larger line was measured. The db values indicated in Figure 5 are the ratios of the power input to the internal coaxial line to the leakage power absorbed in the termination of the larger line.

NEW AND IMPROVED ADAPTORS

Obviously, the Type 874 Adaptors were designed to adapt Type 874 Connectors to other coaxial connectors, but equally important is their ability to interconnect different types of military connectors without introducing major reflections (see Figure 6). The more types of connectors involved, the more attractive are the Type 874 Adaptors. As an illustration, suppose that the

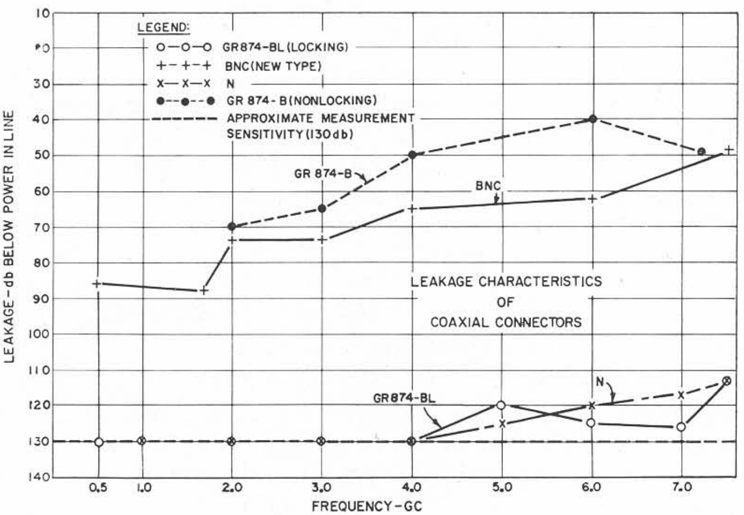


Figure 5. Leakage characteristics of several types of coaxial connectors.

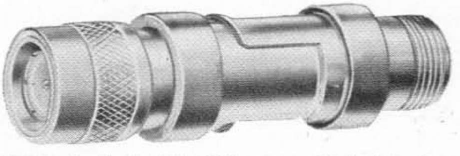


Figure 6. Type 874-QCP and -QNJA Adaptors plugged together. This assembly will connect a Type C jack to a Type N plug.

equipment in a laboratory contained the Types BNC, C, HN, LT, N, and UHF plugs and jacks. The number of direct adaptors needed to interconnect any connector with any other type is 60, while only 12 Type 874 Adaptors will do the same job (and permit connection to Type 874 Connectors as well). Not only is there an economy in adaptors, but, since many of the needed 60 direct adaptors do not exist, a pair of intermediate Type 874 Adaptors often comprises the most direct means available.

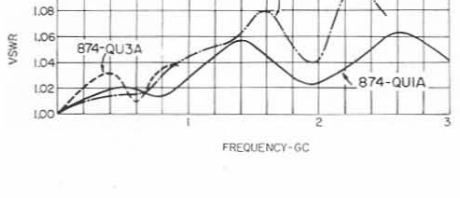
The performance of standard non-locking adaptors has been improved by redesign that incorporates the basic connector improvements already discussed. In addition, most adaptors have been shortened, and at the same time the performance of the "military" end of the connector has been improved. In most cases, the VSWR of an adaptor with its two connectors is as low as, or lower than, that of the corresponding standard military connector (see Fig. 7).

A new, shortened adaptor is identified by a final A in the type number. Eight such adaptors are presently available to connect Type 874 Connectors to Types BNC, HN, and LC plugs and jacks, and Types C and N plugs.

Longer life and more reliable performance will be obtained from all new Type 874 Adaptors than from the standard military connectors to which they mate, because hardened beryllium copper (or, in some types, phosphor bronze) is used in the plug contacts instead of brass.

NEW LOCKING ADAPTORS

To the long list of available Type 874 Adaptors have been added several popular types incorporating the new locking connector. The locking feature is now available in six of the more popular adaptors. Each of these adaptors contains locking Type 874 Connector and a Type BNC, C, N, SC, TNC, or UHF



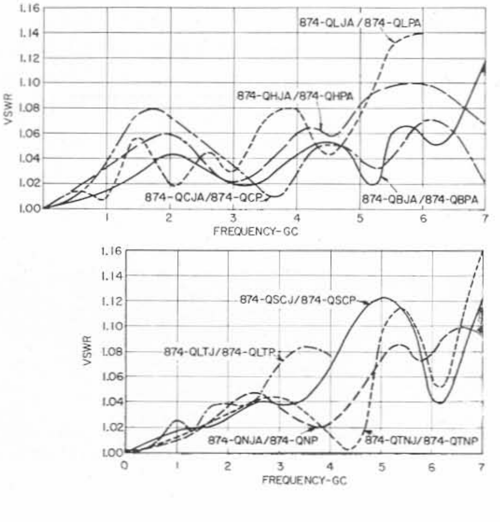
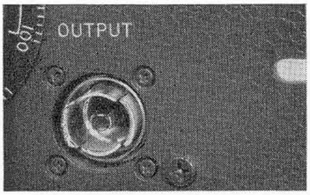
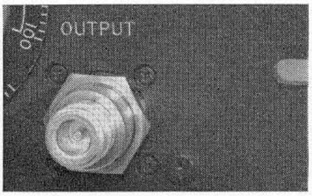


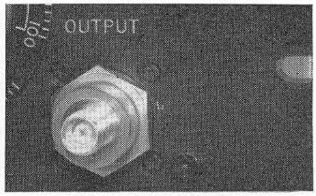
Figure 7. Typical VSWR introduced in line by *pairs* of Type 874 Adaptors plugged together.



Type 874-PRL



Type 874-QNJL



Type 874-QTNJL

Figure 8. A recessed panel connector, Type 874-PRL (shown at left), is converted to other connector types by the addition of adaptors, as shown in the photographs above and in those at the foot of the page.

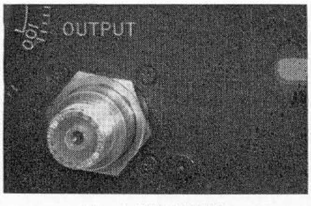
jack. Thus an instrument equipped with Type 874 Locking Panel Connectors can be quickly converted to any of these military connector systems by means of rigid, semi-permanent adaptors as shown in Figure 8.

The quick-conversion capability offers to the instrument manufacturer a basic panel connector that can be quickly adapted to meet individual customer specifications for various coaxial connectors. Furthermore, the user of an instrument equipped with the locking panel connector can readily change from one type of connector to another. If the instrument is equipped with the new recessed locking panel connectors, the conversion is especially neat, for the locking adaptors extend only about an inch in front of the panel.

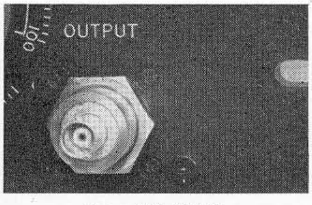
Locking connectors are presently being used on the panels of several new GR instruments so that conversion to Type N, C, BNC, SC, TNC, or UHF connectors can be made merely by locking the desired adaptor firmly in place. The use of locking panel connectors will gradually be extended to most instruments in the GR line. Most components (tees, lines, attenuators, pads, etc.) have been, or will be, modified to permit the use of either locking or non-locking connectors.

The older Type 874 Connectors on these latter components cannot be directly replaced with the locking type, since an additional groove is required and the groove position is different. Components with non-locking connectors having the new construction can be identified by an unused groove in the outer conductor which appears directly behind the coupling nut.

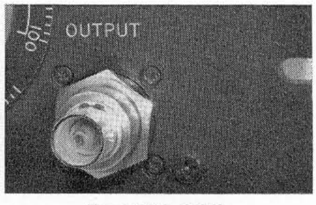
Increased acceptance of the Type 874 Connector has already resulted from the increased versatility and the improvement in performance. This connector is well on the way to the same universal acceptance that has been accorded the banana plug, first introduced in the United States by General Radio in 1924. The development program which produced these design changes is continuing with emphasis on improvement of the cable connectors and on further reductions of VSWR.



Type 874-QUJL

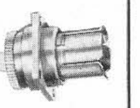
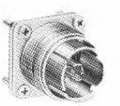
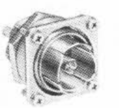


Type 874-QBJL



Type 874-QCJL

CONNECTORS

	Type	*Fits*	*Code Word*	*Price**	
Basic Connectors	**874-B**	50-ohm Rigid Air Line	COAXBRIDGE	**$1.60**	*See Fig. 1*
	874-BL	50-ohm Rigid Air Line (locking)	COAXYPIPIT	**2.50**	
Cable Connectors	**874-C**	874-A2 Cable	COAXCABLER	**2.30**	
	874-C8	RG-8/U Cable	COAXCORDER	**2.30**	
	874-C9	RG-9/U, RG-116/U Cables	COAXCAMMER	**2.30**	
	874-C58	874-A3, RG-29/U, RG-55/U, RG-58/U, RG-58A/U Cables	COAXCALLER	**2.30**	
	874-C62	RG-59/U, RG-62/U Cables (nonconstant impedance)	COAXCANDOR	**2.30**	
Cable Connectors —Locking	**874-CL**	874-A2 Cable	COAXYROBIN	**3.50**	
	874-CL8	RG-8/U Cable	COAXPARROT	**3.50**	
	874-CL9	RG-9/U, RG-116/U Cables	COAXYJUNCO	**3.50**	
	874-CL58	874-A3, RG-29/U, RG-55/U, RG-58/U, RG-58A/U Cables	COAXYSNIPE	**3.50**	
	874-CL62	RG-59/U, RG-62/U Cables (nonconstant impedance)	COAXYSWIFT	**3.50**	
Panel Connectors —Flanged	**874-PB**	874-A2 Cable	COAXAPPLER	**3.20**	
	874-PB8	RG-8/U, RG-9/U, RG-116/U Cables	COAXBATHER	**3.20**	
	874-PB58	874-A3, RG-29/U, RG-55/U, RG-58/U, RG-58A/U Cables	COAXABATER	**3.20**	
	874-PB62	RG-59/U, RG-62/U Cables (nonconstant impedance)	COAXBARKER	**3.20**	
Panel Connectors —Locking	**874-PL**	874-A2 Cable	COAXYFINCH	**3.75**	
	874-PL8	RG-8/U, RG-9/U, RG-116/U Cables	COAXYVIREO	**3.75**	
	874-PL58	874-A3, RG-29/U, RG-55/U, RG-58/U, RG-58A/U Cables	COAXTHRUSH	**3.75**	
	874-PL62	RG-59/U, RG-62/U Cables (nonconstant impedance)	COAXTOUCAN	**3.75**	
	874-PLT	Wire Lead	COAXWILLET	**3.75**	
Panel Connectors —Locking, Recessed	**874-PRL**	874-A2 Cable	COAXYGOOSE	**4.00**	
	874-PRL8	RG-8/U, RG-9/U, RG-116/U Cables	COAXCONDOR	**4.00**	
	874-PRL58	874-A3, RG-29/U, RG-55/U, RG-58/U, RG-58A/U Cables	COAXCURLEW	**4.00**	
	874-PRL62	RG-59/U, RG-62/U Cable (nonconstant impedance)	COAXAVOCET	**4.00**	
	874-PRLT	Wire Lead	COAXMERLIN	**4.00**	

*For quantities of 1 to 99; prices for larger quantities on request.

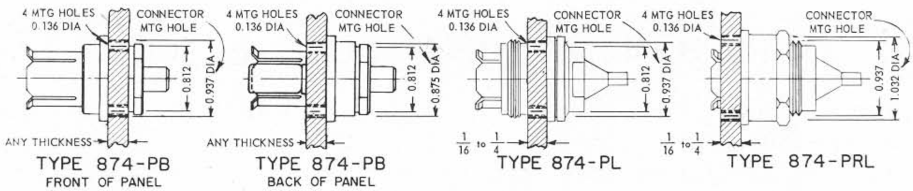
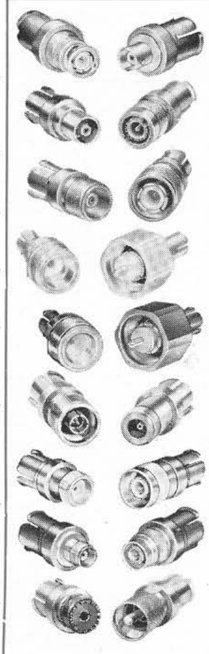
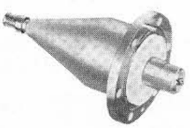


Figure 9. Mounting dimensions for Type 874 Panel Connectors.

ADAPTORS

	*Type**	*Connects Type 874 to . . .*	*Code Word*	*Price*
TO TYPE BNC	874-QBJA	BNC Plug	COAXBOGGER	$4.75
	874-QBJL	BNC Plug (locking 874)	COAXCASHEW	5.75
	874-QBPA	BNC Jack	COAXBUNNER	5.25
TO TYPE C	874-QCJA	C Plug	COAXCOGGER	5.50
	874-QCJL	C Plug (locking 874)	COAXYPECAN	6.50
	874-QCP	C Jack	COAXCUFFER	6.25
TO TYPE HN	874-QHJA	HN Plug	COAXHAWSER	6.00
	874-QHPA	HN Jack	COAXHANGER	7.50
TO TYPE LC	874-QLJA	LC Plug	COAXLITTER	12.00
	874-QLPA	LC Jack	COAXLUGGER	20.00
TO TYPE LT	874-QLTJ	LT Plug	COAXLAGGER	20.00
	874-QLTP	LT Jack	COAXLOBBER	25.00
TO TYPE N	874-QNJA	N Plug	COAXNAGGER	5.00
	874-QNJL	N Plug (locking 874)	COAXWALNUT	6.00
	874-QNP	N Jack	COAXNUTTER	5.00
TO TYPE SC	874-QSCJ	SC Plug (Sandia)	COAXCOSTER	9.00
	874-QSCJL	SC Plug (Sandia) (locking 874)	COAXALMOND	10.00
	874-QSCP	SC Jack (Sandia)	COAXCASHER	9.00
TO TYPE TNC	874-QTNJ	TNC Plug (Sandia)	COAXTUNNER	6.50
	874-QTNJL	TNC Plug (Sandia) (locking 874)	COAXYHAZEL	7.50
	874-QTNP	TNC Jack (Sandia)	COAXTUSKER	6.50
TO TYPE UHF	874-QUJ	UHF Plug	COAXYUNDER	5.00
	874-QUJL	UHF Plug (locking 874)	COAXYBEECH	6.00
	874-QUP	UHF Jack	COAXPUPPER	5.00
TO TYPE 274	874-Q2	274 Plug or Jack	COAXTIPPER	5.50
	874-Q9	938 Binding Posts	COAXPOSTER	6.00
	874-QN6	274-NO Patch Cord	COAXCHOSER	3.75
TO UHF RIGID LINE	874-QU1A	⅞-in. 50Ω UHF Rigid Line, RG-155/U (EIA TR-134)	COAXYUMBER	35.00
	874-QU2	1⅝-in. 50Ω UHF Rigid Line, RG-153/U (EIA TR-134)	COAXYUSHER	80.00
	874-QU3A	3⅛-in. 50Ω UHF Rigid Line, RG-154/U (EIA-TR134)	COAXYULTRA	135.00





*In adaptor type numbers, a J indicates that the adaptor *contains* a jack and a Type 874 Connector; a P indicates that the adaptor *contains* a plug and a Type 874 Connector. For example, a Type 874-QUP Adaptor contains a UHF plug and a Type 874 Connector, and will therefore adapt a Type 874 to a UHF jack.

NEW TOOLS FOR TYPE 874 LOCKING CONNECTORS

Three tools have been added to the Type 874-TOK Tool Kit to help in the installation of locking connectors on air lines and other components. In such installations, it may not be possible to slide back the coupling nut (see Figure 3 in preceding article) enough to expose the retaining-ring grooves because of changes in diameter of the outer conductor or various other obstructions; setting

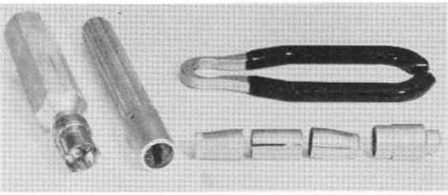


Figure 1. Type 874-TOK Tool Kit consisting of (left) an outer-conductor wrench and an inner-conductor wrench, (right, top) a coupling-nut wrench, and (right, bottom) ring installation tools.

the rings into the grooves can then be difficult, especially inasmuch as the rear ring must pass over the front groove on the way to its position. The three new tools make installation of the retaining rings a simple matter whether grooves are exposed or not. The ring is first placed on one of two cylindrical loaders, depending on which groove it is destined for. The loader is then placed over the outer conductor and the third tool, a cylindrical pusher, is placed over the loader and used to push the ring off the loader and into place in the groove.

The other tools in the Type 874-TOK Tool Kit, described in the May, 1960 *Experimenter,* are an inner-conductor wrench to hold and install the insulating bead and the inner connectors, and an outer-conductor wrench and a coupling-nut wrench to install the outer connector and to tighten the coupling nut.

Type		*Code Word*	*Price*
874-TOK	**Tool Kit**	COAXKITTEN	**$20.00**

ANALOG OUTPUT FROM THE DIGITAL COUNTER

Digital counters offer high precision and accuracy combined with a degree of operating convenience for visual readout that is not easily obtained by other means. In many applications, however, it is desirable to have permanent records. Digital printers are useful for this purpose when individual point-by-point measurements are made, but, when the data vary continuously, the printed information must be evaluated line by line. Unless automatic equipment can be used, this process is tedious and slow.

For instance, if the frequency of a quartz-crystal oscillator as a function of temperature is to be determined, a direct analog plot of frequency versus temperature is usually wanted. Figure 2 shows this information in both forms; the analog curve and the printed data. The curve takes only seconds to evaluate, while little can be deduced from

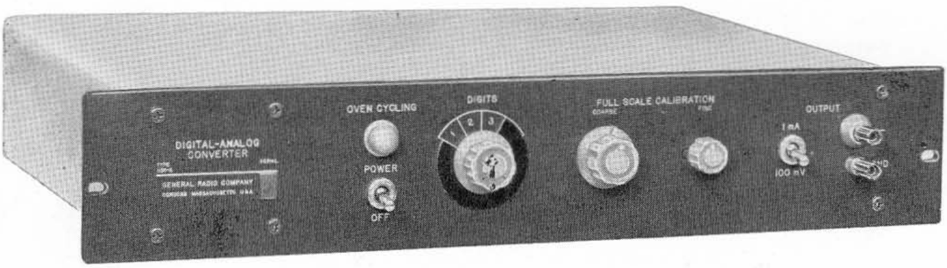


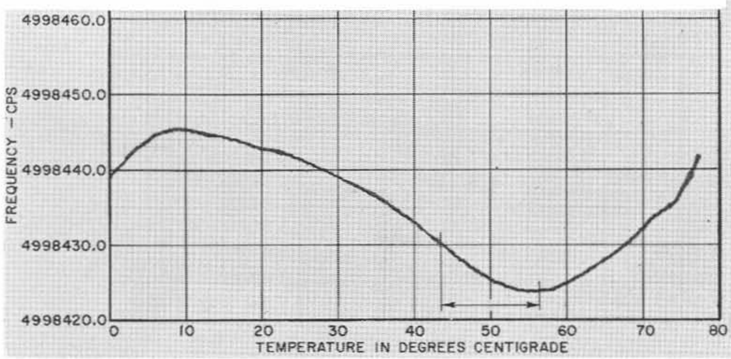
Figure 1. Panel view of the Type 1134-A Digital-to-Analog Converter.

the printed figures without manual plotting. In addition, the temperature values corresponding to individual printed lines are easily available in analog form (from a thermocouple) while conversion into digital form (to print along with the other data) is both cumbersome and costly.

Although no analog output can be accurate to 6 or more places, the analog accuracy is quite adequate for incremental measurements. Operating from a digital counter, the analog system can always be used to interpolate. If the counter displays 8 figures, the analog output can be made to represent any two or three of the 8.

The crystal oscillator frequency in Figure 2 varies only by a few parts per million over the temperature range. The full-scale sensitivity is 20 ppm and with 0.1% incremental accuracy, 2 x 10^{-8} can be observed. Note that the digital record does not provide higher accuracy or resolution; the first five figures remain constant and can be taken as "a priori" knowledge. There really is no need to record them more than once, which can be done manually. Usually, the increments are the only information of interest.

Where the information varies rapidly, mechanical printers are not able to follow the changes. Most are limited to less than 10 lines per second. The cost of higher speed printers is prohibitive for most applications. The analog recorder, on the other hand, can plot curves with much higher speed. Digital-to-analog conversion can be very fast and recorders with better than 1-kc bandwidth are available. Thus, information can be recorded much faster than with a mechanical printer. A typical example is the measurement of short-term stability of oscillators. Samples as short as .01 and .001 second are of interest and the information is collected at a rate approaching 100 or 1000 samples per second. Figure 3 shows the short-term stability



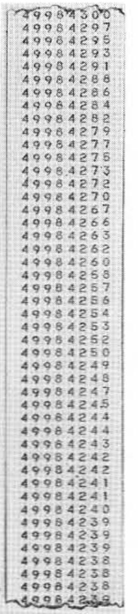


Figure 2. Frequency-vs-temperature characteristic of 5-Mc crystal. Full scale for analog curve was 100 cps, each minor division 1 cps. Only the significant part of the analog record (from 4998420.0 to 4998460.0) is reproduced here. Gate time was 10 seconds. The digital record shown corresponds to the marked section of the curve between 43.3°C and 56.5°C.

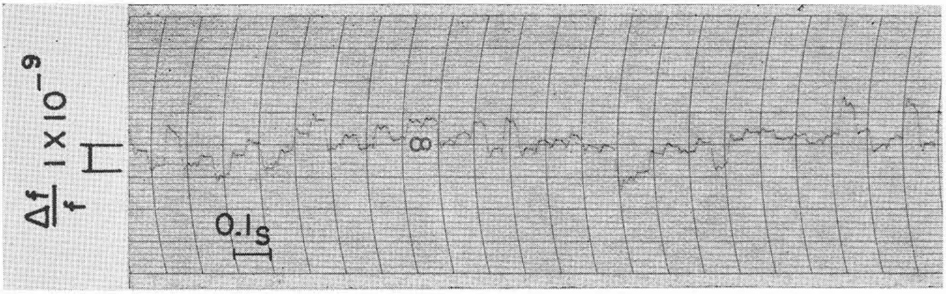


Figure 3. High-speed record of the short-term stability of two GR Type 1113-A Standard-Frequency Oscillators. The 5-Mc outputs are multiplied to 1 Gc each, and the frequency is adjusted for a 105-cycle beat, whose period is recorded. Sampling rate is about 100 samples per second with an averaging time of about 0.01 second. Over-all bandwidth of the measuring system was over 120 cps.

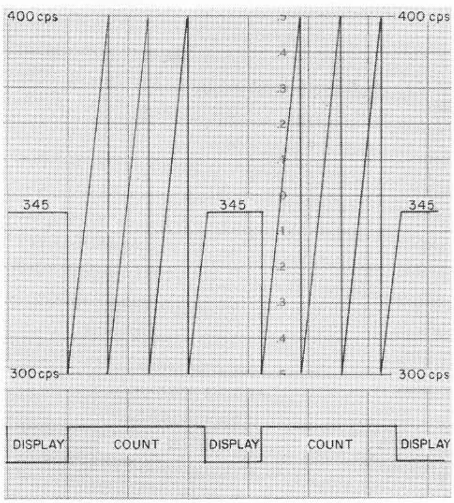
for .01-second samples of a pair of GR Type 1113-A Oscillators. The information is collected at the rate of 100 samples per second, far beyond the speed of mechanical printers.

Until recently a digital printer was necessary for mechanical conversion of digital input to analog output, but the introduction of digital counters with storage facilities[1] has made possible the use of electronic conversion. This has reduced the cost of analog recording well below that of digital printing.

In conventional counters the result of the measurement is displayed intermittently. While the counter is accumulating information, the decade states vary continuously, and information to be printed or plotted is available only during each display time. (Some scheme might be used to disconnect the recorder during counting time, but then the recorder would return to zero each time.) Figure 4 shows the analog output obtained from conventional decades. A frequency of about 345 cps is counted for 10 seconds and displayed for 5 seconds. The analog output is derived from the last three digits of the counter. The zero on the recorder corresponds to 300 cps, the full scale to 400 cps. Note that the analog output during the counting time varies from zero to full scale several times. Usable information is plotted during display time only.

Storage counters, on the other hand, have completely separated storage decades. At the end of each counting interval the data are transferred from

Figure 4. Analog output from 3 conventional decades. Usable information is available during display time only. Gate time was 10 seconds.



[1] R. W. Frank and H. T. McAleer, "A Frequency Counter with a Memory and with Built-In Reliability," *General Radio Experimenter*, 35, 5, May, 1961.

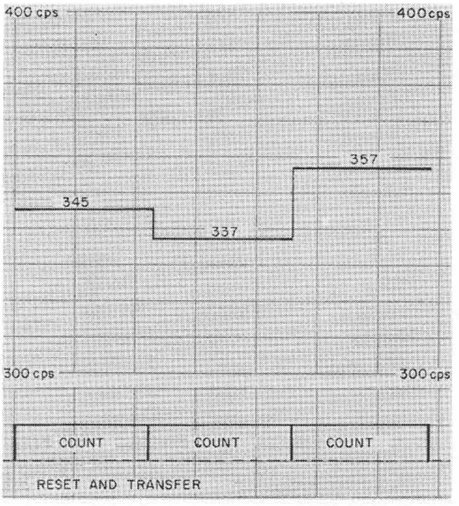


Figure 5. Analog output from 3 storage decades. The output is the result of the previous count.

the counting decades into storage. The counting decades immediately resume counting, and at the end of the next counting interval the new data are transferred again. The information in the storage decades changes only at the transfer time (at the end of each counting interval) and only if the result of the last count is different from the preceding one. Analog output obtained from the storage decades will always represent the result of the previous count and vary only when the input to the counter changes. This results in a faithful reproduction of the input data. If the same measurement as in Figure 4 is made using a storage counter, the analog output is a straight line as long as the input stays constant. In Figure 5 the input frequency is varied. The analog output follows the variations of input data. In Figures 4 and 5 the sampling rate is about 1 sample every 10 seconds. This low sample rate results in the steps shown in the graphs. A smooth curve would result if either the sampling rate were made higher or the paper slowed down.

These advantages have been realized in the GR Type 1130-A Digital Time and Frequency Meter, and the Type 1134-A Digital-to-Analog Converter has been designed as a companion instrument. This converter can be used with other digital equipment if proper input logic voltage levels and weighting are available (see specifications). The important features of this instrument are its accuracy and stability of 0.1% and its high conversion speed of over 1 kc. It can be used to full advantage either with precision recorders or XY plotters of 0.1% accuracy or with high-speed recorders to beyond 1 kc.

CIRCUIT DESCRIPTION

The input signals are obtained from the four storage decades of the counter. A digit-selector switch permits selection of the first three, or the last three, or the last two digits to be recorded. If three digits are recorded, the output increments are 0.1% each. For two digits, the increments are 1% each. The output is either 1 ma for galvanometer recorders, or 100 mv for potentiometer recorders.

Principles of Operation

Figure 6 is a simplified schematic diagram of the converter. Twelve input lines (4 for each decade) connect the electronic switches S_1-S_{12} to the flip-flops in the counter's storage decades. The nominal input voltages are +65 v for a binary 1 and +185 v for a binary 0. For a decade in state 9 (decimal) all four flip-flops are in binary state 1 (+65) and for decimal 0 all flip-flops are in binary state 0 (+185). Each of the electronic switches, S_1-S_{12}, connects the associated output resistor (weighting resistor) to 0 for a +185-v input (binary 0) and to a very stable voltage, E, for +65-v input (binary 1).

Assume that the recorder has zero impedance and a 1-ma full-scale sensitivity and that the voltage E is −30 v. When S_1-S_{12} are in the "on" position, the output is made up of the following currents:

S_1	100 μa	
S_2	200 μa	100's decade
S_3	400 μa	Total — 900 μa
S_4	200 μa	
S_5	10 μa	
S_6	20 μa	10's decade
S_7	40 μa	Total — 90 μa
S_8	20 μa	
S_9	1 μa	
S_{10}	2 μa	1's decade
S_{11}	4 μa	Total — 9 μa
S_{12}	2 μa	

The sum of all branch currents is 999 μa.

If the impedance of the recorder is not small compared with the impedance of this resistive network, then the voltage E can be increased beyond −30 v to allow for the voltage drop across the recorder. For a 1000-ohm recorder, E would be −31 v to produce the proper full-scale reading. Since the counter can be set to 999, calibration is simple, and the recorder impedance need not be known.

To operate a 100-millivolt potentiometer recorder, an internal 100-ohm resistor is switched across the output terminal.

Standardizers (Electronic Switches)

Figure 7 is a detailed schematic of one of the electronic switches. For +185-v input (binary 0) Q_1 is turned off, Q_2 is on. The current through Q_2 would cause point A to be positive, but the clamping diode CR2 conducts and holds point A at a few tenths of a volt positive with respect to 0, say +0.5 v. For +65-v input (binary 1) Q_1 is on, Q_2 is off, and point A is clamped to voltage E by CR1. Again, the forward drop across CR1 causes about 0.5-v offset from E. Assume that E is −29 v. Then A will be either +0.5 v or −29.5 v. This 30-v swing is required for full output into zero load

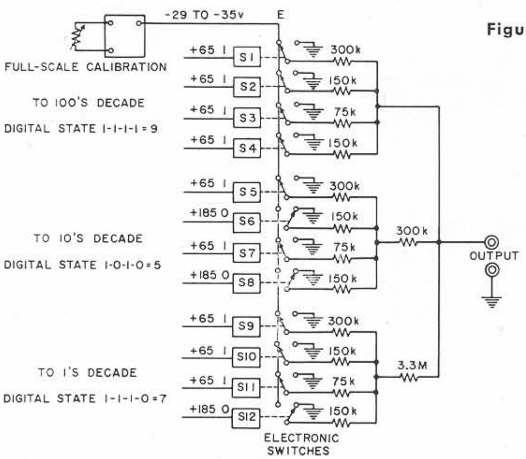
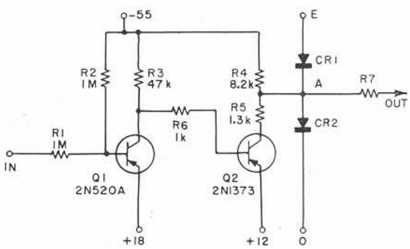


Figure 6. Simplified schematic diagram of the Converter.

Figure 7. Detailed schematic diagram of one of the electronic switches.



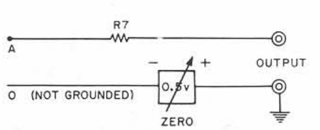


Figure 8. Offset voltage is connected in series with the output terminals.

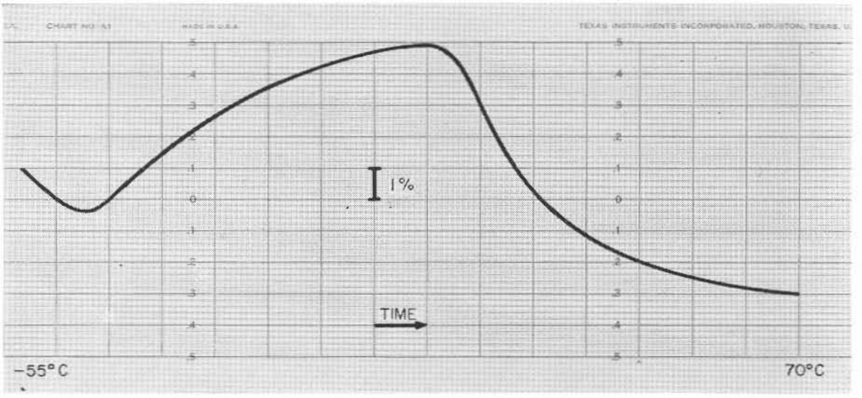


Figure 9. Capacitance-vs-temperature of a capacitor with high dielectric constant. The data were obtained by measuring the period of an RC oscillator.

impedance. To be able to ground one side of the recorder and to prevent current from flowing through it with the +0.5v at A, an offset voltage is connected in series with the output terminals (see Figure 8). The common or low-potential side of the circuit (0) is not grounded to the chassis, but is at about −0.5 v. Because the forward drop of the diodes varies about 2 mv per °C, temperature control was necessary. All critical elements are housed in a constant temperature oven.

Power Supply

There are four regulated voltages of −55 v, +18 v, +12 v and an adjustable supply of −29 to −35 v. The latter (for the standardizer clamp voltage E) directly affects the stability and accuracy of the instrument, and, hence, critical components are temperature controlled. The stability of this supply is better than 0.05% for line, load, and temperature changes. Temperature compensation reduces the warm-up drift to less than 0.5% so that in many applications no warm-up interval is required. The full 0.1% stability is obtained after about 30 minutes.

Applications

Figures 2, 3, and 9 illustrate a few of the many uses of the digital-to-analog converter. In all of these, it is an important advantage to have the data in the form of a continuous curve, rather than a printed digital record that must be analyzed in detail before it can be interpreted. The additional advantage of high-speed plotting is an important one for many applications.

— H. P. Stratemeyer

SPECIFICATIONS

Data Input: BCD, weighted 1-2-4-2 or 1-2-2-4. Binary "1" +90 v max. Binary "0" +150 v min. Source impedance 500 kilohms, max. Input impedance 1 MΩ. Can be driven from General Radio Type 1130-A Digital Time and Frequency Meter or Type 1131-P4 Storage Units. Digit selector switch selects any adjacent 3, or the last 2, of 4-decade input.

Output: 1 ma with 30-kilohm source impedance or 100 mv across 100 ohms. Positive side grounded.

Load: 2000 ohms maximum for 1 ma. 2000 ohms minimum, for 100 mv.

Linearity: ±.05% of full scale.

Stability: ±.02% for ±15% line. ±.03% for ambient from 0–50C.

Warm-Up Drift: Less than .5% of full scale. Thermal equilibrium after 30 minutes.

Power: 100 to 130 (or 200 to 260) volts, 50 to 400 cps 30 watts maximum.

Accessories Supplied: Power cord, spare fuses, cable to connect to Type 1130-A Digital Time and Frequency Meter.

Transistor Complement: One 2N1374, two each 2N1184, 2N1377, fourteen 2N520A, and twelve 2N1373.

Dimensions: Width 19, height 3½, depth 13½ inches (485 by 85 by 345 mm), over-all.

Net Weight: 16¼ pounds (7.4 kg).

Type		*Code Word*	*Price*
1134-AM	**Digital-To-Analog Converter (Bench Model)** ...	MOTTO	**$595.00**
1134-AR	**Digital-To-Analog Converter (Rack Mount)**.....	MINOR	**595.00**

A NEW, NARROW-RANGE DELAY LINE

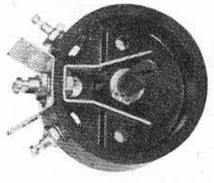


Figure 1. View of the Delay Line.

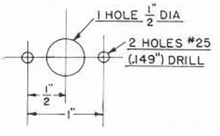


Figure 2. Mounting Dimensions.

There has arisen recently an important group of applications for variable delay lines with short delay ranges. These are used as radio-frequency phase shifters, usually as trimmers for phase adjustment. They have applications in radar, in computers, and in other pulse-operated equipment.

The Type 301-S104 Variable Delay Line, shown in Figure 1, has been designed for these applications. It is a small distributed-winding unit with a sliding tap for the adjustment of the delay. The winding is on a standard potentiometer base, whose dimensions are given in Figure 2. Precious metal wire is used in the winding to ensure reliable contact. Capacitive coupling between the terminals is minimized by shielding.

The pulse response of this delay line is shown in the oscillogram (Figure 3) which is taken from the screen of a Lumatron 112 Oscilloscope. The sweep speed is 5 nanoseconds per centimeter. The photograph shows two sweeps, the first with the delay line set for minimum delay, and the second with the line set for maximum delay. Delay, rise time, baseline ripple, and pulse distortion can be measured from the photograph. Attenuation is low because of the short delay range and may differ slightly between units.

APPLICATIONS

Delay lines of this type are very useful in the various correlation techniques for improving signal-to-noise ratios in radar and space-probe communication links. Other applications include phase trimming for multiple-unit steerable-array (MUSA) antennas in the i-f channels and similar antenna phase trimming in the i-f amplifier systems of monopulse radars.

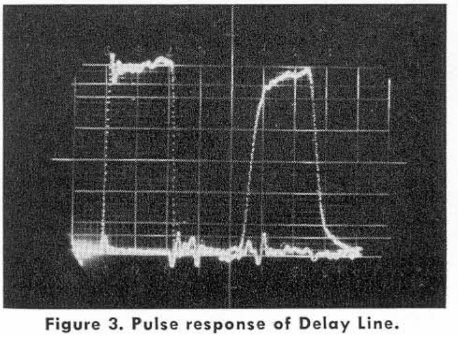


Figure 3. Pulse response of Delay Line.

There are many pulse applications for these narrow-range delay lines. A common one is the use as a patch-cable delay equalizer in a digital computer using short, fast-rise pulses. Others include the adjustment of delay in coincidence circuits of nuclear counters and the trimming of pulse coincidence in computer circuits. There are applications in pulse-forming networks, and as substitutes for coaxial cables in various short-rise-time delay networks. One advantage of the wire-wound type of delay network as compared to coaxial cables is that one can adjust the delay both ways from a median setting, a process that is obviously quite difficult with cables.

— F. D. LEWIS

SPECIFICATIONS

Delay Range: 0 (approx) to 25 nanoseconds (±10%).

Resolution: 0.06 nsec.

Characteristic Impedance: 200 ohms ±20%.

Pulse Rise Time: 2.4 nanoseconds (approx) at maximum delay.

DC Resistance: 5.5 ohms (±20%).

Voltage Rating: 1500 volts, peak, winding to ground.

Dimensions: (Body diameter) 1¾ by 2 by (thickness, exclusive of shaft) 15/16 inches (45 by 51 by 24 mm); shaft diameter, ¼ inch (6.4 mm); shaft extension beyond body, ¾ inch (19 mm).

Net Weight: 1½ oz (45 grams).

Type		*Code Word*	*Price*
301-S104	**Variable Delay Line**	NEEDY	$48.00

NEW DISTRICT OFFICES

In September, the General Radio Company opened two new sales offices — Syracuse, New York, and Orlando, Florida, for the convenience of our many customers in these areas.

The Syracuse Office is managed by Leo J. Chamberlain, formerly of our New York District Office. The Syracuse address:

General Radio Company
Pickard Building
East Molloy Road
Syracuse 11, New York
Telephone: GLenview 4-9323

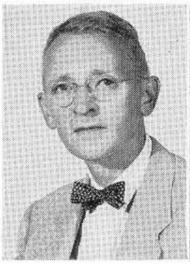
In Florida, the manager is John C. Held, formerly of the Washington District Office. The Orlando address:

General Radio Company
113 East Colonial Drive
Orlando, Florida
Telephone: GArden 5-4671

Both men hold engineering degrees and have several years' experience with General Radio instruments, both at the factory and in the field. They and their staff are prepared to give prompt technical and commercial service to our customers in the busy industrial areas of upper New York State and Florida. Please feel free to make use of these new facilities if you are located in either of these areas.

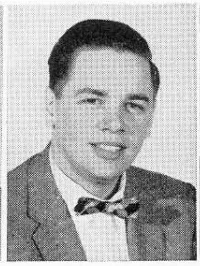
J. C. Held

L. J. Chamberlain

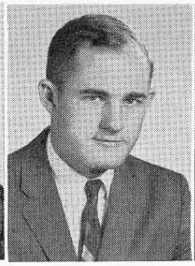


K. Adams

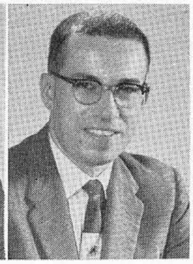
J. E. Snook



C. W. Alsen



J. P. Eadie



J. L. Lanphear

Other Personnel Changes in Our Sales Offices

Kipling Adams, formerly manager of our Philadelphia area office in Abington, Pa., has returned to our main office as Assistant to Sales Manager to aid in the administration of our growing number of district sales offices. His many years of sales experience in our district offices is a valuable asset in his new activity.

John E. Snook, who for several years has been a sales engineer in our Philadelphia Office, is now the manager. He is assisted by Carl W. Alsen who was recently transferred to this office from our main office. Our Philadelphia office is responsible for sales in the important industrial states of Pennsylvania and southern New Jersey.

J. Peter Eadie has been transferred to our New York District Office from our main office at Concord, Mass. He is responsible for sales coverage in the Long Island area.

James L. Lanphear has recently been transferred from our main office to our Washington, D.C., area office located in Silver Spring, Maryland.

ERRATA

Several errors of omission and commission in past issues have recently come to our attention.

July-August, 1960

Page 5 (Tunnel-Diode Measurements)

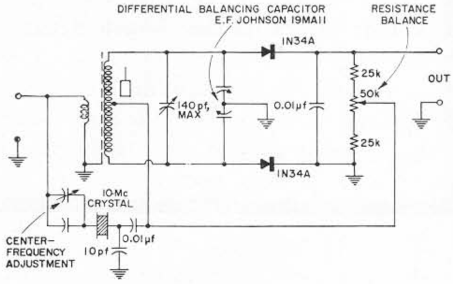
Equation (1), last term in denominator of expression for G_e should be

$$\left(\frac{\omega L}{R}\right)^2 \left(1 - \frac{RR_sC}{L}\right)^2$$

November-December, 1960

Page 11, Figure 2. (Crystal Discriminator)

A ground was omitted from this diagram. Corrected diagram is shown here.



April, 1961

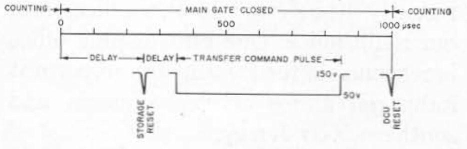
Page 14 (Type 1120 Frequency Standards)

Net weights given are too low. Corrected values are TYPE 1120-A, 275 pounds (125 kg); TYPE 1120-AH, 325 pounds (148 kg).

May, 1961

Page 14, Figure 12. (Type 1130-A Digital Time and Frequency Meter)

The timing diagram for the counting and storage decade is not too clear and contained some errors. The diagram shown herewith should be used.



In the first column on this page, this time sequence is described. Item 1 should read: After a 250-μsec delay, the storage units are . . .

Page 19, Sensitivity Specification

The sensitivity as given is 0.25 volts rms. This is the worst case, and the instrument's sensitivity is 100 millivolts up to 3 Mc, rising to 0.25 volts at 10 Mc.

Page 20, Price Table

The first two items should read "Including TYPE 1130-P1 Coupling Unit . . ." (Please note that the TYPE 1130-P1 is *not* a complete time-base unit and must be fed from an external oscillator.)

July, 1961

Page 9 (RC Null Circuits)

The tuning law of the circuit used in the TYPE 1232-A Tuned Amplifier and Null Detector and its dual is incorrect. It should read:

$$\omega_o = \frac{1}{RC\sqrt{(1 + 2K)\,\alpha\,(1 - \alpha)}}$$

Page 10 (Transfer Voltage Ratio)

In the next to last sentence, " . . . (or a real Z_{12}) . . ." should read " . . . (or a real z_{21}) . . ."

K. L. NYMAN

Karl Lauri Nyman, of the firm K. L. Nyman, of Helsinki, died on August 27th. Mr. Nyman has represented the General Radio Company in Finland for more than twenty years. His loss will be keenly felt by his many friends in Europe and in the General Radio organization, both in the United States and overseas.

The K. L. Nyman firm continues as GR's exclusive representative in Finland under the capable direction of Mrs. Nyman who for many years has been closely associated with all phases of the firm's operation.

General Radio Company

PRINTED IN U.S.A.

THE GENERAL RADIO EXPERIMENTER

VOLUME 35 No. 11 NOVEMBER, 1961

IN THIS ISSUE

New Vibration Meter

New Service Laboratory for Canada

THE GENERAL RADIO

EXPERIMENTER

Published Monthly by the General Radio Company

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The General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in electronic techniques in measurement. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

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THE TYPE 1553-A VIBRATION METER

The new General Radio Vibration Meter, TYPE 1553-A, is a portable easy-to-use instrument for the quantitative measurement of vibration. With its accelerometer, the TYPE 1560-P51 Ceramic Vibration Pickup,[1] it is direct reading in acceleration, velocity, displacement, and jerk. Other pickups can also be used, among them velocity-type transducers and special-purpose accelerometers responding to frequencies up to 20 kc. With many of these, the vibration meter can be adjusted to be direct reading.

The excellent performance of this instrument is made possible in large part by its stable, high-gain, wide-band, low-noise amplifier, which can also be used as a sensitive voltmeter for audio and sub-audio frequencies and as a calibrated, multi-range preamplifier for analyzers; stroboscopes; tape, graphic level, or direct-reading oscillographic recorders; and oscilloscopes.

The cover photograph shows the external features of the new TYPE 1553-A Vibration Meter. The instrument is housed in an aluminum Flip-Tilt[2] case, which combines convenience in use with protection during transportation or storage. The pickup, cable, six-inch probe, and probe tips are stored in the cover. The panel layout and readout dials have been designed to avoid ambiguities and to make the instrument simple and easy to use and to read.

[1]E. E. Gross, Jr., "Type 1560-P11 Vibration Pickup System," *General Radio Experimenter*, 34, 11 & 12, November-December, 1960.

[2]H. C. Littlejohn, "The Case of the Well Designed Instrument," *General Radio Experimenter*, 34, 3, March, 1960.

CIRCUITS

The electrical signal from the vibration pickup (accelerometer) is processed by the following electrical systems that make up the indicating instrument: the amplifier, a calibrated attenuator, three ac voltmeters, integrating circuits to convert acceleration signals to velocity or displacement signals, a differentiating circuit to convert acceleration signals to jerk signals, and a calibration circuit for maintaining amplifier gain or for setting amplifier gain to accommodate alternate pickups with different sensitivities. These are indicated graphically in Figure 1.

Amplifiers

Experience gained in the design and building of amplifiers for portable sound-level meters[3,4,5] has been put to direct

[3]E. E. Gross, Jr., "Type 1551-A Sound-Level Meter," *General Radio Experimenter*, 26, 10, March, 1952.

[4]E. E. Gross, Jr., "Improved Performance Plus New Look for the Sound-Level Meter," *General Radio Experimenter*, 32, 17, October, 1958.

[5]E. E. Gross, Jr., "Type 1551-C Sound-Level Meter," *General Radio Experimenter*, 35, 8, August, 1961.

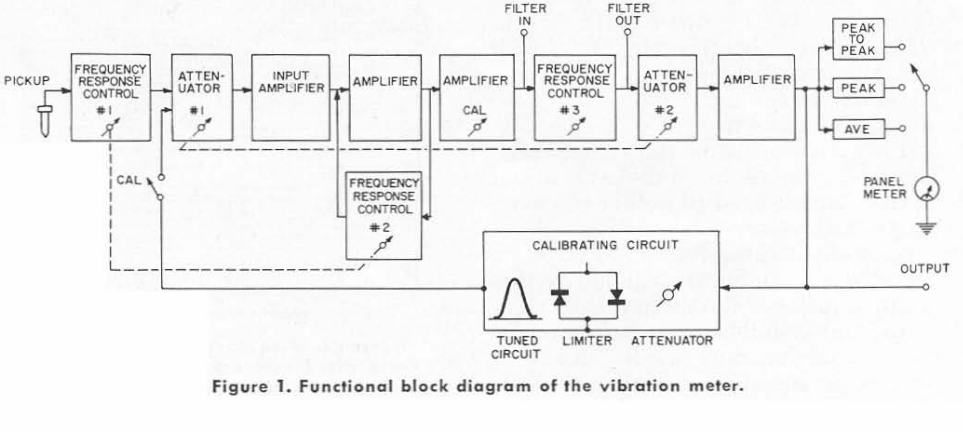

Figure 1. Functional block diagram of the vibration meter.

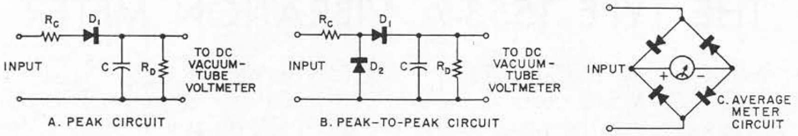

Figure 2. Elementary schematics of the voltmeter circuits.

use in the amplifiers of the Type 1553-A Vibration Meter. Similar circuitry as well as resilient mountings and supports for microphonic suppression have been employed. Transistors have been used where characteristics and stability achieved surpassed that previously obtained with vacuum tubes. In some instances, however, the requirements are, even today, better met with vacuum tubes. For example, transistorized versions of the high-impedance low-noise input amplifier are not competitive economically or reliably with vacuum-tube models. In addition, coupling and by-pass capacitors often become prohibitively bulky and expensive when low-impedance transistor amplifiers replace tube amplifiers that must have flat response to 2 cps or lower.

Voltmeters

The three voltmeter circuits with responses, respectively, of peak, peak-to-peak, and average are shown in Figure 2. The peak-indicating circuit (Figure 2a) is the well known combination of a diode rectifier, a capacitor and a dc voltmeter system. The peak-to-peak reading circuit (Figure 2b) is obtained by the addition of a second diode D_2 which detects the other peak of the voltage wave. In this circuit, the dc voltage across capacitor C, which is presented to the dc vacuum-tube voltmeter, is equal to the sum of the positive and negative peaks of the signal wave. Figure 2c shows the full-wave bridge rectifier circuit used to obtain the average reading voltmeter.

Each of the three voltmeter circuits is operated in its linear region, so that common meter scales are possible.

An emitter-follower output amplifier and silicon-junction diodes make it possible to maintain a high ratio (10^5) of $\frac{R_D}{R_C}$ (see Figures 2a and 2b) to provide true peak and peak-to-peak responses, even for very complex wave forms.[6,7] The sensitivity of the average-reading meter circuit is adjusted to be 10 db

[6] Arnold P. G. Peterson, "Response of Peak Voltmeter to Random Noise," *General Radio Experimenter*, 31, 7, December, 1956.

[7] L. L. Beranek, *Acoustic Measurements*, John Wiley & Sons, New York, 1949, pp 475-479.

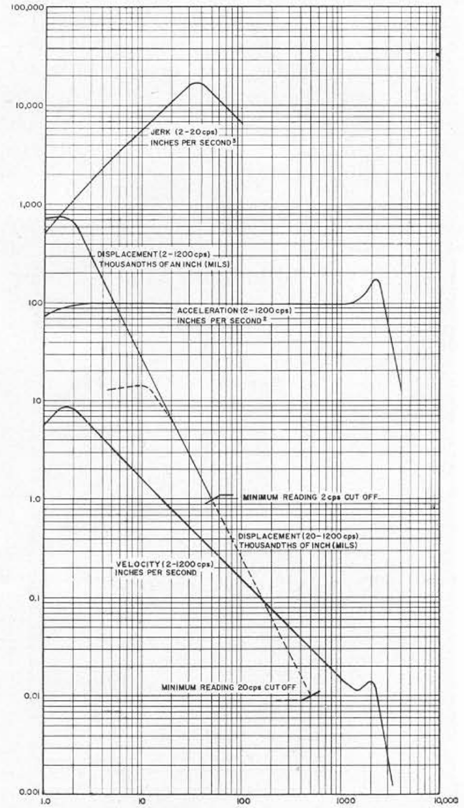

Figure 3. Frequency-response characteristics for a constant acceleration of 100 in./sec².

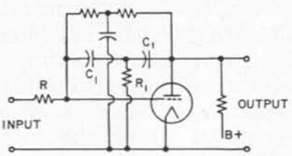

Figure 4. Schematic of improved integrating circuit.

greater than the sensitivity of the peak-to-peak reading, so that for a sine wave the same current flows through the indicating meter for average and peak-to-peak voltmeter selection. This change in sensitivity is automatically indicated in the window showing the meter full-scale reading.

Integrating Circuits

The frequency-response characteristics available in the Type 1553-A Vibration Meter with the Type 1560-P51 Pickup are shown in Figure 3. These curves show the readings obtained on the vibration meter as a function of frequency for a constant acceleration of 100 inches per second per second. Over their specified frequency ranges all responses are well within 10% of their respective design objectives. It is worth noting that the high sensitivity and good low-frequency response for velocity and displacement measurements have been achieved by an integrating circuit that performs the desired frequency-response shaping without the losses inherent in conventional integrating circuits. The circuit (Figure 4) is a modification of the familiar Miller-type integrator.[8] The grid-plate capacitor of the Miller circuit is replaced here by a form of parallel-T tuned circuit. Advantages of the new circuit are illustrated in Figure 5 which shows the low-frequency portion of the displacement response of the Type 1553-A and the computed response for two *RC* or Miller-type integrators. At f_1, the minimum desired response frequency, both responses are within 5% of the true displacement response. The difference in maximum responses (A) represents the saving in gain requirements for equivalent sensitivity on displacement afforded by the new circuit. This reduced gain requirement also means one can obtain higher sensitivity with no increase in noise level. A further improvement in noise level accrues from the new circuit because its response falls off just below its normal operating range of f_1 to nf_1.

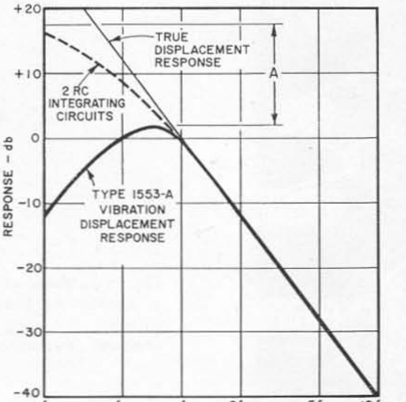

Figure 5. Low-frequency displacement response.

JERK RESPONSE

Jerk,[9,10,11,12] the time rate of change of acceleration, is the response obtained when the output of an accelerometer is differentiated. Jerk is a measure of any sudden change in acceleration of a body. It is this sudden change that is related to the riding quality of automobiles or elevators. It is important in load tie-down in railroad cars, trucks, and aircraft. Low frequencies (usually 1 to 20 cps) are of interest in jerk measurements. The rated response of the Type 1553-A for jerk measurement is 2 to 20 cps. The actual response, obtained by use of a differentiator of design* similar to the integrator described above, is, as shown

[8] *Reference Data for Radio Engineers — Fourth Edition*, International Telephone & Telegraph Corp., New York, 1957.

[9] *Ride and Vibration Data*, Special Pub. Dept. (SPC) Society of Automotive Engineers, New York, 1950.

[10] T. A. Pearls and C. W. Kissenger, "A Jerkmeter for Ballistocardiography," *NBS Report No. 4132*, Washington, D. C., June, 1955.

[11] Donald P. Eckman, *Industrial Instrumentation*, Wiley & Sons, New York 1951, p 213.

[12] Arnold P. G. Peterson and E. E. Gross, Jr., *Handbook of Noise Measurement (Fourth Edition)*, General Radio Company, 1960.

*Here the parallel-T circuit is used below its null frequency while the integrator operates above the null frequency of the parallel-T network.

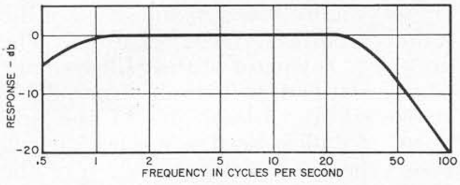

Figure 6. Response to constant jerk signal as a function of frequency.

in Figure 6, very good from 1 to 25 cps. A welcome by-product of this type of differentiator is the very good high-frequency cut-off.

READOUT SYSTEM

The information available from the Type 1553-A is indicated in a simple unconfusing manner. Figure 7 shows the appearance of the two main readout dials. The meter full-scale sensitivity always appears in the left-hand window, while the appropriate units always appear in the right-hand window. Any one of three panel controls can change the setting of the meter full-scale dial, each independently of the other two. As one might expect the SCALE SELECTOR knob controls this dial over a wide range of meter sensitivities (ten 10-db steps). In addition to pointing to the measurement characteristic and changing the units appearing in the right-hand window the FUNCTION knob also controls the number appearing in the left-hand window. The METER READS knob is the third control affecting the number appearing in this left-hand window of Figure 7. As explained earlier, the number is decreased by 3 to 1 when the knob is turned from PEAK to AVE.

CALIBRATION

Internal calibration of the vibration meter is accomplished by a method similar to that employed to calibrate the General Radio Sound-Level Meter.[4] A feedback system from output to input containing a tuned circuit, a calibrated attenuator, and limiters is adjusted to produce a 100-cycle oscillation at a level indicated on the meter when the gain of the instrument is correct. The attenuator is calibrated for pickup sensitivities of 30 to 150 mv/g. A precise setting of the meter indication in the CAL position is not required because the meter indication multiplies any change in amplifier gain, i.e. the meter reading changes approximately ten percent for each one percent change in gain. Complete system calibration including the pickup at 100 cps can readily be made with the Type 1557-A Vibration Calibrator.[13]

[13]E. E. Gross, Jr., "Little Dithers," *General Radio Experimenter*, 34, 11 & 12, November-December, 1960.

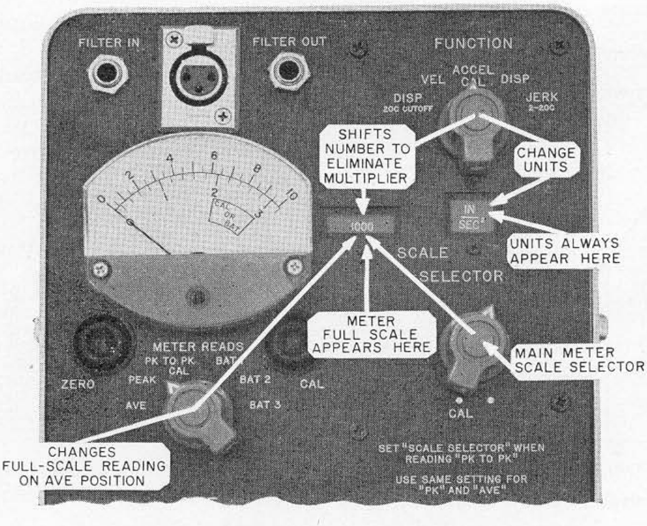

Figure 7. View of a portion of the panel showing readout system.

TABLE
TYPE 1553-A VIBRATION METER
MEASURED QUANTITIES AND MINIMUM SIGNALS

QUANTITY	MINIMUM READING PEAK TO PEAK	MINIMUM READING AVERAGE	MINIMUM SIGNAL μv rms	FREQUENCY RANGE CPS
Jerk	30 in/sec^3	10 in/sec^3	5.5	2-20
Acceleration	0.3 in/sec^2	0.1 in/sec^2	10	2-1200
Velocity	0.03 in/sec	0.01 in/sec	13	2-1200
Displacement	0.003 in	0.001 in	8.2	2-1200
Displacement	0.00003 in	0.00001 in	8.2	20-1200

SENSITIVITY AND NOISE LEVEL

Table 1 lists the effective sensitivity of the TYPE 1553-A for each measured quantity. In each case the minimum reading is 1/10 full scale. The minimum signal is the rms input voltage required to produce the minimum readings. The internal noise level of the TYPE 1553-A causes a meter reading of less than 3%, and so the signal-to-noise ratio exceeds 10 db at the minimum reading tabulated. On acceleration, which is the response one would choose when using the instrument as a voltmeter or preamplifier for auxiliary equipment, the maximum full-scale sensitivity is 100 μv rms. This is true for the 2-to-20,000 cps bandwidth as well as the 2-to-1200 cps bandwidth shown.

AUXILIARY EQUIPMENT

Analyzers

The output from the TYPE 1553-A Vibration Meter can be fed to the TYPE 1554-A Sound and Vibration Analyzer[14] when spectrum analysis of the vibration waveform is required. The combination of these two instruments permits one to obtain detailed frequency and amplitude information for all four of the vibration quantities measured with the TYPE 1553-A. Frequency analysis is necessary in many mechanical design problems and in most vibration control problems.

For shock measurements the TYPE 1556-B[15] Impact Noise Analyzer can be operated from the vibration meter output. The storage feature of the impact noise analyzer makes it possible to measure the peak value of a single shock on impact, while the time-average measuring circuit provides a measure of the shock duration.

Strobotac

The 5-volt output from the vibration meter is adequate to trigger the TYPE 1531-A Strobotac® Electronic Stroboscope,[16] so that the strobe light is synchronized with a signal from the vibration being studied.

SUMMARY

The TYPE 1553-A Vibration Meter is a small, battery-operated, portable, complex but easily operated instrument for measuring one or more of four quantities of a vibratory motion. It is normally supplied with a rugged piezoceramic accelerometer pickup that has a very good low-frequency response. Excellent high-frequency performance permits the use of many small high-impedance accelerometers for measurements up to 20 kc. Efforts to keep the operation simple have resulted in a direct readout system in which the meter full scale and proper units are always correctly displayed — no multipliers. A

[14] J. J. Faran, "A New Analyzer for Sound and Vibration," *General Radio Experimenter*, 33, 12, December, 1959.
[15] Arnold P. G. Peterson, "The Impact Noise Analyzer," *General Radio Experimenter*, 35, 9, September, 1961.
[16] M. J. Fitzmorris, C. J. Lahanas, and W. R. Thurston, "New Eyes for Industry," *General Radio Experimenter*, 34, 9, September, 1960.

true peak-to-peak meter circuit is employed and frequency-response shaping circuits are designed to give maximum sensitivity with low noise.

— E. E. GROSS, JR.

CREDITS

The TYPE 1553-A Vibration Meter was developed by E. E. Gross, author of the foregoing article. Two who contributed to the packaging and general appearance of the instrument are George Clemow, who designed the direct readout system, and Henry Sterling, who was responsible for the general mechanical design of the instrument. The project was under the direction of Dr. A. P. G. Peterson.

— EDITOR

SPECIFICATIONS

Ranges

Acceleration: 0.3 to 300,000 in./sec² peak-to-peak, 0.1 to 100,000 in./sec² average.

Velocity: 0.03 to 30,000 in./sec peak-to-peak, 0.01 to 10,000 in./sec average.

Displacement: 0.003 to 300 in. (peak-to-peak), 0.001 to 300 in. (average) from 2 to 1200 cps; 0.00003 to 30 in. (peak-to-peak), 0.00001 to 10 in. (average) from 20 to 1200 cps.

Jerk: 30 to 300,000 in./sec³ (peak-to-peak), 10 to 300,000 in./sec³ (average).

Frequency Range: Amplifier response, 2-20,000 cps; with TYPE 1560-P51 Pickup, 2 to 1200 cps for acceleration, velocity, and displacement, 2 to 20 cps for jerk.

Accuracy: ±10% of full scale.

Input Impedance: 25 megohms.

Voltage at Output Jack: 5 volts 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.

Calibration: Internal.

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

Terminals: A panel jack is provided for plugging in headphones, TYPE 1554-A Sound and Vibration Analyzer, TYPE 1556-B Impact Noise Analyzer, TYPE 1531-A Strobotac® Electronic Stroboscope, or oscilloscope.

Tube and Transistor Complement: Two CK512AX, five CK6418, one 2N520A, one 2N525, and one 2N377A.

Batteries: 3 size D cells and one 67-volt battery (Burgess Type XX45 or equivalent) supplied. Typical battery life, 7 days at 8 hours per day.

Accessory Supplied: TYPE 1560-P51 Vibration Pickup.

Case: Flip-tilt aluminum case; pickup and probe store inside.

Dimensions: Width 8, height 9¼, depth 7½ inches (205 by 235 by 195 mm), over-all (case closed).

Net Weight: 10½ lb (4.8 kg).

Type		*Code Word*	*Price*
1553-A†	Vibration Meter	WAGER	$675.00
1560-P51	Replacement Pickup*	VIBRO	80.00
	Set of Replacement Batteries	WAGERADBAT	4.10
1560-P35	Permanent-Magnet Clamp	MAGNO	6.50

*Give instrument and serial number when ordering. †U.S. Patent Nos. 2,966,257 and D187,740.

GENERAL RADIO SERVICE LABORATORY OPENED IN TORONTO

For the convenience of our Canadian customers, a new Service Laboratory was opened November 1 at the General Radio Canadian Office, 99 Floral Parkway, Toronto 15, Ontario. This Laboratory provides complete repair and calibration facilities for General Radio products. For customers who wish to make their own repairs, a stock of replacement parts is available.

THE GENERAL RADIO
EXPERIMENTER

FREQUENCY STABILITY MEASUREMENTS OF STANDARD-SIGNAL GENERATORS

- FREQUENCY DRIFT
- RESIDUAL FM
- INCIDENTAL FM
- MICROPHONICS

INTRODUCTION

Present-day uses impose rather severe performance requirements on standard-signal generators, to a degree not predictable only a few years ago. The increasing crowding of the frequency spectrum has fostered the growth of narrow-band techniques, which in turn has drawn increased attention to some of the residual frequency instabilities in the generator output. Among these are (1) frequency change with time, usually called frequency drift, (2) short-period instability, usually called fm noise or residual frequency modulation, (3) incidental frequency modulation (resulting from amplitude modulation), and (4) microphonics, or frequency changes of mechanical or acoustical origin. For a signal generator to be most generally useful in today's technology, these quantities should be held to a minimum.

An example of the extreme stability requirements is found in the testing of crystal filters, which have very sharp cut-off characteristics, with slopes as steep as a few tenths db per cycle at frequencies of the order of 10 megacycles. Obviously any appreciable frequency instability in the test source will obscure the quantity under measurement.

MEASUREMENT TECHNIQUES

With an electronic digital counter one can set the frequency of the signal generator very precisely. Since the counter measures frequency directly and continuously, it can also indicate the frequency drift, but it cannot measure the short-period frequency instability. The shortest gating-time interval (in currently available counters) is about a millisecond, which corresponds to a large number of rf cycles, one thousand of them at one megacycle. The counter thus measures the *average* frequency within the counting-time interval. To measure frequency stability over much shorter intervals requires different techniques of measurement.

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A block diagram of a measurement system for the above quantities is shown in Figure 1. This equipment is suitable for measuring the frequency drift, the residual frequency modulation, and the incidental frequency modulation, and it can display microphonically induced frequency instabilities on the oscilloscope.

FM NOISE or RESIDUAL FM

A convenient method of measuring residual fm employs a pulse-count discriminator as used in the TYPE 1142-A Frequency Meter and Discriminator. This instrument can be operated directly up to 1.5 Mc; and, by means of heterodyne techniques, at higher frequencies. The output can be fed directly to a TYPE 736-A Wave Analyzer, which will selectively measure the various frequency components of the fm noise. Most of the residual frequency modulation occurs at power-supply fundamental and harmonic frequencies, which the analyzer can easily identify. FM arising from other sources, however, may require a wide-band measurement. A calibrated, high-gain amplifier covering the full audio spectrum will show up, for example, disturbances caused by variations in power-line voltage. The residual fm may consist of a dominant 60-cycle component, corresponding to a deviation of many carrier cycles from the average frequency, at a 60-cycle rate. However, owing to transients existing on the power line, this fm signal may fluctuate violently in intensity. A narrow-band analyzer cannot respond to these fluctuations and will simply average the results in accordance with its own bandwidth.

MICROPHONICS

Another capability of a wide-band fm test system is the measurement of mechanically induced frequency shifts,

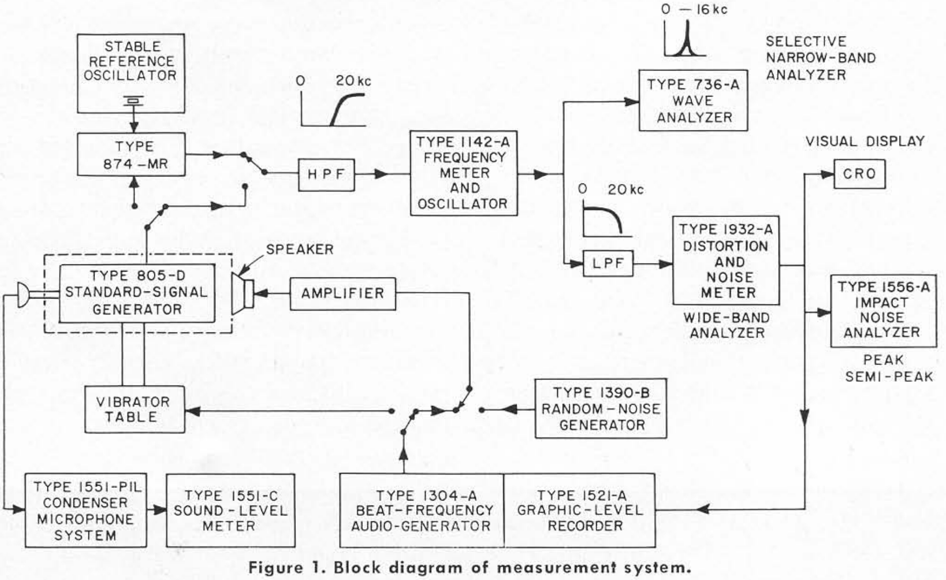


Figure 1. Block diagram of measurement system.

commonly referred to as microphonics. When one wants to reach the extreme limits of stability for a signal generator, microphonics and high acoustic noise levels may prove to be the limiting factors. When a signal generator is operated in acoustically noisy environments, it may exhibit carrier-frequency instability at frequencies related to internal mechanical resonances. It is of interest to know where these resonances are and how much frequency deviation they may be able to generate in a given environment, in order to minimize them where possible and to provide vibration isolation and acoustical insulation where practical.

A bandwidth covering at least the audio spectrum is highly desirable in the test equipment. An oscilloscope provides a convenient visual display of the audio-frequency signal from the discriminator output. An approximate frequency analysis of microphonics can easily be made by use of a shake table to vibrate the generator under test. Dominant mechanical resonances can be quickly located by visual observation on the oscilloscope as the vibrator drive-frequency is varied.

Acoustical effects, which are similar to microphonics, can be examined by use of the speaker system shown in Figure 1. For most accurate results, the generator under test should be enclosed in an anechoic chamber, although very useful results can be obtained with very much simpler enclosures. A Type 1551-C Sound-Level Meter is recommended to monitor the sound level within the enclosure.

To determine the effect of white noise upon the generator under test, the speaker can be driven by the Type 1390-B Random Noise Generator. It is perhaps more significant to examine the response to single-frequency sound as the frequency is varied over the entire audio spectrum. This can be done conveniently by use of a combination of the Type 1304-B Beat-Frequency Audio Generator and the Type 1521-A Graphic Level Recorder, as shown in Figure 1. A chart of signal-generator fm deviation magnitude vs. acoustical-excitation frequency will be obtained. Such a chart is very useful in predicting generator performance in high-level acoustical environments and serves as a guide toward elimination of unwanted mechanical resonances within the generator.

Many systems are concerned with maximum peak-amplitude signals (as opposed to rms or average), which tend to overload them, sometimes to the point of complete loss of amplification for several seconds. In such cases, the knowledge of the peak amplitude is important. The amplitude corresponding to the peak deviation of a signal generator's carrier frequency is easily measured with the Type 1556-A Impact Noise Analyzer to indicate peak deviations of the signal. A choice of time-average, quasi-peak, or peak response is provided for either polarity of the signal being measured. This permits the measurement of transient deviations, such as may result from shock or vibration.

INCIDENTAL FM

When a signal generator is amplitude-modulated, some incidental frequency modulation also occurs. The measurement of this effect imposes severe requirements on the measuring apparatus, which must be capable of handling the rf input signal without phase distortion, at any modulating frequency within the capabilities of the generator under test. A variation of phase in the generator carrier frequency during the modulation cycle will result in incidental fm. Similar phase shifts can also occur in the test apparatus and can lead to erroneous results unless adequate design precautions are taken. Measurements at very low levels of incidental fm are usually limited by this effect, especially at the high audio modulation frequencies.

While a carrier signal can be examined visually on a panoramic display device, it is difficult to identify separately the am and fm sidebands when both are simultaneously present. For this reason, the system shown in Figure 1, which employs an fm discriminator, is recommended.

One of the most important factors in the measurement of incidental fm is the complex waveform involved. As pointed out previously, signals that represent the residual fm noise of a signal-generator carrier frequency are commonly complex waveforms, dominated by strong components related to the power-line frequency. Similarly, the signals that represent the incidental fm of an amplitude-modulated carrier will vary considerably in waveform. They will contain frequencies related to the amplitude-modulation fundamental frequency. Over a wide range in modulation levels and modulation frequency, the measured signal may change from nearly sinusoidal to a highly distorted complex signal.

Thus, either the bandwidth of the measuring system must be adequate, or corrections must be made for it. Correlation between various methods of measurement can be made where the response characteristics of each system are known.

MEASURED CHARACTERISTICS OF THE TYPE 805-D STANDARD-SIGNAL GENERATOR

The measurement system of Figure 1 was used to evaluate the performance of the TYPE 805-D Standard-Signal Generator, with results as detailed below.

Residual FM Noise

In tests on the TYPE 805-D Standard-Signal Generator for frequency stability, measurements were first made of the residual-fm-noise characteristics over the entire carrier-frequency range (16 kc to 50 Mc). Records were made directly in cycles-per-second deviation, since this is the most directly useful parameter for evaluating generator performance in narrow-band systems. Pertinent data are shown in Table 1. A typical production-run instrument was taken for these measurements and the results are to be viewed as typical, rather than guaranteed.

The results show that an observed unmodulated carrier-frequency stability of the order of one- or two-cycle deviation can be achieved over much of the carrier-frequency range of the generator. Moreover, the greatest contributing factor causing this degree of instability is related to the power-supply frequency. This is evident when the dominant power-frequency-generated component is filtered out. This suggests that for critical uses improvement can be obtained through the use of a dc heater supply. The generous cabinet size and low internal-temperature rise will permit the installation of an internal transistor-regulated heater supply. With such an arrangement, the residual fm noise should approach one-cycle deviation over most of the carrier-frequency range,

TABLE I

CARRIER FREQUENCY	RESIDUAL FM			INCIDENTAL FM With 400 ~ AM at 30% AM	80% AM	MICROPHONICS Resulting from Mechanical Shock	
In Mc	± Δf Peak Deviation in cps	Major Component of Peak Deviation in cps	± Δf Peak Deviation — in cps with Major Component Removed	± Δf Peak Deviation in cps	± Δf Peak Deviation in cps	± Δf Peak Deviation in cps	Major Component of Deviation in cps
0.5	2	60	<1	75	260	500	290
1.6	1	240	<1	240	400	50	280
1.6	2	240	<1	60	260	1000	280
5	2	240	<1	360	1000	500	290
5	15	240	<1	50	200	1000	280
10	30	240	10	150	400	2000	290
16	6	30	4	290	800	500	280
16	26	240	10	425	1000	5000	280
20	35	240	13	300	700	3000	280
40	60	240	14	1500	3800	10,000	275
50	70	120	15	4200	10,000	5000	275

when the generator is operated in a normal laboratory environment.

Microphonic FM Noise

The Type 805-D Standard-Signal Generator has but one dominant mechanical resonance, and this is in the region of 275 to 290 cycles per second for most conditions. This was determined by mechanical and acoustical excitation of the generator over a wide-frequency range.

The data given in Table 1 illustrate what can happen to the carrier-frequency stability when the panel is struck a sharp blow (exceeding that likely to be encountered in normal use). A substantial frequency deviation can occur. The rate at which it will occur is largely determined by the frequency of the major mechanical resonance of the generator, while the magnitude of the deviation produced will be a function of the resonance Q and the nature of the impact.

The data shown are extreme; for normal laboratory conditions incidental fm resulting from microphonics are seldom significant.

Frequency Drift

A low-fm-noise signal generator will be of maximum utility only if its frequency-drift rate is also low. This should be low enough to enable the user to set a specific frequency and have it remain constant long enough to complete his measurement without reset annoyance. Here, again, the requirements are determined by the intended use of the generator. Since the minimum frequency drift will be obtained under constant operating conditions, it is always best to keep the generator in continuous operation to avoid the usual warm-up cycle. For those cases where this is not possible, the curves of typical frequency

Range Switching Effect

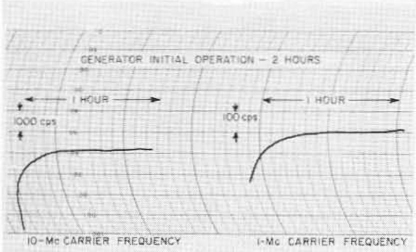
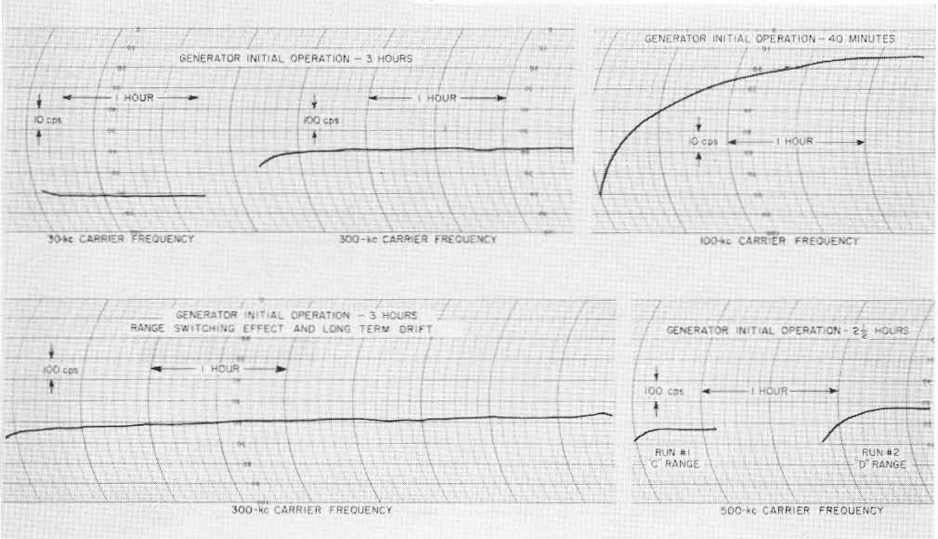
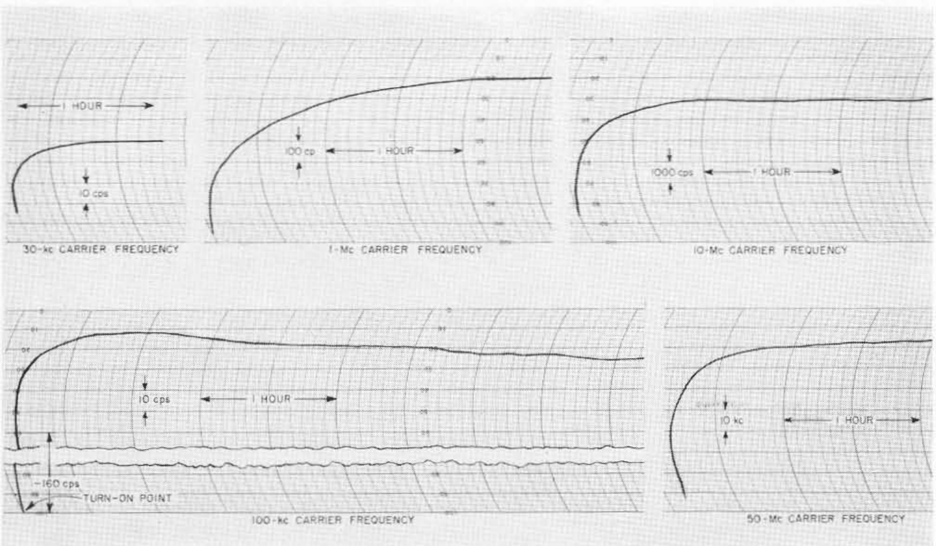


Figure 2. Graphic records of frequency drift. The upper set of curves shows the effects of range switching. The lower group shows drift at a constant switch setting. The records at the lower left in each group show typical long-term drift.



Generator Operation from Turn-On Point at Room Temperature — Cold Start



drift shown in Figure 2 will be helpful. These data represent the change in frequency beginning with the start of oscillations following turn-on of the power switch. Asymptotic stability will be reached within the first hour of operation.

Another source of frequency drift is sudden changes in oscillator-circuit conditions. Major contributors to this type of drift are band-switching and, to a lesser extent, changes in the frequency-dial setting. With the generator in normal operation (long enough to have passed through the initial warm-up cycle), a change from one frequency range to another will bring about a secondary frequency drift. Typical of the results to be expected are the curves shown in Figure 2. This characteristic appropriately defines the practical limit of frequency stability, rather than the final value reached under long-term, constant-operating conditions.

Incidental FM

In general, the incidental fm in a signal generator will be a function of carrier frequency, amplitude-modulation percentage, and modulating frequency. This last can be quite important at low carrier frequencies. The narrow bandwidths of the tuned circuits may result in substantial incidental fm being generated at high modulation frequencies. Figure 3 shows this condition for carrier frequencies in the 50- to 150-kc range. No great change in the level of incidental fm is found over this range of carrier frequency. Note, however, the rapid rise in incidental fm as the modulating frequency increases. This behavior suggests phase modulation arising from asymmetrical phases and amplitudes of the side-bands.

Figure 4 shows the incidental fm produced at the high carrier frequencies. The presence of a substantially higher level of incidental fm is clearly apparent,

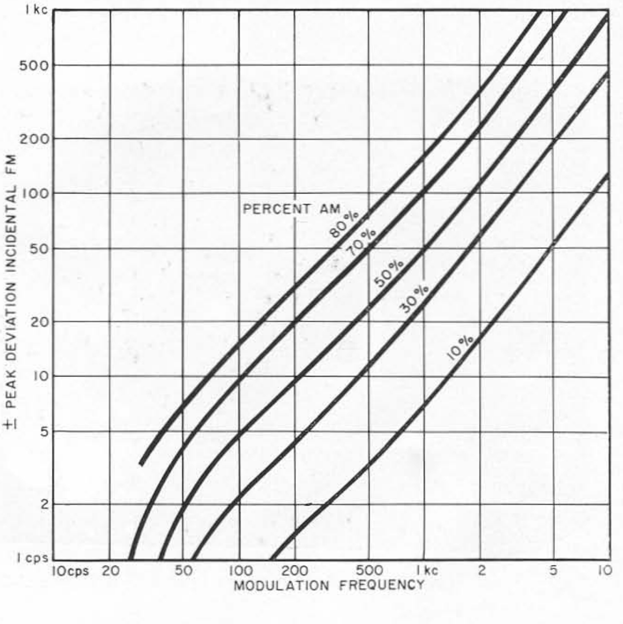


Figure 3. Incidental fm as a function of percentage modulation at carrier frequencies between 50 and 150 kc.

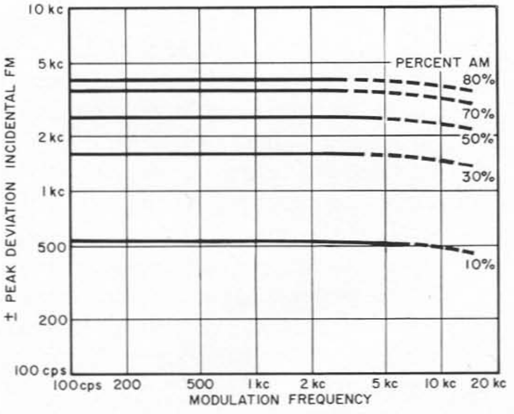


Figure 4. Incidental fm as a function of percentage modulation at high carrier frequencies.

but note the absence of a change with modulation frequency. This behavior suggests pure frequency modulation resulting from reaction on the oscillator.

Table 1 shows typical performance at two specific amplitude-modulation levels for various carrier frequencies throughout the range of the signal generator. As might be expected, the magnitude of incidental fm will increase on any given carrier-frequency range as the carrier frequency increases.

Carrier Distortion

Another characteristic of general interest to signal generator users is carrier-frequency distortion, which is important in wide-band testing. In tests on video amplifiers, for instance, carrier distortion should be held at a minimum.

Some compromise between carrier distortion and envelope (amplitude-modulation) distortion is usually necessary in an instrument covering a wide frequency range. This results from over-

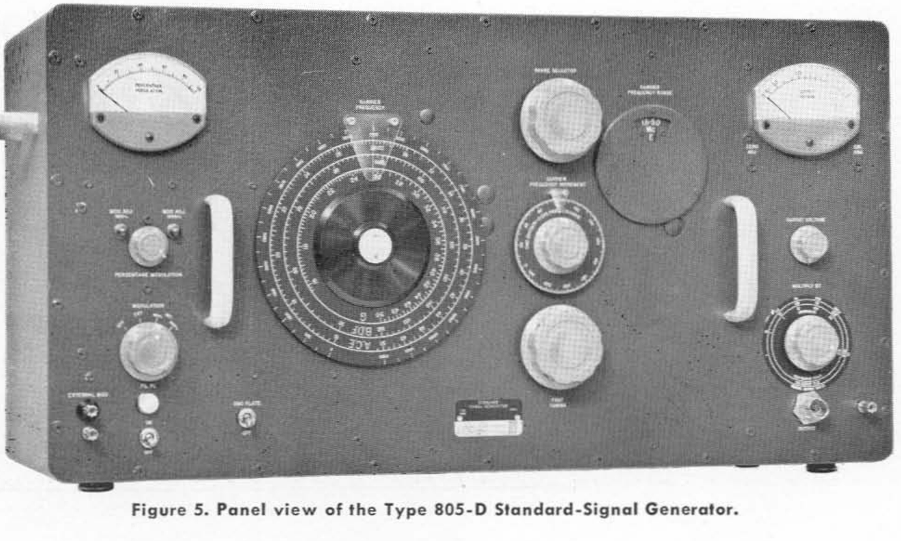


Figure 5. Panel view of the Type 805-D Standard-Signal Generator.

TABLE 2

CARRIER FREQUENCY IN Mc	CARRIER HARMONIC DISTORTION
1.6	2.3%
5	5.5%
5	1.0%
16	3.1%
16	1.2%
50	3.1%

lapping requirements in the frequency ranges, as for example, the maximum modulation frequency at the minimum carrier frequency. In the TYPE 805-D Standard-Signal Generator, these frequencies are identical but would not be used simultaneously. This imposes a practical limitation on the isolation of audio-modulation stages from the low-frequency carrier stages. Some distortion exists at low carrier frequencies from this cause. At the higher carrier frequencies, less carrier distortion is found. This results from the increasing selectivity at higher carrier frequencies. Table 2 shows results typical of the TYPE 805-D Standard-Signal Generator.

— C. A. CADY

The TYPE 805-D Standard-Signal Generator supersedes the TYPE 805-C. Older types of tubes, meters, and other components have been replaced with current types, and there have been some mechanical changes. Performance specifications and price remain unchanged and are listed in our current catalog.

A CONNECTOR IS KNOWN BY THE CONNECTIONS IT MAKES

The hermaphrodite coaxial connector (General Radio TYPE 874*) was initially greeted, upon its introduction in 1948, with reactions ranging from "Oh, no! Not another connector!" to "Good! It's about time!" Since then, this connector has seen increasing use each year and recently has been selected by several well-known manufacturers for use on new and advanced instruments. Examples of some of these large-scale uses are shown in the accompanying photographs. These manufacturers certainly have not based their selection on whim or novelty, but on sound engineering judgment and common sense. Here is a brief report about why the General Radio connector has been chosen by some of its large-scale users.

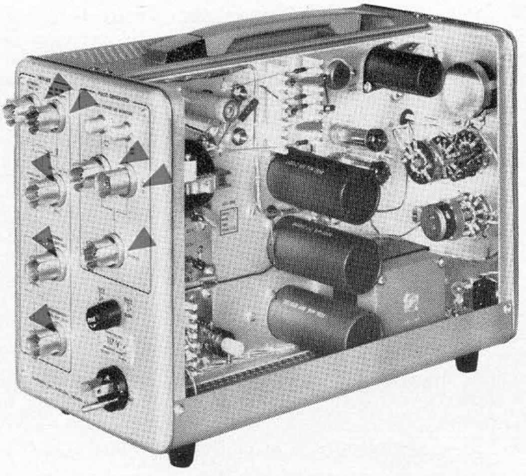
*U.S. Patent No. 2,548,457

Most people feel that there are already too many different types of coaxial connectors. This feeling poses a formidable hurdle that must be surmounted before any connector can become widely accepted. A new connector must prove that any possible complication it may bring is greatly outweighed by its advantages. For the GR connector, the major advantages are:

1. Hermaphrodite design — the resulting elimination of plugs and jacks greatly simplifies interconnections and drastically reduces stocks of adaptors and patch cords needed.

2. Reflections considerably lower than those of other coaxial connectors, and recently improved even further.

3. Convenience of quick-connect/disconnect connections — now enhanced by



Tektronix, Inc., uses the GR Connector on several new oscilloscopes, including the Model 519 DC to 1 Gigacycle Oscilloscope (125-ohm version—see paragraph at end of article), the Pulse Sampling Systems, and the recently announced Model 567 Digital Readout Oscilloscope. The versatility of these instrument systems is reflected in the various ways they can be connected, and the convenience of the quick-connect/disconnect hermaphrodite connector is very important. The ability to handle extremely fast pulses with negligible reflections was also an essential factor in the selection of the GR Connector by Tektronix.

provision of a locking arrangement,[1] effective at the user's option and compatible with non-locking versions.

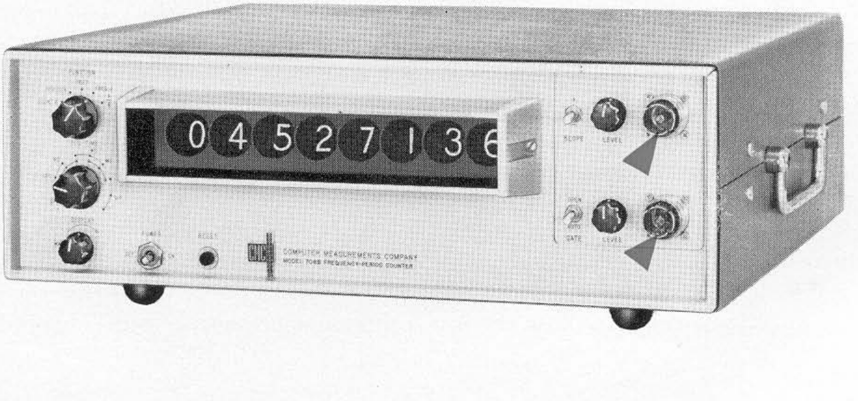
4. Availability of low-VSWR adaptors to all commonly used connector systems, with fewer adaptor types needed.

HERMAPHRODITE CONNECTORS VERSUS PLUGS AND JACKS

It was not easy to introduce the hermaphrodite connector into a well-established world of male and female connectors. It certainly was easier, though, than if the situation had been reversed, and plugs and jacks were trying to gain acceptance against the established convenience of hermaphrodite connectors. The plug-and-jack system for *power* connections has an essential, practical advantage in terms of safety, but the carry-over of the plug-and-jack

[1] "New and Improved Coaxial Connectors," *General Radio Experimenter*, 35, 10, October, 1961.

Computer-Measurements Company selected the GR Recessed Locking Connector for use on their Model 708B 100 Mc Frequency-Period Counter for several reasons. The fact that a low-VSWR adaptor to any common connector type can be locked in place on the instrument allows CMC to meet differing customer requirements very easily — and the hermaphrodite characteristic greatly reduces the number of adaptor types required. Finally, excellent shielding and low VSWR are mandatory. CMC sees this locking connector as an excellent solution to an old problem and expects it to find increasing use on modern electronic test instruments in the future.



Eldorado Electronics has selected the GR Connector for use on their Model 1-109 2-Nanosecond Time-Interval Meter. The high-frequency pulses handled by this new instrument impose severe frequency-response conditions on the connector, which must have constant-impedance characteristcs at gigacycle frequencies and excellent pulse response. The electrical performance of the GR Connector, its convenience, and the wide variety of available accessories make it ideally suited to this application.

concept into low-power, high-frequency *communications* and *measurement* equipment rarely has any basic advantage and results instead in a basic nuisance. A major reason for the adoption of the Type 874 Connector by its large-scale users has been the elimination of this nuisance — there is only one basic type, and any connector connects directly with any other. For example, the comprehensive General Radio line of vhf-uhf instruments and coaxial elements, many of which are two or more port devices, would have been much less practical and flexible without the hermaphrodite connector.

REFLECTIONS AND VSWR

Another, and important, reason for General Radio's development of the Type 874 Connector was the lack of any other connector with low enough VSWR to allow its use in a flexible system of coaxial elements for measurement pur-

At Sage Laboratories, Inc., GR Connectors are widely used in their production and laboratory test work to save time. Many of the measurements made on Sage microwave components, such as their TEMLINE Hybrid 3 db Couplers, involve many connect/disconnect operations to determine coupling, directivity, and VSWR for each unit over its frequency range. These components are temporarily fitted with GR adaptors to make the operator's work easier and to avoid wear on the equipment under test.

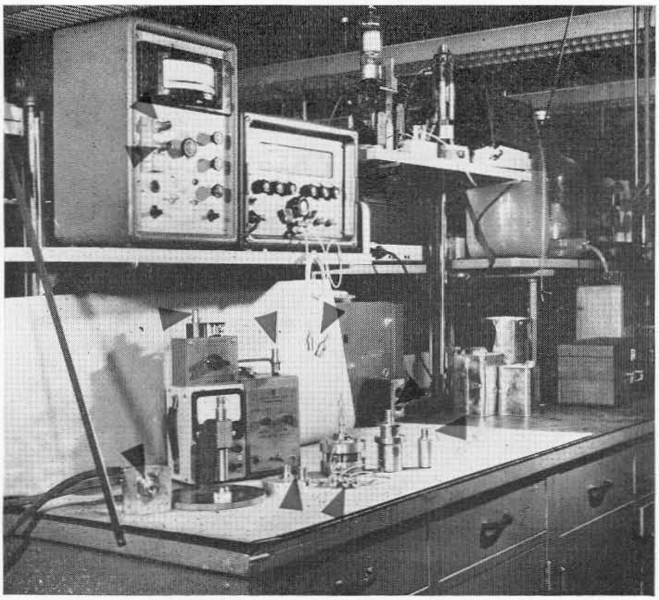
Edgerton, Germeshausen & Grier, Inc., uses the GR Connector on their Model 751 Pulse Generator. The major factors that influenced their selection are ease of use ("no plugs or jacks to worry about"), excellent electrical characteristics, and ruggedness ("a good, rugged connector").

poses. Since the GR connector's introduction, other connector types have been substantially improved (and many *new* types created — e.g., C, HC, SC, TNC, etc.), but the GR connector, which itself has been improved by many refinements, *still* has the lowest reflections of any general-purpose coaxial connector in its frequency range (dc to 7 Gc).

Some of the reasons for this performance are:

1. Larger internal diameters (about twice the dimensions of Type N) reduce

The General Electric Company's Chemical and Materials Engineering Laboratory in Schenectady has largely eliminated connector problems in the wide variety of measurements they make between DC and 50 Mc by selecting the GR Connector for use on their equipment. This equipment includes screened rooms, controlled-temperature chambers, dielectric-specimen holders, and measuring instruments of various makes, which are modified on arrival to use the GR Connector. This laboratory uses Teflon beads (available on special order) in the GR Connectors in order to permit use in high-temperature tests and to reduce difficulties from dirt and moisture in measuring systems involving extremely high impedance levels.



Ballantine Laboratories, Inc., needed a well-shielded connector that would mate without any kind of twisting action for their Model 393 High-Frequency Transfer Voltmeter. In this highly accurate instrument the interchangeable measuring probes are plugged straight into a deep panel recess, with the connector joint inaccessible, for DC standardization after first being connected to an unknown rf voltage to be measured.

errors due to any specified absolute tolerance in dimensions. However, the *outside* diameter of the GR connector is *not* greater in proportion to its larger internal diameters, because its design is simpler and more efficient in this respect.

2. Tighter *absolute* tolerances of internal dimensions of *mated* connectors resulting from more favorable connector geometry and through use of special control methods in fabrication processes (to be described in a future article).

3. Hardened beryllium-copper inner-conductor spring contacts give stability and permanence to the initial low VSWR of the GR connector.

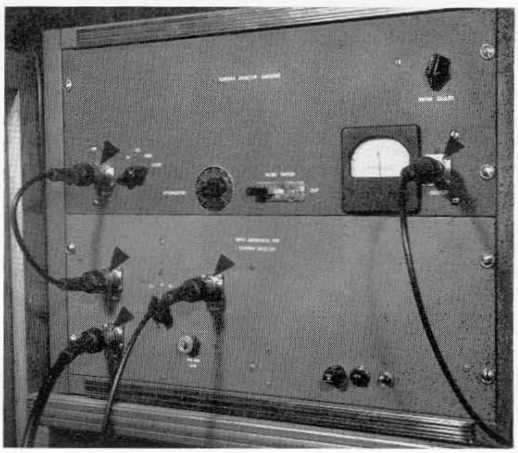
4. Optimum insulator design, in terms of diameter compensation, spacing-to-thickness ratio, etc.

The advent of fast-pulse counting circuits and oscilloscopes covering a spectrum to hundreds or thousands of megacycles has further accelerated the demand for low-VSWR connectors.

CONNECTION CONVENIENCE

Other connectors are of two basic styles — bayonet-lock types (such as Types C and BNC) for use where connect/disconnect speed is most important, and screw-on types (such as Types N, SC, and TNC) for use where the mechanical weakness and electrical leakage of bayonet-lock types are intolerable. A choice must be made — convenience versus strength and shielding.

No such choice is necessary with the



The Physics-of-Insulation Section of the Westinghouse Research Laboratories uses the GR Connector widely on measuring equipment operating at frequencies from DC to microwaves. Ten to fifteen years ago, before adopting this connector, they used three or four different connector types, each with male and female versions, and found them to be a continual source of inconvenience. Now the single GR hermaphrodite type is used wherever possible on such instruments as standard oscilloscopes, special fast-pulse corona test apparatus, amplifiers, special capacitance bridges, and interconnecting cables. As a result, more time can be spent on the measurement and less on the setup.

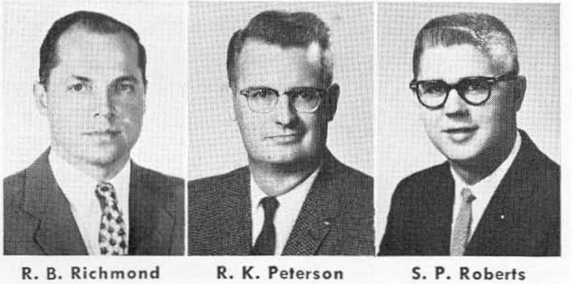
new TYPE 874 Locking Connector. A locking sleeve is provided and is always ready, but its use is optional. Therefore, *in one connector*, *speed* and *convenience* have been *combined with* high mechanical *strength* and *low* electrical *leakage*.

HIGH-IMPEDANCE CONNECTORS

Several organizations have satisfactorily adapted the GR connector to 100-ohm and 125-ohm impedance levels. The 9/16-inch electrical diameter of the outer conductor allows inner-conductor dimensions large enough to be practical, and the basic connector design makes it relatively simple to use high-impedance bead and inner-conductor designs while still retaining the desirable hermaphrodite characteristic. These high-impedance designs are used on equipment associated with ion or radiation detectors in order to obtain maximum output from the detectors, which are constant-current devices. Large-scale users of these high-impedance versions of the GR connector are Tektronix, Inc., and Edgerton, Germeshausen & Grier, Inc. In every instance so far, General Radio has supplied the outer conductor parts only, with the user furnishing the high-impedance beads and inner conductors to obtain the desired impedance level of either 100 ohms or 125 ohms.

— W. R. THURSTON

THE NEW ENGLAND OFFICE



R. B. Richmond R. K. Peterson S. P. Roberts

While the New England District Office is physically located at our home office in Concord, it is operated in much the same manner as our other district offices. The New England Office is responsible for sales in all the New England states, except for the Southern Connecticut area which is served by our New York Office.

The New England Manager is Robert B. Richmond. He is assisted by Ralph K. Peterson and Stuart P. Roberts. Mr. Peterson has recently transferred from the general sales engineering group and will devote his full time to our Connecticut and Massachusetts customers. Mr. Roberts joined the General Radio Company two years ago and will be responsible for much of the sales coverage in Eastern Massachusetts and Rhode Island.

A telephone call to these engineers at EMerson 9-4400 or MIssion 6-7400 will bring prompt information about General Radio products.

GENERAL RADIO IN FLORIDA

The accompanying photograph shows the entrance to our new Florida office, announced in the October issue of the EXPERIMENTER. Located at 113 East Colonial Drive, Orlando, the office is managed by John C. Held of our Sales Engineering Staff. Telephone is GArden 5-4671.

General Radio Company

extends to all *Experimenter* readers its best wishes

for a Happy and Prosperous 1962.

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