the GENERAL RADIO Experimenter

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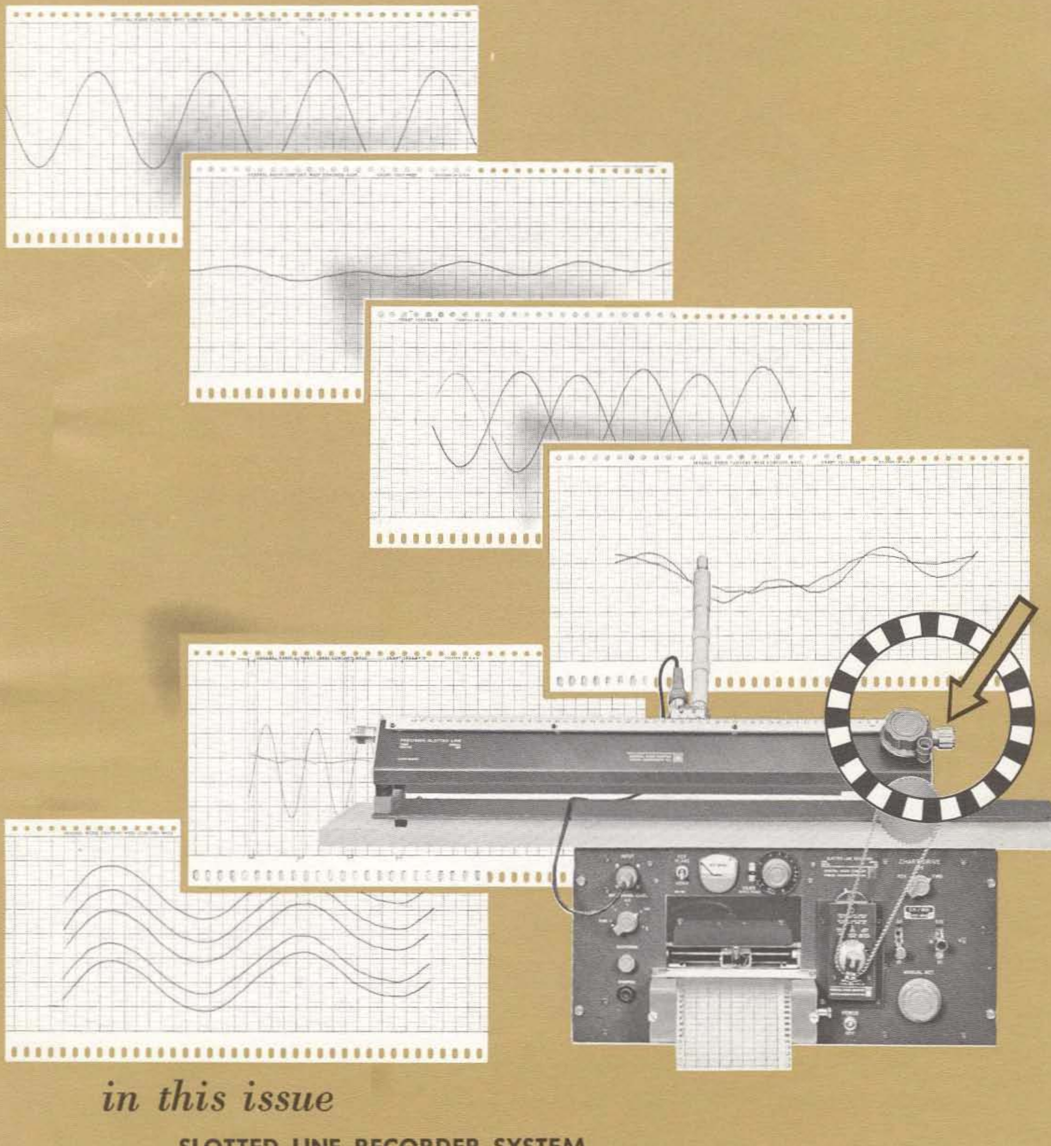

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SLOTTED LINE RECORDER SYSTEM

NEW PRECISION COAXIAL ELEMENTS—

Reference Air Lines, Tuner, Terminations, Adaptors, Co

the GENERAL RADIO experimenter

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A SLOTTED LINE RECORDER SYSTEM

With the introduction of the GR900 Precision Coaxial Connector[1] and associated equipment[2], the trend to greater accuracy and precision in microwave impedance measurements has been greatly accelerated. Not only does the connector itself boast a VSWR an order of magnitude better than that of any previous connector, but the availability of such a true precision connector has led to the development of a GR900 line of components and devices, all of which share the connector's electrical and mechanical excellence.

An expanding, self-refining technology demands improvements not only in devices but in techniques. Given the new tools of the GR900 line, we were able to reappraise the traditional methods of measurement, to see whether remaining limitations were imposed by the procedures themselves, by the available equipment, by the method of data presentation, or by some other factor capable of improvement.

As the basic tool in coaxial impedance measurements, the slotted line remains unsurpassed; its accuracy is absolute, since its standard impedance is the characteristic impedance of a coaxial line. The inherent accuracy of the slotted line, as well as its stability and broad bandwidth, led to the investigation of the limitations of this instrument for low VSWR measurements. As might be expected, we found the limiting factors to be not in the slotted line itself but in the noise level and limited scale expansion of commercial standing-wave indicators. This conclusion led to the development of the TYPE 1640-A Slotted Line Recorder System.

The combination of a slotted line and a graphic recorder produces a recording of the slotted-line probe output as a function of probe position that far exceeds, in resolution and usefulness, the conventional meter readout. The noise figure of the transistorized TYPE 1640-A System is held to less than 5 dB, and the high signal-to-noise ratio at the crystal detector (normally over 80 dB) is preserved through the amplifier chain and the recording process. The recording of VSWR's as low as 1.001 with excellent signal-to-noise ratio is entirely practical.

The use of a slotted line recorder system not only overcomes the traditional scale-factor and noise problems but also offers the many advantages of a permanent recording. The chart record, for example, can be analyzed graphically for the most accurate measurement of VSWR, position of minimum, and other waveform characteristics. The minima of low-VSWR patterns are particularly difficult to locate by traditional techniques, because of their shallowness and because of the apparent shift of position if tilt exists in the flatness curve. On a chart record, the positions of minima are strikingly easier to locate, not only because the pattern is greatly expanded, but also because the VSWR pattern and the flatness curve are easily disentangled when both are visible together.

[1] A. E. Sanderson, "A Radically New Coaxial Connector for High-Precision Measurements," *General Radio Experimenter*, February–March 1963.
[2] John Zorzy, "Precision Coaxial Equipment — The 900 Series," *General Radio Experimenter*, November 1963.

Several plots can be made on the same chart so that, for example, the positions of minima with short-circuit termination and with unknown at the reference plane can be intercompared directly. Wherever the *difference* between two measurement conditions is important, any irregularities in the slotted line (in constancy of probe penetration, for instance) effectively cancel out in a multiple plot, and the difference shows up clearly as a sinusoidal wobble of one trace about the other (see Figure 1). Because of the effective elimination of slotted line imperfections from the measurement, the substitution method by graphic recording yields the most accurate, repeatable measurements of low VSWR — with the TYPE 1640-A, down to 1.001.

Repeatability and comparison measurements are also facilitated by the multiple-recording technique. A series of measurements, for instance, can be plotted on the same section of chart paper as a rapid method of comparison-checking components against a standard. The graphic record also quickly reveals whether the measurement is a true one or whether it is being distorted by a noisy signal generator, a connector that doesn't repeat, or some other unforeseen factor. Finally, as a continuous monitor on equipment operation, the recording far surpasses the usual VSWR meter in convenience.

THE TYPE 1640-A SLOTTED LINE RECORDER SYSTEM

The new Slotted Line Recorder System, shown in Figure 2, comprises a standard TYPE 900-LB Precision Slotted Line and a modified version of the TYPE 1521 Graphic Level Recorder (TYPE 1521-SL), along with the necessary interconnecting linkage and mounting hardware. The slotted line is mounted in its usual bench-top position, and the recorder is beneath the bench, either on a shelf or suspended from the bench top with the bolts provided. The metal mounting plate on which the slotted line rests has four studs, which engage the rubber feet of the slotted line, and a projecting shaft. A gear on one end of this shaft is coupled to the probe-carriage drive, and a sprocket on the front end engages the external chain-link drive of the recorder. The motor that powers the chart drive thus also drives the probe carriage of the slotted line, and the chart paper is automatically given the correct horizontal axis for the desired VSWR plot. The vertical axis of the plot is supplied by the audio output of the crystal detector, which is connected by a coaxial cable from the probe

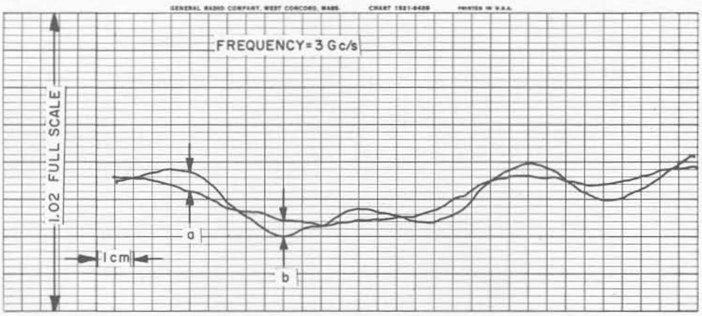

Figure 1. Multiple plot used to measure difference between two measurement conditions. Note that the difference in the recording (a + b) is a sine wave corresponding to a VSWR of 1.002!

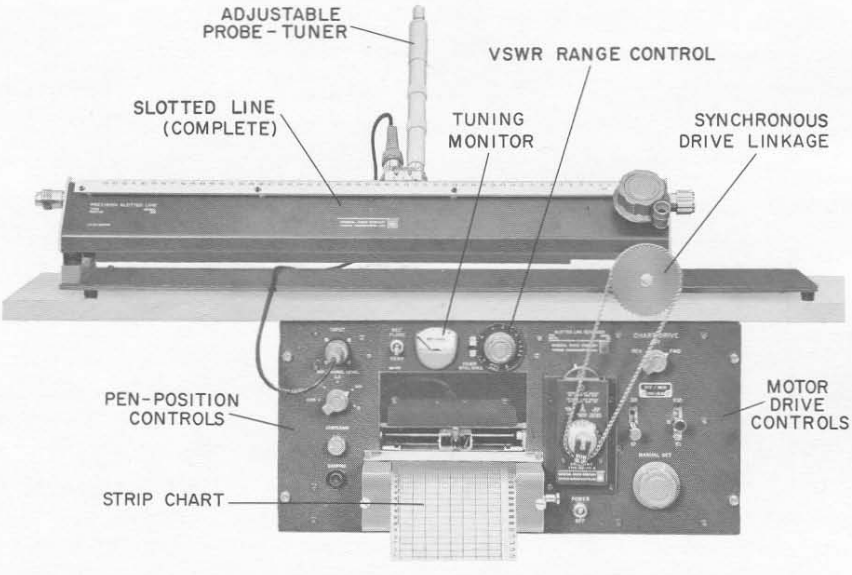

Figure 2. Type 1640-A Slotted Line Recorder System. Owners of Type 900-LB Slotted Lines can easily add recorder and connecting linkage. Prices are available on request.

carriage to the recorder input connector. The recorder suppresses the zero level and applies the resulting greatly expanded VSWR pattern to the vertical axis of the strip chart. The degree of scale expansion is remarkable: On a typical VSWR meter a VSWR of 1.10 takes up two inches of scale, whereas a VSWR of *1.008* can be expanded to the full 4-inch width of the chart paper!

THE SLOTTED LINE

The TYPE 900-LB Precision Slotted Line[2] is the most precise coaxial impedance-measuring instrument available commercially, with a residual VSWR of $1.001 + 0.001 f_{Gc}$ from 300 Mc/s to 9 Gc/s; it is, moreover, an extremely rugged, reliable instrument whose calibration can be expected to stay within specification indefinitely. The forged outer conductor joins its connectors smoothly, without the reflection-causing steps and discontinuities found in noncylindrical coaxial slotted lines.

The chrome-plated outer conductor of the line is a 26-inch, precision-forged, brass tube, lined with a 0.0005-inch layer of pure silver for low loss. The finished inner diameter is 0.5625 inch $\pm$ 100 microinches. The inner conductor is steel with a 0.0005-inch layer of silver and is centerless-ground to a tolerance of $\pm$ 50 microinches. Both inner and outer conductors are stress-relieved to resist diameter changes due to machining.

Two interchangeable electrostatic probe assemblies are supplied: a tunable probe for use with the built-in detector for modulated signals and an rf probe to couple an unmodulated signal to an external detector. Either mounts in the carriage that transports the probe through the entire 50-cm length of the slot. This cast brass carriage, with its honed sleeve bearing, rides

[2] Zorzy, op. cit.

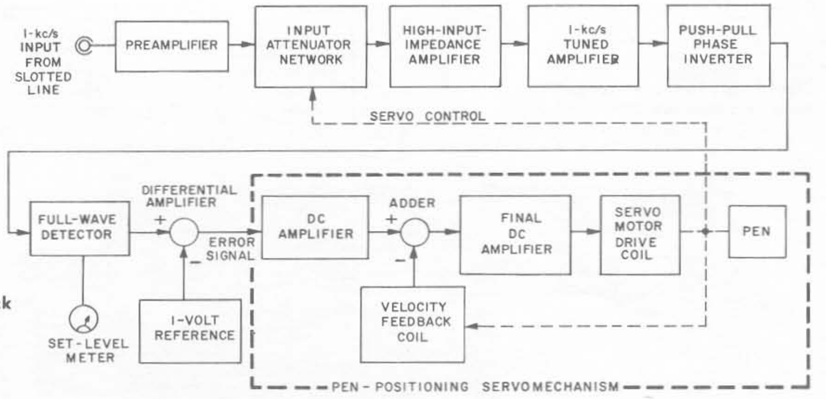

Figure 3. Block diagram of Type 1521-SL Slotted Line Recorder.

smoothly on the finely ground surface of the outer conductor.

Probe position along the 50-cm slot, relative to the reference plane of the GR900 connector, is indicated to within 0.1 millimeter by a calibrated millimeter scale with attached vernier.

Depth of penetration of the tunable probe is controlled and indicated by a micrometer adjustment. The scale is preset to indicate directly the distance between the probe tip and the center conductor (smallest marked interval: 0.001 inch). A positive stop prevents the probe from striking the center conductor.

The probe is tuned to resonance (at any frequency from 300 Mc/s to 9 Gc/s) with a built-in short-circuited stub, whose length is adjusted by means of a rotating barrel drive. One turn of the barrel moves the short circuit 1 cm. A logging scale indicates position of the short circuit within the barrel.

SLOTTED LINE RECORDER

The Type 1521-SL Slotted Line Recorder is a transistorized, single-frequency, servo-type instrument (see block diagram, Figure 3), which produces, on white chart paper, an ink record of the standing-wave pattern of the slotted line. Scale expansion is continuously adjustable, with the control calibrated in VSWR, % FULL SCALE (a VSWR of 1.01 is defined as equivalent to 1%). Standing-wave patterns of 1.2 to 1.008 in VSWR can be expanded to occupy full scale.

The VSWR accuracy of the strip-chart

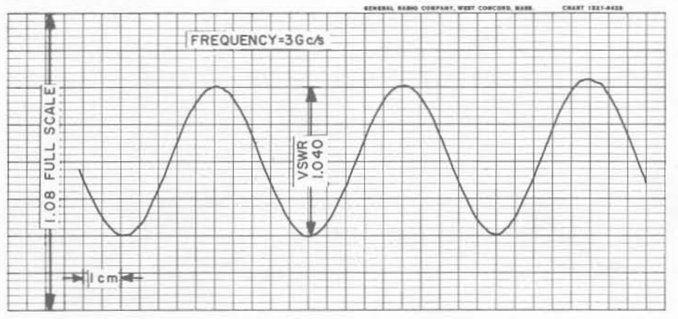

Figure 4. Typical direct recording of VSWR.

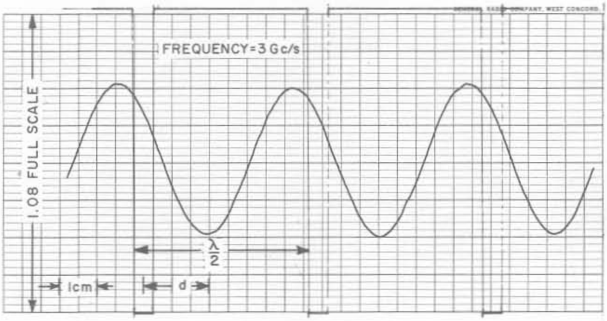

Figure 5. Multiple recording used in direct measurement of VSWR and phase.

recording depends only on three stable, wire-wound potentiometers in the servo loop. These are custom-calibrated in each instrument. The accuracy is within one minor division of the chart paper (1/40th of full scale) for all positions of the VSWR, % FULL SCALE control.

Sensitivity (the minimum signal level for an on-scale indication) is continuously adjustable from 50 microvolts to 2 millivolts. The 2-millivolt upper limit is set by the square-law characteristic of the crystal detector, the 50-microvolt lower limit by the degradation in signal-to-noise-ratio (which also determines the minimum detectable VSWR).

The amplifier is fixed-tuned to 990 c/s (avoiding harmonics of 60 c/s and 50 c/s) and has a 35-cycle bandwidth. The 5-dB noise figure at this bandwidth results in a VSWR-equivalent noise level of 1.0001 (0.01%) at an audio input signal level of 1.0 millivolt.

Chart Drive

The chart drive has four speeds; since two sprockets of 2:1 different sizes are supplied, there are eight possible slotted-line carriage drive speeds, from 5 to 0.08 centimeters per second. One horizontal division on the chart paper corresponds to either 1 or 0.5 centimeter on the slotted-line scale, depending on which sprocket is used. Fast chart speeds and the 1-cm/division sprocket are used at lower frequencies, while the slower speeds and the 0.5-cm/division sprocket expand the horizontal scale for better precision at the high end of the band. *At any frequency from 0.6 to 9 Gc/s, two full cycles of the standing-wave pattern can be scanned in five seconds, without perceptible distortion of the standing-wave pattern.*

APPLICATIONS

Direct VSWR Measurement

The primary application of the Slotted Line Recorder System is, of course, the measurement of the VSWR of an unknown one-port component by the direct method. If VSWR alone is desired, the recorder motor drive is engaged for at least one cycle of the standing-wave pattern, to produce a record similar to that shown in Figure 4. If the phase of the VSWR pattern is also important, then a TYPE 900-WN Short-Circuit Termination (supplied with the system) is connected in place of the unknown, and a second curve is superimposed on the first (see Figure 5). The distance between positions of minima is then measured directly on the chart paper, as is wavelength, and the value of d/λ, thus determined, is transferred to the Smith chart as wavelengths-toward-load. The ease with which the

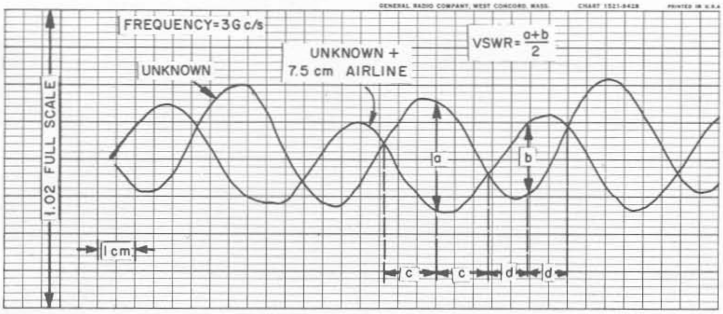

Figure 6. Multiple recording used in substitution-method VSWR measurement.

positions of minima can be located graphically ensures excellent phase measurements, even for VSWR's as low as 1.01.

Direct VSWR measurements can be made on connector systems other than GR900 by means of GR900 precision, low-VSWR adaptors. These are now available to types BNC, C, N, TNC, and GR874 connectors (see page 17).

Substitution VSWR Measurement

For even greater accuracy, a substitution technique can be used,[3] with a TYPE 900-LZ Reference Air Line acting as an impedance standard. Accuracy of measurement is increased by a factor of from 2 to 5, depending on frequency, and the position of minimum can be located accurately for a VSWR as low as 1.001.

In the substitution method, a multiple plot is recorded, showing (1) the VSWR of the unknown connected directly to the slotted line and (2) the VSWR with the reference air line inserted between the unknown and the slotted line. (See Figure 6.) With the impedance transformation of a quarter-wave air-line section, the difference between the two curves represents twice the VSWR of the unknown impedance with respect to the reference air line. The residual VSWR of the slotted line effectively cancels out.

To determine phase, a curve is run with a short circuit at the reference plane, as before (see Figure 7). The position of minimum of the unknown is halfway between two adjacent intersections on the multiple VSWR plot and can thus be located with pinpoint accuracy,

[3] A. E. Sanderson, "A New High-Precision Method for the Measurement of the VSWR of Coaxial Connectors," *IRE Transactions on Microwave Theory and Techniques*, Vol MTT-9, No 6, November 1961, pp 524–528.

[4] A. E. Sanderson, "Calibration Techniques for One- and Two-Port Devices Using Coaxial Reference Air Lines as Absolute Impedance Standards," Instrument Society of America Preprint 21.6–3–64.

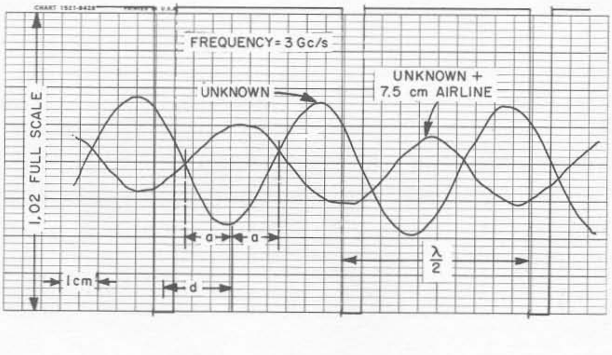

Figure 7. Multiple recording used in substitution-method VSWR and phase measurement.

no matter how low the VSWR may be. As before, d and λ are both on the chart paper, and their quotient becomes the "wavelengths-toward-load" reading on the Smith chart.

Insertion VSWR

Many of the most common design problems can be cast in the form of two-port unknowns, and the insertion VSWR of a two-port unknown can be measured very accurately on the slotted-line recorder system by a substitution method.[3, 4] Examples of design problems centering on the insertion VSWR are the design of coaxial connectors, of isolated bead supports, or of transitions between coaxial lines of different diameters. Separating the reflections of the two-port unknown from those of the slotted line and termination has always been difficult in such design problems. In the substitution method with the recorder system, separation is easily achieved, since the undesired reflections cancel out, while the desired reflections do not. The insertion VSWR of the two-port is the difference between two curves recorded on the same section of chart paper, just as in the one-port substitution method described above. The short-circuit reference plane marks can also be recorded on the chart paper for Smith-chart plots of the measurement (see Figure 8).

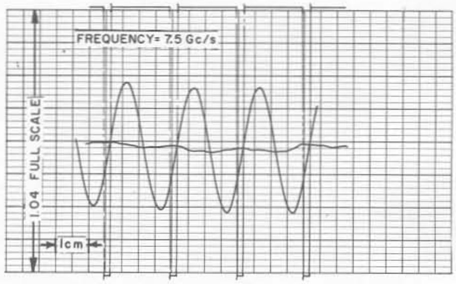

Figure 8. Recording showing insertion VSWR of a mated pair of GR900 adaptors (Types 900-QNJ and -QNP) at 7.5 Gc/s.

Repeatability

In the process of any VSWR measurement it is important to check periodically that the measurement is repeatable, that is, that it can be duplicated several times in succession with a variation no greater than the rated repeatability of the connector (for the GR900, 0.05%). The TYPE 1640-A system is well suited for such checks, because several successive curves can be plotted on the chart for direct intercomparison, as shown in Figure 9. For this check, it is desirable to match the slotted line to its load by means of the TYPE 900-TUA Tuner (see page 15) for maximum recorder scale expansion (1.008 full-scale). The successive curves are spaced with the recorder CENTERING control and should agree within 0.05%, or 1.0005.

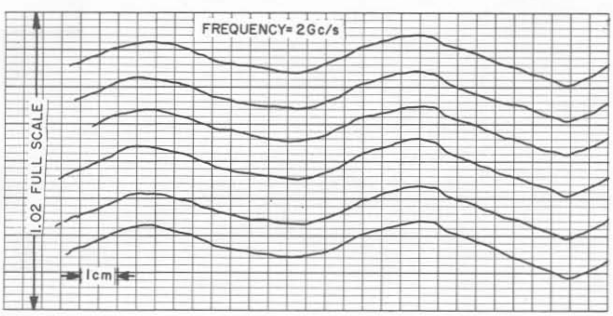

Figure 9. Multiple recording showing excellent repeatability of GR900 joint with connectors at six different orientations, in a very low VSWR measurement.

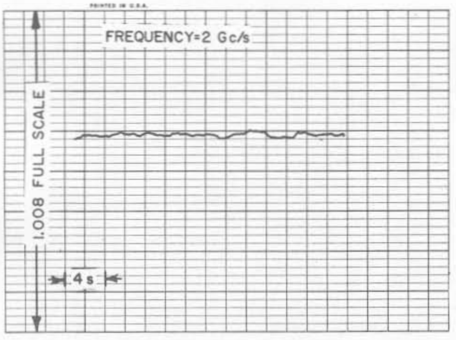

Figure 10. Typical recording of system noise at 2 Gc/s, with Type 1360-B Microwave Oscillator used as signal source. Chart speed was 30 div/min. Note that total excursion over entire 25-second recording is equivalent to VSWR of only 1.0002.

System Noise Check

The equivalent noise level of the system, all-important in precision VSWR measurements, can be checked easily with the TYPE 1640-A Slotted Line Recorder System. Contributing about equally to the system noise are three sources: the signal sources, the crystal detector, and the recorder itself. To measure the VSWR equivalent of system noise, the probe carriage drive is declutched, the recorder set for maximum resolution, and the chart drive activated. Since the probe is not moving, the sole cause of any wiggles on the chart is system noise. The peak-to-valley noise excursions can then be translated into an approximately equivalent VSWR. In the example of Figure 10, the peak-to-valley ratio is 0.02%, for a VSWR equivalent of 1.0002. This amounts to a basic figure of merit for the system, since the VSWR of the unknown must be comfortably above that of the noise level in order to give accurate results.

SUMMARY

The use of a graphic level recorder greatly enhances the usefulness of the precision slotted line. Among the benefits derived from this synergistic alliance are:

— a scale expansion that makes the recorder the equivalent of a VSWR meter with a 10-foot-long scale,

— a signal-to-noise ratio of over 80 dB,

— the pinpoint location of positions of minima,

— the many advantages of multiple recording (in substitution measurements, for example),

— the possibilities of graphical analysis of recordings,

— the availability of permanent recording for reference and later study.

For engineers working on coaxial design problems, for instructors wishing to demonstrate standing-wave phenomena most effectively, for anyone concerned with slotted-line measurements, the TYPE 1640-A Slotted Line Recorder System merits very serious appraisal.

— A. E. SANDERSON

SPECIFICATIONS

SLOTTED LINE (TYPE 900-LB)

Characteristic Impedance: 50.0 ohms ±0.1%.

Probe Travel: 50 cm. Scale calibrated in centimeters from reference plane. Attached vernier can be read to 0.1 mm.

Scale Accuracy: ±(0.1 mm + 0.05%).

Frequency Range: 0.3 to 9 Gc/s. At 300 Mc/s, covers a half wavelength. Operates below 300 Mc/s with TYPE 900 Precision Air Line.

Constancy of Probe Pickup: ±0.5%.

Residual VSWR: Less than 1.001 + $0.001f_{Gc}$ (e.g., 1.002 at 1 Gc/s).

Accessories Required: Generator and detector.

Dimensions: Width 27½, height 10, depth 4¾ inches (700, 255, 125 mm).

RECORDER (TYPE 1521-SL)

Sensitivity: Continuously adjustable from 0.05 to 2.0 mV (on-scale).

Frequency: 990 c/s ± 2%.

Bandwidth: 35 c/s ±7 c/s (at 3 dB).

VSWR Range: Continuously adjustable from 1.008 (0.8%) to 1.20 (20%) full-scale; accurate to within one minor division.

Noise Level (referred to input): Short-circuit, less than 0.1 μV; open-circuit, less than 3.0 pA. Noise figure less than 5 dB at the optimum source resistance (about 30 kilohms).

Power Required: 105 to 125 or 210 to 250 V, 60 c/s, 35 W. Type 1521–SLQ1 Recorder, used with Type 1640-AQ1 System, 50 c/s.

Chart Paper: 4-inch recording on 5-inch paper; 40 minor and 8 major divisions vertically. Horizontal scale ruling, ¼ inch.

Paper Speeds: Adjustable, 2.5 to 75 inches per minute; plots correspond to 5- to 300-cm/min carriage travel on slotted line. Two interchangeable sprockets advance paper 1 or 2 horizontal divisions per cm probe travel.

Servo Bandwidth of Pen Drive: More than 4 c/s.

Input Connector: GR874 Coaxial Connector, locking, recessed.

SYSTEM

Accessories Supplied: Type 874-R22A Patch Cord; Type 900-WN Precision Short Circuit; Type 900-WO Precision Open Circuit; tuning stub — probe assembly (including 1N21C and 1N23C crystals); rf-probe assembly (with Type 874-BL Connector); micrometer carriage drive (accurate to 0.01 mm); spare drive cable; storage box; Smith charts; two pens; 2 oz red ink; 2 oz green ink; potentiometer cleaner; 10 100-ft rolls of chart paper; eyedroppers for filling pen; power cord; spare fuses.

Bench Space Required: Width 48, depth 14 in (1220 bv 355 mm); height above bench, 12 in, depth below bench, 9 in (315 and 230 mm).

Net Weight: 67 lb (37 kg).

Shipping Weight: 120 lb (55 kg).

Type		*Price*
1640-A	**Slotted Line Recorder System** (for 60-cycle supply)	**$1975.00**
1640-AQ1	**Slotted Line Recorder System** (for 50-cycle supply)	**1975.00**

U.S. Patent No 2,581,133; 2,548,457.

REFERENCE AIR LINES FOR THE GR900 SERIES

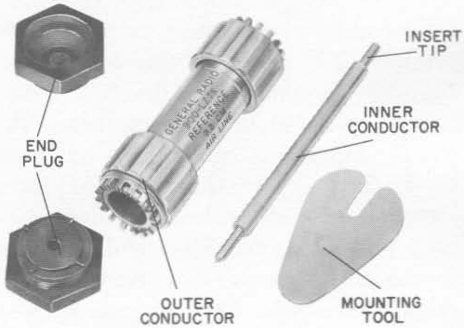

Figure 1.

New GR900 Reference Air Lines derive exceptionally low vswr chiefly by the elimination of bead supports. The inner conductor is suspended instead by the center contacts of the GR900 connectors with which the air line is mated (see Figure 1 above and Figure 1, page 19). Use of the beadless GR900 connection helps make the accuracy of these air lines several times that of the Type 900-BT Connector. Thus GR900-equipped instruments and components can now be quickly and conveniently calibrated with respect to the new standards. For example, the Type 900-LB Precision Slotted Line, whose vswr accuracy specification is 1.001 + $0.001f_{Gc}$, can typically be calibrated to an accuracy of 1.0008 or better with the Type 900-LZ Reference Air Lines and the new Type 900-TUA Tuner. With this new calibration system, the customer can now verify the performance of any GR900 device and, if he desires, correct measured data for the effect of the small residual VSWR's that are present. Furthermore, the reference air lines are themselves "checkable" by means of electrical half-wave-substitution measurements and mechanical measurements of diameter and length (in turn traceable to the National Bureau of Standards).

The ultimate standard of 50-ohm impedance upon which the entire GR-900 line is based is the characteristic impedance of the TYPE 900-LZ Reference Air Lines shown in Figure 1. These are coaxial transmission lines of very accurately controlled mechanical dimensions, and thus of known characteristic impedance and electrical length. The characteristic impedance depends primarily on the ratio of diameters of the inner and outer conductors and is controlled to 50 ohms ±0.05% with tolerances of 100 and 50 microinches on outer and inner conductors, respectively. Both inner and outer conductors are overlaid with pure silver for minimum loss. The electrical lengths are controlled to ±0.002 cm and are slightly shorter than the nominal length to allow for the dielectric constant of air (1.0007) and for the fact that the velocity of light is not exactly 3×10^{10} cm/second but 2.997925×10^{10} cm/second. This adjustment makes the line lengths exactly integral numbers of wavelengths at integral frequencies (1 Gc/s, 2 Gc/s, etc) for convenience in calibrations. Since the time delay and capacitance of each line also come out in round numbers, the air lines are convenient standards of these parameters as well as of impedance. The specifications table lists quarter-wave-

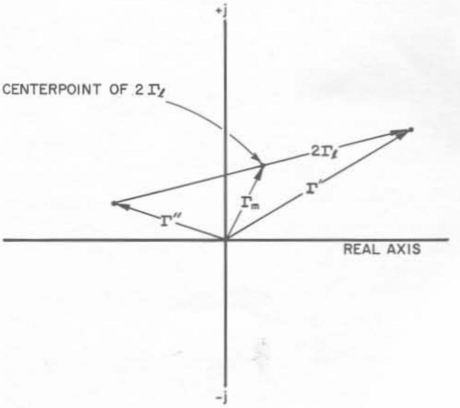

Figure 2. Smith-chart determination of instrument reflection coefficient (Γ_m) and load reflection coefficient (Γ_l) from measured values of Γ' and Γ'', with quarter-wave reference air line.

length frequencies, capacitances, and time delays for the six reference air lines presently available (5, 6, 7.5, 10, 15, and 30 cm).

The inner conductor of the reference air line derives its support from the connectors in the system under test, obviating the need for dielectric bead supports within the air line. The inner and outer conductors are of equal length and without steps, joints, or slots, which would destroy their usefulness as calculable standards of microwave impedance. When connected to a system under test, the reference air line is an ideal section of transmission line from the reference plane on the input connector to the reference plane on the output connector.

Applications

The use of ideal sections of transmission line to calibrate measuring instruments and components is illustrated in Figure 2. When a termination with a finite reflection coefficient is measured on an instrument having a finite error, the measured reflection coefficient equals the *vector* sum of the reflection coefficients of the two devices. The equation for small reflection coefficients ($\Gamma < 0.1$) is:

$$\Gamma' = \Gamma_m + \Gamma_l \quad (1)$$

where

Γ' = initial indicated reflection coefficient,

Γ_m = residual reflection coefficient of the instrument,

Γ_l = load reflection coefficient.

The insertion of a reference air line of electrical length L between the measuring instrument and the load has no effect upon the Γ_m vector, but rotates the phase of the Γ_l vector by $4\pi L/\lambda$ radians about a point on the Smith chart equal to the characteristic impedance of the air line. This fact is the key to the separation of instrument error from load error and to their measurement with respect to a known and calculable rf impedance, the characteristic impedance of the reference air line.

For calibration purposes, the most convenient lengths of reference air line are the odd quarter wavelengths, for the rotation of the Γ_l vector is then π radians, or 180 degrees, corresponding to a change of sign of the Γ_l vector. The measured value of reflection coefficient after insertion of the reference air line, Γ'', is therefore:

$$\Gamma'' = \Gamma_m - \Gamma_l. \quad (2)$$

Vector addition of equations (1) and (2) and rearrangement yield the residual reflection coefficient of the measuring instrument:

$$\Gamma_m = \frac{\Gamma' + \Gamma''}{2} \quad (3)$$

Vector subtraction of equation (2) from equation (3) yields the reflection coefficient of the load:

$$\Gamma_l = \frac{\Gamma' - \Gamma''}{2}. \quad (4)$$

The corresponding VSWR's are obtained from the formula:

$$\text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

The above results can be generalized to apply to lengths other than odd quarter wavelengths and to two-port as well as one-port unknowns, to achieve the same high accuracy at any frequency in the measurement of any

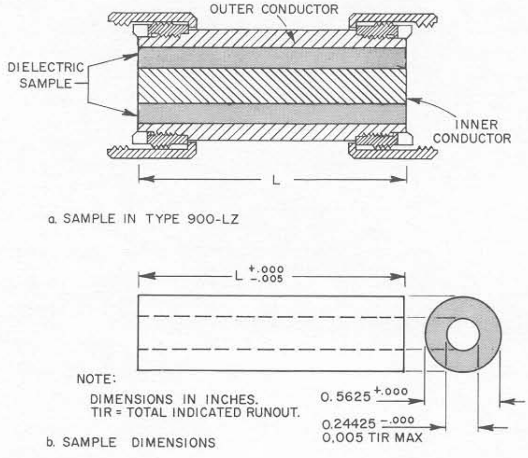

Figure 3. Dielectric-sample fabrication for measurement in Type 900-LZ Reference Air Line.

microwave component. The general formulas and required techniques are described fully in References 1 and 2.

The TYPE 900-LZ Air Lines can also be used in the measurement of dielectrics. The air lines, being open at both ends, serve as convenient holders for dielectric samples fabricated in the coaxial cross-section shown in Figure 3. The electrical length and the attenuation of the dielectric-filled line can be measured with high accuracy on the TYPE 900-LB Slotted Line as described in the operating instructions for the Slotted Line, and these quantities are related to the dielectric constant and the loss tangent of the material with the formulas:

$$\epsilon_r = \left(\frac{L_e}{L_p}\right)^2$$

$$\tan\delta = \frac{0.0366\,A\lambda}{L_e},$$

where ϵ_r = relative dielectric constant,
$\tan\delta$ = loss tangent,
L_e = electrical length of dielectric specimen, in cm,
L_p = physical length, in cm,
A = attenuation in specimen owing to dielectric losses, in dB,
λ = wavelength at test frequency, in cm.

All quantities in the formulas can be accurately measured with the TYPE 900-LB Precision Slotted Line and the Micrometer Carriage Drive. The accuracy of this technique is about ±0.2% in dielectric constant and $\pm 0.0001/\sqrt{f_{Gc}}$ in loss tangent from 300 Mc/s to 9 Gc/s.

— A. E. SANDERSON

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1. A. E. Sanderson, "Calibration Techniques for One- and Two-Port Devices Using Coaxial Reference Air Lines as Absolute Impedance Standards," Instrument Society of America Preprint 21.6–3–64.

2. A. E. Sanderson, "A New High-Precision Method for the Measurement of the VSWR of Coaxial Connectors," *IRE Transactions on Microwave Theory and Techniques*, Vol MTT-9, No 6, November 1961, pp 524–528.

3. D. Woods, "A Coaxial Connector System for Precision R.F. Measuring Instruments and Standards," *Proceedings of the IEE*, Vol 108, Part B, No 38, March 1961, p 205–213.

SPECIFICATIONS

Frequency Range: Dc to 9 Gc/s.

Characteristic Impedance: 50 ohms ±0.050%.

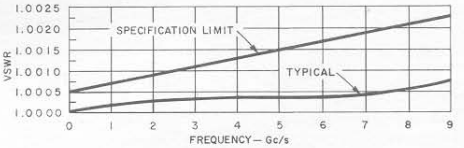


Figure 4. VSWR characteristics.

Additional skin-effect error is calculable.

VSWR: Less than $1.0005 + 0.0002 f_{Gc}$.

Repeatability: Within $(0.010 + 0.003 f_{Gc})$%.

Leakage: Better than 130 dB below signal.

Insertion Loss: Less than $0.0008\sqrt{f_{Gc}}$ dB/cm.

Maximum Voltage: 3000 V peak.

Maximum Power: $20\text{ kW}/\sqrt{f_{Mc}}$.

Dc Contact Resistance (each end, mated with GR900); Inner conductor, less than 0.5 milliohm; outer conductor, less than 0.07 milliohm.

Type	*Electrical Length—cm (±0.002 cm)*	*Capacitance—pF (±0.07%)*	*Time Delay—ps (±0.1 ps)*	*Odd λ/4 Frequencies* —Gc/s*	*Physical Length in—mm*	*Net Weight oz—g*	*Price*
900-LZ5	4.997	3.3333	166.7	(2n+1)1.50	2⅛– 55	4.0–115	**$60.00**
900-LZ6	5.996	4.0000	200.0	(2n+1)1.25	2½– 65	5.0–140	**61.00**
900-LZ7H	7.495	5.0000	250.0	(2n+1)1.00	3¹⁄₁₆– 80	5.5–160	**62.50**
900-LZ10	9.993	6.6667	333.3	(2n+1)0.75	4¹⁄₁₆–105	7.0–200	**65.00**
900-LZ15	14.990	10.000	500.0	(2n+1)0.50	6 –155	10.5–295	**70.00**
900-LZ30	29.979	20.000	1000.0	(2n+1)0.25	12 –305	20 –555	**85.00**

* Frequencies at which air-line section is an odd multiple of a quarter wavelength, where n is zero or any integer.

NEW COAXIAL TUNER WITH NEUTRAL SETTING

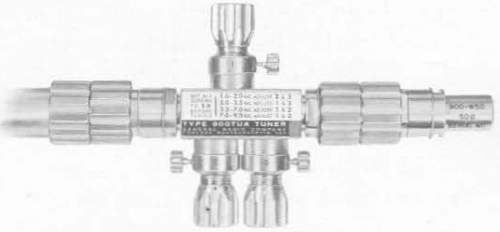


Figure 1. Type 900-TUA Tuner, shown in place between reference air line and Type 900-W50 50-ohm Standard Termination.

In many measurements with the GR900 system, there is the need to tune out the small residual reflections of the GR900 components. For example, by matching the TYPE 900-W50 50-ohm Termination to the TYPE 900-LB Precision Slotted Line, one can effectively upgrade the performance of the termination to the level of the slotted line — a fivefold improvement. In substitution measurements, accuracy and speed are improved considerably when a matching tuner is used to set the initial conditions to a perfect match ($\Gamma' = 0$ in equations (3) and (4), page 13).

The TYPE 900-TUA Tuner (see Figure 1), designed with the above requirements in mind, has the stability, fineness of control, and resettability necessary to tune out VSWR's as low as 1.001 or lower and to keep them tuned out. In addition, wide bandwidth (1 to 9 Gc/s), a unique "neutral" position, and reasonably orthogonal tuning adjustments (for easy, rapid balance) have been achieved with the design shown in Figure 2. Each of three tuning adjustments consists of a capacitive tuning screw in the wall of the outer conductor and an inductive groove in the inner conductor, in the same plane as the tuning screw. Turning the screw counterclockwise places a small inductance in series with the line, while turning the screw clockwise adds a small capacitance in shunt with the line; positive or negative increments are thus produced along the imaginary axis of a Smith-chart impedance plot. To produce incremental changes along the real axis, another tuning screw is placed one-eighth wavelength (or an odd multiple of one-eighth wavelength) from the first, for this separation provides orthogonality of the two adjustments on the Smith chart. The Smith-chart coverage of the two adjustments at band center is a square in the middle of the Smith chart. Off center fre-

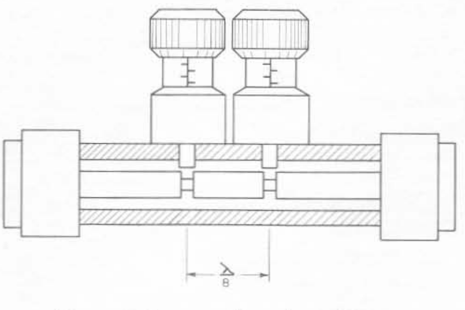


Figure 2. Cross-section view of tuner.

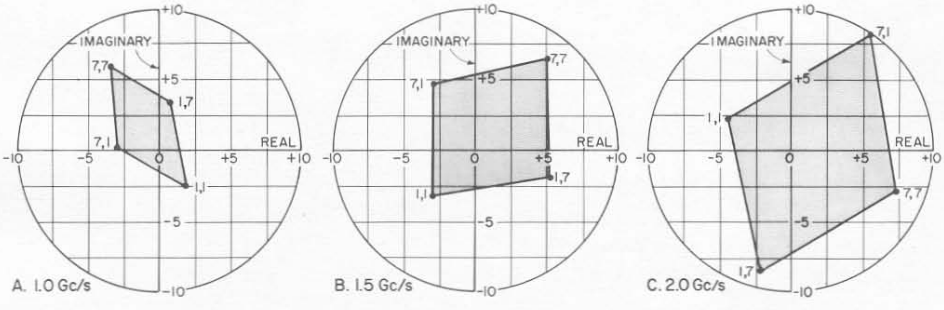


Figure 3. Smith-chart plots showing tuning range of Type 900-TUA Tuner. Numbers at corners are settings of screws 2 and 3, respectively. Tuning screw 1 is set at 5.00. Axis values are in terms of percent deviation from match. A 10-percent mismatch corresponds to a VSWR of 1.100.

quency, the square becomes a diamond of smaller area but is still centered on the Smith chart (see Figure 3). The reduction of matching area limits the useful frequency range of a given pair of screws to the octave between two-thirds and four-thirds of the center frequency.

Each tuning screw can be set so that its shunt susceptance exactly cancels the series inductance of the groove, and the net effect of the two discontinuities is zero. This is called the neutral position of the tuning adjustment. Because the effects of both shunt susceptance and series inductance increase with frequency at the same rate, and because the screw and the groove are placed at the same point in the transmission line, *the neutral setting is independent of frequency*. The neutral-setting feature was, in fact, fundamental to the design of the tuner; only with such provision could several screws be placed in the transmission line at different spacings to satisfy the odd-eighth-wavelength condition at many frequencies and to provide reasonably orthogonal tuning adjustments over a broad and continuous frequency range. In operation, two of the three screws in the tuner are adjusted for match (which pair depends on frequency), while the unused screw is simply set to neutral. Each tuning screw can be locked in any position, affording maximum stability and repeatability.

SPECIFICATIONS

Frequency Range: 1.0 to 9.0 Gc/s.

Characteristic Impedance: 50 ohms, nominal.

VSWR Matching Range: $1.00 + 0.012 f_{Gc}$, or $1.2 f_{Gc}$%, minimum.

VSWR Resettability: Within $1.0005 + 0.0003\ f_{Gc}$ or $(0.05 + 0.03 f_{Gc})$ %.

Connectors: GR900 at each end.

Residual VSWR: At neutral, less than 1.03 from 1.0 to 5.0 Gc/s; less than 1.05 from 5.0 to 7.0 Gc/s.

Repeatability of Connection: 0.05%.

Electrical Length: 12.0 cm, nominal.

Dimensions: 4½ by 3½ by 1 in (115, 89, 25 mm).

Net Weight: 1 lb (0.5 kg).

Shipping Weight: 4 lb (1.9 kg).

Type		*Price*
900-TUA	**Tuner**	**$165.00**

NEW GR900 TERMINATIONS

A new short-circuit termination has been developed specifically for use with the reference air lines described in this issue. The TYPE 900-WNC Short-Circuit Termination is essentially a simple short-circuiting disk with a standard GR900 center contact to support the inner conductor of a beadless TYPE 900-LZ Reference Air Line. The reference plane of the termination occurs exactly at the reference plane of the GR900 connector. Reflection coefficient is 0.999 or greater to 9.0 Gc/s.

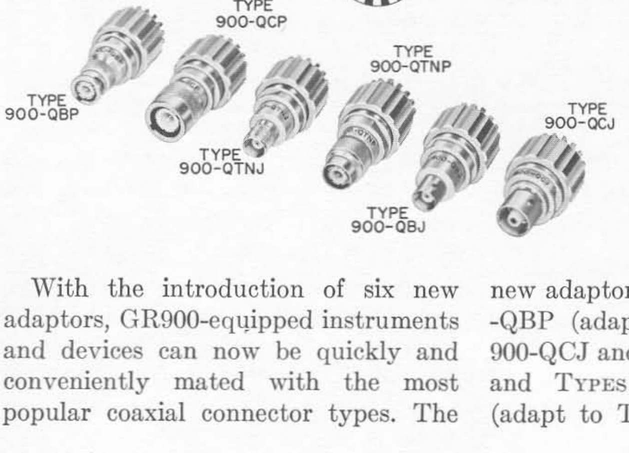
Because of the effects of fringing capacitance, the reference plane of the standard TYPE 900-WO Open-Circuit Termination[1] occurs 0.26 cm (electrical distance) beyond the reference plane of the GR900 connector. To facilitate measurements requiring coplanar short- and open-circuit terminations, we have developed the TYPE 900-WNE Short-Circuit Termination, whose reference plane is also displaced 0.26 cm. This termination, like the TYPE 900-WNC, contains a standard center contact to support the inner conductor of a TYPE 900-LZ Reference Air Line. Reflection coefficient is greater than 0.998 to 9.0 Gc/s.

[1] John Zorzy, "Precision Coaxial Equipment — The 900 Series," *General Radio Experimenter*, November 1963.

Type		*Length*	*Net Weight*	*Price*
900-WNC	**Reference-Line Short-Circuit Termination**	1 1/16 in (27 mm)	2½ oz (70 g)	**$16.00**
900-WNE	**Short-Circuit Termination** (0.26 cm)	1 1/16 in (27 mm)	2½ oz (70 g)	**17.00**

GR900 ADAPTORS

NEW ADAPTORS TO TYPE BNC, TNC, AND C SERIES



With the introduction of six new adaptors, GR900-equipped instruments and devices can now be quickly and conveniently mated with the most popular coaxial connector types. The new adaptors are: TYPES 900-QBJ and -QBP (adapt to BNC series); TYPES 900-QCJ and -QCP (adapt to C series); and TYPES 900-QTNJ and -QTNP (adapt to TNC series). In each case, the suffix J indicates that the adaptor is female (contains a jack), whereas a P suffix denotes a male adaptor (i.e., one containing a plug).

Other GR900 Adaptors, described in an earlier issue, are the TYPE 900-QNJ and -QNP (adapt to N series) and the TYPE 900-Q874 (adapts to GR874 Connectors).

The availability of adaptors from GR900 to nine other coaxial connectors greatly extends the usefulness of all GR900-equipped instruments and components. A TYPE 900-LB Slotted Line with a TYPE 900-QBJ Adaptor, for instance, constitutes a BNC slotted line capable of outstanding performance. Also, since the electrical performance of each adaptor approaches the theoretical limit imposed by the design of the other-series connector, a GR900 adaptor and a GR900 termination can be combined to form an other-series termination of near optimum performance.

Combined VSWR specifications for the TYPE 900-LB Precision Slotted Line and the TYPE 900-W50 50-ohm Termination, each equipped with various GR900 Adaptors, are given in the accompanying table.

VSWR OF GR900 DEVICES EQUIPPED FOR OTHER COAXIAL SERIES

	Slotted Line (Type 900-LB Plus GR900 Adaptor)	*50-ohm Standard Termination (Type 900-W50 Plus GR900 Adaptor)*
Types BNC, TNC, C	$1.006 + 0.016f_{Gc}$ to 1 Gc/s $1.016 + 0.006f_{Gc}$ from 1 to 9 Gc/s	$1.010 + 0.020f_{Gc}$ to 1 Gc/s $1.020 + 0.010f_{Gc}$ from 1 to 9 Gc/s
Type N	$1.005 + 0.005f_{Gc}$	$1.009 + 0.009f_{Gc}$
Type GR874	$1.001 + 0.016f_{Gc}$ to 1 Gc/s $1.011 + 0.006f_{Gc}$ from 1 to 9 Gc/s	$1.005 + 0.020f_{Gc}$ to 1 Gc/s $1.015 + 0.010f_{Gc}$ from 1 to 9 Gc/s

SPECIFICATIONS

Type	*Contains GR900 and*	*Connects to*	*Length in—mm*	*Net Weight oz—g*	*Price*
900-QBJ	BNC jack	BNC plug	2 1/16—52	3½—100	55.00
900-QBP	BNC plug	BNC jack	2⅛—54	4 —115	55.00
900-QJC	C jack	C plug	1⅞—48	3½—100	55.00
900-QCP	C plug	C jack	2 1/16—52	4 —115	55.00
900-QTNJ	TNC jack	TNC plug	2 1/16—52	3½—100	55.00
900-QTNP	TNC plug	TNC jack	2 1/16—52	4 —115	55.00

GR900 CONNECTOR KITS

Three new connector kits permit custom fabrication of reference air lines and components compatible with GR-900 connectors.

The Type 900-AP Laboratory Precision Connector Kit is designed for use with coaxial elements with unsupported inner conductors. A reference air line of custom length, for instance, can be assembled from a pair of these kits and appropriate lengths of precision rod and tubing (General Radio No. 0900–9508 and 0900–9509, respectively).

The Type 900-AC Laboratory Precision Connector Kit contains the coupling hardware and center contact of a standard GR900 connector. It can be used in place of a TYPE 900-BT connector

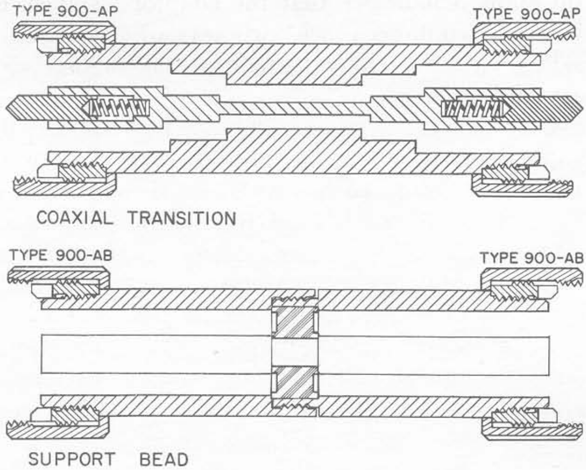


Figure 1. Cross-section view of coaxial line sections fitted with Types 900-AP (top) and 900-AB Precision Coaxial Connector Kits. Type 900-AP connection is same as that used in the Type 900-LZ Reference Air Lines.

when the component's inner conductor is supported within the component itself. Since it includes only the connector parts necessary for such applications, this kit offers the user superior electrical performance at a considerable saving in cost.

One GR900 center contact is all that is necessary for electrical connection in a GR900 joint. Therefore, when a component is to be used exclusively with GR900 connectors, the connector kit need not include a center contact. *The Type 900-AB Laboratory Precision Connector Kit,* which contains GR900 coupling hardware, is intended for such applications.

Type		*Length*	*Net Weight*	*Price*
900-AB	**Laboratory Precision Connector Kit**	**1 3/16 in (30 mm)**	**1 oz (28 g)**	**4.80**
900-AC	**Laboratory Precision Connector Kit**	**1 3/16 in (30 mm)**	**1 oz (28 g)**	**7.10**
900-AP	**Laboratory Precision Connector Kit**	**1 1/4 in (32 mm)**	**1 1/4 oz (35 g)**	**5.40**

We'll be fifty years old this year.

You'd never guess it to look at us. We pursue our business with the enthusiasm of youth. Our plants are new, cleanly designed, smartly suburban. Our instruments are modern in shape and color. On appearances, you might take us for a spirited teen-ager.

But look *inside* one of our bridges or sound-level meters or frequency standards, and you know right away that we've been at that sort of thing for a long, long time. Take our new automatic capacitance bridge: it's streamlined, space-age, sophisticated, a state-of-the-art instrument if there ever was one. But somewhere in its marrow is a half century of bridge-designing and bridge-making know-how. We've written off the cost of all this experience; it's yours as a bonus in every GR instrument you buy.

We've come a long way since Melville Eastham first hung out the General Radio shingle in the summer of 1915. Some of the milestones (if you'll permit us a semicentennial reminiscence) are the first commercial electronic stroboscope, crystal frequency standard, heterodyne wave analyzer, standard-signal generator and continuously adjustable autotransformer. Yes, it's been a long road, but it's been a straight one. We have the same corporate identity we started with, and, from 1915 wave meter to 1965 frequency counters, our main product line has unwaveringly been electrical measuring apparatus. End of reminiscence. To us, the success of 50 years isn't a cushion, it's a springboard.

Now to the future. Instruments now in development convince us that, at GR, "the best is yet to be." Here are some examples of what we mean:

The GR automatic capacitance bridge will soon begin working for component makers all over the world, measuring their products at the rate of two or more per second and feeding the answers to the latest data-processing equipment.

Our frequency-synthesizer engineers are synthesizing again, and they talk of having a large family.

New STROBOTAC® stroboscopes will flash into view with battery operation and flashing rates to 150,000 rpm.

The GR900 line of precision coaxial components will grow like guppies, with the development of adaptors, important new instruments, terminations, and many other elements.

Our acoustic program is full of sound and fury, signifying, among other things, a precision sound-level meter and a new GR-made, measurement-grade microphone.

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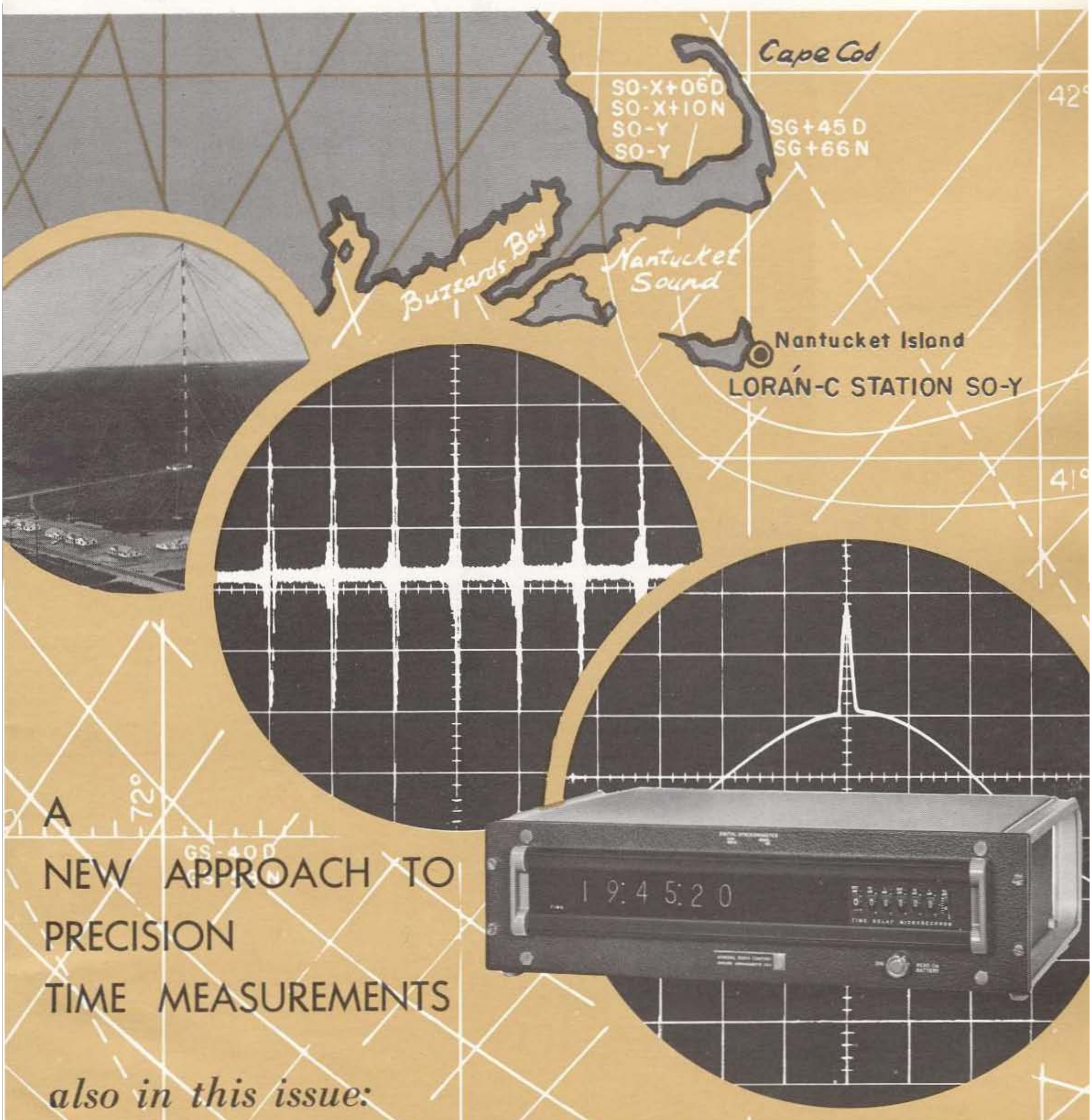

A NEW APPROACH TO PRECISION TIME MEASUREMENTS

also in this issue:

SOUND-POWER MEASUREMENTS
TRANSISTOR MOUNTS FOR THE TRANSFER-FUNCTION BRIDGE
A NEW FREQUENCY STANDARD
COAXIAL MICROWAVE NEWS

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About the Cover

The use of Loran-C radio transmissions for precise time measurement is discussed in this month's lead article. Shown against the background of a Loran-C chart are the Coast Guard's slave transmitting station at Nantucket, signals from that station as received at our Concord plant, and the new Digital Syncronometer® time comparator.

Loran-C station photo courtesy of U S Coast Guard. Background: Air/Surface Loran-C Navigation Chart VLC 30-22 U.S. Naval Oceanographic Office.

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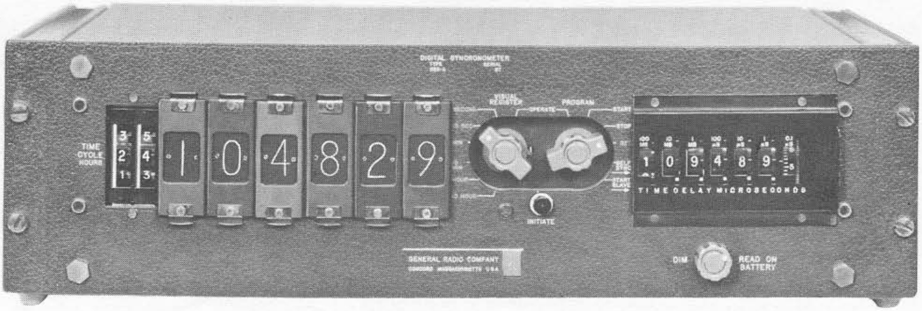
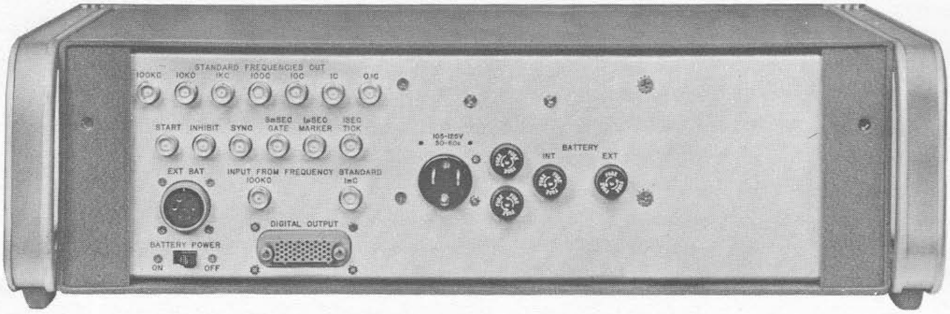


Figure 1. Type 1123-A Digital Syncronometer® time comparator, front (less bezel) and rear views.



A NEW APPROACH TO PRECISION TIME MEASUREMENTS

The accurate, precise measurement and keeping of time are more than exercises for astronomers and guardians of the national standard. They are also matters of great concern to navigators, telemetry and communications specialists, data-system technologists, and many others who must establish time intervals and record local time with microsecond precision.

The modern method of precise local timekeeping involves (1) the use of standard time signals (such as those broadcast on WWV), (2) a standard-frequency oscillator, (3) some means of converting the oscillator's frequency into a time indication, and (4) a means for precisely comparing it against the broadcast time signals. The last two functions have traditionally been performed by such time comparators as General Radio's Type 1103,[1] a synchronous-motor clock driven by the output of a frequency standard, with the time of day displayed on a standard clock face. Inevitably limiting the resolution of such comparators have been the uncertainties inherent in any mechanical device, which have become progressively more troublesome with the increasing need for accurate resolution of short time intervals. Not even the most advanced mechanical com-

[1] R. W. Frank, F. D. Lewis, H. P. Stratemeyer, "The New GR Frequency Standard," *General Radio Experimenter*, Vol 35 No 4, April 1961.

parator gives results repeatable to better than a microsecond, and to this disadvantage must be added the problems of wear and maintenance intrinsic in mechanical devices.

General Radio's new TYPE 1123-A Digital Syncronometer (Figure 1), a digital time comparator, avoids the problems of moving parts simply by avoiding the moving parts. There is no mechanical resolver, with its inherent inaccuracies in translating electrical angles to mechanical, no synchronous motor with its inherent starting delays. Instead, solid-state logic circuits, used in a new type of time comparator, are designed specifically to meet the stringent demands of modern time-standardizing and data-handling applications. Accuracy is limited only by the accuracy of the driving frequency standard and not by resolution. Time information is, in fact, given with a precision that challenges one's ability to extract it.

The TYPE 1123-A Digital Syncronometer ® time comparator is designed to be driven by the 100-kc output of the TYPE 1115-B Standard-Frequency Oscillator.[2] The time comparator's input circuits translate the oscillator's 100-kc sine-wave zero crossings into a 100-kc pulse train, which is applied to a series of five decade dividers to produce a one-pulse-per-second master tick. These pulses are accumulated in six digital counting circuits, and the totals are displayed by in-line incandescent-lamp indicators as hours, minutes, and seconds. In addition, all 11 decades (five dividing and six counting and displaying) supply BCD electrical outputs at a rear-panel connector.

The one-second master tick can be easily compared with any other one-second signal on an oscilloscope. A set of seven thumb wheels on the front panel controls a precisely known delay between the master tick and a delayed pulse. To measure the time interval between master tick and a broadcast time signal, one simply brings the delayed pulse into coincidence with the broadcast signal and reads the time interval on the calibrated thumb wheels. Synchronizing the master tick with the time signals is then simply a matter of pushing a button on the comparator. Standard time can just as easily be transferred from one digital SYNCRONOMETER time comparator to another or to several others.

The new comparator can reproduce its time measurements with a precision approaching a nanosecond, and its master tick can be compared with suitable time signals with an accuracy of better than 100 nanoseconds. With appropriate terminal equipment for interrogation, it can provide time data in increments as small as 10 microseconds.

[2] H. P. Stratemeyer, "The Stability of Standard-Frequency Oscillators," *General Radio Experimenter*, Vol 38 No 6, June 1964.

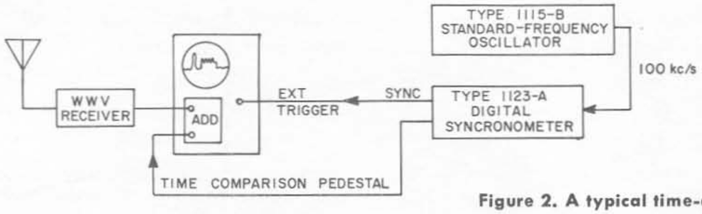


Figure 2. A typical time-comparison setup.

The low power consumption of the all-solid-state circuits makes it practical to operate the comparator from a small, self-contained, nickel-cadmium battery, which takes over automatically if the ac line fails and supplies power for at least 24 hours. Although the primary purpose of the built-in power pack is emergency operation, the fact that this instrument and the TYPE 1115-B Standard-Frequency Oscillator have built-in power supplies in effect makes both instruments and local time portable.

PHYSICAL CHARACTERISTICS

The digital SYNCRONOMETER time comparator is housed in a standard relay-rack-width cabinet, 5¼ inches high. Prominent on the front panel is the hours-minutes-seconds register, an in-line series of six digital indicators. At the right-hand side of the panel are the seven delay thumb-wheel controls used in time-comparison measurements and in the synchronization procedure. The only other normally exposed control is the dimmer adjustment for the time register. Controls that can affect clock time are normally kept out of harm's way by a protective bezel plate. These are the VISUAL REGISTER and PROGRAM controls and the INITIATE button. The latter ultimately controls all comparator operations (as well as the operations of any slave units), and, as a further precaution against accidental loss of accumulated time, both the VISUAL REGISTER and PROGRAM switches have OPERATE positions that lock out the INITIATE button; it takes very deliberate action by the operator to upset the time kept by the clock.

Standard frequency outputs in the form of pulse trains at 100 kc/s, 10 kc/s, 1 kc/s . . . . 0.1 c/s are available at rear-panel BNC connectors, as are various other pulse outputs to be described.

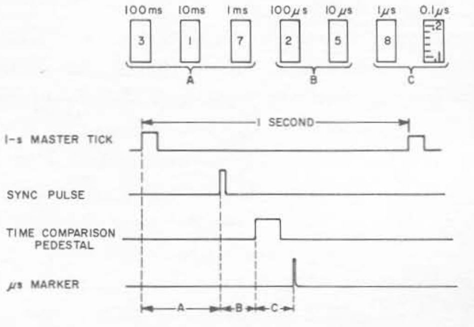


Figure 3. Timing diagram showing relations between panel thumb-wheel controls and the various timing pulses.

TIME COMPARISON

Once the comparator has been started and set in rough synchronism with a standard time signal, it is possible to determine the time interval between the comparator's master tick and the standard time signal. This interval is measured in terms of the time difference between the master tick and a pulse of 8-millisecond duration, whose occurrence the operator adjusts to coincide with the external reference. The comparator also supplies an oscilloscope-synchronizing pulse, slightly in advance of the 8-millisecond pulse, so that the latter can be moved away from the start of the oscilloscope sweep. Lagging the 8-millisecond pulse is another, very brief (0.2 microsecond), time-comparison marker pulse for super-precise measurements.

Figure 2 shows a typical time-comparison setup; the relations between the seven front-panel thumb-wheel controls and the various timing pulses are shown in Figure 3. When the leading edge of the 8-millisecond pedestal is aligned with the standard time signal, the exact interval between the comparator's master tick and the standard time signal is displayed on the five thumb-wheel controls designated A and B in Figure 3. The two controls designated C are calibrated to adjust and indicate the interval between the leading edge of the 8-millisecond pedestal and the 0.2-microsecond pulse. One of these controls is a step switch with 1-microsecond increments; the other is a continuous control covering the range from 0 to 1 microsecond and marked in 20-nanosecond increments.

Use of the 0.2-microsecond marker for a precise measurement of local time against a Loran C transmission is shown in Figure 4. Note the precision with which the 0.2-microsecond marker pulse of the comparator can be centered on the received Loran signal as displayed with a 1-μs/cm sweep rate. Time comparison to 0.1 microsecond is entirely practical, and a local precision oscillator can thus be rated within 1 part in 10^{10} in a measuring interval of only 17 minutes (1000 seconds)!

An important feature of this comparator is that, since all time comparisons are made by adjustment of delay pulses and independently of the clock's own master tick, several standard time sources can be intercompared without interference with the comparator's local time. For example, the theoretical interval between a WWV time tick and a Loran C burst can be calculated from the relative locations of the two transmitters and the receiver. This calculated interval can then be added to the WWV tick by means of the delay controls, and a specific Loran C burst can thus be identified and subsequently used to establish local time much more accurately than the WWV signal alone would permit.

SYNCHRONIZATION

Once a time comparison has been made, the instrument can easily be synchronized so that its master tick is time-coincident, within 10 microseconds, with the standard time signal. The operator simply backs off the delay dials 50 microseconds to compensate for the program time, sets the PROGRAM switch to SELF SYNC, and pushes the INITIATE button. Within the next second, the instrument falls into synchronism.

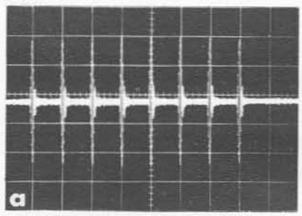
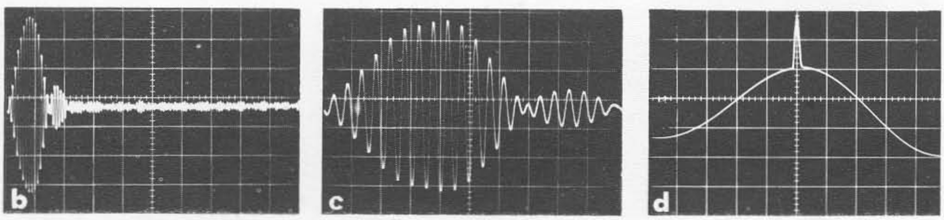
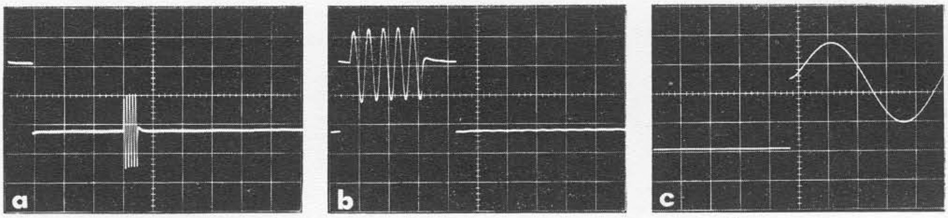


Figure 4. Time comparison of marker pulse and Loran-C 100-kc pulses. (Loran-C signals are those from Nantucket slave station, as received in Concord, Massachusetts.)

- **a. Sweep rate 1 ms/cm.**
- **b. Sweep rate 100 μs/cm.**
- **c. Sweep rate 20 μs/cm. (Note marker pulse on third cycle.)**
- **d. Sweep rate 1 μs/cm, pulse centered.**





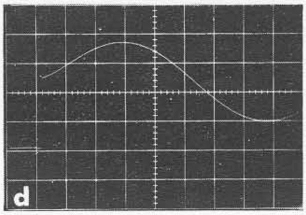


Figure 5. Time comparison of 8-ms pedestal and WWV time tick (5 cycles at 1 kc/s).

a. Sweep rate 10 ms/cm.
b. Sweep rate 2 ms/cm.
c. Sweep rate 0.2 ms/cm.
d. Sweep rate 100 μs/cm.

Similarly, one or more slave comparators can be synchronized with a master unit, through wire lines. The PROGRAM switch on the slaves is set to STOP, the master comparator is set to START SLAVE, and the INITIATE button on the master is pushed. The slaves then start at the precise fraction of a second set on the master's delay controls (subject to the propagation delay of the starting signal and the relative phase of the 100-kc standard-frequency inputs). If the master's delay controls are set to 00000, the slave's master ticks will coincide with those of the master; if the master's delay setting is 50000, the slaves will lag the master by 0.5 second.

CIRCUIT DESCRIPTION

It is most convenient to examine the circuits of the comparator in terms of its various programs, or modes of operation, as indicated by the positions of the front-panel PROGRAM switch: START, STOP, SET, SELF SYNC, and START SLAVE.

Start Program

The purpose of the start program is to initiate the series of master ticks derived from the 100-kc standard-frequency input and to ensure that the instrument stops if the standard-frequency input changes frequency or misses even one cycle. Such fail-safe operation is, of course, necessary to prevent the comparator from making an error by ignoring even a momentary interruption or aberration of input.

In Figure 6, the 100-kc input is seen driving a Schmitt trigger circuit, which applies a series of pulses, 10 microseconds apart, to coincidence gate G1. By pushing the INITIATE button, the user applies an 11-microsecond start pulse

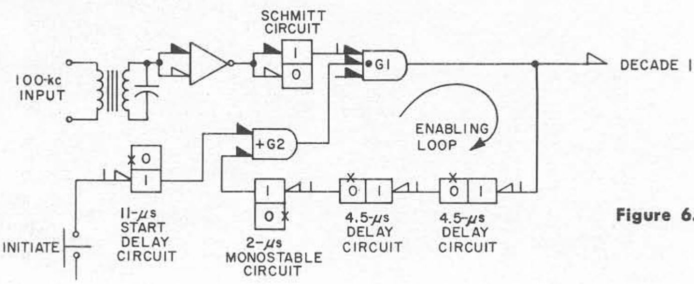


Figure 6. Start program.

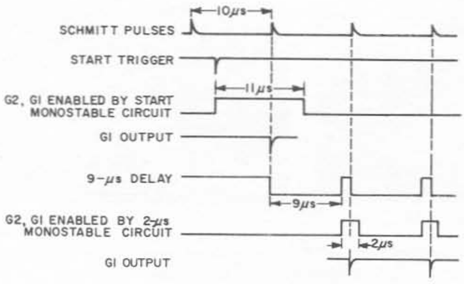


Figure 7. Timing diagram showing operation of the enabling loop and locking gate.

through OR gate G2 to coincidence gate G1. G1, thus enabled for 11 microseconds, passes at least one output pulse from the Schmitt circuit, and the comparator has been placed in operation. Each pulse is fed back through two 4.5-microsecond delay circuits to a 2-microsecond monostable multivibrator, which enables G1 for the passing of the next input pulse. If no pulse reaches G1 during the 2-microsecond period when it is enabled (9 to 11 microseconds after the passage of the last pulse), the enabling loop remains inactive, G1 is disabled, and the instrument is stopped to indicate failure of the 100-kc input. The sequence of operations for the enabling loop is shown in the timing diagram, Figure 7.

Stop Program

When the PROGRAM switch is set to STOP, and the INITIATE button is pushed, a 45-microsecond monostable multivibrator disables coincidence gate G1, stopping the instrument, and sets the first five (dividing) decades to zero. The time displayed on the visual register is not affected. (See Figure 8.)

Set Program

The set program allows the visual register to be set to any time of day without affecting the normal operation of the five dividing decades. When one of the counting units (SECOND, 10 SEC, MIN, 10 MIN, HOUR, 10 HOUR) is selected by the VISUAL REGISTER switch, each push of the INITIATE button advances the corresponding register one digit. The first command pulse from the INITIATE switch also triggers a carry-inhibit circuit, which opens diode gates between the six counting units. Thus one register can be set independently of the next.

Addition or omission of 1-cycle counts is also possible while the instrument is running. With the VISUAL REGISTER switch at OPERATE and the PROGRAM switch at SET, the INITIATE button can be used to add counts to the seconds register. One-second counts are prevented from accumulating when the VISUAL REGISTER switch is set to its fully clockwise position.

Self-Sync Program

This program (see Figure 9) allows automatic synchronism of the comparator's master tick within 10 microseconds of an external reference (e.g., a

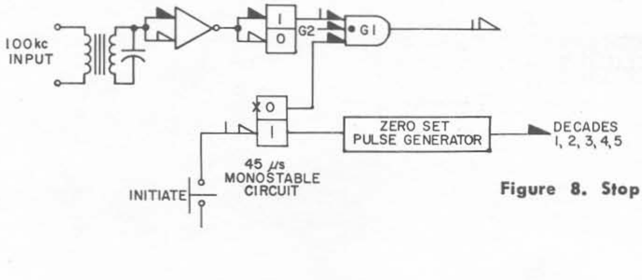


Figure 8. Stop program.

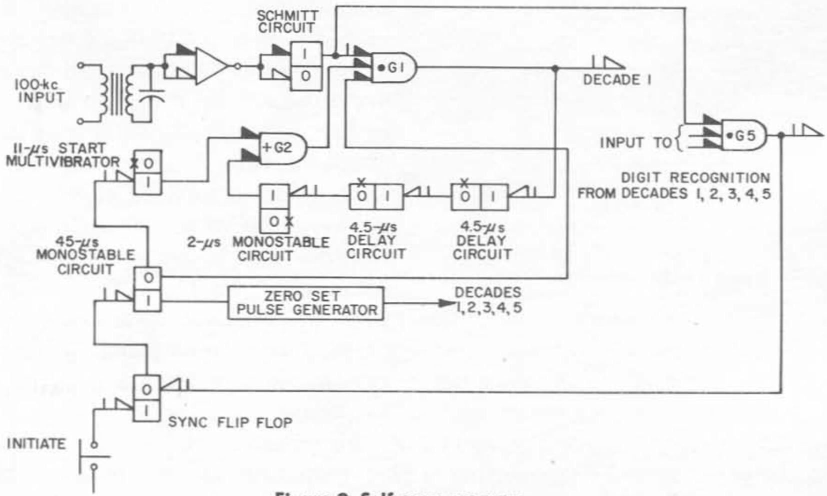


Figure 9. Self-sync program.

WWV time tick or a local, independent clock). The first step, as mentioned earlier, is to set the front-panel delay controls so that the internally generated 8-millisecond pedestal is brought into coincidence with the received time signals, as seen on an oscilloscope. Since the synchronizing operation will consume 50 microseconds, the delay-control setting is decreased by that amount. When the INITIATE button is pushed, the synchronizing flip-flop is set to the "1" state. The instrument keeps counting until the programmed delay setting is recognized by gate G5. G5 then sets the synchronizing flip-flop to "0" and triggers the 45-microsecond zero-set pulse generator. G1 is disabled, stopping the instrument, and the first five decades are set to zero. At the end of the 45 microseconds, a start pulse is automatically generated to restart the instrument on the next input pulse from the Schmitt circuit. As shown in the timing diagram (Figure 10), a total of 50 microseconds is lost during the entire synchronizing operation. Since the delay-control settings were originally reduced by 50 microseconds, this time is accounted for. The internal master tick is now synchronized within 10 microseconds of the external standard. The time coincidence between the comparison pedestal and the external standard can then be observed with the delay controls set at zero.

Start-Slave Program

The start-slave program allows a second comparator to be started with a given time relationship to the master comparator. The start pulse is programmed by the time-delay setting of the master comparator. The slave can be set to lag the master by any amount

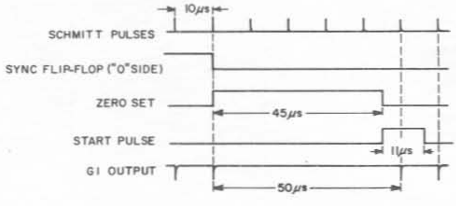


Figure 10. Timing diagram for the self-sync program.

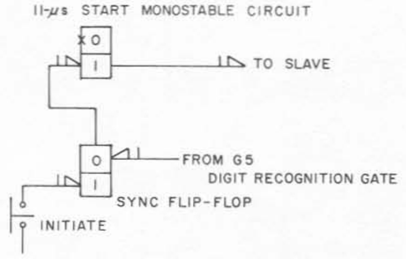


Figure 11. Start-slave program.

from 0 to 999.99 milliseconds. Once the desired delay is set on the master's delay controls, the master's INITIATE button is pushed once, setting the synchronizing flip-flop to "1" (see Figure 11). When the programmed delay setting is recognized by gate G5, the synchronizing flip-flop is reset to "0," generating a start pulse to the slave. The exact time relationship of the slave to the master is determined by the phase of the 100-kc input signals to the two instruments and by the length of the interconnecting cable.

Power Supply

The main power supply is a conventional transistor series-regulator circuit (see Figure 12). A built-in, explosion-proof, 16-volt nickel-cadmium battery of 4.5-ampere-hour capacity is connected through rectifier CR1 to the counting circuits at all times. A temperature-compensated charging circuit supplies a trickle current to the battery so that it stays fully charged. Supply voltages are so set that the battery normally supplies no current to the counting circuits (CR1 is back-biased). If the ac line voltage fails or drops so that the regulator voltage goes below 17 volts, CR1 becomes forward-biased, and the battery supplies current to the counting circuits. The indicator lamps are disconnected from the battery supply by CR2 to eliminate their heavy current drain, but a front-panel spring-return switch allows momentary operation of the lamps.

An external 24- to 32-volt battery, connected to the comparator through a rear-panel connector, can be used to supply the regulator directly in the event of a prolonged line-voltage failure.

Hours Reset Circuit

The comparator's time indicators can be set to recycle to 0 at any integral number of hours from 1 to 99. The desired full-scale hours indication is set by means of two front-panel thumbwheel controls, which select a particular matrix line from the hours and 10's-of-hours decades (see Figure 13). When the preset number is recognized by gate G8, the two counting units are set to 0. The setting 24, for example, recycles the clock from 23:59:59 to 00:00:00 on the next 1-second count.

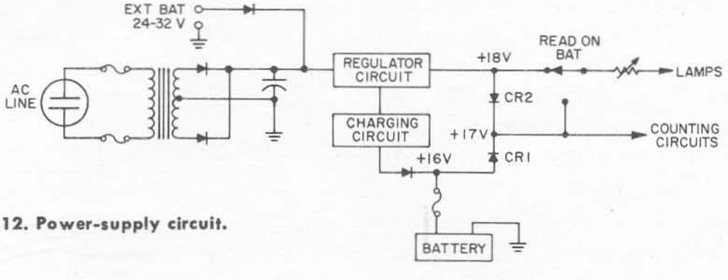


Figure 12. Power-supply circuit.

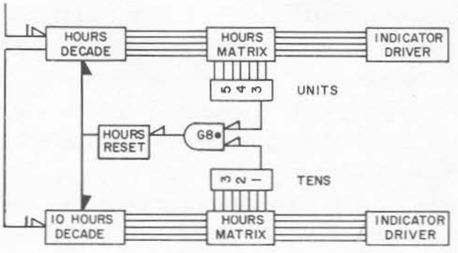


Figure 13. Hours-reset circuit.

0–10 Microsecond Delay Circuit

The 10-μs marker pulse is generated by an analog delay circuit. A negative-going ramp is initiated by the leading edge of the 8-millisecond comparison pedestal (see Figure 14). A Schmitt circuit, which generates the marker, triggers when the ramp decays to a preset voltage. The time delay between the start of the 8-millisecond pedestal and the transition of the Schmitt trigger depends on the slope of the ramp, which is in turn set by the front-panel 1-microsecond thumb wheel. This delay is quantized and set to the nearest exact multiple of 1 microsecond by combination with the 1-Mc input signal in gate G3. The output from G3 sets the flip-flop to 1 and initiates a second ramp, whose slope is continuously adjustable to produce an additional 0 to 1-microsecond delay. The 0.2-microsecond Schmitt trigger output is shaped with a monostable multivibrator and amplifier to produce a 10-volt, 0.2-microsecond pulse with rise and fall times of about 20 nanoseconds.

AUXILIARY TIME-STORAGE EQUIPMENT

No commercial equipment presently available can accept time readings as fast as the comparator can supply them. Required is a parallel-entry storage register with a capacity of 11 four-bit binary words. The register must accept and store the data from the clock in a time well under 5 microseconds. (The comparator contains full inhibit circuitry to prevent errors that could be caused by interrogation during time transfer.) We have developed such a storage register, capable of storing data in less than 1 microsecond, and can supply such equipment on special order.

APPLICATIONS

The Type 1123-A Digital Syncronometer time comparator is a general-purpose precision laboratory instrument for registering, measuring, and generating time. Driven by the Type 1115-B Standard-Frequency Oscillator, or other frequency standard with 100-kc output, it can be used:

(1) as a precise time-of-event source or accumulator of time in 10-microsecond increments up to 99 hours. (A modified comparator, supplied on special order, can accumulate decimal seconds up to a total of 999,999.) Thus decimal seconds from the start of an

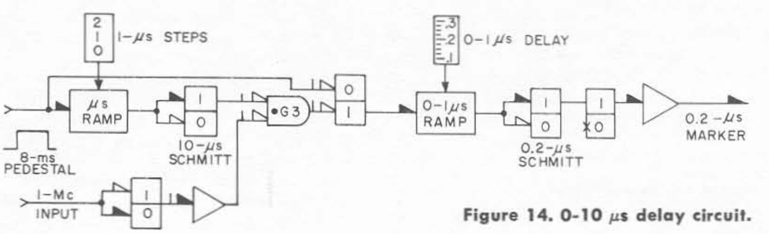


Figure 14. 0-10 μs delay circuit.

event, in increments as small as 10 microseconds, can be logged in data-processing systems.

(2) as a source of precisely timed pulses to initiate experiments,

(3) as a precise, low-jitter source of timing pulses in decade sequence from 100 kc/s to 0.1 c/s,

(4) to transport precise time,

(5) to rate standard-frequency oscillators against transmitted time signals.

SUMMARY

The development of a solid-state time comparator is a significant step forward in the field of time-standard instrumentation. The TYPE 1123-A Digital Syncronometer time comparator is the most versatile instrument of its type, yet is the easiest to operate. Its low-power transistor circuits and built-in battery mean that one can literally carry reference time from one location to another. Its fail-safe regenerative circuits and absence of moving parts make it the most reliable comparator available. And its BCD-electrical, as well as visual, output ensures its usefulness with data-acquisition systems of today and tomorrow.

D. O. FISHER
R. W. FRANK

SPECIFICATIONS

Input: BNC connectors.
0.5 V at 100 kc/s (sinusoid or square wave).
0.5 V at 1 Mc/s (sinusoid or square wave).
Normally provided from TYPE 1115-B Standard-Frequency Oscillator (1 V into 50 Ω).

Outputs:

Time of Day: From all decades, parallel 1-2-4-2 BCD. 1-2-4-8 BCD available on special order.
Logical 0: Approx 0.5 V.
Logical 1: Approx +15 V (open circuit).
Logical Line Source Impedance: 100 kΩ.

Timing Pulses: 10 kc/s, 100, 10, 1, and 0.1 c/s are available at output fittings on rear. These are +15-V pulses with approx 100-Ω source impedance and a duty ratio of 0.2. In addition, a 100-kc pulse signal is available.

Oscilloscope Sync Pulse: Settable in 1-ms steps 0.000 to 0.999 s.
Positive pulse, 13 V, $Z_o = 2.2$ kΩ.
Duration, ≈7.5 μs.

Time-Comparison Pedestal: Follows oscilloscope sync by 000 to 990 μs (100- and 10-μs steps).
Positive pulse, 10 V from emitter follower.
Duration, ≈8 ms.
$T_r = 0.5$ μs, $T_f = 0.5$ μs.

0.2-μs Mark: 10-V positive pulse, 0.2-μs duration, with approximately 20-ns rise and fall times, and 100-Ω source impedance. This marker is variable in 1-μs steps and a continuous 0- to 1-μs range from 0 to 10 μs after the 8-ms pedestal.

1-s Master-Tick Output: Positive pulse from emitter follower.
Amplitude, 10 V. Duration, ≈7.5 ms. $T_r = 2$ μs, $T_f = 2$ μs.

Input Start Pulse: Logical 0 (0 V) to 1 (+15 V) holding for > 10 μs. May come from second clock or external system.

Output Start Pulse: 11 μs, 0 to +15 V, from emitter follower.

Inhibit Pulse Output: Logical 1 (+15 V) to 0 (0 V); lasting approx 9 to 11 time units at lower frequencies, established by setting internal links for desired inhibit rate (no print on carry).

Visual Indication: 6 dimmable digital indicators for h, m, s.

Delay Setting for Time Measurement: 6 digital thumbwheel switches and 1 continuous (0-1 μs) control calibrated in 20-ns increments.

Visual Register Setting: Direct access to all six visual decades, carries inhibited.

Clock Functions: All control and setting functions are operated by a single pushbutton and are normally locked out and covered.

1. Operate: All program controls locked out.

2. Start: Clock will be started by 11-μs start pulse from pushbutton or from external source (BNC connector on rear). Start pulse produced and fed from instrument.

3. Stop: Clock will be stopped and all counting decades from 100 kc/s to 1 c/s will be set to zero by pushbutton. Zero will hold until start command is received.

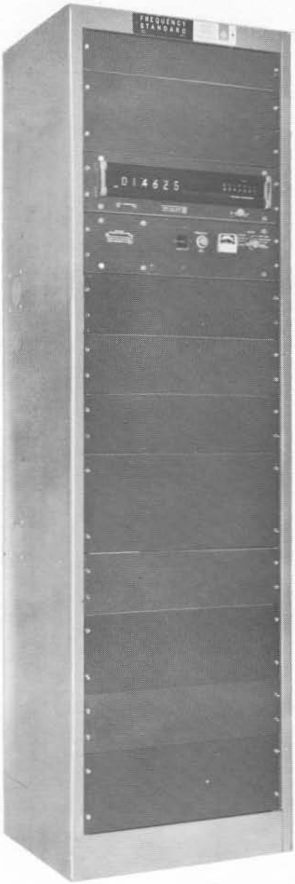
4. Set: Permits setting visual register. All-visual register carries interrupted; 100-kc to 1-cycle dividers not affected. Selected decade is advanced by 1 count for each push of the initiate pushbutton.

5. Self Sync: Permits synchronizing master tick to within 10 μs of a measured time in another time system, as WWV on UT-2.

6. Start-Slave: Permits setting a second clock from the first. After the actuate button is pushed, a start pulse will be produced when the count reaches the setting of the time-delay switches of the first clock.
Measurement Rate: Switch permits oscilloscope sync at 10-cycle rate rather than the standard one-cycle rate.
Power Required: 90 to 130 or 180 to 260 V, 50 to 60 c/s, 32 W approx. Self-contained, pressure-relief, nickel-cadmium battery for approx 24-hour off-line operation is supplied.
Accessories Supplied: Digital-output plug assembly, Type CAP-22 Power Cord, spare fuses.
Mounting: Rack-bench cabinet.
Dimensions: Bench model—width 19, height 6, depth 14½ inches (485 by 155 by 370 mm); rack model—panel 19 by 5¼ inches (485 by 135 mm), depth behind panel 12 inches (305 mm).
Net Weight: 30 lb (14 kg).
Shipping Weight: 40 lb (18.5 kg).

Type		*Price*
1123-AM	**Digital Syncronometer, Bench Model**	**$2950.00**
1123-AR	**Digital Syncronometer, Rack Model**	**2950.00**

A NEW FREQUENCY STANDARD



Type 1121-A

The new standard-frequency oscillator introduced several months ago [1] and the new digital SYNCRONOMETER® time comparator announced in this issue lead logically to a new General Radio frequency standard. It is called the TYPE 1121 Frequency and Time Standard, and it is available in any of four versions, depending on the output frequencies desired.

The TYPE 1121-A Frequency and Time Standard includes a TYPE 1115-B Standard-Frequency Oscillator and a TYPE 1123-A Digital Syncronometer time comparator, assembled in a relay rack and complete with all necessary interconnecting cables. The TYPE 1115-B Standard-Frequency Oscillator uses a 5-Mc fifth-overtone quartz crystal and supplies standard-frequency outputs at 5 Mc/s, 1 Mc/s, and 100 kc/s. The digital SYNCRONOMETER time comparator integrates the oscillator frequency to produce precise time-of-

[1] H. P. Stratemeyer, "The Stability of Standard-Frequency Oscillators," *General Radio Experimenter*, Vol 38 No 6, June 1964.

day data, permits accurate comparison of the frequency standard with standard-time radio transmissions, and generates timing pulses at frequencies from 0.1 c/s to 100 kc/s in decade multiples.

In the Type 1121-AH model, Types 1112-A and 1112-B Standard-Frequency Multipliers are added to supply output frequencies of 10, 100, and 1000 Mc/s. The vhf and uhf signals are virtually free from submultiple output frequencies. The spectrum of the 5-Mc output of the crystal oscillator is unaffected by the presence of the multipliers.

In the TYPE 1121-AL model, a TYPE 1114-A Frequency Divider is added to the TYPE 1121-A assembly to produce low-frequency sine waves of 10 and 1 kc/s, 400, 100, and 60 c/s, and 10-kc square waves.

The TYPE 1121-AHL 1000-Mc Frequency and Time Standard includes all the components of both the -AH and the -AL models, and its output frequencies extend from 60 c/s to 1 Gc/s.

SPECIFICATIONS

TYPE 1121-A

Components: TYPE 1115-B Standard-Frequency Oscillator, TYPE 1123-A Digital Syncronometer time comparator.

Output Frequencies: Sine waves at 5 and 1 Mc/s and 100 kc/s; timing pulses at 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.

Power Required: 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc. Internal nickel-cadmium batteries provide at least 24-hour emergency operation.

Net Weight: 170 lb (78 kg).

Shipping Weight: 350 lb (161 kg).

TYPE 1121-AH

Components: TYPE 1115-B Standard-Frequency Oscillator, TYPE 1123-A Digital Syncronometer time comparator, TYPE 1112-A Standard-Frequency Multiplier, TYPE 1112-B Standard-Frequency Multiplier.

Output Frequencies: Sine waves at 1000, 100, 10, 5, 1 Mc/s, 100 kc/s; timing pulses at 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.

Power Required: Frequency multipliers, 235 W max at 105 to 125 or 210 to 250 V, 50 to 60 c/s. Oscillator and comparator, 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for standard-frequency oscillator and time comparator.

Net Weight: 220 lb (102 kg).

Shipping Weight: 400 lb (184 kg).

TYPE 1121-AL

Components: TYPE 1115-B Standard-Frequency Oscillator, TYPE 1123-A Digital Syncronometer time comparator, TYPE 1114-A Frequency Divider (less Types 1114-P1 and -P2 plug-ins), Types 1114-P6 and -P7 Plug-In Units.

Output Frequencies: Sine waves at 5, 1 Mc/s, 100, 10, 1 kc/s, 400, 100, 60 c/s. Timing pulses at 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.

Power Required: Oscillator and comparator, 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc; frequency divider, 7 W max at 105 to 125 or 210 to 250 V, 50 to 400 c/s. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for oscillator and comparator.

Net Weight: 190 lb (87 kg).

Shipping Weight: 360 lb (160 kg).

TYPE 1121-AHL

Components: Type 1115-B Standard-Frequency Oscillator, Type 1123-A Digital Syncronometer time comparator, Type 1112-A Standard-Frequency Multiplier, TYPE 1112-B Standard-Frequency Multiplier, TYPE 1114-A Frequency Divider (less Types 1114-P1 and -P2 plug-ins), Types 1114-P6 and -P7 Plug-In Units.

Output Frequencies: Sine waves at 1000, 100, 10, 1 Mc/s, 100, 10, 1 kc/s, 400, 100, 60 c/s, and 10-kc square waves. Timing pulses at 100, 10, 1 kc/s, 100, 10, 1 and 0.1 c/s.

Power Required: Oscillator and comparator, 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc; frequency multipliers, 235 W max at 105 to 125 or 210 to 250 V, 50 to 60 c/s; frequency divider, 7 W max at 105 to 125 or 210 to 250 V, 50 to 400 c/s. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for oscillator and comparator.

Net Weight: 230 lb (106 kg).

Shipping Weight: 410 lb (189 kg).

Type		*Price*
1121-A	**Frequency and Time Standard**	**$5295.00**
1121-AH	**1000-Mc Frequency and Time Standard**	**8110.00**
1121-AL	**Frequency and Time Standard**	**6300.00**
1121-AHL	**1000-Mc Frequency and Time Standard**	**9115.00**

PRECISION COAXIAL CONNECTOR STANDARDIZATION AND THE GR900 CONNECTOR

The GR900 Precision Coaxial Connector is the only commercial connector that meets the IEEE Recommended Practice for 14-mm General Precision Coaxial Connectors.

At its meeting on November 12, 1964, the IEEE Standards Committee approved sections of a standards document on Recommended Practices for Precision Coaxial Connectors, which is of special importance to all those concerned with coaxial systems and measurements. The document was prepared by the Subcommittee on Precision Coaxial Connectors,[1] after this subcommittee had studied the problems of designing, fabricating, and measuring the performance of precision connectors and had evaluated a number of designs. No particular connector is selected as a standard, but the document does set forth certain design and performance specifications for a standard connector. The mechanical requirements ensure that any connector meeting the specifications will mate with any other of the same line size but do not specify the actual coupling mechanism.

Two line diameters are specified by the document: a 14-mm diameter for precision applications up to 9 Gc/s and a 7-mm diameter for use up to 18 Gc/s. The larger-diameter line has about twice the accuracy of the smaller line. For each diameter, two types of connector are described: (1) a General Precision Connector (GPC), which includes a dielectric support for the center conductor, and (2) a Laboratory Precision Connector (LPC), which does not.

The IEEE Standards Committee's approval was given only to those parts of the Subcommittee document having to do with general requirements and definitions, parameters to be specified, and detailed specifications for 7- and 14-mm general precision connectors. The 7-mm section was approved for trial use and is not in final form, since the Subcommittee has yet to determine through evaluations of samples whether the specifications can be met in a practical connector and has still to specify the design of the critical mating surfaces or coupling arrangements. The 14-mm section, however, is complete, since these decisions and evaluations have already been made. The specifications, as proposed by the Subcommittee, appear in the December, 1964 *IEEE Transactions on Instrumentation and Measurements.*

In 1959, General Radio began investigating possible designs for a precision coaxial connector. Our own development program led to the GR900 Precision Coaxial Connector, several thousand of which have been produced over the past two years. This connector

[1] Of the IEEE Committee on Electronic and High-Frequency Measurements, G-IM.

has been thoroughly evaluated by several independent laboratories cooperating with the Subcommittee on Precision Coaxial Connectors and has been found to meet the specifications for the 14-mm general precision connector. Ever since the formation of the original committee in 1960, our engineers have cooperated with that group and have freely exchanged technical information on connector design problems and on improved measurement methods. General Radio's cooperation with the Subcommittee has extended to the waiving of patent and other proprietary rights to the basic dimensioning and design of the GR900 Connector.

HIGH-FREQUENCY TRANSISTOR MEASUREMENT STANDARD

Another standards committee, that of the EIA, recently agreed on a proposed JEDEC standard on high-frequency transistor *Y* and *H* parameters and sent the standard out to industry for review. All transistor measurements specified can be performed by GR's Type 1607-A Transfer-Function and Immittance Bridge and the new transistor mounts described below.

MOUNTS FOR TRANSISTOR MEASUREMENTS WITH THE TRANSFER-FUNCTION BRIDGE

Accurate measurements of high-frequency transistors rapidly became commonplace after the introduction, in 1959,[1] of commercially available transistor mounts for use with the Type 1607-A Transfer-Function and Immittance Bridge. These mounts, designed primarily for development applications, left some problems for the production tester, who had either to clip the leads of his transistors or to leave most of the leads exposed and in circuit.

A new series of transistor mounts now permits the insertion and accurate measurement of transistors with leads up to two inches long. The leads are hidden from the field, the connection point is just below the transistor header, and parasitic lead inductance and capacitance are just about eliminated. In the new mounts, the transistor leads are inserted into hollow inner conductors of tiny coaxial lines. A short section of each inner conductor, near the top, is compressed to a narrow diameter to make a stable electrical contact with the transistor lead. An incidental feature, useful to the circuit designer, is that the transistor can be connected to the mount with just the right amount of lead left in circuit to simulate its

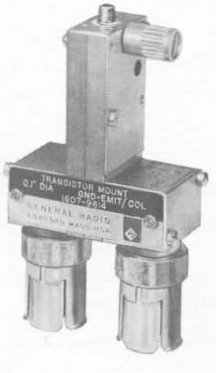


Figure 1. One of the new transistor mounts, with transistor fully seated in socket.

[1] W. R. Thurston, R. A. Soderman, "The Type 1607-A Transfer-Function and Immittance Bridge," *General Radio Experimenter*, Vol 33 No 5, May 1959.

eventual connection. The transistor can thus be measured to include the parasitic lead effects that will be present in the circuit. Four such mounts are now available: two for transistors with a 0.2-inch-diameter pin circle (TO-5 packages) and two for the 0.1-inch pin circle (TO-18 packages). A grounded-base and a grounded-emitter mount are available for each size. (The grounded-emitter mounts can also be used for the grounded-collector configuration; the transistor is simply oriented differently upon insertion.) Four-hole sockets in all mounts include a connection for dc or metallic ground.

INTERNAL CONFIGURATION

The internal configuration of the new mounts is shown in Figure 2. Two jogs

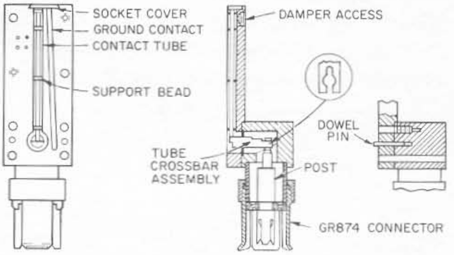


Figure 2. Cross-section drawings showing internal configuration of new mounts.

in the internal coaxial line are used to make the substantial transition from GR874 Connector to the small transistor lead spacing. A more obvious design would have employed tilted conical tapers converging to the small socket size. The step transition was chosen because it allows the transistor leads to go straight into the socket, it is easier to control in manufacture, and it is not at all difficult to compensate locally for the discontinuities existing at the 90°

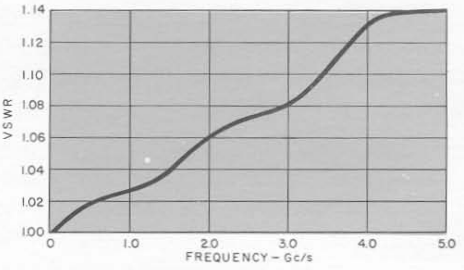


Figure 3. Typical VSWR characteristics of new transistor mounts.

jogs. How well this has been done is shown by the mounts' VSWR characteristics (Figure 3).

The small coaxial lines inside the mounts consist of square outer conductors and round inner conductors (see Figure 4). This configuration was necessary to achieve the close spacing of the coaxial line pair, corresponding to the transistor lead spacing. In the 0.2-inch pin-circle mounts, the coaxial-line dimensions are 0.132 inch (square) and 0.062 inch (diameter of the round inner conductor). In the 0.1-inch pin-circle mounts, these dimensions are 0.068 and 0.032 inch, respectively.

The use of such small coaxial lines in the mounts offers several advantages. Discontinuities between coaxial lines and transistor leads are minimized; a colinear relation exists between lines and leads; and the damper (a 50-ohm dc-block resistor assembly used to suppress transistor oscillation) can be located closer to the reference plane (ac-

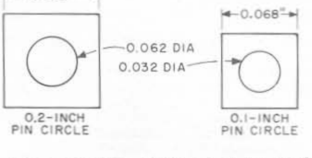


Figure 4. Cross section of internal coaxial leads.

tual distance is 3/32 inch) to reduce its effect on the measurement. All these factors add up to greatly increased accuracy of transistor measurements.

The reference plane of the new mounts (the point on the transistor lead to which the measured values apply) is 0.025 inch below the top of the mount socket, or 0.025 inch below the header when the transistor is firmly seated in the mount. The electrical length from the reference plane to the short-circuit plane of a TYPE 874-WN Short-Circuit Termination is 9.5 cm.

The elements used to set up the reference plane on the older mounts cannot be used for this purpose with the new mounts. A new set based on the 9.5-cm length is available as the TYPE 1607-P40 Termination Kit.

The new mounts will be useful to the circuit designer, the transistor developer, and the production-line tester. A procedure has been devised for the rapid production-line measurement of β, and some companies guarantee Y parameters measured with this equipment.

One especially important transistor-design application involves the use of Linvill charts.[2] Transistor parameters are measured, and the charts are then used to determine circuit parameters. Examples of this and other procedures are given in several papers.[3, 4, 5]

LEAD ACCOMMODATION

The mounts accept transistor leads as long as two inches. The TYPES 1607-P41 and -P42 (0.2-inch pin circle) mounts can accommodate leads with diameters from 0.014 to 0.032 inch. The TYPES 1607-P43 and -P44 (0.1-inch pin circle) mounts accept leads with diameters from 0.014 to 0.021 inch.

The mounts will not accept very crooked leads, and leads should be straightened and made perpendicular to the header to ensure accurate measurement.

SOCKET ACCESSIBILITY AND FEATURES

On each mount, the socket is out in the open and readily accessible. A marker indicates the proper orientation of the transistor tab. Four tapped holes surround the socket to permit attachment of a heat sink. Socket contacts are heat-treated beryllium copper and are quite rugged.

The socket itself is made of polycarbonate, an extremely tough plastic with a dielectric constant of 2.73.

APPLICATIONS

The mounts can be used with the TYPE 1607-A Transfer-Function and Immittance Bridge to measure all immittance and hybrid transistor parameters directly, in the frequency range from 25 Mc/s to 1.5 Gc/s. They can also be used with a slotted line to measure driving-point parameters up to about 5 Gc/s.

NOTE: The older mounts (TYPES 1607-P101, -P102, -P111, -P401) will continue to be available and are recommended for those applications that do not require the long-lead capability or the four-lead socket.

—J. ZORZY

[2] Linvill and Gibson, *Transistors and Active Circuits* McGraw-Hill, 1961.
[3] V. Gelnovatch and G. E. Hambleton, "1 Gc Transistor Amplifier Stage Using Linvill Technique," *Proceedings of the IEEE*, Vol 52 No 10, p 1262.
[4] P. E. Kolk, "Design of Three UHF Transistor Circuits," *Micro Waves*, November 1964, p 32-37.
[5] G. E. Hambleton and V. Gelnovatch, "L-Band and Germanium Mesa Transistors," *Microwave Journal*, Vol 8 No 1, January 1965, p 42–46, 67–68.

SPECIFICATIONS

	Types 1607-P41, -P42	*Types 1607-P43, -P44*
Transistor Packages Accepted:	TO-5, 9, 11, 12, 16, 26, 31, 33, 37, 38, 39, 43; MD-14; MM-4, 8; MT-13, 20, 28,37; RO-2, 3, 4, 5, 10, 24, 30, 33, 34, 46, 49, 50, 61, 62, 79, etc.	TO-18 28, 52, 54; MT-30, 38; RO-44, 48, 51, 64, 65, 66, 70, 73, 78; U-3; X-8, etc.
Characteristic Impedance (of coaxial lines):	50 Ω ± 0.8%	50 Ω ± 1.6%
Pin-Circle Diameter:	0.2 inch	0.1 inch
Range of Transistor Lead Diameters:	0.014 to 0.032 inch	0.014 to 0.021 inch
Maximum Transistor Lead Length:	2 inches	
Frequency Range:	dc to 5 Gc/s	
Accessory Supplied:	One Type 1607-P30 Damper (to prevent oscillation)	
Accessory Required:	Type 1607-P40 Termination Kit	
Net Weight:	Mount, approximately 12 oz (0.4 g); Termination Kit, approximately 14.5 oz (0.5 g)	

Type		*Price*
1607-P41	**Transistor Mount** (0.2-in pin circle, grounded base)	**$115.00**
1607-P42	**Transistor Mount** (0.2-in pin circle, grounded emitter/collector)	**115.00**
1607-P43	**Transistor Mount** (0.1-in pin circle, grounded base)	**115.00**
1607-P44	**Transistor Mount** (0.1-in pin circle, grounded emitter/collector)	**115.00**
1607-P40	**Termination Kit**	**42.50**

SOUND-POWER MEASUREMENTS ABOVE A REFLECTING SURFACE

A preferred method of rating the noise output of a device is to determine the sound power radiated from it.[1] General procedures for measuring sound power are specified in an American standard (S1.2–1962, American Standard Method for the Physical Measurement of Sound), and some specialized test codes are based on that standard.

One basic test procedure requires suspending the noisy device in the middle of an anechoic chamber. Twenty microphones are placed at points uniformly distributed on a hypothetical measurement sphere surrounding the source. The sound-pressure level at each of these points is then measured, and the radiated sound power is calculated from the results of these measurements.

[1] For a general discussion of sound-power measurements and a list of references, see A. P. G. Peterson and E. E. Gross, Jr., *Handbook of Noise Measurement*, Chapter 7, General Radio Company, West Concord, Massachusetts, 1963.

If the device being measured is large and heavy, suspending it in a chamber may be impractical. It is often easier and more sensible to place it on a large concrete foundation, as it might be mounted in actual use; any surrounding walls are made anechoic. Or the device may be placed on a large paved area in the open. The flat mounting surface then becomes a reflecting plane for the sound, and the measurement positions are distributed on a hypothetical hemisphere above the plane and surrounding the device. The 12 microphone positions usually chosen for these measurements have not been as satisfactory as those for the complete sphere, because four of the points are in the reflecting plane. (P. K. Baade, "Sound Radiation of Air-Conditioning Equipment; Measurement in the Free-Field Above a Reflecting Plane," *Technical papers on sound*

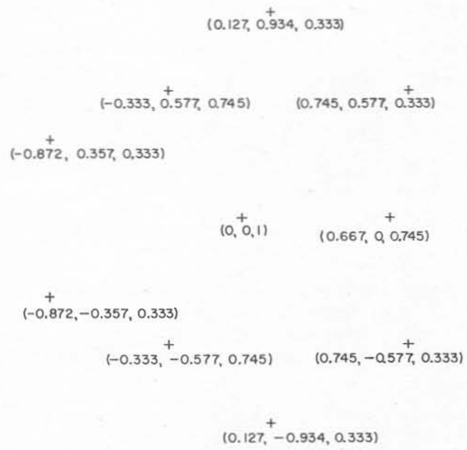


Figure 1. Plan view of 10 points distributed on a hemisphere of unit radius. Coordinates are given in terms of distances from center along three mutually perpendicular axes (X, Y, Z).

measurement, presented ASHRAE 71st annual meeting, Cleveland 1964.)

Another, related set of measurement points can be used to avoid making measurements in the reflecting plane. This new set, shown in Figure 1, is in effect the earlier set rotated 20.9° about an axis in the reflecting plane passing through the source. This set has 10 points, and, although the distribution is not strictly uniform, the deviations from uniformity are so small that equal weight can be given to all the points.

The sound power is then computed from the measured values of sound-pressure level by the equations given in the standard (ASA S1.2–1962). Thus:

$$L_W = \overline{L}_P + 20 \log_{10} r - 2.5$$

where L_W = sound-power level in decibels referred to 10^{-12} watt,

$\overline{L}_P$ = mean-square sound-pressure level over the test hemisphere in decibels referred to 0.0002 microbar,

r = radius of the test hemisphere in feet.

(If r is in meters, the formula is

$$L_W = \overline{L}_P + 20 \log_{10} r + 7.8.)$$

$\overline{L}_P$ can be calculated from the 10 sound-pressure-level measurements in the following way. Convert each decibel level to an equivalent power ratio by means of a decibel conversion table (such as that given in the General Radio *Handbook of Noise Measurement*). Add the 10 power ratios, divide by 10, and reconvert to a decibel value. The result is $\overline{L}_P$.

This new set of measurement points avoids the error that can occur with a nondirectional pattern for the 12-point system, but, if the source is highly directional, any such set of relatively few points can give serious errors. The first time any new device is measured, some exploration of the field is desirable in order to check its directivity pattern. If it is highly directional, more detailed exploration of the field will be necessary.

—A. P. G. PETERSON

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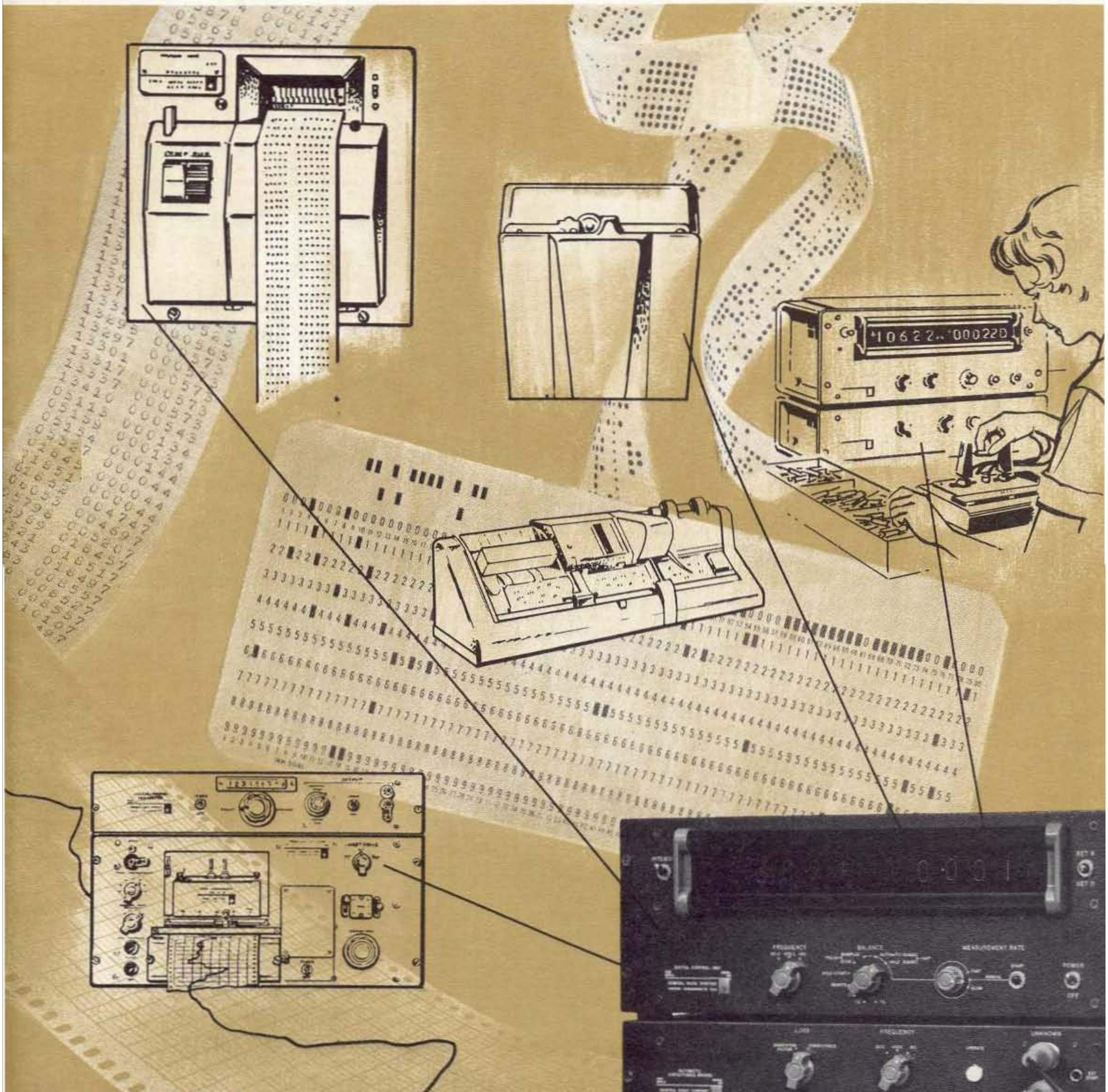

in this issue:

THE AUTOMATIC CAPACITANCE BRIDGE
COAXIAL MICROWAVE NEWS
OPEN HOUSE

the GENERAL RADIO
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Figure 1. Type 1680-A Automatic Capacitance Bridge Assembly.

THE AUTOMATIC CAPACITANCE BRIDGE

The ideal measuring instrument is one that requires only that the unknown be connected to its terminals and which thereupon indicates the measured value, with not so much as a single control being manipulated. A few such automatic instruments have been developed; many more are sure to come. General Radio's first entry in a projected series of automatic digital instruments is the TYPE 1680-A Automatic Capacitance Bridge, which selects range, balances capacitance and loss simultaneously, generates coded digital output data, and displays the measured values, complete with decimal points and units, on illuminated indicators — all in a half second or so. This new bridge not only permits a dramatic speedup in the measurement of capacitors, but also couples easily into systems for automatic, error-free recording of data.

The exceptional speed and self-balancing capability of the automatic bridge are not bought at the expense of accuracy or capacitance range. Basic accuracy is $\pm 0.1\%$, and the capacitance range for useful measurements is 1 picofarad to 1000 microfarads (see Specifications). Dissipation-factor range is 0.0001 to 1.0, and the bridge also measures parallel conductance from 0.1 nanomho to 1 mho.

HOW IT WORKS

The bridge circuit is a transformer ratio-arm bridge, in which balance is achieved by the adjustment of the voltage impressed on the standard capacitor. The method by which this voltage is automatically adjusted to produce balance is shown in Figure 2. Any unbalance current from the bridge is separated into real and imaginary components by two phase-sensitive de-

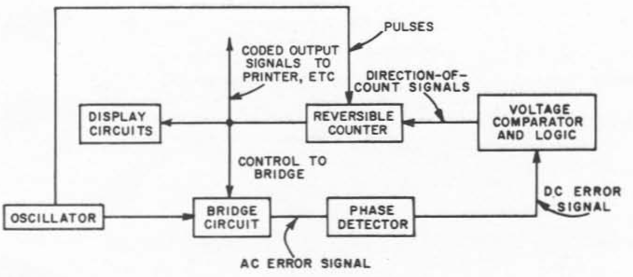


Figure 2. Elementary block diagram of the automatic bridge.

tectors. The dc output from each detector controls the direction in which a reversible counting decade counts pulses derived from the bridge generator. If, for instance, the capacitance value indicated by the counting decade is too high, the dc output from the phase detector will cause counts to be subtracted from the decade. The coded output of each counting decade is, in turn, fed back through a digital-to-analog converter to change the voltage on the bridge standard until balance is reached.

To minimize balancing time, as well as to afford the greatest versatility of operation, four operating modes are provided. The optimum mode depends on the kind of measurements being made and on how much each component differs in value from the next.

In the two FAST modes, the initial value is set to 02000, and the pulses are counted first in the *most* significant digit until it is balanced, then in the next most significant, and so on until the least significant digit is balanced. The balance speed in these modes is essentially independent of the value of the unknown.

The AUTOMATIC RANGE mode is used for highest-resolution measurements of capacitors that vary widely in value from one to the next. For such measurements, this is the fastest mode. The bridge quickly selects the right range and the balance sequence starts at the most significant digit and works to the least.

The HOLD RANGE mode is identical to the AUTOMATIC RANGE mode except that the bridge will not shift to a lower range and thus displays a series of measured values in a form for easy comparison. Operating in this mode, the bridge would not, for instance, indicate two successive measurements as 1263.1 nF and 13.107 nF. Instead, the second measurement would be made on the same range as the first, for a reading of 0013.1 nF. Although the bridge will not change to a lower range, it will go to a higher one, so that a correct answer will always be indicated.

In the two CONTINUOUS modes, the pulse count starts at the least significant digit of the counter, so that balance time depends on the difference

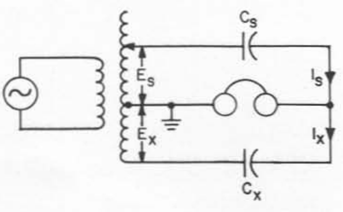


Figure 3. Simplified schematic diagram of transformer ratio-arm bridge.

between the last value measured and the true value of the unknown.

In the continuous-tracking (TRACK CONT) mode, the balance begins at the previous measured value and proceeds from the least significant figure to the most, as with a conventional counter. The bridge then follows changes in capacitance as they occur, always indicating the current capacitance value. This mode is used if the application involves small changes in the capacitance being measured, as, for instance, in temperature-coefficient testing.

In the TRACK SAMPLED mode, the bridge, instead of automatically following changes in capacitance, makes measurements only on command of the operator. Balance starts at the previous value and proceeds from the least significant figure to the most, and this mode is thus especially useful in the testing of many capacitors of the same nominal value.

The Transformer Ratio-Arm Bridge

The transformer ratio-arm bridge (see Figure 3) has enjoyed recent favor in commercial designs and is used in the most accurate capacitance bridges available today.[1] The chief advantage of this type of bridge is that a precisely known turns ratio can be used to extend the usefulness of a single high-precision standard component over a very wide range. This turns ratio, moreover, is unaffected by age, temperature, or voltage variation.

To balance the bridge, the voltage on the standard capacitor is adjusted so that the current through the standard arms equals the current flowing through the unknown arm. Under this condition, the detector current is zero and the detector indicates a null. At balance, therefore:

$$E_s j\omega C_s = E_x j\omega C_x$$

or

$$C_x = \frac{E_s}{E_x} C_s.$$

The ratio transformer in the TYPE 1680-A Bridge is a high-permeability toroid with 1-, 10-, 100-, and 1000-turn windings. The internal standards, which basically determine the accuracy and stability of any bridge, are a 0.1-μF polystyrene and silvered-mica capacitor, with a temperature coefficient of only a few parts per million/°C, for capacitance measurements at 1 kc/s and 400 c/s; a 1-μF precision polystyrene capacitor for 120-cycle capacitance measurements; and, as conductance standards, several precision resistors wound on flat card forms to an initial tolerance of better than $\pm 0.01\%$ and sealed against atmospheric effects.

The Phase Detector

Since the detector signal is zero at balance, the phase-detector characteristics do not affect accuracy. They do, however, affect speed of balance. The TYPE 1680-A Bridge uses a sampling, or keyed, phase detector,[2] which arrives at its final output value within only one period of the signal frequency. The principle of operation is shown in Figure 4. The phase detector stores the instantaneous value of the input signal at a particular point in the ac cycle. So that the detector can sample the value of the in-phase component, a

[1] J. F. Hersh, "Accuracy, Precision, and Convenience for Capacitance Measurements," *General Radio Experimenter*, August–September 1962.

[2] K. E. Schreiner, "High-Performance Demodulations for Servo Mechanisms," *Proceedings of the National Electronics Conference*, 1946, Vol 2, p 393–403.

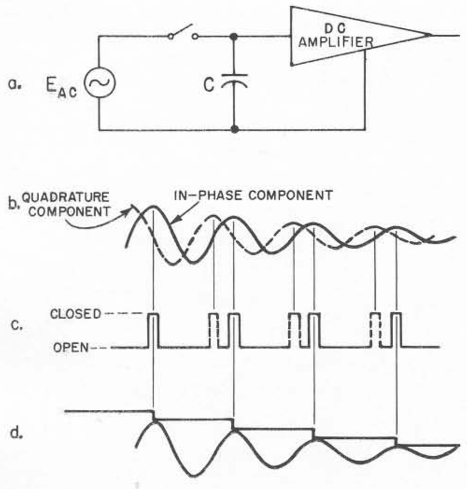


Figure 4. The sampled phase detector. a. Elementary block diagram. b. The error signal, E_{AC}, resolved into in-phase and quadrature components. c. The switch closes when the signal component reaches its peak value. d. The resulting dc output closely follows the peak value of the signal component as the error signal approaches zero.

switch is closed briefly when this component reaches its peak amplitude, and this peak value is stored in a storage capacitor. The quadrature component is zero at this time and thus does not affect the voltage. The dc output of this type of detector follows the instantaneous value very closely and supplies the necessary up-to-date information to the logic circuits.

The Reversible Counter

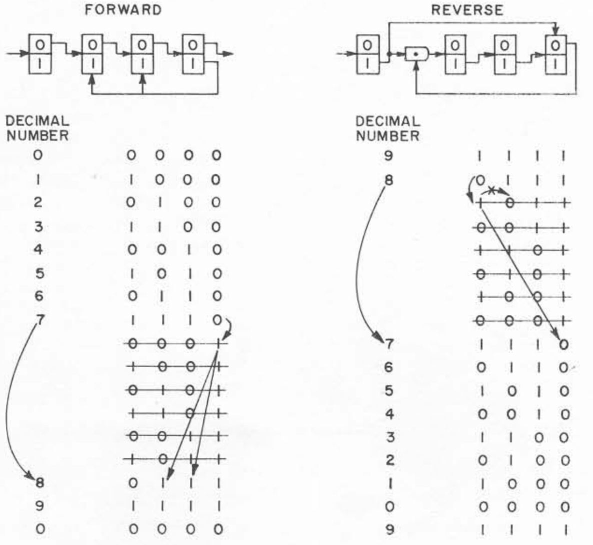
There are two reversible decade counters, one for capacitance balance, one for loss. Each consists of four complementary flip-flops coupled together by gates that can arrange the circuit for either forward or reverse counting. The digital logic[3] by which the four flip-flops are used to generate a scale of 10 is shown in Figure 5. A 1-2-4-2 coded output is supplied at a rear-panel connector to drive auxiliary output devices, such as printers, tape-punches, etc.

Voltage-Adjusting Network

To balance the bridge to a null, the voltage on the standard capacitor must be adjusted precisely in steps as small as the least significant digit, which is

[3] Patent applied for.

Figure 5. (*Left*) Feedback system for converting 16 states of four flip-flops into a scale of 10. Carry pulses are generated during transitions from state 1 to state 0, feedback pulses during transitions from state 0 to state 1. The crossed-out states do not occur but are bypassed by the feedback reset operations.
(*Right*) In the reverse direction, carry pulses are generated during transitions from state 0 to state 1. After state 8, the carry pulse from the first flip-flop does not reach the second flip-flop because of the gate, but it is used to set the fourth flip-flop to the zero state.



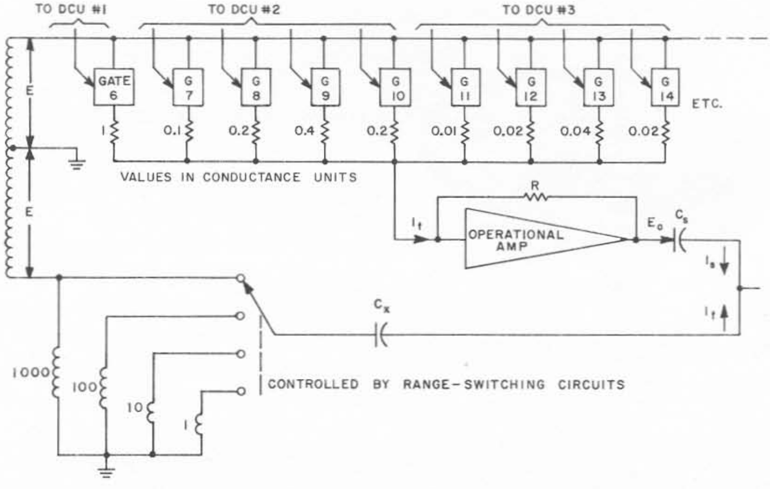


Figure 6. Resistive current-adding network used to control voltage on standard capacitor.

0.01% of full scale. Figure 6 illustrates the principle of the resistive current-adding network used for this purpose. The bridge voltage E is applied through transistor gating circuits to a series of weighted conductances. There are four conductances for each full counting decade, weighted in a 1-2-4-2 series to match the decade output code. If, for example, the unknown capacitor is 1.37 μF, the counting decades will continue to operate until the transistor gating circuits connect conductances weighted 1, 0.2, 0.1, 0.01, 0.02, and 0.04 (a total of 1.37) to the bridge transformer. When this condition is reached, a current of 1.37 units flows to the input of an operational amplifier and feedback resistor, which converts the current into 1.37 units of voltage to balance the bridge.

The transistor gating circuits do not significantly affect accuracy. With the high-gain operational amplifier, the digital-to-analog conversion accuracy is determined by the resistors to within a few parts per million.

Accuracy

The basic accuracy of the bridge is ±0.1% of reading for capacitance and conductance. In cases where this high accuracy is not required — in production-testing of 10% capacitors, for example — the balance speed can be increased by reduction of bridge sensitivity. A rear-panel sensitivity control is available for such purposes.

No error is introduced by stray capacitance if shielded cables are used. A three-terminal connection is thus made to the capacitors under test — both of the leads to the unknown being shielded by a grounded guard terminal. The stray capacitances to guard shunt the low-impedance ratio transformer and detector and therefore do not affect the accuracy. Series resistance of leads, however, can cause errors on the highest capacitance range. The curves given in the specifications include the effects of lead resistance up to 50 milliohms.

Figure 7. Type 1680-P1 Test Fixture.

ASSOCIATED EQUIPMENT

Type 1680-P1 Test Fixture

As mentioned earlier, the automatic bridge is an amazing time-saver even without auxiliary instruments. One operator using one automatic bridge to measure capacitors can replace several operators using manually balanced bridges. The only auxiliary equipment really needed is some means of connecting the capacitors to the bridge terminals. The TYPE 1680-P1 Test Fixture (Figure 7) is ideal for this purpose. It includes adjustable, insulated, fast-action spring clips to receive the component leads and a built-in switch to start the balance procedure. Its top plate is removable so that it can be easily adapted to specialized contact arrangements. Shielded cables connect this jig to the bridge. Although it is designed primarily for axial lead components, the jig is easily adapted to accept parallel-lead units.

Automatic Input Devices

The process of connecting capacitors to the bridge can be completely automated. Automatic input equipment may be justified where the fastest possible measurement rate is required or where capacitors are to be measured in a test environment, out of human reach.

The scanner is the most likely instrument for sequentially connecting capacitors to the bridge. This is basically an electronic or mechanical switch, with a number of shielded leads to the components to be tested and a single pair of shielded leads to the bridge. Important requirements of such a scanner are low series contact resistance and low stray capacitance across the terminals.

Automatic Output Devices

Manual recording of measurement data can be every bit as time-consuming — and just as subject to error — as manual bridge balancing. Fortunately, the technology of data processing has advanced to the point where there is a fairly wide range of reasonably priced, relatively simple instruments to record data automatically. These include printers, tape- and card-

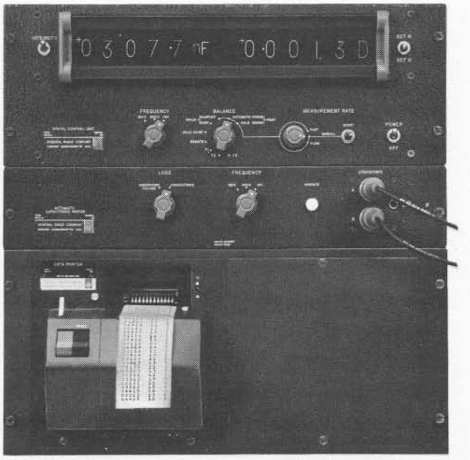


Figure 8. Type 1137-A Data Printer rack-mounted with the automatic bridge.

punches, analog recorders, typewriters, and magnetic-tape recorders.

Printers

The General Radio TYPE 1137-A Data Printer (Figure 8) is designed for use with GR digital equipment. This is a 12-column printer, which therefore handles the full capacitance and dissipation-factor readouts (five digits each), with two columns left over. Since the printer does not print out the decimal point and units as they appear on the bridge's visual readout, one of the remaining two columns is usually used to indicate the range on which the bridge was balanced.

The printer is probably the simplest and least expensive way to record measurements made by the automatic bridge. Its disadvantage is that the printed tape it produces is not machine-readable, and it cannot, therefore, be fed into a computer for processing.

Tape Punch

A tape punch is the least expensive way to record data in machine-readable form. The measured values from the bridge are punched on the tape in binary-coded form, the presence or absence of a hole on the tape indicating a binary 1 or 0.

Binary-coded output data corresponding to all digits of the bridge readout are presented simultaneously (i.e., in parallel) at the bridge output connector. The tape punch, on the other hand, can accept and punch the data only one digit at a time (i.e., in series). Therefore, a parallel-to-serial converter (sometimes called an interface or intercoupler) is required between the bridge and the tape punch.

Fig. 9. IBM Model Printing Summary Punch operating from output of automatic bridge. Capacitance values are automatically punched; operator adds serial numbers. Also in relay rack are data printer and (top) intercoupler required for parallel-to-serial conversion.

Card Punch

The punched card has many advantages as a data-storage device. It is machine-readable. Cards can be automatically sorted or rearranged. A single card, bearing complete measurement data on a component, can travel with the component.

Figure 9 shows the bridge driving an IBM Model 526 Card Punch, with the aid of a parallel-to-serial converter.

Analog Recorders

In certain applications (in the plotting of temperature coefficients of capacitors, for example), an analog recording is the most useful presentation. This can be an X-Y chart or a strip chart, such as that produced by the GR TYPE 1521-B Graphic Level Recorder. Either way, a digital-to-analog converter is needed to translate the digital output of the bridge into a voltage analog. The TYPE 1136-A Digital-to-Analog Converter is compatible with recorders made by General Radio and by other manufacturers.

Digital Limit Comparators

In almost all high-volume capacitor test programs, a decision immediately follows each measurement. The capacitor is good or not good, higher or lower than nominal, inside or outside tolerance. A human operator can make these decisions, or they, too, can be handled automatically. A two-limit digital comparator can be programmed to indicate whether each capacitor is within a given set of limits, too high, or too low. The indication can be a simple set of panel lights or it can be in the form of relay contact closures used to sort capacitors into various bins. If the comparator is combined with a data printer, the latter can be made to print out-of-tolerance results in a second color.

The limit comparator is especially valuable in quality-control, production testing, and acceptance applications, where it can reduce hours of work to minutes. One can select a group of components, for example, measure them, and then glance at a printed tape to check for rejects. The tape can be filed with the acceptance report or returned to the supplier.

Other Output Devices

Typewriters and magnetic tape recorders are among the other output devices that can be used to record data from the automatic bridge. Both require a parallel-to-serial converter.

Realizing that the automatic bridge will more often than not be part of a larger measurement system, General Radio has arranged to supply complete systems incorporating auxiliary instrumentation described above.

APPLICATIONS

The automatic bridge was designed primarily for the rapid, automatic measurement of capacitance. The following are some of the specific applications calling for such a capability:

Incoming inspection

The automatic bridge is of obvious value in incoming-inspection applications, and especially in those involving many short runs of widely differing values. No set-up time, no sets of standards are required; the bridge can measure capacitors as fast as an operator can drop them into a test jig.

Environmental testing

A batch of capacitors can be measured over and over to determine the effect of aging, humidity, etc, on capacitance. For such measurements, a scanner is useful at the input, and a tape or card punch at the output.

Temperature-coefficient tests

The capacitance of a component can be measured as a function of temperature. An obvious arrangement consists of an X-Y plotter accepting capacitance data from the bridge, temperature data from a thermocouple and preamplifier.

Production testing

Large quantities of capacitors can be presented sequentially to the bridge by means of a belt, reel, or other type of component handler. A tape or card punch is recommended to store data.

Production sorting

A digital limit comparator, as noted earlier, can be used with the bridge to inspect components rapidly on a go-no-go basis or according to programmed tolerances.

Other applications

Several ingenious customers have already discovered ways to use the bridge for applications other than the straightforward measurement of capacitors. The bridge, for instance, becomes a capacitance comparator if an external reference capacitor is connected to the proper terminals on the bridge. The bridge will then indicate the difference, positive or negative, between the unknown capacitor and the external standard. This permits extra accuracy and resolution over some of the range, and it is also useful where large numbers of capacitors must be padded to a given value. As each capacitor is connected to the bridge, the bridge indicates directly the value of the required padding capacitor.

The bridge will balance not only for capacitors, but also for resistors, inductors, and complex impedances. When measuring resistors, the bridge will automatically select the range and indicate the effective conductance ($G = 1/R$) of the resistor along with its stray capacitance. For inductors, the indicated value will be in terms of a negative capacitance ($C = -\frac{1}{(2\pi f)^2 L}$). The bridge will balance for impedances between about 1 ohm and 100 megohms at 1 kc/s. This range covers most of the complex networks and integrated-circuit values. While the units indicated on the bridge are not particularly convenient for such measurements, tolerance-checking and sorting can easily be accomplished if the test limits are first converted into equivalent capacitance or conductance values.

Remote-Control applications

Most of the front-panel controls can be operated remotely. This feature, along with the digital outputs, makes the bridge suitable for inclusion in specialized systems for automatic sorting of components or controlling of production processes.

SERVICE FEATURES

Just as surely as automatic equipment saves its users money when it is working, it is very costly when it is forced out of action for service. Therefore, we have designed into the bridge several features to help keep "down time" to a minimum. All components except some in the power supply are mounted on plug-in, easily replaceable fiberglass etched boards (see Figure 10). "Test" positions of the front-panel BALANCE control allow the user to "walk" the bridge through the complicated balance logic one step at

Figure 10. Plug-in etched boards are easily removed for service or replacement.

a time to check operation. With this troubleshooting aid, a faulty circuit card can quickly be isolated.

CONCLUSION

With this, the first in a projected series of automatic instruments, General Radio has combined a classic bridge circuit with modern digital control techniques to produce the first true bridge that is truly automatic. The practical consequence of this development is the speedup, by a factor of 10 or more, in the measurement of capacitors. The resulting economic advantage to any large-scale producer or user of capacitors needs no elaboration.

— R. G. Fulks

ACKNOWLEDGMENTS

Many people assisted in the development of the automatic bridge. The author wishes particularly to acknowledge the assistance of M. J. Fitzmorris in the development of the instrument.

SPECIFICATIONS

		At 120 c/s	*At 400 c/s*	*At 1000 c/s*
RANGES	**Capacitance (parallel)*:**	100 pF-1000 μF	0.01 pF-100 μF	0.01 pF-100 μF
	Conductance (parallel):	0.1 μmho-1.0 mho	100 pmho-1.0 mho	100 pmho-1.0 mho
	Dissipation Factor (direct reading)	0.0001-1.00 (100%)	0.0001-1.00 (100%)	0.0001-1.00 (100%)
	(Measured as conductance):	0 to ∞	0 to ∞	0 to ∞
BASIC ACCURACY (see curves)	**Capacitance:**	0.1% of reading	0.1% of reading	0.1% of reading
	Conductance:	0.1% of reading	0.1% of reading	0.1% of reading
	Dissipation Factor:	1% of reading	1% of reading	1% of reading
SPEED OF BALANCE (approx) (Speed may be somewhat slower than that listed when dissipation factor is measured near the low end of each range.)	**Fast Modes:**			
	No range changes	2.5 seconds	0.35 second	0.25 second
	With range changes	5.0 seconds	0.6 second	0.5 second
	Tracking Modes:			
	10-count change	1.0 second	0.1 second	0.1 second
	100-count change	2.0 seconds	0.35 second	0.2 second
	1000-count change	11.0 seconds	2.6 seconds	1.1 seconds

* For series capacitance measurements a correction (chart supplied) can be used: If D_x = 0.1 (10%), correction = 1%.
If D_x = 0.03 (3%), correction = 0.1%.

EFFECTS OF LEADS: There is no error introduced by stray capacitance if shielded cables are used. Series resistance of leads can cause errors on the highest range. Accuracy curves include the effects of up to 50 mΩ of external cable.

VOLTAGE ACROSS UNKNOWN: 1 V on lower capacitance ranges, decreasing to 1 mV on highest range. Can be set (internally) as low as 1/10 of these values with a proportionate loss in resolution.

DISPLAY: Two 5-digit banks of bright-light, numerical indicators, with decimal points and units of measurement. Lamp burnout does not affect instrument operation or coded output. Lamps can be replaced from front panel.

DC BIAS: Can be introduced from external source.

REMOTE CONTROL: Start and balance controls can be activated remotely by contact closures.

OUTPUT SIGNALS

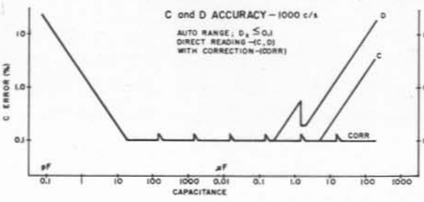
Numerical Data: 10 digits BCD 1-2-4-2 code.

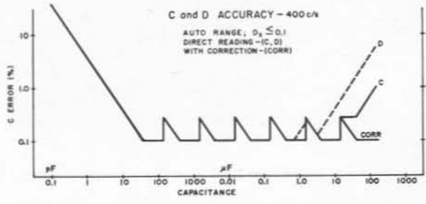
Range Code (1 to 7): 1 digit BCD 1-2-4-2 code.

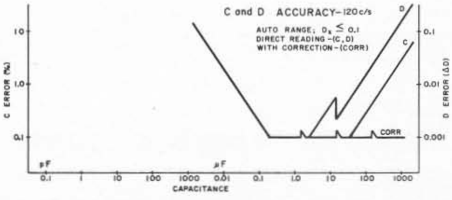
Print Command at Completion of Balance: Change from "1" level to "0" level — returns to "1" level at end of display interval.

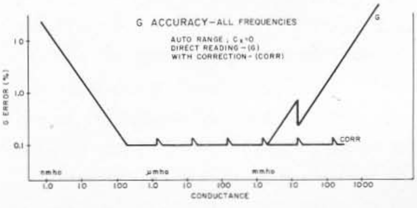
Signal Levels: "1" level, 0 V; "0" level, — 12 V; both with respect to reference line, which is at +6 V above chassis ground. Impedance of lines = 12 kΩ.

MEASUREMENT RATE: Panel control allows adjustment of measurement rate so that display time between measurements is between approxi-









mately 0.1 and 5 s. The rate can be set manually (or remotely) at any rate compatible with balance time.

OPERATION AT OTHER MEASUREMENT FREQUENCIES: With internal factory modification, the measurement frequencies can be changed to any frequency between 100 c/s and 2 kc/s.

DIFFERENCE MEASUREMENTS: By the addition of a suitable standard to terminals provided, the bridge can be made to indicate the deviation, either positive or negative, from a nominal value, over part of the range.

GENERAL

Power Required: 105 to 125 V, 195 to 235, or 210 to 250 V, 50 or 60 c/s, 100 W. Internal 120-cycle oscillator is locked to power line for 60-cycle operation.

Auxiliary Controls: A rear-panel sensitivity control can be used to minimize balance time by a decrease in resolution.

Mounting: The Automatic Capacitance Bridge Assembly consists of two components, Type 1672-A Digital Control Unit and Type 1673-A Automatic Capacitance Bridge. End frames for bench mount and hardware for rack mount are both supplied.

Dimensions: Panel 19 by 10½ in (485 by 270 mm), depth behind panel 18 in (460 mm).

Net Weight: 71 lb (33 kg).

Shipping Weight: 145 lb (67 kg).

Catalog Number	*Description*	*Price*
1680–9701	**Type 1680-A Automatic Capacitance Bridge Assembly**	**$4850.00**
1680–9601	**Type 1680-P1 Test Fixture**	**75.00**

U. S. Patent No. 2,548,457. Patents applied for.

The agony and the ecstasy. A GR Type 1551-C Sound-Level Meter registers 115 dB at a Beatles' concert in Sydney, Australia. (Photo courtesy Australian Consolidated Press Ltd.)

COAXIAL MICROWAVE NEWS

PRECISION COAXIAL CONNECTOR PAIRS WITH CALIBRATION CERTIFICATE

Since the introduction of the TYPE 900-BT Precision Coaxial Connector in 1963, every one of these connectors has been VSWR-tested before shipment. Connectors are tested in *pairs* at 1.5, 3, 4.5, 6, 7.5, and 9 Gc/s and are then separated and sold singly, with the actual test specification for the pair used as the guaranteed specification for the single connector. The VSWR of two connectors bought singly could be as high as twice that specified for a single connector, even though it is almost certainly much lower than that. On the other hand, if one could be sure of buying the same two connectors that were tested together, he would effectively halve the guaranteed VSWR of the pair. For the benefit of those whose applications demand exact calibration data or connector-pair performance guaranteed within the specifications of the IEEE Recommended Practice,[1] we are now offering pairs of Type 900-BT Connectors, together with calibration certificates.

The 0900–9407 Connector Pair comprises a pair of serial-numbered con-

[1] "Coaxial Microwave News," *The General Radio Experimenter*, February–March 1965.

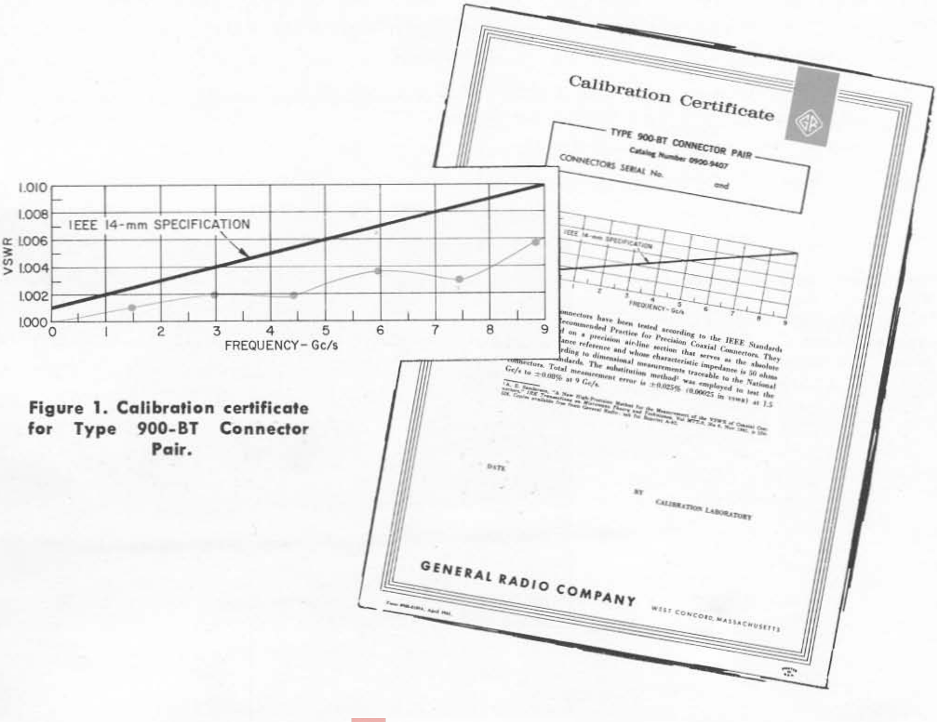


Figure 1. Calibration certificate for Type 900-BT Connector Pair.

nectors and a certificate of compliance with VSWR specifications. Specified VSWR data apply whether the two connectors are mated together or mounted on opposite ends of low-loss, low-VSWR lines, 10, 20, 30, or 40 cm long (including connectors). When the connectors are installed on lines of other lengths, the insertion VSWR may differ from the calibration values. This is also true when only one connector of the pair is used. In practice, this discrepancy is small because of the excellent basic design of the connector.

The discontinuities in the connectors are small, and the connectors are relatively short electrically; it is therefore valid to connect the six calibration points with a continuous curve on the calibration chart (see Figure 1).

Test Procedure

The connectors are mounted on precision 50-ohm air-line sections and are tested by the substitution method.[2,3] The air lines, including the connectors, are 10 cm long and are therefore half-wave multiples at the test frequencies. Characteristic impedance of the air-line section is held to better than ±0.015%. Except for the influence of skin effect, the impedance of a rigid air line is strictly a function of its diameters. These diameters are measured with precision gauges, whose accuracy is traceable to the National Bureau of Standards. The total measurement error including repeatability is 0.025% at 1.5 Gc/s, increasing linearly to 0.08% at 9 Gc/s.

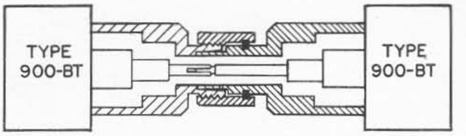


Figure 2. Use of calibrated connector pair to test UG adaptor pair. Electrical length of complete test device should be multiple of 10 cm.

At lower frequencies, the test-line impedance deviates from 50 ohms because of skin effect. In precision applications, the connectors are installed on air-line sections similar to those on which the connectors were tested. Therefore, the skin-effect impedance deviation does not introduce reflections in the transmission-line system. Skin-effect corrections are, however, required for some applications at frequencies below about 500 Mc/s. Such corrections have been discussed in the literature.[4]

Applications

The 0900–9407 Connector Pair is recommended for use where a mated pair of connectors having an accurately known VSWR is required, where guaranteed compliance with the pertinent sections of the IEEE Recommended Practice is sought, and in the testing of transitions, connectors, adaptors, and other low-loss transmission devices (see Figure 2).

— J. Zorzy

[2] A. E. Sanderson, "A New High-Precision Method for the Measurement of the VSWR of Coaxial Connectors," *IRE Transactions on Microwave Theory and Techniques* Vol MTT-9 No 6, p 524–548.
[3] A. E. Sanderson, "An Accurate Substitution Method for Measuring the VSWR of Coaxial Connectors," *The Microwave Journal*, Vol 5, No 1, Jan 1962, p 69–73.
[4] I. A. Harris and R. E. Spinney, "The Realization of High Frequency Impedance Standards Using Air-Spaced Coaxial Lines," Conference on Precision Electromagnetic Measurements, National Bureau of Standards, Boulder, Colo, June 1964. (Publication scheduled in *IEEE Transactions on Instrumentation and Measurement*, Dec 1964.)

Catalog No.		*Price*
0900–9407	**Type 900-BT Precision Coaxial Connector Pair with Calibration Certificate**	**$72.00**

OPEN HOUSE

It is our pleasure to extend to all *Experimenter* readers an invitation to attend an Open House at General Radio Company, Monday, June 14. One reason for this festivity is our fiftieth anniversary — which happens to fall on that very day. Another is the desire to introduce our new Bolton plant, now in full operation. If you can conveniently visit us at West Concord or at nearby Bolton, we'd be very pleased to see you. Hours at both plants are 10:30 AM to 3:30 PM.

1964 INDEX

The index to Volume 38 of the *Experimenter* is now available. A letter or postcard to General Radio at West Concord or to one of our sales engineering offices (see page 2) will bring you a copy promptly.

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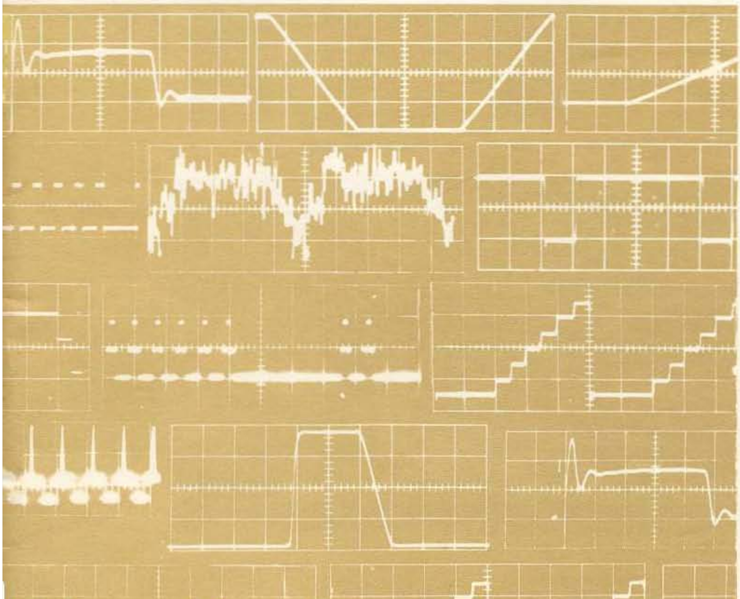

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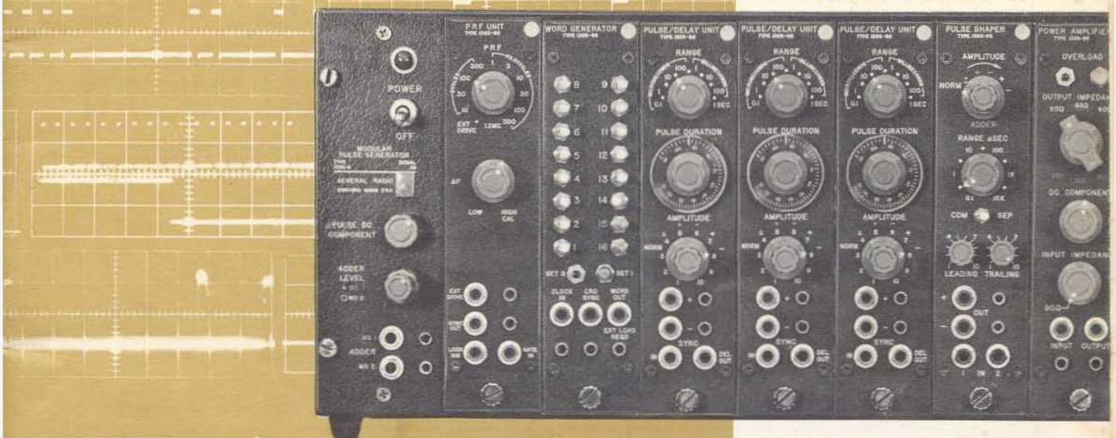

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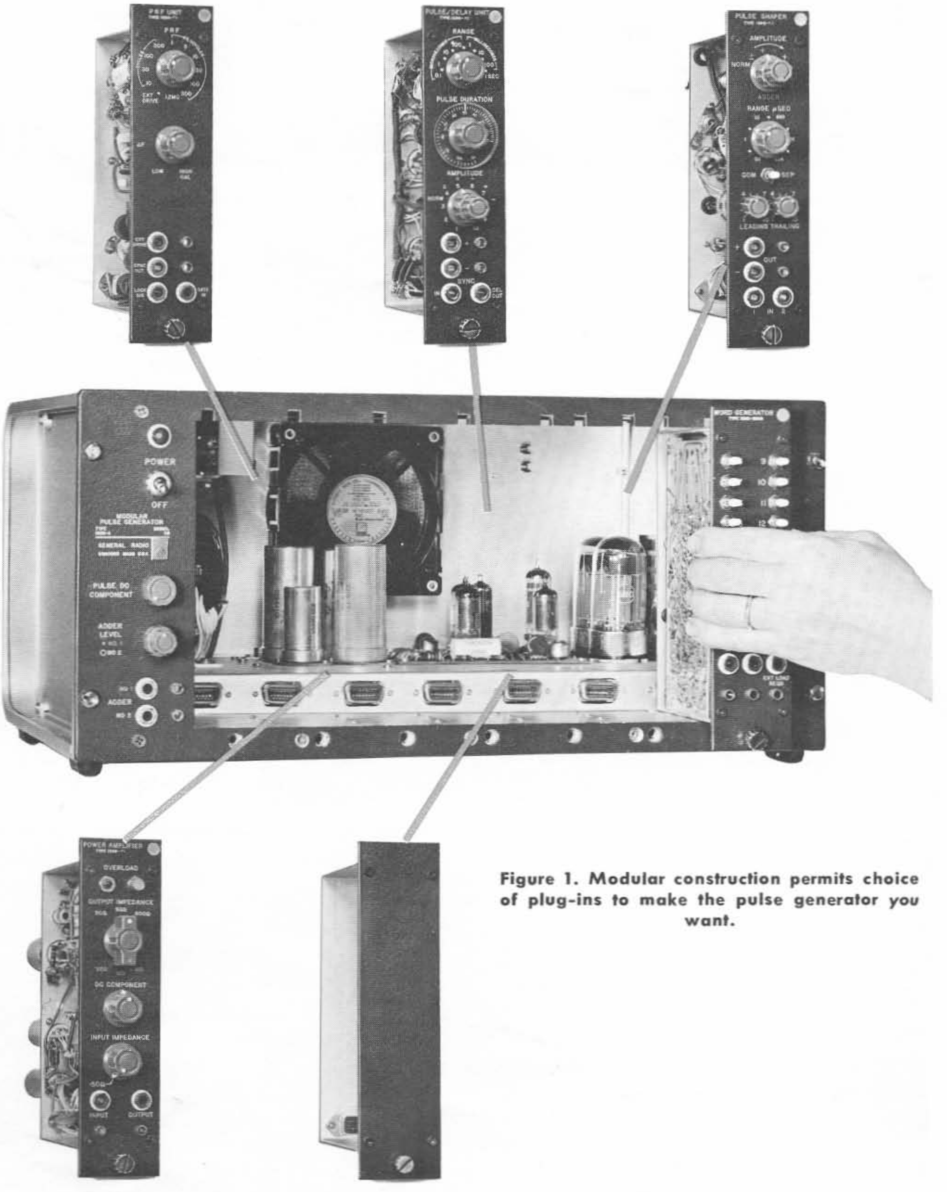

Figure 1. Modular construction permits choice of plug-ins to make the pulse generator you want.

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PULSES TO ORDER

The TYPE 1395-A Modular Pulse Generator is a pulse kit of almost infinite possibilities. With it one can construct, to suit his requirements or his fancy, a practically infinite number of pulse shapes and combinations. As shown in Figure 1, the generator consists of a number of basic modules and a frame to hold them. The photograph shows only one of 38,400 combinations that can be assembled from currently available modules.

Of course, some selection must be made among these capabilities; the Modular Pulse Generator will not do everything at once. So the next matter to consider is what modules are available, what functions they perform, and how they can be combined for maximum usefulness.

The TYPE 1395-A Modular Pulse Generator produces any or all of the following signals:

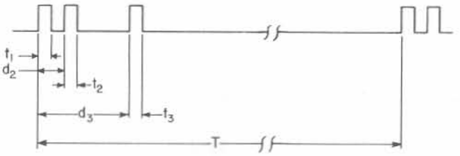
- conventional rectangular pulses
- pulse bursts
- doublet pulses
- pulses with pedestals
- ascending and descending staircases
- triangles
- trapezoids
- peculiar pulses
- single pulses
- binary patterns or words from 2 to 112 bits long

In addition, it

- locks on higher frequencies up to ratios of about 15:1
- scales in true digital fashion by any quantity that can be formed as the product of up to 7 numbers between 2 and 16
- generates time delays
- operates at pulse repetition frequencies as low as 2.5 c/s and up to 1.5 Mc/s internally; down to dc and up to 2 Mc/s with external drive
- allows noise or sine waves to be added to pulses
- gives independent control over amplitudes, durations, and delays in all parts of complex pulses
- amplifies the pulses it produces (up to 400 mA in 50 ohms)
- gives both positive and negative polarities simultaneously

One of the first commercial pulse generators was the General Radio Type 869-A,[1] designed and built originally for defense research projects in World War II. Square-wave generators, among them the GR Type 769-A, had been available for some years and were widely used for transient response measurements.[2] For design and test of pulsed equipment such as radar, television, and pulse-modulated communication systems, however, test signals of variable duty-cycle and fast rise and fall times were needed. The Type 869-A filled the bill in the early days. It was followed by the Type 1391-A Pulse, Sweep, and Time-Delay Generator and the Type 1217 Unit Pulse Generator, of which the current Type 1217-C is the latest design. The new Type 1395-A Modular Pulse Generator goes several steps further and allows the user to build pulses of practically any shape that he wishes.

[1] H. H. Scott and C. A. Cady, "The General Radio Pulse Generator," *General Radio Experimenter*, January–February 1945.
[2] L. B. Arguimbau, "Network Testing with Square Waves," *General Radio Experimenter*, December 1939; "Transient Response of a Broadcast System," *Ibid.* April 1940.



$t_1 = 2\ \mu s$ $d_3 = 14\ \mu s$, more or less.
$d_2 = 4\ \mu s$ $t_3 = 2\ \mu s$, more or less.
$t_2 = 2\ \mu s$ $T = 100\ \mu s$

Figure 2. A design objective

AVAILABLE MODULES

An initial complement of six modules is offered for this instrument.

Type 1395-P1 PRF Unit. A master clock, generating pulses for synchronizing and triggering other plug-ins. It also provides gating and locking functions and accepts external drive signals, buffering them to other modules.

Type 1395-P2 Pulse/Delay Unit. Generates rectangular pulses from 0.1 microsecond to 1.1 seconds, choice of positive or negative polarity or both simultaneously. Generates time delays from 0.1 microsecond to 1.1 seconds.

Type 1395-P3 Pulse Shaper. Gives independent control over the rise and fall times of leading and trailing edges of pulses. Rise and fall times can be varied from 0.1 microsecond to 10,000 microseconds; the only restriction is that both times must be within the same decade range.

Type 1395-P4 Power Amplifier. Makes big pulses out of little ones. Up to 400 mA into 50-ohm load; also matches 93- and 600-ohm loads. Offers variable dc baseline, variable input impedance. Low distortion allows its use on sine waves and assures faithful reproduction of pulses of complicated shapes. Upper half-power frequency: 5 Mc/s with low impedance loads; 1.5 Mc/s with 600-ohm load.

Type 1395-P6 Word Generator. A binary word generator, providing up to 16 bits of *ones* and *zeros* per module. Modules can be cascaded, so that as many as 112 bits are possible in a single main frame. Can also be used as a digital scaler.

Type 1395-P7 Skeleton Frame. An empty module, having only the rear-panel power plug. You can build your own auxiliary circuits into this module.

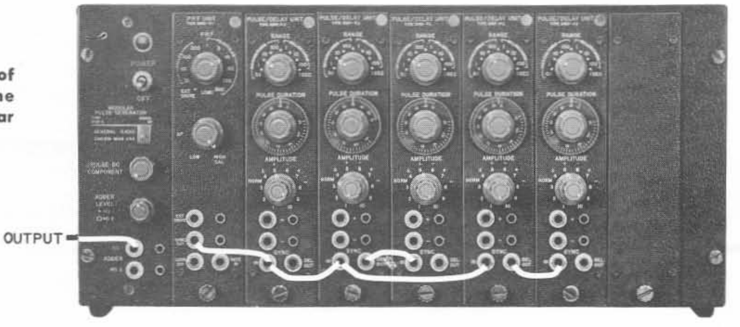
APPLICATIONS

To demonstrate the versatility of this pulse generator, we have selected, from the almost infinite number of possible applications, a few examples drawn from a representative assortment of disciplines.

Something from the Communications Art

Suppose that the problem arises of testing a communications system using

Figure 3. Simulation of PDM or PPM with the Type 1395 Modular Pulse Generator.



either pulse-duration (width) modulation (PDM or PWM) or pulse-position modulation (PPM). Such a system usually involves time multiplexing, and so a synchronizing pulse is required. We assume this to be a doublet, so the test signal might take the form of Figure 2.

There are three pulse durations to be set up and two delay intervals, indicated by t_1, t_2, t_3, and d_2, d_3, respectively. Thus, five Pulse/Delay Units are required. One master clock, a PRF Unit, generates the 10-kc repetition frequency corresponding to the period of 100 microseconds.

The necessary connection of modules is illustrated in Figure 3. Six units are required altogether. The right-hand space is covered with a blank panel. Four such panels are furnished with each instrument, on the assumption that at least three plug-ins will always be used. Figure 4 shows an oscillogram of the pulses actually generated.

In Figure 2, several times were given as "more-or-less." These are the times that would be varied during the simulation of PPM or PDM. However, *any* of the three pulses can be varied in amplitude and duration, and even reversed in polarity! Both of the time delays are completely adjustable.

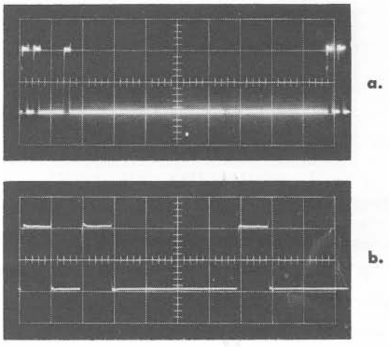


Figure 4. (a) The waveform sketched in Figure 2. Scale: Vertical, 0.5 volt per major division; horizontal, 10 microseconds per major division. (b) Enlargement of the left-hand area of Figure 4(a). Scale: Vertical, 0.5 volt per major division; horizontal, 2 microseconds per major division.

An Application from the Encoder Art

Let us consider the case of testing an analog-to-digital converter. Several rapidly cycling levels are required to verify that the encoder is operating both quickly and correctly. A staircase waveform is recommended for this application. Figure 5 shows how to get it.

Here one master clock drives six Pulse/Delay Units. Each of these has an output lasting at least 1 microsecond. Therefore, for 1 microsecond, the sum of all the contributions at the ADDER terminal is 6 units. After 1 microsecond, the first Pulse/Delay Unit output ends, leaving 5 units of ampli-

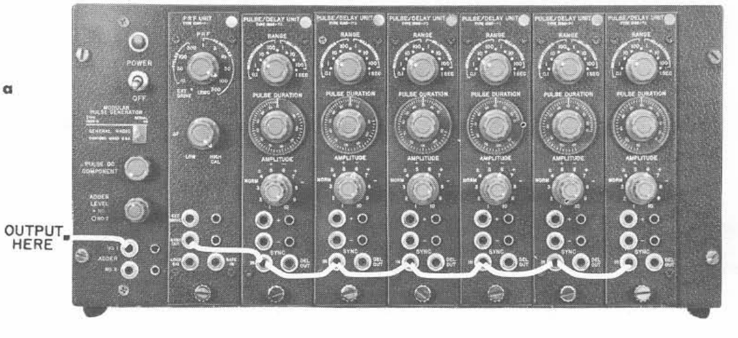


Figure 5. Generating a negative staircase.

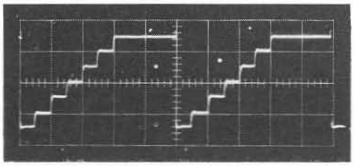


Figure 6. A staircase designed to test an analog-to-digital converter. Scale: Vertical, each step in the staircase is 0.75 volt; horizontal, 2 microseconds per major division.

tude for another microsecond. The process continues until after 6 microseconds the waveform is back at the baseline. The resulting staircase is shown in Figure 6. The dc voltage is adjustable by a front-panel control marked PULSE DC COMPONENT, a most useful feature. In Figure 6, this control has been set to place 0 volts dc at the center of the oscilloscope graticule. Therefore, there are three positive voltages, ground, and three negative levels available to test the encoder. The entire pattern repeats at a rate of 100 kc/s.

An Unusual Quality-Control Application

A pre-production model of the TYPE 1395-A Modular Pulse Generator has been in use at General Radio Company for several months, testing the reversible counters used in our TYPE 1680-A Automatic Capacitance Bridge Assembly. The problem here is to be sure the counters count correctly both forward and backwards. The technique is to apply 17 pulses, then rest for about one-half second to let the inspector read the number stored in the counter. After the first 9 pulses, a reverse command is applied to the counters. The net result is that they count forward nine times, backward eight times, and therefore the number shown is just one digit larger each time the count is interrupted for display.

This is an interesting problem because it demonstrates several properties of the modules not shown in the previous examples. These are the *locking* and *gating* functions. In order to keep all action coherent in time, one PRF Unit is used as a system master clock, running continuously at 1 kc/s. This triggers the EXTERNAL DRIVE terminal of a Pulse/Delay Unit, fourth from left in Figure 7. It also drives the LOCKING terminal of the PRF Unit in the second-from-left position. This PRF Unit locks at 1/15th the original frequency, or about 67 c/s. Its output drives still a third PRF Unit LOCKING input. The third PRF Unit locks at about 1/25th of the 67 c/s, or approximately 2.7 c/s. The exact value of this lowest frequency doesn't matter, as

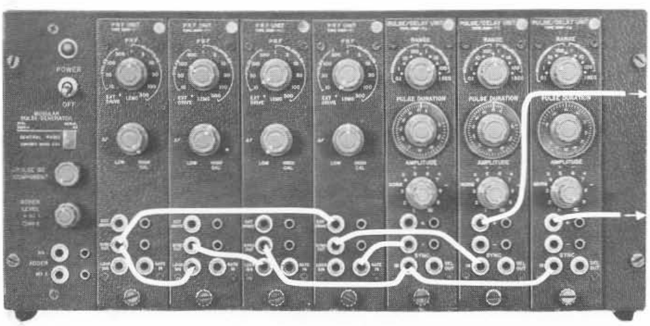


Figure 7. The Modular Pulse Generator testing reversible counters.

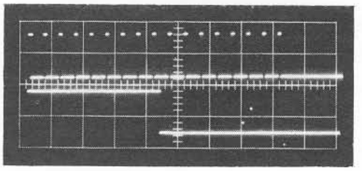


Figure 8. A test pattern for checking reversible counters. The burst of 17 pulses is interpreted as nine forward counts and eight reverse counts. The forward-reverse command is given by the step in the bottom half of the picture. Scale: Vertical, none (waveforms placed on scope to give best display of principle involved); horizontal, 2 milliseconds per major division.

long as the operator has time enough to read the number appearing on the counter.

The 2.7-cycle PRF Unit triggers two Pulse/Delay Units. One generates a pulse 17 milliseconds long; the second gives a 9-millisecond pulse. The 17-millisecond pulse controls the gate of the *same* PRF Unit that receives the 1-kc external drive from the master clock. Note that, even though the operating frequency has been dropped to 2.7 c/s, everything is tied to the master. There is no possibility of the gate closing in time to cause a "half pulse" and give an ambiguous result. Exactly 17 pulses come out. These trigger another Pulse/Delay Unit (6th from left), which generates pulses of the proper duration and amplitude to operate the counter being tested.

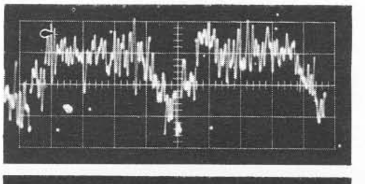
At the same time the 17 pulses start, the last unit on the right generates a pulse 9 milliseconds long. This tells the counters to count forward. Nine counts are added in, followed by 8 subtracted back out. The net result is the +1 count we were seeking. And this occurs slowly enough (2.7 times per second) to allow the inspector to see that the counters are operating properly. The pulses generated for this test are shown in Figure 8.

A Problem in Signal Detection

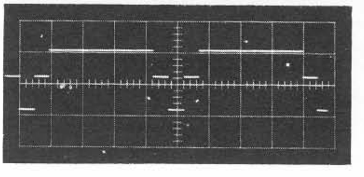
One truly handy feature of the TYPE 1395-A Modular Pulse Generator is the provision for external access to the adder circuits. These adders are normally used for combining pulses of different durations and amplitudes in order to produce pulses of complicated form. But noise, sine waves, or other signals can be injected as well.

Suppose that a pulse signal similar to that shown in Figure 9b is expected but must be detected in the presence of noise. The pulse as actually received is shown in Figure 9a. We want to simulate this signal in order to adjust our detector circuits for optimum response. Obviously the first step is to generate a "clean" pattern. Then the noise is added to it.

Figure 10 gives the configuration for producing the desired results. A PRF Unit, as always, acts as a master clock. The first Pulse/Delay Unit generates a negative-going pulse 300 microseconds in duration. This is connected to the adder. The second Pulse/Delay Unit serves as delay only. This starts a 100-microsecond time interval at the same



a.



b.

Figure 9. (a) A noisy pulse train, taken with single sweep on the oscilloscope. (b) The same signal without noise. Scale: Vertical, 0.5 volt per major division; horizontal, 0.2 millisecond per major division.

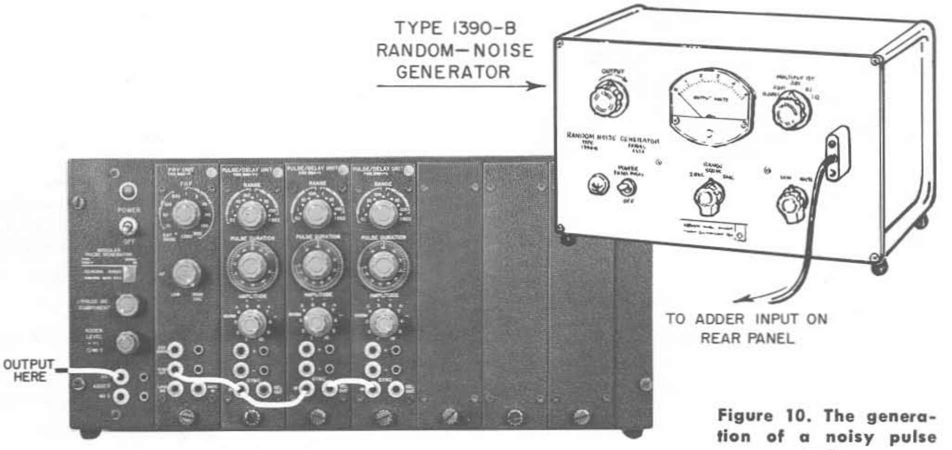


Figure 10. The generation of a noisy pulse train.

moment that the 300-microsecond pulse begins. After the 100-microsecond interval, the third Pulse/Delay Unit is triggered by the delayed output synchronizing signal. The third unit gives an output of 100 microseconds, which is switched to the same adder. Finally, a General Radio Type 1390-B Random-Noise Generator produces the noise to give the "dirty" signal of Figure 9a.

Will the Flip-Flop Work?

Some pulses are so called only as a matter of courtesy. In a world limited to finite rise times, there may be some question about just when a pulse *is* a pulse. A number of circuits such as gates, flip-flops, and other logic elements may change their behavior from *go* to *no-go* as their input signals become degraded. The effects of deteriorating rise and fall times are easily evaluated with the Type 1395-A Modular Pulse Generator, fitted out with the Type 1395-P3 Pulse Shaper.

The Pulse Shaper is basically a maker of slanting edges. It starts a leading edge upon receiving one input trigger and starts the trailing edge when the next trigger comes along. Both leading and trailing edges are linear, rather than exponential. Both can be varied independently in duration within the same decade range. For example, the leading edge could rise in 17 microseconds and the trailing edge fall in 84, but 17 and 112 microseconds is not a possible combination. Trapezoids are readily made, and triangles are formed when the start of the trailing edge is moved up to the end of the leading edge.

Figure 11 illustrates the Type 1395-A Modular Pulse Generator connected to test the effect of rise time on a circuit. The objective is a pulse with a rise time of 100 nanoseconds, a fall time of 1000 nanoseconds, and a flat top lasting 2 microseconds. The pulse repetition frequency is set at 100 kc/s by the PRF Unit. (It should be noted that the Pulse Shaper draws a good deal more current than most of the other modules. To prevent connection of enough shapers to overload the power supplies, the shapers are keyed to fit only the three extreme right-hand positions.)

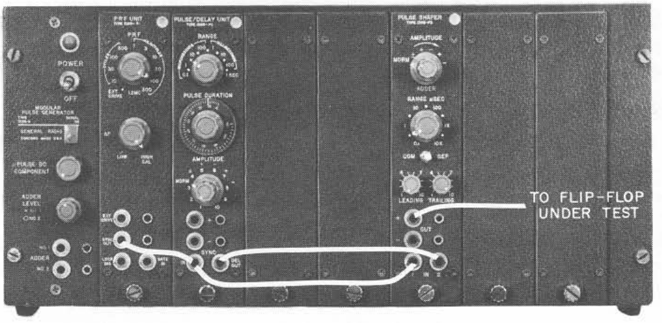


Figure 11. The basic Pulse Shaper arrangement.

An example of the output is shown in Figure 12. Here we see that the objectives in the preceding paragraph are indeed met. This oscillogram was taken under open-circuit conditions. The amplitude would be less under load, since the shaper output is basically from a current source. The Pulse Shaper may be connected to the adders; examples of what this may lead to are given later.

An Application to Component Testing

Small iron-core inductors, especially those wound on lossy material, are difficult to measure. Measurements made on a low-frequency bridge are plagued by a very small Q, because ωL is low. With a high-frequency bridge, losses are high, and so Q is again low.

But consider the equation for the voltage across an inductor:

$$e = L\frac{di}{dt} + iR \qquad (1)$$

If di/dt has a constant value, and the value of e across the coil may be measured, then L is readily found as

$$L = e\frac{\Delta t}{\Delta i} \qquad (R \cong 0) \qquad (2)$$

where Δ rather than d notation is chosen for reasons that will be apparent.

The assumption of a constant di/dt is met well if a Type 1395-P3 Pulse Shaper drives a smooth ramp of voltage into a high resistance. Suppose we try to set up a convenient scale — say 1 millivolt developed across the inductor corresponds to 10 microhenrys inductance.

Let L in Equation (2) be 10^{-5} and e be 10^{-3} volts. Solving for $\Delta t/\Delta i$ gives 10^{-2}. Picking a reasonable but arbitrary number for either quantity, suppose we make $\Delta t = 5$ microseconds. Then $\Delta i = 5 \times 10^{-6}/10^{-2} = 5 \times 10^{-4}$, or 0.5 milliamperes. Then, if we had a current waveform that changed from 0 to 0.5 mA in 5 microseconds and impressed that current on the inductor, we would develop 1 millivolt for every 10 microhenrys. This current is easily achieved if the Pulse Shaper generates a 10-volt amplitude ramp in 5 microseconds and a 20,000-ohm precision resistor is connected between the shaper and the inductor, as shown in Figure 13.

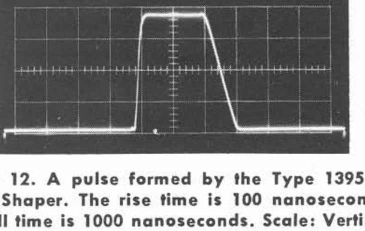


Figure 12. A pulse formed by the Type 1395-P3 Pulse Shaper. The rise time is 100 nanoseconds; the fall time is 1000 nanoseconds. Scale: Vertical, about 6 volts per major division; horizontal, 1 microsecond per major division.

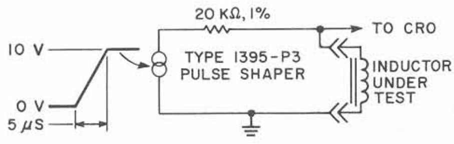


Figure 13. A calibrated tester for the inductance of small iron-core coils.

The actual interconnection of modules would be as in Figure 11, but with different settings of the knobs, of course.

Figure 14 shows the step of voltage applied to the 20,000-ohm resistor. This does indeed rise from 0 to 10 volts in 5 microseconds. The voltage across a sample inductor is illustrated in Figure 15. The transients at the leading edge are associated with stray capacitance and inductance and soon die out. From then on, the voltage remains quite steady for 5 microseconds and then drops to zero as the ramp ends and *di/dt* changes from a constant to 0. (Actually, there is a current flowing, even though *di/dt* is 0, and hence the *iR* drop in the inductor gives a small remaining voltage). The value of the inductor can be read right off the scope graticule. It is seen to be 830 microhenrys.

And Something for the Data-Processing Field

Data-processing, data-transmitting, and data-interpreting circuits and systems all require inputs for test purposes. Except for a little decade notation at the human-machine interface, binary is the rule. To those working with bits, we offer the Type 1395-P6 Word Generator.

As the name suggests, the Word Generator is designed to produce sequences of 1's and 0's. The built-in capacity is 16 bits. This may be shortened to 14 bits by means of a rear-panel switch. If one 16-bit unit is cascaded with one 14-bit unit, 30 bits are made available. Thus, just two Word Generators can provide any number of word lengths based on 32, 30, or 28. For example, four 7-bit words or six 5-bit words could be had. For those who prefer one-word-per-module of the bit length they please, any bit capacity from 2 to 16 can be had through changes in an internal plug-in patch wire. Any number of modules up to 7 can be cascaded, giving a maximum bit capacity in a Type 1395-A Main Frame of $16 \times 7 = 112$.

Another use for the Word Generator is as a digital scaler. For example, a Word Generator connected for 11-bit capacity will give one output for eleven inputs when just one bit switch is turned on. Larger ratios are achieved when we let one Word Generator drive another. The scaler of 11, for example,

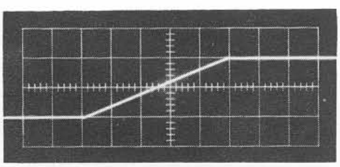


Figure 14. Voltage applied by the Type 1395-P3 Pulse Shaper to drive the inductance testing assembly. Scale: Vertical, 5 volts per major division; horizontal, 1 microsecond per major division.

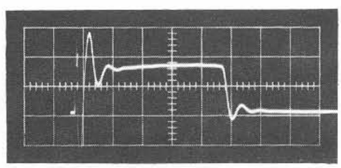
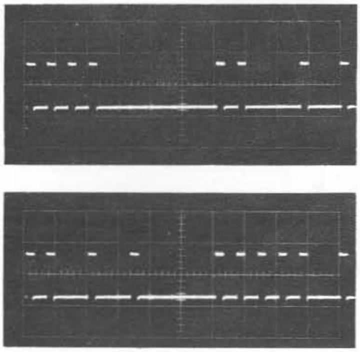


Figure 15. Voltage across an inductor tested by the arrangement in Figure 13. Scale: Vertical, 50 millivolts per major division; horizontal, 1 microsecond per major division. One millivolt represents 10 microhenrys inductance.



a.

b.

Figure 16. Patterns produced by the Type 1395-P6 Word Generator driving a Type 1395-P2 Pulse/Delay Unit. Positive pulses into 50-ohm loads, 3.5-microsecond duration, 100-kc bit rate, and 6.25-kc word rate.

(a) 16-bit word 1111000001100101
(b) 16-bit word 1101010001111101

could drive a second Word Generator connected for 14 bits, and the two together scale by a ratio of $11 \times 14 = 154$.

Figures 16a and b show two sample patterns set on Word Generators. Both use the 16-bit capacity. The connection of modules is very simple: a PRF Unit drives the Word Generator, and its output drives a Pulse/Delay Unit.

One extremely useful feature is that, unlike many similar devices, the Type 1395-P6 Word Generator is not limited to producing rectangular pulses. Its output is simply a set of trigger pulses, turned on or off at the front-panel switches. You can generate any pulse shapes you wish by letting these triggers drive other Type 1395 modules. An

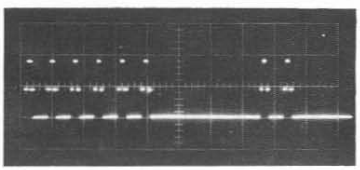


Figure 17. A 14-bit word of "top hat" pulses generated by a PRF Unit, a Word Generator, and three Pulse/Delay Units. Bit rate 10-kc, word rate about 714 words per second. Pattern is 11111100001100.

example is given in Figure 17, where a Word Generator connected for 14-bit capacity triggers other modules to generate a binary pattern of "top hat" pulses.

Is There an Application for This Pulse?

A device as versatile as the Type 1395-A Modular Pulse Generator will allow the creation of some weird waveforms indeed. Just as an example of what can be done, we point to Figure 18. This can only be described as a witch's hat sitting on a dented pedestal. It is produced by a combination of Pulse/Delay Units and a Pulse Shaper, all connected together via the built-in adder circuits. We have no idea what it might be used for.

DESIGN HIGHLIGHTS OF THE MODULAR PULSE GENERATOR

Earlier in this article, the performance of the General Radio Type

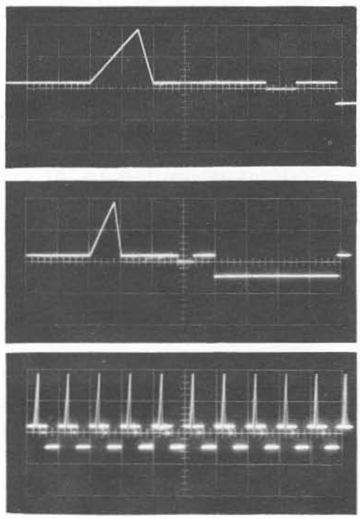


Figure 18. An example of the extraordinary pulse shapes that can be produced by the Type 1395-A Modular Pulse Generator. Scale: Vertical, all 0.5 volt per major division; horizontal: top, 50 microseconds per major division; center, 100 microseconds; bottom, 1 millisecond.

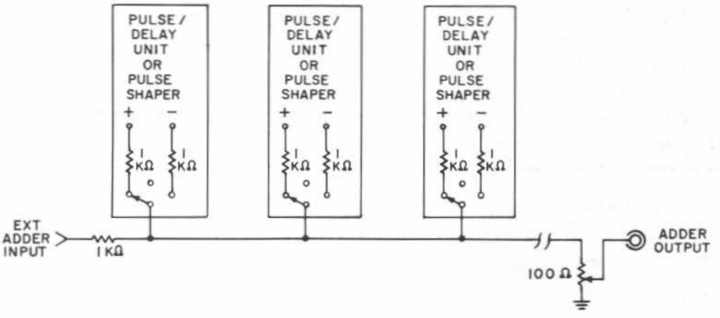


Figure 19. One of the adder circuits.

1217-C[1] was mentioned as a starting-point for the Type 1395-A Modular Pulse Generator. To those familiar with the Type 1217 in either its B or C versions, it will be interesting to note that the Type 1395-P1 PRF Unit and the Type 1395-P2 Pulse/Delay Unit together equal (approximately) one Type 1217-C Unit Pulse Generator.

The Type 1395-A Modular Pulse Generator contains a common power supply for operating as many as seven units. Some modules, such as the Pulse Shaper and the Power Amplifier, consume a considerable amount of current. Therefore, the output of the Pulse/Delay modules is limited to 20 mA to ensure there is enough power supply capability to operate any "mix" of modules that may be chosen.

We shall now look at some of the features and principles of operation of the various Modular Pulse Generator units in more detail.

[1] R. W. Frank, "Improved Performance from the Unit Pulse Generator," *General Radio Experimenter*, December 1964.

The Adder System

A sketch, considerably simplified, of one adder is shown in Figure 19. Each module that can be connected to the adders is fitted out with a switch. This allows both the positive- and negative-polarity output pulses to be connected to either of the two adder busses. Another position allows the positive polarity to be connected to ADDER NO 1 and the negative polarity to ADDER NO 2. The actual output terminals are the source of the signals to the adders. Resistors of 1000 ohms are provided for buffering.

Resistive adders of this type are about the most trouble-free and wide-band adders that can be had. However, they do cost in terms of amplitude. The output signal from the adders will be appreciably less (more than 20 dB less) than the output directly from

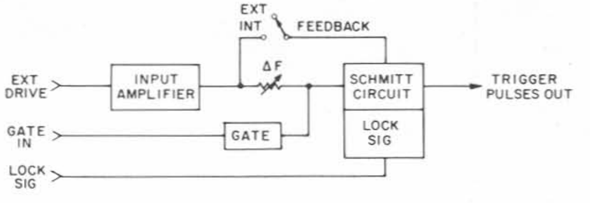


Figure 20. Block diagram of the Type 1395-P1 PRF Unit.

an individual module. The TYPE 1395-P4 Power Amplifier is recommended for bringing the signal level from an adder bus up to a higher level.

The Type 1395-P1 PRF Unit

A block diagram of the PRF module is shown in Figure 20. In the EXT DRIVE position, signals from the input amplifier trigger the Schmitt circuit. In the INTERNAL positions, the Schmitt circuit becomes a free-running oscillator. In either case, the grid can be clamped by the GATE circuit to stop operation. The LOCK SIGNAL injects synchronizing signals into the Schmitt circuit to tie its operating frequency to that of an external source, usually for frequency-dividing purposes.

More details of the circuit operation can be seen in Figure 21. Note that the GATE IN and LOCK SIGNAL tubes (*V103B* and *V103A*, respectively) are normally biased below cutoff. On the GATE IN terminal, a signal that moves the grid of *V103B* more positive than about −1.5 volts will cause the production of pulses to cease. The LOCK SIGNAL terminal requires about 10 volts, peak, (i.e., pulses 10 volts in amplitude or sine waves of 7+ volts, rms) to start *V103A* into conduction. Once *V103A* does conduct, it raises the potential on timing capacitor *C* and causes the grid of Schmitt trigger tube *V102A* to rise in potential. If the Schmitt circuit was about to fire anyway, the voltage rise transmitted through *C* will make it fire at once, and thus the Schmitt trigger locks in with the external synchronizing signal.

Capacitor *C* is simply a representation of any of ten different capacitors that are switched into the circuit as the frequency range is varied. Within any range, vernier frequency control is achieved by adjustment of *R103*. The time constant (*R102* + *R103*) *C* is the chief determiner of the operating frequency.

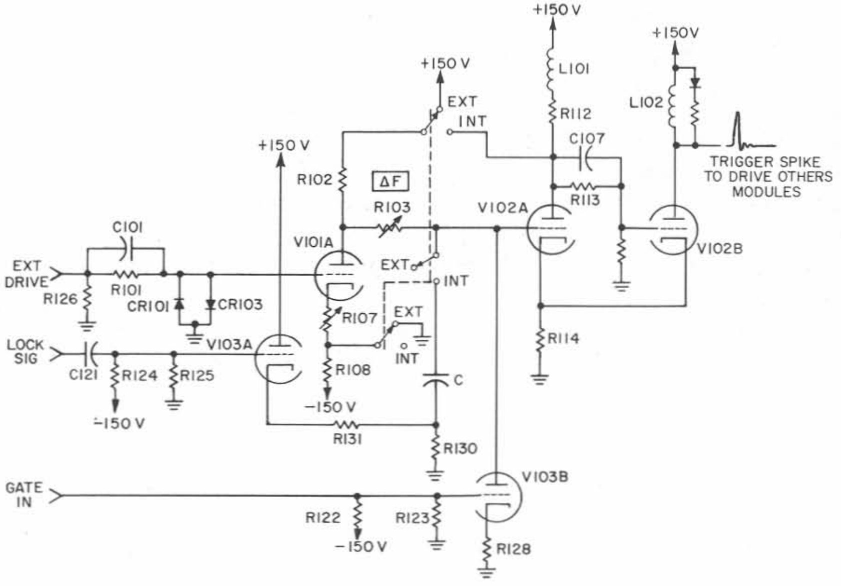


Figure 21. The chief circuits in the PRF module.

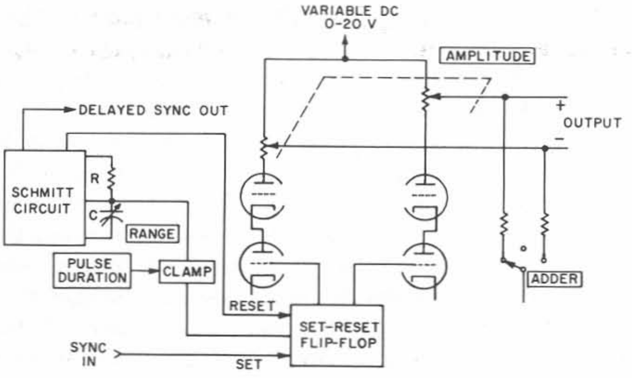


Figure 22. Block diagram of the Type 1395-P2 Pulse/Delay Unit.

The Type 1395-P2 Pulse/Delay Unit

Figure 22 is a block diagram of the Pulse/Delay Unit. The SYNC IN pulse from a PRF Unit "sets" a set-reset flip-flop. The act of setting it turns on one output tube and turns off the other. In this way, both the negative and positive pulses are generated. At the same time, a clamp is released from the Schmitt circuit. This permits the *RC* network to start charging to a voltage level that will trigger the Schmitt circuit. The releasing of the clamp also deposits a controlled amount of initial charge into capacitor *C*. The more charge, the sooner the added charge entering through resistor *R* will develop enough voltage to fire the Schmitt. Therefore, the pre-charge controls the pulse duration within the range selected by the value of capacitor *C*.

As soon as the Schmitt circuit triggers, it generates a DELAYED SYNC OUTPUT pulse. This is available at the front panel for any purposes requiring time delay (see, for example, Figures 2 and 3). Simultaneously, a reset pulse is generated to return the flip-flop to its original state, and the pulse-generating sequence ends.

It is seen in Figure 22 that the output tubes obtain their power from a variable dc supply. This is built into the TYPE 1395-A Modular Pulse Generator and adjusted from the front panel with a knob marked PULSE DC COMPONENT. The setting of this knob allows the output pulse to be placed anywhere relative to ground, from entirely below ground to entirely above.

The Type 1395-P3 Pulse Shaper

The Pulse Shaper generates leading and trailing edges of straight-line form rather than exponential. This result is achieved by the charge and discharge of a capacitor through constant-current sources. These sources take the form of grounded-base silicon transistors, which receive their emitter currents from large, although variable, resistors connected to the +150- and −150-volt power supplies in the main frame.

A circuit diagram of the pulse-shaping portion of the device is shown in Figure 23. The input stage is a set-reset flip-flop. A trigger pulse applied to INPUT 1 starts the leading edges, and a trigger applied to INPUT 2 starts the trailing edge. If there is no signal at INPUT 2, the flip-flop operates in a complementing mode, giving symmetri-

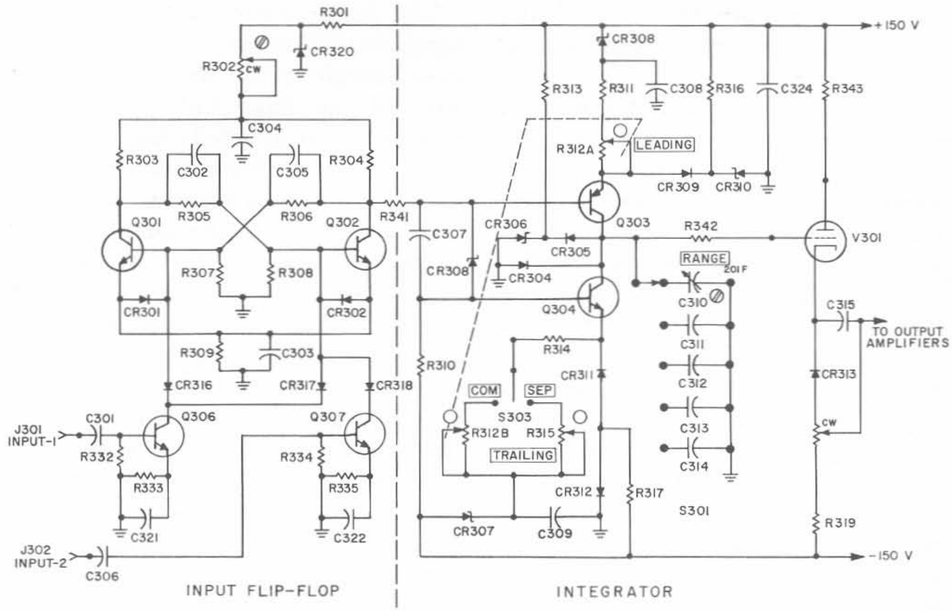


Figure 23. The pulse-shaping circuits of the Type 1395-P3 Pulse Shaper.

cal operation in the sense of equal time intervals between the start of leading and trailing edges.

The state of the flip-flop commands either *Q303* or *Q304* to conduct. *Q303* charges whichever capacitor is selected by the RANGE switch, and *Q304* discharges it. Diodes *CR309*, *CR310*, *CR311*, *CR312*, *CR304*, *CR305*, and *CR306* act as various clamps or reference voltages to limit voltage swings and to protect the transistors. Resistors *R312A*, *R312B*, and *R315* determine the emitter currents in *Q303* and *Q304* and thereby act as vernier controls on the rise and fall times of the pulse edges.

The output stage is not shown, since it does not differ significantly in end results from that of the Pulse/Delay Unit. However, in order to achieve linear operation, it is designed as a long-tailed pair with a constant-current source in the common cathode lead.

Just how straight the leading and trailing edges are is a fair question. We are prepared to answer. Most of the engineers who read this article will recall their freshman mechanical-drawing class and how they were told to check a straight-edge for straightness.

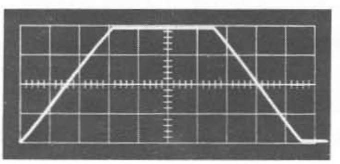


Figure 24. A demonstration of the linearity of the edges in the Type 1395-P3 Pulse Shaper. Scale: Vertical, about 4 volts per major division; horizontal, 3 microseconds per major division.

Draw a line, turn the straight-edge over, and see how close another line will fall on top of the first one. We have done this in Figure 24. A dual-trace oscilloscope was connected with the "A" channel on the positive output terminal of the Pulse Shaper. The "B" channel was switched to invert its display and connected to the negative output terminal of the Pulse Shaper. This results in two positive-going trapezoidal pulses being displayed on alternate channels. They may differ slightly in amplitude because the output potentiometers in the two Pulse Shaper channels are not identical. Since linearity rather than amplitude is undergoing scrutiny, we felt it would not be cheating to make the display heights equal on the CRO screen. The two traces were then superimposed as nearly as possible, with the result shown in Figure 24. Remember this figure shows departures from linearity not only in the Pulse Shaper but in the CRO circuits as well. We are almost embarrassed to print this photograph — it looks like a fraud, but it isn't.

The Type 1395-P4 Power Amplifier

We have not said much about this amplifier heretofore. An amplifier just isn't as exciting as some of the pulse circuits. Nevertheless, it is worthwhile to point out its main features.

Three output impedances are available: 50 ohms, 93 ohms, and 600 ohms. These impedances allow matching to most of the common transmission lines encountered in pulse and telephone practice. Likewise, the input impedance is variable from 50 ohms to 1050 ohms permitting the Power Amplifier to terminate transmission lines on the receiving end as well as the sending.

The Power Amplifier has been designed as a linear amplifier. This is true even though it will deal with pulses most of the time. Unlike the pulse amplifiers that are really high-powered switches, an amplifier that reproduces pulses of complex shape must be "hi-fi" in good measure. A photograph similar to that of Figure 24 was taken in the course of work on this article, but the waveforms showing the input and output from the Power Amplifier so nearly coincided that the difference would have vanished in the course of preparing the engravings for printing. It must be confessed that, seen on the oscilloscope, the two traces diverged in the center by about the width of the trace on the cathode-ray tube phosphor.

The Power Amplifier employs a unique protective circuit. A small lamp bulb, of the type usually used in pilot lights, is in series with the +150-volt lead, and a second lamp in series with the −150-volt lead. Both of these are mounted in a light-tight plastic can, together with a photoresistor. The photoresistor is in a voltage divider arrangement connected to the grid of a tube that controls an overload relay. If either the +150 or −150 supply tries to draw excessive current, its lamp glows and changes the resistance of the photoresistor. This alters the grid bias, and the tube switches the relay, turning off the power to the amplifier.

The Power Amplifier is not direct-coupled and will not retain the dc level of the input signal. However, a DC COMPONENT control makes it possible to shift the dc level of output pulses from at least −1.5 volts to at least +1.5 volts with a 50-ohm load, and more with loads of higher impedance.

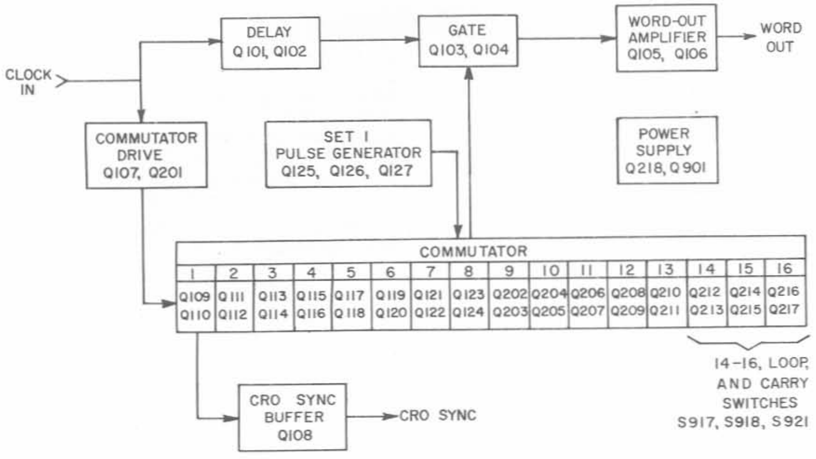


Figure 25. Block diagram of the Word Generator module.

The Type 1395-P6 Word Generator

A block diagram of the Word Generator is given in Figure 25. The Word Generator may be visualized as a commutator sweeping around to a number of contact points, usually either 14 or 16. After it comes to rest at each point, a pulse is applied to the commutator. If the switch between the contact point and the gate (*Q103-Q104*) is closed, the pulse goes to the output stages (*Q105-Q106*) and appears at the WORD OUT terminal. The rate at which the commutator moves around is determined by the frequency applied to the CLOCK IN terminal. In other words, this frequency is the bit rate. The word rate is the bit rate divided by 14, 16, or whatever other bit capacity may have been connected by the internal patch wire.

Whenever the commutator comes to rest in the No. 1 position, a pulse is generated in the CRO sync buffer (*Q108*). This permits an oscilloscope to be synchronized to the word rate rather than the bit rate and prevents the scope from locking to some pulse in the pattern, which would change with every change in the word set on the front panel switches.

If greater bit capacity is desired, the commutator is "broken open" and another commutator is spliced in from another Word Generator. Naturally, this is all handled by switches and interconnections within the TYPE 1395-A Modular Pulse Generator. Up to seven units, the capacity of a complete main frame, can be employed, giving 112 as the maximum number of bits that can form a single word.

WHAT COMES NEXT?

Other modules are currently under development. If any of you who read this article feel some particular device would be an especially welcome addition, we would appreciate hearing from you.

— GORDON R. PARTRIDGE

ACKNOWLEDGMENTS

The TYPE 1395-A Modular Pulse Generator was conceived by Mr. R. W. Frank, who also did a goodly portion of the early development of the instrument.

— GORDON R. PARTRIDGE

SPECIFICATIONS

MAIN FRAME

ADDER Output Level: 0 to 1 V or more, depending on number of modules used (continuously adjustable).
ADDER Output Impedance: 100 Ω or less (100-Ω pot).
PULSE DC COMPONENT Range: 0 to +20 V (continuously adjustable).
Power Required: 105 to 125 V, 195 to 235 V, or 210 to 250 V, 50 to 60 c/s; approximately 250 W, depending on quantity and type of plug-ins.
Accessories Supplied: Type CAP-22 Power Cord; spare fuses; six patch cords — one each TYPES 274-LMB and 274-LMR, two each TYPES 274-LSB and 274-LSR; four blank cover panels; one 14-conductor module extension cable.
Accessories Available: All modules in the TYPE 1395 series, TYPE 1217-P2 Single-Pulse Trigger.
Mounting: Rack-bench cabinet.
Dimensions: Bench model — width 19, height 9⅛, depth 14½ inches (485 by 230 by 370 mm), over-all; rack model — panel 19 by 8¾ inches (485 by 220 mm), depth behind panel 13¼ inches (340 mm).
Net Weight (without modules): Bench model, 29 lb (13.2 kg); rack model, 27 lb (12.3 kg).
Shipping Weight (without modules): 42 lb (19.5 kg).

TYPE 1395-P1 PRF UNIT

PULSE REPETITION FREQUENCY

Internally Generated: 2.5 c/s to 1.2 Mc/s with 12-position switch and uncalibrated ΔF control.
Externally Controlled: After adjustment for maximum sensitivity, sine-wave input of 0.5 V, rms, required for prf from dc to 0.5 Mc/s, rising to 1.5 V, rms, at 2 Mc/s. Input impedance at 0.5 V is approx 100 kΩ shunted by 50 pF. Non-sinusoidal signal requires a negative-going step of 1 V.

INPUT AND OUTPUT SIGNALS

Sync Out Pulses: At least 10 V, positive, with duration between 75 and 150 ns (nominally 100 ns); rise time approx 25 ns and output impedance approx 35 Ω.
Lock Signal: PRF Unit operating at 1 kc/s can be locked to a frequency of 10 kc/s by 10-V positive pulses with 100-ns duration or with a sine wave of 7 V, rms. Required positive-pulse amplitude increases to about 12 V to lock the 1 kc/s to a frequency of 2 kc/s.
Gate Input: A potential more positive than −1 V at this terminal stops the generation of SYNC OUT pulses.
Stability: Prf jitter is 0.05% when the PRF Unit is operated from the power supply in the TYPE 1395-A main frame.

GENERAL

Power Consumption: +150 V at 25 mA; −150 V at 5 mA; +15 V at 5 mA; 6.3 V, 60 c/s, 1 A.
Accessories Supplied: Six patch cords — one each TYPES 274-LMB and 274-LMR, two each TYPES 274-LSB and 274-LSR; two insulated plugs, one each TYPES 274-DB1 and 274-DB2.
Accessories Available: TYPE 1217-P2 Single-Pulse Trigger, other TYPE 1395 modules.
Net Weight: 1½ lb (0.7 kg).
Shipping Weight: 4½ lb (2.1 kg).

TYPE 1395-P2 PULSE/DELAY UNIT

Pulse and Delay Durations: 100 ns to 1 s, accurate to ±5% of reading or ±2% of full scale, or ±35 ns, whichever is greater.
Pulse Repetition Frequency: Determined by input sync signal — range dc to 2.4 Mc/s. Input signals can be randomly spaced if separated by at least 400 ns.
Rise and Fall Times: Less than 15 ns with 50-Ω load. On high-voltage output (20 V into 1 kΩ), transitions are typically 80 ns + 2 ns/pF of load capacitance.
Output Voltage: ±20 V pulses into 1-kΩ internal load impedance (±1 V into 50-Ω load).
Input Sync Requirements: Positive-going pulse, 10 to 20 V, with 75- to 150-ns duration.
Delayed Output: Positive pulse of at least 10-V amplitude and 75- to 150-ns duration. Output impedance approx 125 Ω. Time between SYNC IN and DEL OUT pulses set by PULSE DURATION control.
Stability: Pulse-duration jitter is 0.05% when Pulse/Delay Unit is operated in the TYPE 1395-A main frame.
Power Consumption: +150 V at 15 mA; −150 V at 30 mA; 6.3 V, 60 c/s, 0.7 A; 6.3 V, 60 c/s, 1.3 A; +15 V at 5 mA; 0 to +20 V, variable, at 25 mA.
Accessories Supplied: Five patch cords — two each TYPES 274-LSB and 274-LSR, one TYPE 274-LMR; two insulated plugs, one each TYPES 274-DB1 and 274-DB2.
Net Weight: 1¾ lb (0.8 kg).
Shipping Weight: 4¾ lb (2.2 kg).

TYPE 1395-P3 PULSE SHAPER

INPUT PULSES: 10 V to 20 V in amplitude and 75 ns minimum duration.

OUTPUT PULSES

Duration: Time between pulses at IN 1 and IN 2 plus duration of trailing edge.
Rise and Fall Times: 100 ns to 10 ms in five decade ranges, ± 10% of full scale, from the 0 to 100% points. Rise and fall times can be adjusted, independently by separate controls or simultaneously by a single control, within the same decade range. To obtain times less than a few hundred nanoseconds, output must be terminated in 50 to 100 Ω.

Linearity: A leading or trailing edge voltage $e(t)$ making a transition of E volts in time T will not at any time t depart from the equation $e = \frac{E\,t}{T}\ (O \leq t \leq T)$ by more than 0.1 E (typically better than 0.05 E). The fastest transitions will not yield this performance unless outputs are terminated in 50 to 100 Ω.

Voltage: ±20-V pulses into 1-kΩ internal load impedance (±1 V into 50-Ω load).

GENERAL

Power Consumption: +150 V at 45 mA; −150 V at 55 mA; 6.3 V, 60 c/s, 0.15 A; 6.3 V, 60 c/s, 0.6 A; 0 to +20 V, variable, at 30 mA.

Accessories Supplied: Five patch cords — two each Types 274-LSB and 274-LSR, one Type 274-LMR; two insulated plugs, one each Types 274-DB1 and 274-DB2.

Net Weight: 1¾ lb (0.8 kg).

Shipping Weight: 4¾ lb (2.2 kg).

TYPE 1395-P4 POWER AMPLIFIER

Output Impedances: 50, 93, and 600 Ω, all ±10%.

Gains: 20, 20, and 26 dB, respectively, at the above impedances and with matched loads, all ±2 dB.

Pulse Output Voltage: ±20 V pulses into 50-Ω load with 10% duty cycle. Larger duty cycles may be used at lower output levels.

Rise and Fall Times: Less than 60 ns on all transitions with a 50-Ω load and selector switch set for 50-Ω impedance.

Sine-Wave Amplifier: Power output into 50- and 93-Ω loads is at least 2.5 W (3% distortion typical); into 600-Ω load, at least 1.5 W (distortion, 1.5% typical).

Frequency Response: Down less than 3 dB at 20 c/s and 5 Mc/s with 50- and 93-Ω loads; 20 c/s and 1.5 Mc/s with 600-Ω load.

Dc Level: Dc baseline of pulses and centerline of sine waves can be moved at least ±1.5 V. dc with 50-Ω loads, and more with higher impedance loads.

Input Impedance: Adjustable from 50 to 1050 Ω, shunted by approx 45 pF.

Power Consumption: +150 V at 150 mA, max; −150 V at 150 mA, max; 6.3 V, 60 c/s, 2.2 A; 6.3 V, 60 c/s, 1.9 A.

Accessories Supplied: Four patch cords — one each Types 274-LMB, 274-LMR, 274-LSB, and 274-LSR; two insulated plugs, one each Types 274-DB1 and 274-DB2.

Net Weight: 2 lb (1 kg).

Shipping Weight: 5 lb (2.3 kg).

TYPE 1395-P6 WORD GENERATOR

INPUT

Pulse Repetition Frequency: Dc to 2.5 Mc/s, externally controlled by Type 1395-P1 PRF Unit (or similar unit).

Trigger-Pulse Requirements: 10- to 20-V positive-going pulses of 75- to 150-ns duration. Square waves can be used above 10 kc/s; sine waves, above 500 kc/s.

Impedance: 400 to 600 Ω, depending upon trigger amplitude.

OUTPUTS

Word Out: 10- to 20-V positive-going pulses of 75- to 150-ns duration. Output impedance approx 150 Ω, but termination in 500 to 1000 Ω is recommended.

Pattern: Set by front-panel switches. Choice of 16-bit or 14-bit capacity by rear-panel switch. One can achieve capacities other than 14 and 16 by modification of internal wiring. Interconnection of up to seven units provided by the Type 1395-A Main Frame.

Oscilloscope Sync: Rectangular pulse of 2-V min amplitude and duration equal to period of driving-signal prf. Occurs approx 50 ns before the Switch #1 output pulse, whether or not the switch is on.

GENERAL

Power Consumption: +15 V at 5 mA; 6.3 V, 60 c/s, 0.8 A.

Accessories Supplied: Five patch cords — one each Types 274-LSB, 274-LSR, 274-LMB, 274-LMR, and 274-LLR; two insulated plugs, one each Types 274-DB1 and 274-DB2.

Net Weight: 2½ lb (1.2 kg).

Shipping Weight: 5½ lb (2.5 kg).

TYPE 1395-P7 SKELETON FRAME

A blank module suitable for mounting the components of a user-designed circuit.

Dimensions: Width 2⅛, height 8½, depth 5 in (55, 220, 130 mm), over-all.

Net Weight: ½ lb (0.3 kg).

Shipping Weight: 3½ lb (1.6 kg).

Catalog Number	*Description*	*Price in USA*
1395–9801	**Type 1395-A Modular Pulse Generator, Bench Model**	**$500.00**
1395–9811	**Type 1395-A Modular Pulse Generator, Rack Model**	**500.00**
1395–9601	**Type 1395-P1 PRF Unit**	**150.00**
1395–9602	**Type 1395-P2 Pulse/Delay Unit**	**165.00**
1395–9603	**Type 1395-P3 Pulse Shaper**	**375.00**
1395–9604	**Type 1395-P4 Power Amplifier**	**250.00**
1395–9606	**Type 1395-P6 Word Generator**	**400.00**
1393–9607	**Type 1395-P7 Skeleton Frame**	**12.00**

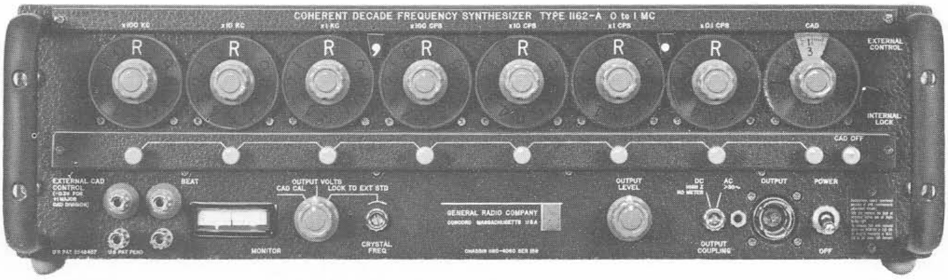


Figure 1. Panel view of the Type 1162-AR7C Coherent Decade Frequency Synthesizer with programmable decades. See complete listing of models on page 24.

REMOTE PROGRAMMING FOR GR SYNTHESIZERS

When the first two GR synthesizers were described in the September 1964 issue, provision for remote frequency selection was mentioned only briefly. The RDI-1 Remote Digit-Insertion Unit is now in production and is described in this article. One of the outstanding characteristics of the GR synthesizers is their modular design. This permits initial choice of resolution to satisfy a particular need while retaining full flexibility for future expansion. In a logical extension of the modular concept, remote programming is offered now as an option.

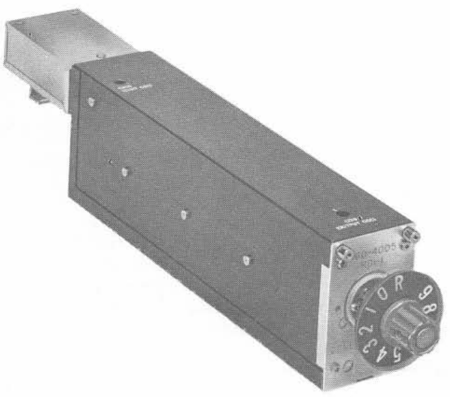


Figure 2. View of the Type 1160-RDI-1 Digit-Insertion Unit. The filter and matrix plug can be seen projecting from the rear.

The Type 1160-RDI-1 Digit-Insertion Unit (Figure 2), together with its filter and matrix plug and remote cabling, brings to the GR synthesizer line *complete* or *partial* remote frequency programming at the user's option. The RDI-1 can be used in all digit stations in the Type 1161-A and Type 1162-A Synthesizers, and in all but the 1-Mc station in the Type 1163-A. In all cases, it is directly and quickly interchangeable with the DI-1 unit. Control can easily be transferred digit by digit from remote to manual, lending additional flexibility.

During the development of the GR synthesizers, it became apparent that these generators, by their very nature, are more readily programmed than are conventional signal sources. While a necessity in certain applications, a programming capability obviously adds to the price and complexity of the instrument for users not requiring it. Hence, remote programming is offered as an option.

In the design of the plug-in Digit-Insertion Units, space was provided for the additional elements necessary

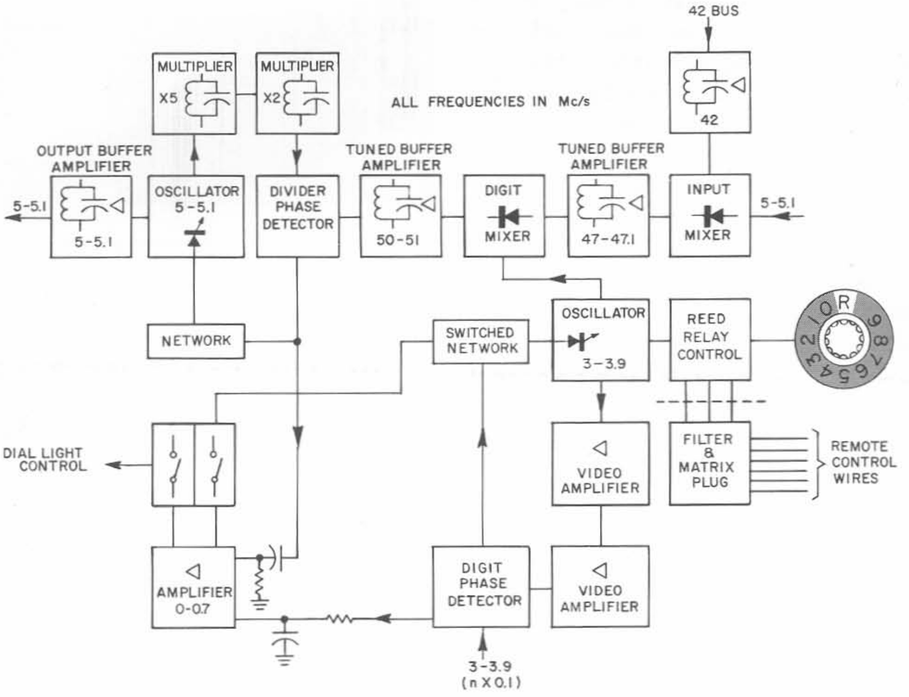


Figure 3. Block diagram of the RDI-1 Remote Digit-Insertion Unit.

for remote operation. It was also considered desirable that a programmable module be capable of manual operation. Taking full advantage of the unique packaging of the DI units, the RDI-1 is so designed that it uses a maximum of common parts with the DI-1. The RDI-1 dial has the usual ten positions, 0 to 9, and an 11th position marked R, in which frequency selection is made by contact closure on the remote wires. If the dial is moved from the R position, the manual selection overrides the remotely programmed information.

As can be seen in the block diagram in Figure 3, selection of a digit in the RDI-1 is accomplished by the change of frequency in the so-called digit oscillator, which for each setting is locked to a "picket fence" of standard frequencies from 3.0 to 3.9 Mc/s in 100-kc steps. Capacitors in the digit-oscillator circuit are switched by low-loss, rf-type reed relays. The reed driver coils are energized from the internal supply but can also be operated from an external supply. To select a particular digit, one has merely to establish connection between the designated digit wire and the common wire.

The reed relays are directly associated with the rf circuitry in the digit oscillator, and capacitive coupling exists to the driver coils. To reduce rf voltages on the remote wiring, an internal two-section filter is used, which reduces the rf level to approximately 50 μV. In addition, the cable supplied has a grounded shield to prevent RFI. The components of this filter are housed in a small, separate, plug-in shield engaging a connector that protrudes from the rear of the RDI (Figure 2). This filter plug also contains the diode matrix that converts from an internal biquinary code to a 10-line code. The unit can be remotely programmed in either code; the filter plug is normally wired for 10-line, but removal of one jumper wire converts it to the biquinary code. In the latter mode of operation, the digit 9 is produced with no external closures; 8, 7, 6, 5 are selected by connection of the appropriate wire to the common wire. The lower digits 4, 3, 2, 1, 0 are obtained with the same closures used already for the higher digits but with the additional closure of a range (or shift) wire to common. The 8 wire produces digit 3 when connected to common, 7 selects digit 2, and so on. In the 10-line mode, where one wire corresponds to each digit, the digit 9 is also selected with no closures. The 12 leads in the cable supplied are the maximum needed (10-line with external power).

A device is suitable for direct connection to the RDI-1's if it provides either

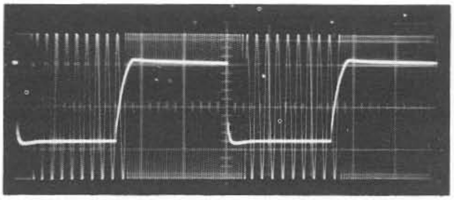


Figure 4. Oscillogram showing switching time (see text).

mechanical or electrical contact closure in the 10-line or biquinary form and maintains continuous closure as long as a particular frequency setting is desired. If a transistor switch is used, voltage drop must not exceed 0.5 volt for currents from 2.5 to 9 mA. The internal supply places the common lead at ground potential, whereas the open wires are at +18 volts with respect to ground. With an external supply of 18 volts, these potentials can be moved up to +50 and +32 volts (common) and to −32 and −50 (common). Voltages inside this range are acceptable; 18 volts are required to operate the relays, and the common must be negative. For operation with external supply, two jumper wires are removed in the RDI-1. This should facilitate

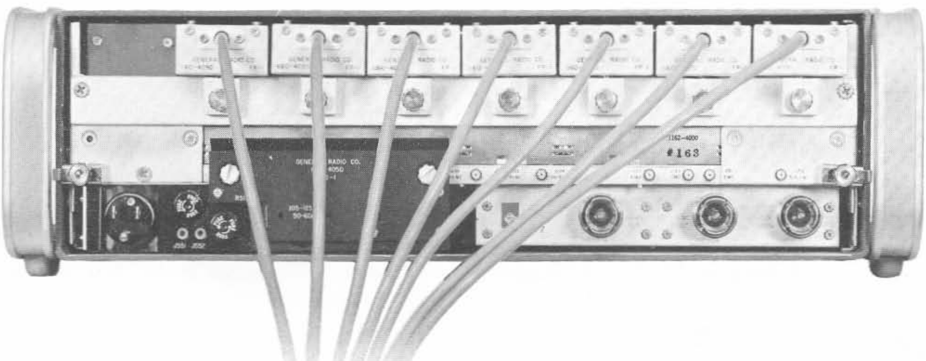


Figure 5. Rear view of the synthesizer of Figure 1, showing plug-in filters and remote cabling.

direct tie-in with existing equipment, particularly with transistor-switch output.

Many applications will require the programming of synthesizer frequencies by digital equipment in binary-coded decimals. Storage may be called for if entry is in serial rather than in parallel form. Suitable conversion equipment is under consideration.

The reed relays combine simplicity of circuitry with speed sufficient for most applications. Switching time is less than 2 milliseconds. This is the time interval between the external contact closure and the presence of the newly selected frequency. The actual transition from one frequency to another is appreciably faster as can be seen in Figure 4, which shows a switch from 9.0924 kc/s to 2.0361 kc/s. The heavy trace is the voltage across the external contact (of the first digit). The lower portion shows closed contact (0 volts) and the upper portion open contact. Time scale is 2 ms/cm.

The capability of fast, remote frequency selection adds another dimension of versatility to the GR synthesizer line, thus opening up a new range of applications.

— G. H. Lohrer

SPECIFICATIONS

Switching Speed: 2 ms or less.
Code: 10-line or biquinary (contact closure).
Power: Internal supply, provision for external supply 18 V, 9 mA.
Net Weight: 1½ lb (0.7 kg).
Instrument specifications of the Types 1161-A, 1162-A, and 1163-A remain unchanged if RDI-1's are substituted for DI-1 units.

Catalog Number	*Description*	*Price in USA*
1160–9479	**Type 1160-RDI-1 Digit-Insertion Unit** (Remote or manual control), including Filter Plug	$535.00

Sold only as replacements or to fill out partially equipped synthesizers.

HOOK-UP CABLE FOR RDI-1

A special, 12-conductor, shielded cable is recommended for connection of the 12-pin filter-plug to remote equipment. One 50-foot roll of cable is furnished with each synthesizer containing an RDI-1 unit but is not supplied with an individually purchased RDI-1. Additional 50-foot lengths can be ordered separately.

Net Weight: 2½ lb (1.2 kg).

Catalog Number	*Description*	*Price in USA*
1160–9650	**Hook-Up Cable** for RDI-1, 50 feet	$15.00

COMPLETE SYNTHESIZERS FOR PROGRAMMABLE OPERATION

The TYPE 1161-A (0 to 100 kc/s) and TYPE 1162-A (0 to 1 Mc/s) Synthesizers are now available equipped with RDI units. For synthesizer specifications, see the *Experimenter* for September 1964.

TYPE 1162-A COHERENT DECADE FREQUENCY SYNTHESIZER 0 to 1 Mc/s

Catalog Number	*Type*	*Units Included*	*Calibrated Digits*		*Smallest Step (Digits Only)*	*Price in USA*
			Decades Only	*Decades + CAD**		
1162–9527	**1162-AR7C**	7 RDI Units + CAD	7	9	0.1 c/s	**$6195.00**
1162–9526	**1162-AR6C**	6 RDI Units + CAD	6	8	1 c/s	**5670.00**
1162–9525	**1162-AR5C**	5 RDI Units + CAD	5	7	10 c/s	**5145.00**
1162–9524	**1162-AR4C**	4 RDI Units + CAD	4	6	100 c/s	**4620.00**
1162–9523	**1162-AR3C**	3 RDI Units + CAD	3	5	1 kc/s	**4095.00**
1162–9507	**1162-AR7**	7 RDI Units	7		0.1 c/s	**5695.00**
1162–9506	**1162-AR6**	6 RDI Units	6		1 c/s	**5170.00**
1162–9505	**1162-AR5**	5 RDI Units	5		10 c/s	**4645.00**
1162–9504	**1162-AR4**	4 RDI Units	4		100 c/s	**4120.00**
1162–9503	**1162-AR3**	3 RDI Units	3		1 kc/s	**3595.00**

TYPE 1161-A COHERENT DECADE FREQUENCY SYNTHESIZER 0 to 100 kc/s

Catalog Number	*Type*	*Units Included*	*Calibrated Digits*		*Smallest Step (Digits Only)*	*Price in USA*
			Decades Only	*Decades + CAD**		
1161–9527	**1161-AR7C**	7 RDI Units + CAD	7	9	0.01 c/s	**$6055.00**
1161–9526	**1161-AR6C**	6 RDI Units + CAD	6	8	0.1 c/s	**5530.00**
1161–9525	**1161-AR5C**	5 RDI Units + CAD	5	7	1.0 c/s	**5005.00**
1161–9524	**1161-AR4C**	4 RDI Units + CAD	4	6	10 c/s	**4480.00**
1161–9523	**1161-AR3C**	3 RDI Units + CAD	3	5	100 c/s	**3955.00**
1161–9507	**1161-AR7**	7 RDI Units	7		0.01 c/s	**5555.00**
1161–9506	**1161-AR6**	6 RDI Units	6		0.1 c/s	**5030.00**
1161–9505	**1161-AR5**	5 RDI Units	5		1.0 c/s	**4505.00**
1161–9504	**1161-AR4**	4 RDI Units	4		10 c/s	**3980.00**
1161–9503	**1161-AR3**	3 RDI Units	3		100 c/s	**3455.00**

* Direct reading. If CAD is calibrated in terms of the step decades, at least one more significant figure can be added.
U. S. Patent No. 2,548,457. Patents applied for.

NEW GRO REPRESENTATIVE FOR NORWAY

We announce the appointment of the Norwegian firm of Gustav A. Ring A/S as exclusive General Radio Company (Overseas) representative for Norway, succeeding the firm of Maskin-Aktieselskapet Zeta, who have represented us in that country since 1948. Effective in *February, 1965*, Gustav A. Ring A/S took over these responsibilities, and is now directly serving our customers in Norway with competent technical assistance.

All inquiries, whether technical or commercial, concerning General Radio products should be addre[illegible] to:

Gustav A [illegible]
Sørke[illegible]
Os[illegible]
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the GENERAL RADIO
experimenter

VOLUME 39 NO 6 JUNE 1965

A NEW LOW-NOISE PREAMPLIFIER

Figure 1.

Recent advances in the semiconductor field, notably in the development of low-noise, field-effect transistors, have made practical a preamplifier particularly suited for use in sound-level and vibration measurements, as well as for general use. Among other characteristics, such a preamplifier should be small and rugged, have a high input impedance, add little noise to the signal, be able to drive other devices through long cables, and consume little power.

The recently developed TYPE 1560-P40 Preamplifier, shown in Figure 1, meets the above requirements admirably. Its physical shape was designed to enhance its use in acoustical measurements, and its electrical properties suit it for many other uses as well. Voltage gain is either unity or 20 dB, as selected by a switch. The 20-dB gain position is particularly helpful in augmenting the gain of analyzers for work at low sound and electrical levels.

DESCRIPTION

When one is making acoustical measurements at low levels, it is preferable to attach a microphone directly on the preamplifier. Since it is important that the structure disturb the acoustic field as little as possible, the preamplifier case is cylindrical and has approximately the same diameter as the microphone. Anechoic chamber tests prove that the preamplifier structure has a negligible effect on a measurement when used with a directly attached microphone, such as the GR TYPE 1560-P5 Microphone. On one end of the case is the input connector, which will accept the cartridge of the GR TYPE 1560-P5 Microphone and various adaptors. On the other end is a three-terminal audio connector that provides

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the output and power connections. Power is supplied from an external source, either a rechargeable battery power supply or the instrument with which the preamplifier is being used. A recessed slide switch provides the choice of 1:1 or 10:1 gain.

A preamplifier for use after microphones and other high-impedance sources should have a very high input impedance. To minimize the effect of load impedance on the operating characteristics, it should also have a low output impedance. The TYPE 1560-P40 Preamplifier achieves an input impedance greater than 500 megohms shunted by 6 picofarads through the use of a field-effect transistor operating as a source follower in the first stage. Low output impedance, low distortion, and gain stability are achieved in the second and third stages by use of conventional transistors within a negative feedback loop. The preamplifier gain is changed by adjustment of the negative feedback. All three transistors are low-noise types, and the circuit was designed for minimum noise consistent with other requirements. The typical internal equivalent input noise voltage when the preamplifier is connected to a piezoelectric microphone is 2.0 microvolts for the C-weighted sound-level meter characteristic.[1] For a microphone with a sensitivity of −60 dB re 1 volt/μbar this noise corresponds to an equivalent sound level (C) = 20 dB. When an analyzer is used, the equivalent level will be even lower, as determined by the bandwidth. Typical frequency spectra of the equivalent e_n and i_n generators[2] are shown in Figure 2.

The frequency response is flat (±1 dB) from 5 to 500,000 c/s for output voltages up to 1 volt, peak-to-peak, across a high impedance load. Even more output, up to 5 volts, peak-to-peak, across a high impedance load, with less than 1% distortion, can be obtained if the frequency range is restricted to 5 to 20,000 c/s.

APPLICATIONS

The very high input impedance and low output impedance make the TYPE 1560-P40 Preamplifier an excellent amplifier and impedance converter for use with microphones, vibration pickups, or other high impedance sources. The low output impedance makes it possible to use long cables to connect the output of the preamplifier to the measuring instrument. Use of one mile of cable at unity gain or one-half mile at 10:1 gain is practical, with some re-

[1] *S1.4—1961, American Standard Specification for General-Purpose Sound-Level Meters.*
[2] A. E. Sanderson and R. G. Fulks, "A Simplified Noise Theory and Its Application to the Design of Low-Noise Amplifiers," *NEREM 1960 Record*, General Radio Reprint No A-88.
I.R.E. Transactions on Audio, Vol AU-9, No 4, July-August 1961, p 106.

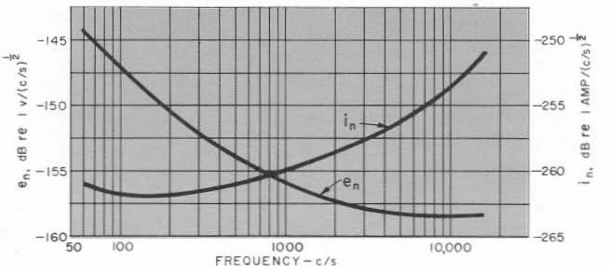


Figure 2. Typical frequency spectra of internal noise.

striction on signal level as shown in Figure 3.

PREAMPLIFIER SETS

The preamplifier is sold separately or as the main component of three different sets, each consisting of the preamplifier and a group of accessories suited for a particular type of use.

Adaptors supplied convert the preamplifier input connector to a 3-terminal, shielded, audio connector, to a GR-874 Connector, and to a connector that will receive the cartridge from a General Radio Type 1560-P3 Microphone. Cables supplied connect the preamplifier to the measuring instrument or to the power supply and transfer the output signal from the power supply to the measuring instrument.

Type 1560-P96 Adaptor—Preamplifier input to 3-terminal, shielded, audio connector.

Type 1560-P97 Adaptor—Preamplifier input to cartridge of Type 1560-P3 Microphone.

Type 1560-P98 Adaptor—Preamplifier input to GR874 Coaxial Connector.

Type 1560-P72 25-ft Cable, Type 1560-P72C 4-ft Cable—Preamplifier to power supply or other device supplying power. Also carries preamplifier output signal.

Type 1560-P95 Adaptor Cable—Preamplifier output signal from power supply through cable to a Type 274-M Double Plug.

Type 1560-P99 Adaptor Cable—Phone plug to 3-terminal, shielded, audio connector.

Type 874-Q2 Adaptor—GR874 Coaxial Connector to Type 274 Jacks (banana pin) on ¾-inch spacing.

The Type 1560-P40H Preamplifier and Power Supply Set

This set includes a rechargeable battery power supply and a group of adaptors and is intended for applications where power for the preamplifier is not otherwise available and where only electrical signals are to be amplified or a suitable microphone is available for acoustical measurements. The set is made up of the following items:

Type 1560-P40 Preamplifier
Type 1560-4100 Power Supply
Types 1560-P96 and -P98 Adaptors
Types 1560-P95 and -P99 Adaptor Cables
Type 1560-P72C Cable
Type 874-Q2 Adaptor

Shipping Weight: 10 lb (4.6 kg).

The power supply consists of two standard nickel-cadmium batteries, a battery checking device, and a battery charger. The output signal from the preamplifier is available at a jack in the power-supply unit.

The Type 1560-P40H Preamplifier and Power Supply Set can provide added sensitivity at a very high input

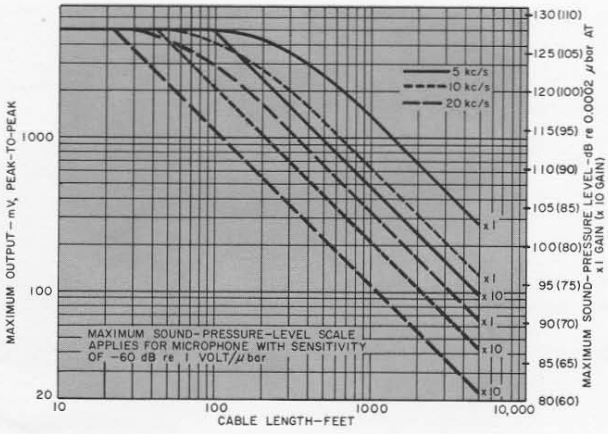


Figure 3. Maximum output as a function of length of cable between preamplifier and measuring instrument.

impedance to a wide variety of instruments, for example, the TYPES 1900-A Wave Analyzer, 1142-A Frequency Meter and Discriminator, 1150-series Digital Frequency Meters, 1206-B Unit Amplifier, 1232-A Tuned Amplifier and Null Detector, 1233-A Power Amplifier, 1521-B Graphic Level Recorder, and 1806-A Electronic Voltmeter. For the TYPES 1551 Sound-Level Meters and 1553 Vibration Meters this set makes possible the use of very long cables between the transducer and the meter without loss in signal or deterioration in signal-to-noise ratio.

To illustrate what can be achieved with the added sensitivity, the combination of this preamplifier set and the TYPE 1900-A Wave Analyzer yields an analysis system with as much sensitivity as 3 microvolts, full-scale, at an input impedance of greater than 500 megohms shunted by 6 picofarads. Because the preamplifier can usually be placed very close to the source of the signal being measured, full advantage can be taken of the very high input impedance.

Type 1560-P40J Preamplifier and Adaptor Set, Type 1560-P40K Preamplifier and Microphone Set

The TYPES 1560-P40J Preamplifier and Adaptor Set and 1560-P40K Preamplifier and Microphone Set do not include the power supply and are intended for use with measuring instruments that supply power to the preamplifier. Power is available from recent models* of the TYPES 1564-A Sound and Vibration Analyzer and 1558 Octave-Band Noise Analyzer at the microphone connector. Thus the connection of the proper cable between the preamplifiers and those analyzers will not only provide the path for the signal but also will connect the dc power from the instrument to the preamplifier.

TYPE 1560-P40J Preamplifier and Adaptor Set consists of:

TYPE 1560-P40 Preamplifier
TYPES 1560-P96, -P97, and -P98 Adaptors
TYPE 1560-P72C Cable

Shipping Weight: 4 lb (1.9 kg).

* Earlier models of the TYPES 1564-A, 1558-A and 1558-AP can be readily adapted to supply this power.

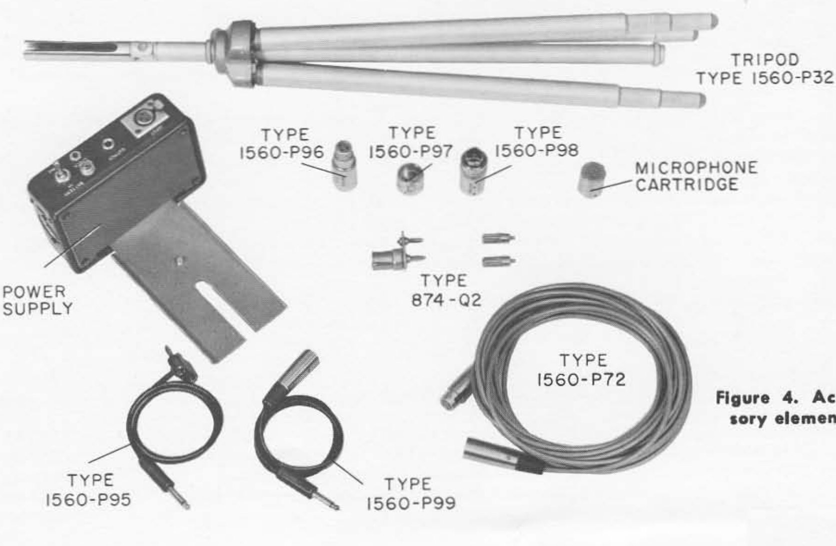


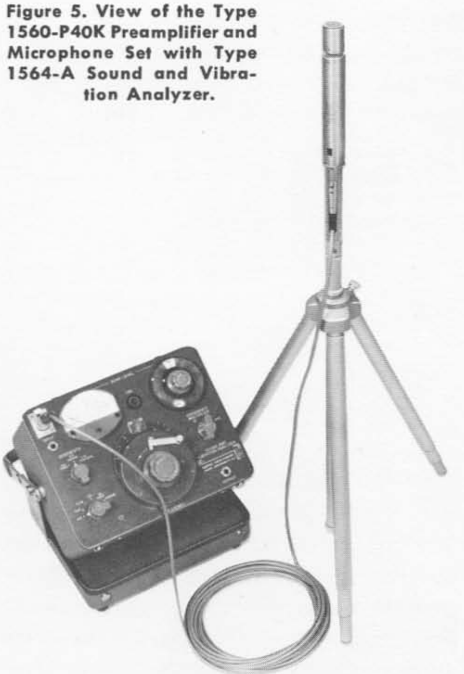
Figure 4. Accessory elements.

Type 1560-P40K Preamplifier and Microphone Set consists of:

- Type 1560-P40 Preamplifier
- Type 1560-2131 Microphone Cartridge
- Types 1560-P72 and -P72C Cables
- Type 1560-P32 Tripod

Shipping Weight: 14 lb (6.5 kg).

Figure 5. View of the Type 1560-P40K Preamplifier and Microphone Set with Type 1564-A Sound and Vibration Analyzer.



Microphone Cartridge

The microphone cartridge supplied with the Type 1560-P40K Set is from the new Type 1560-P5 Microphone. The cartridge fastens securely to the preamplifier so that there is no electrical noise that can result from relative motion of the two mated connectors.

Because of its low noise level the preamplifier is excellent for increasing the sensitivity of analyzers, level recorders, voltmeters, and amplifiers by 20 dB. The combination of the Type 1560-P40K Preamplifier and Microphone Set and a Type 1564-A, 1558-A, or 1558-AP Analyzer will permit measurements down to a sound-pressure level of 24 dB re 20 μN/m^2 (0.0002 μbar). In addition, the use of a cable between the preamplifier and the analyzer makes it possible for the observer to be far from the microphone, thus avoiding interference with the sound field.

— C. A. Woodward

SPECIFICATIONS

For Type 1560-P40 Preamplifier

Gain: 1:1 or 10:1 (20 dB) $\pm$0.3 dB.
Input Capacitance: 6 pF.
Input Resistance: > 500 MΩ at low audio frequencies.
Output Resistance: 1:1 gain—approx 5 Ω.
10:1 gain—approx 100 Ω.
Noise: $\leq$2.5 μV equivalent input voltage (400-pF source impedance, C-weighted, 10-kc effective bandwidth).
Frequency Response: $\pm$1 dB from 5 c/s to 500 kc/s.
Harmonic Distortion at Audio Frequencies: Open circuit, at 1 V, peak-to-peak: < 0.25%. Capacitor load of 0.01 μF (equivalent to a cable over 200 ft long): Maximum output (peak-to-peak) at 1% distortion is 5 V for 1 kc/s, 2 V for 10 kc/s.
Power Required: 15 V to 25 V, 1 mA to 2 mA, dc.
Dimensions: length 6⅞, diameter 1 in (175, 26 mm).
Net Weight: 9 oz (0.3 kg).
Shipping Weight: 3 lb (1.4 kg).

Catalog Number	*Description*	*Price in USA*
1560-9640	**Type 1560-P40 Preamplifier**	**$140.00**
1560-9500	**Type 1560-P40H Preamplifier and Power Supply Set**	**310.00**
1560-9510	**Type 1560-P40J Preamplifier and Adaptor Set**	**184.00**
1560-9520	**Type 1560-P40K Preamplifier and Microphone Set**	**251.00**

OSCILLATOR-POWER-SUPPLY COMBINATIONS FOR FREQUENCIES FROM 0.5 Mc/s TO 2 Gc/s

General Radio high-frequency oscillators are compact, low-priced power sources, which provide continuous coverage from 500 kc/s to 2000 Mc/s with single-dial control and output in the order of several hundred milliwatts. Tuning ranges of a simple oscillator range from slightly over an octave at the highest frequencies to 100:1 at the lowest. In conjunction with one of the companion group of power supplies, any oscillator becomes a complete signal source with characteristics adapted to the customer's application. By appropriate choice of power supply, the oscillator can deliver (1) maximum power, (2) optimum frequency stability with minimum residual fm and a-m, (3) pulse- and square-wave-modulated output, (4) amplitude-regulated output for sweeping applications, or can be incorporated into a heterodyne detector system. Power supplies and oscillators are designed for semi-permanent attachment for bench use or relay-rack mounting.

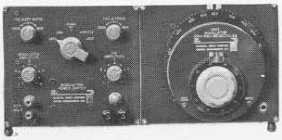
Each possible operable combination has now been assigned an individual type number to simplify selection and ordering.

Both bench- and rack-mount combinations are available. The rack-mounted combinations include panel extensions, necessary to convert the bench-mount instruments for rack mounting, and a coaxial cable, which permits the user to have the rf output available at either front panel or rear.

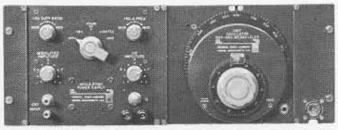
Combinations originally purchased for bench mounting can subsequently be converted for rack mounting by means of rack-adaptor kits, which are also available separately. Conversely, conversion from rack to bench is accomplished simply by removal of the panel extensions. Bench models have output at rear, except for TYPE 1361-A, which has its output jack on the front panel. The output connector is a locking GR874, to which adaptors to other types are easily attached. All adaptors lock securely in place and are neat in appearance since they protrude little further than would a standard panel jack of similar connector series. The locking-type adaptors in the table below are recommended.

Adaptor to	*Type Number*	*Contains* **GR874** *and . . .*	*Connects* **GR874** *to . . .*	*Net Weight*	*Catalog Number*	*Price in USA*
Type BNC	874-QBJL	BNC Jack	BNC Plug	1½ oz (45 g)	0874-9701	$5.75
Type C	874-QCJL	C Jack	C Plug	2 oz (60 g)	0874-9703	8.50
Microdot	874-QMDJL	Microdot Jack	Microdot Plug	1½ oz (45 g)	0874-9721	11.00
Type N	874-QNJL	N Jack	N Plug	2 oz (60 g)	0874-9711	6.00
	874-QNPL	N Plug	N Jack	2¼ oz (70 g)	0874-9811	6.50
Type	874-QMMJL	OSM/BRM Jack*	OSM/BRM Plug	1½ oz (45 g)	0874-9723	12.00
OSM/BRM	874-QMMPL	OSM/BRM Plug*	OSM/BRM Jack	1½ oz (45 g)	0874-9823	12.00
Type SC	874-QSCJL	SC Jack	SC Plug (Sandia)	2 oz (60 g)	0874-9713	11.00
Type TNC	874-QTNJL	TNC Jack	TNC Plug	1½ oz (45 g)	0874-9717	9.50

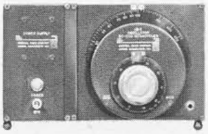
*Mates also with NPM and STM.



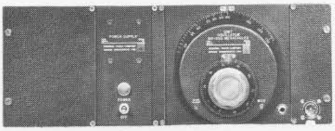
(Left) **Type 1209-C4; Types 1209-CL4, 1215-C4, 1361-A4, 1211-C3, 1215-C3, 1209-CL3, 1209-C3 and 1361-A3 are similar in appearance.**



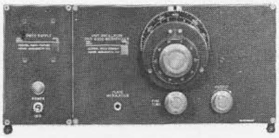
(Right) **Rack-mount version (Type 1209-C4R) of the combination shown above.**



(Left) **Type 1215-C9; similar in appearance are Types 1211-C9, 1211-C7, 1215-C7, 1208-C7, 1208-C9, 1209-CL7, 1209-CL9, 1209-C7, 1209-C9, 1361-A7, and 1361-A9.**

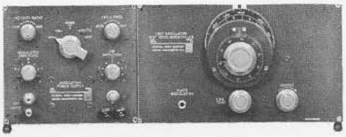


(Right) **Rack-mount version (Type 1215-C9R) of the combination shown above.**

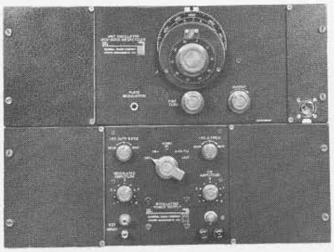


(Left) **Type 1218-B9; Type 1218-B7 is similar.**

(Right) **Type 1218-B9R; Type 1218-B7R is similar.**



(Left) **Type 1218-B4; Type 1218-B3 is similar.**



(Right) **Type 1218-B4R; Type 1218-B3R is similar.**

Frequency Range and (Oscillator Type) ↓	*Performance* →	
	(Power Supply Type)	
	Input Line Voltage	
500 kc/s-50 Mc/s (Type 1211-C)	*Bench Mount*	*Catalog No. Type Price in USA*
	Rack Mount	*Catalog No. Type Price in USA*
50-250 Mc/s (Type 1215-C)	*Bench Mount*	*Catalog No. Type Price in USA*
	Rack Mount	*Catalog No. Type Price in USA*
65-500 Mc/s (Type 1208-C)	*Bench Mount*	*Catalog No. Type Price in USA*
	Rack Mount	*Catalog No. Type Price in USA*
180-600 Mc/s (Type 1209-CL)	*Bench Mount*	*Catalog No. Type Price in USA*
	Rack Mount	*Catalog No. Type Price in USA*
250-960 Mc/s (Type 1209-C)	*Bench Mount*	*Catalog No. Type Price in USA*
	Rack Mount	*Catalog No. Type Price in USA*
450-1050 Mc/s (Type 1361-A)	*Bench Mount*	*Catalog No. Type Price in USA*
	Rack Mount	*Catalog No. Type Price in USA*
900-2000 Mc/s (Type 1218-B)	*Bench Mount*	*Catalog No. Type Price in USA*
	Rack Mount	*Catalog No. Type Price in USA*

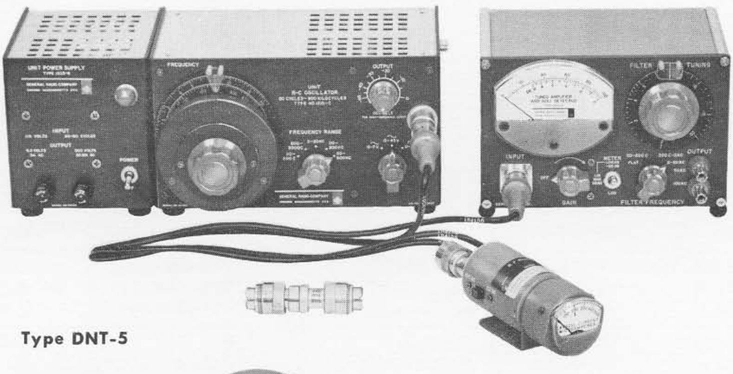
Maximum power; lowest cost (1269-A)	*Ultimate cw stability; very low residual fm* (1267-A)	(1267-AQ18)	*Stable cw; 100% square-wave & pulse modulation; internal 1-kc square-wave* (1264-A)	*Amplitude-leveled output behind 50-Ω source impedance; metered output level; 1-kc square-wave modulation, or cw* (1263-B)
105 to 125 V or 195 to 250 V	105 to 125 V	195 to 250 V	105 to 125 V or 210 to 250 V	105 to 125 V or 210 to 250 V
1211-9439 1211-C9 **$415.00**	1211-9437 1211-C7 **$510.00**	1211-9438 1211-C7Q18 **on request**	Not Available	1211-9433 1211-C3 **$765.00**
1211-9579 1211-C9R **$435.00**	1211-9577 1211-C7R **$530.00**	1211-9578 1211-C7RQ18 **on request**		1211-9573 1211-C3R **$786.00**
1215-9439 1215-C9 **$300.00**	1215-9437 1215-C7 **$395.00**	1215-9438 1215-C7Q18 **on request**	1215-9434 1215-C4 **$525.00**	1215-9433 1215-C3 **$650.00**
1215-9579 1215-C9R **$320.00**	1215-9577 1215-C7R **$415.00**	1215-9578 1215-C7RQ18 **on request**	1215-9574 1215-C4R **$546.00**	1215-9573 1215-C3R **$671.00**
1208-9439 1208-C9 **$340.00**	1208-9437 1208-C7 **$435.00**	1208-9438 1208-C7Q18 **on request**	Not Available	Not Available
1208-9579 1208-C9R **$360.00**	1208-9577 1208-C7R **$455.00**	1208-9578 1208-C7RQ18 **on request**		
1209-9539 1209-CL9 **$375.00**	1209-9537 1209-CL7 **$470.00**	1209-9538 1209-CL7Q18 **on request**	1209-9534 1209-CL4 **$600.00**	1209-9533 1209-CL3 **$725.00**
1209-9589 1209-CL9R **$395.00**	1209-9587 1209-CL7R **$490.00**	1209-9588 1209-CL7RQ18 **on request**	1209-9584 1209-CL4R **$621.00**	1209-9583 1209-CL3R **$746.00**
1209-9439 1209-C9 **$375.00**	1209-9437 1209-C7 **$470.00**	1209-9438 1209-C7Q18 **on request**	1209-9434 1209-C4 **$600.00**	1209-9433 1209-C3 **$725.00**
1209-9579 1209-C9R **$395.00**	1209-9577 1209-C7R **$490.00**	1209-9578 1209-C7RQ18 **on request**	1209-9574 1209-C4R **$621.00**	1209-9573 1209-C3R **$746.00**
1361-9419 1361-A9 **$375.00**	1361-9417 1361-A7 **$470.00**	1361-9418 1361-A7Q18 **on request**	1361-9414 1361-A4 **$585.00**	1361-9413 1361-A3 **$725.00**
1361-9509 1361-A9R **$395.00**	1361-9507 1361-A7R **$490.00**	1361-9508 1361-A7RQ18 **on request**	1361-9504 1361-A4R **$606.00**	1361-9503 1361-A3R **$746.00**
1218-9429 1218-B9 **$540.00**	1218-9427 1218-B7 **$635.00**	1218-9428 1218-B7Q18 **on request**	1218-9424 1218-B4 **$750.00**	1218-9423 1218-B3 **$890.00**
1218-9549 1218-B9R **$561.00**	1218-9547 1218-B7R **$656.00**	1218-9548 1218-B7RQ18 **on request**	1218-9544 1218-B4R **$774.00**	1218-9543 1218-B3R **$914.00**

HETERODYNE DETECTORS FOR THE LF, MF, AND HF RANGES

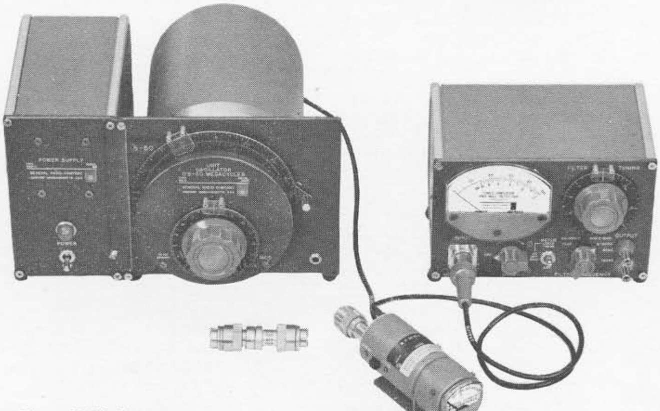
Of the kinds of detectors useful at radio frequencies, the so-called heterodyne type (actually superheterodyne) has the most to recommend it. Among its many advantages are (1) high sensitivity, (2) wide frequency range, (3) excellent selectivity, and (4) excellent effective shielding.

The GR Types DNT-1, -2, -3 and -4 Detectors have found widespread use at very-high and ultra-high frequencies. The new Types DNT-5, -6, and -7 now bring the heterodyne detector's definite advantages to the low-, medium-, and high-frequency ranges. These detectors use the crystal mixers previously described.[1] The i-f amplifier for Types DNT-5 and DNT-6 is the Type 1232-A Tuned Amplifier and Null Detector; for the Type DNT-7, it is the Type 1212-A Unit Null Detector. Each detector combination is complete with local oscillator, mixer, i-f amplifier, and isolating attenuator pad, as shown.

[1] "Two New Mixers for the Detection of RF Signals," *General Radio Experimenter*, December 1963.



Type DNT-5



Type DNT-6

TYPE DNT-5 AND TYPE DNT-6 HETERODYNE DETECTORS

The TYPE 1232-A Tuned Amplifier and Null Detector, which in these combinations is the i-f amplifier, covers, by itself, frequencies from 20 c/s to 20 kc/s and has spot frequencies at 50 kc/s and 100 kc/s. Thus, the TYPE DNT-5 gives nearly continuous coverage from 20 c/s to 500 kc/s. Present users of the TYPE 1232-A can extend the coverage to higher frequencies by buying only those components that they do not already have (see list below).

In addition to the advantages of the heterodyne detector, as listed above, the TYPES DNT-5 and DNT-6 have a linear response and are suitable as indicators for measurements of attenuation, relative signal levels, leakage, and crosstalk by the substitution method with the aid of a calibrated attenuator. A complete list of components for each detector is shown below.

TYPE DNT-5 HETERODYNE DETECTOR

70 TO 500 kc/s

1 TYPE 1232-A Tuned Amplifier and Null Detector
1 TYPE 1210-C Unit R-C Oscillator
1 TYPE 1203 Unit Power Supply
1 TYPE 1232-P1 RF Mixer
1 TYPE 874-G10L Fixed Attenuator

Net Weight: 17½ lb (8 kg).
Shipping Weight: 24 lb (11 kg).

Catalog Number	*Description*	*Price in USA*
1235-9605	**Type DNT-5 Heterodyne Detector,** for 105-to-125-volt supply	**$737.00**
1235-9795	**Type DNT-5Q18 Heterodyne Detector,** for 195-to-250-volt supply	**on request**

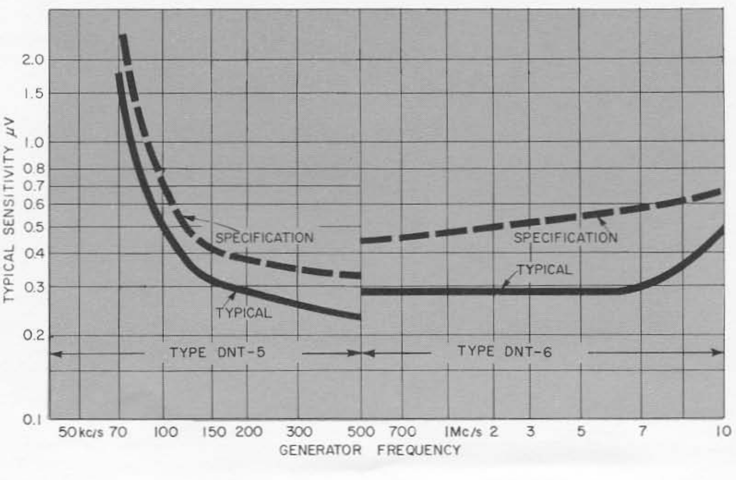
TYPE DNT-6 HETERODYNE DETECTOR

500 kc/s TO 10 Mc/s

1 TYPE 1232-A Tuned Amplifier and Null Detector
1 TYPE 1211-C Unit Oscillator
1 TYPE 1269-A Unit Power Supply
1 TYPE 1232-P1 RF Mixer
1 TYPE 874-G10L Fixed Attenuator

Net Weight: 24½ lb (11.5 kg).
Shipping Weight: 33 lb (15 kg).

Catalog Number	*Description*	*Price in USA*
1235-9606	**Type DNT-6 Heterodyne Detector,** for 105-to-125-, 195-to-235-, or 210-to-250-volt supply	**$912.00**

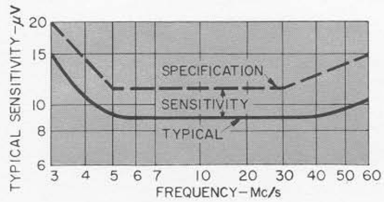


Sensitivity vs frequency for Type DNT-5 and Type DNT-6 Heterodyne Detector.

TYPE DNT-7 HETERODYNE DETECTOR

Type DNT-7

The Type 1212-A Unit Null Detector, used as the i-f amplifier in this combination, is a broadband amplifier covering frequencies from about 20 c/s to about 3 Mc/s. In addition, it is a narrow-band tuned device when used with the Type 1212-P3 1-Mc Filter.



Type 900-C9 Cable Connector

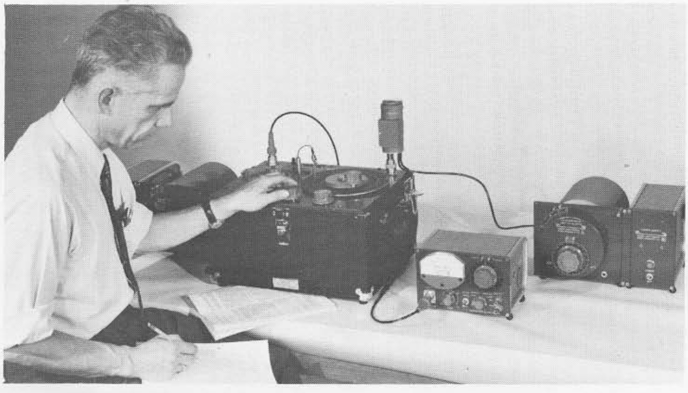
TYPE DNT-7 HETERODYNE DETECTOR

3 TO 50 Mc/s

1 Type 1212-A Unit Null Detector
1 Type 1212-P3 RF Mixer
1 Type 1211-C Unit Oscillator
1 Type 1269-A Unit Power Supply
1 Type 1203 Unit Power Supply
1 Type 874-G10L Fixed Attenuator

Net Weight: 28½ lb (13 kg).
Shipping Weight: 39 lb (18 kg).

Catalog Number	*Description*	*Price in USA*
1235-9607	**Type DNT-7 Heterodyne Detector,** for 105-to-125-volt line	**$802.00**
1235-9797	**Type DNT-7Q18 Heterodyne Detector,** for 195-to-250-volt line	**on request**



Type DNT-5 Heterodyne Detector in use with the Type 916-AL RF Bridge.

PRECISION CONNECTOR FOR COAXIAL CABLE

A precision flexible-cable connector, the GR Type 900-C9, is the latest addition to the GR900 line.

Why is such a connector needed? Connector manufacturers argue that there is a limit to how good a cable connector need be because cables are generally poorer (some cable manufacturers indicate that cable VSWR of 1.20 is considered good). Some cable manufacturers hold that the cables are good and the connectors have been generally poor (recent MIL connector VSWR specifications are 1.200—1.30). Actually, both views are valid. Most flexible cables have random characteristic-impedance variations that produce significant reflections at microwaves; but nevertheless, very good pieces of cable can be selected. The connector reflections in this case may limit the performance. Hence the need for a good flexible-cable connector. The Type 900-C9 Precision Cable Connector meets this need.

DESIGN CONSIDERATIONS

The principal performance goal in the design of the Type 900-C9 Cable Connector was the achievement of low VSWR and its maintenance by means of reliable techniques for assembly and for attachment to the cable. These were the same goals sought in the GR874 "A" series cable connectors [1] but which could not be fully realized there because of the general requirement for the crimped-ferrule method of attachment.

Crimping, which is used with many UG connectors, compresses the cable and produces a significant reflection at the joint. In the Type 900-C9 a new method of attachment is used, which eliminates this compression.

The assembly procedure is an important design consideration. The principal aims are precise axial location of the internal connector parts and a good solder joint without flow of cable dielectric. These aims have been achieved in the Type 900-C9 by the use of an assembly that is self-aligning, the use of a Teflon* heat-barrier

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[1] J. Zorzy, "New Coaxial Cable Connectors," *General Radio Experimenter*, August–September, 1962.

*Registered trademark of E. I. du Pont de Nemours and Company.

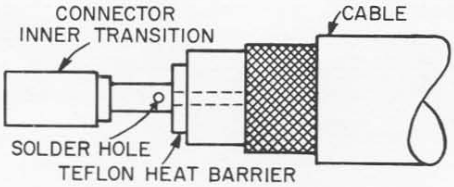


Figure 1. Inner-transition assembly showing Teflon disk.

disk [2], and the use of low-temperature solder, which is furnished with each connector. The disk in position is shown in Figure 1.

Three important requirements affect the design of the mechanical attachment for the cable braid and jacket: (1) the electrical connection between the braid and the connector must not produce discontinuities; (2) the assembly must stand up under typical use by resisting twisting and/or pulling forces; and (3) the cable must not be compressed. These requirements are met by the attachment method shown in Figure 2. The braid is captured by a combination of butt and radial forces. The outer transition has a diamond-pattern knurl similar to that used on the GR874-series connectors. The radial forces come into play as the rubber gasket presses both the jacket and the braid against the knurled portion of the outer transition when the retainer body is threaded up tight. To obtain continuous and reliable electrical connection between the cable braid and the outer transition, the end of the transition is faired in, and the rubber gasket is extended into this region to press the braid against the faired-in edge.

[2] *Op. Cit.*

The resulting joint is strong and resists the pull and torsion ordinarily encountered in use of a cable connector. In a pull test the connector assembly supported the 170-pound weight of the writer.

A low-VSWR junction is achieved at the braid joint, and it does not deteriorate with use.

The inner and outer transitions are accurately positioned in the connector by means of the modified GR900 connector to which these are assembled. Axial relations are maintained automatically; nothing is left to skill or special tools. After assembly of the connector, the retention system described above is tightened, and the braid is automatically positioned as the connection is tightened.

The GR900 connector used is similar to the Type 900-BT except that the Teflon support, instead of being a press-fit into the body, is a sliding fit, which is necessary to facilitate the assembly of the cable connector.

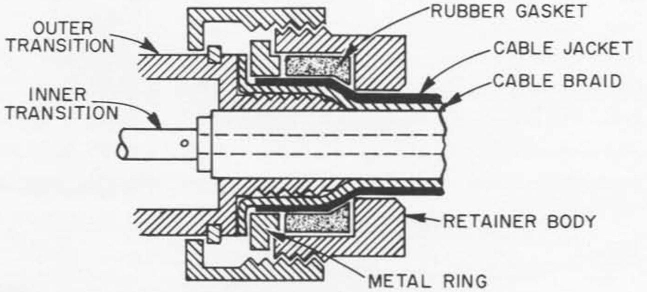


Figure 2. Braid and jacket-retention system shown before coupling ring is tightened.

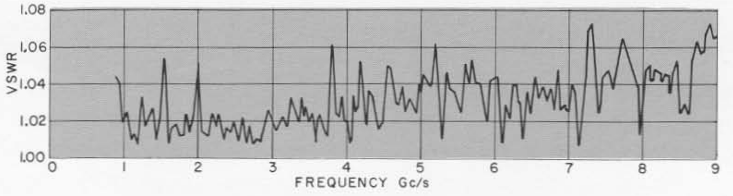


Figure 3. Typical VSWR of a single Type 900-C9 Connector on "infinite" length of RG-214/4 cable.

VSWR PERFORMANCE

In order to assess the VSWR characteristics of this connector, a good piece of RG-214/U cable was obtained. Its characteristic impedance was $50 \pm 1\%$, and it was free of any significant impedance nonuniformities. The VSWR characteristics of the TYPE 900-C9 Connector mounted on this cable are shown in Figure 3. The cable was taken as infinite in length.

APPLICATIONS

The TYPE 900-C9 Cable Connector is recommended for any indoor flexible-cable application when an extremely low VSWR connection is required or when a connection to other GR900 components is required. This connector also makes possible the accurate measurement of the VSWR characteristics of cables at microwaves and VSWR tests of cable connectors to new MIL specs, such as MIL-C-39012.

It is difficult to get a perfect 50-ohm termination for a cable. The so-called infinite cable termination is a poor one, because most cables have both random and periodic impedance variations. A relatively short piece of cable (in a short piece, the multitudes of small reflections cannot add up to cause a large reflection), terminated in the TYPE 900-C9 and the TYPE 900-W50 Termination, is better.

The TYPE 900-C9 Precision Cable Connector was designed for use with the RG-214/U and for the RG-9 cables. It can be used with other popular cables of this size, for example, the RG-213/U or the RG-8 cables, but, because these cable diameters are smaller, the hole in the retainer body provides too much clearance. A turn or two of electrical tape, however, will build up the diameter to fit. The connector can be used with still other cables, but the mechanical clamping may not be effective because of deviations of over-all diameter or, with armored cable, lack of means for clamping the armor.

— JOHN ZORZY

SPECIFICATIONS

Frequency Range: Dc to 9 Gc/s.

Characteristic Impedance: 50 Ω.

Leakage: Better than 130 dB below signal.

Insertion Loss: Less than 0.006 $\sqrt{f_{Gc}}$ dB per pair.

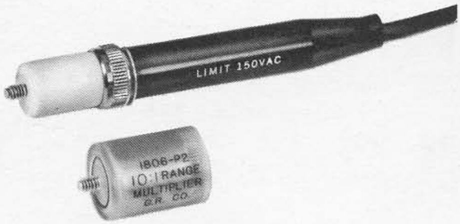
Maximum Voltage: 1500 V peak.

Dimensions: Length of one connector, 2⅛ inches (54 mm); maximum diameter, 1$\frac{1}{16}$ inches (27 mm).

Net Weight: 2½ oz (75 g).

Catalog Number	*Description*	*Price in USA*
0900-9421	**Type 900-C9 Precision Coaxial Cable Connector**	**$50.00**

A 10:1 MULTIPLIER FOR THE ELECTRONIC VOLTMETER



The TYPE 1806-P2 10:1 Range Multiplier attaches to the probe of TYPE 1806-A Electronic Voltmeter and permits the probe to be used directly for the measurement of ac voltages up to 1500 volts.

In addition to its range-extension use, it can be used advantageously at all voltages at frequencies up to about 200 Mc/s. Transit-time effects at these frequencies increase the input conductance of the probe often to the point where the voltmeter may constitute too great a load on the source under measurement. This capacitive voltage divider produces an improvement of about one-hundred fold in this situation.

SPECIFICATIONS

Voltage Division Ratio: 10:1 ± 5%, as received. An adjustment is provided for matching the multiplier to the voltmeter within ±2%.

Input Impedance: Equivalent input resistance of the probe-multiplier combination is 100 times that of the probe alone. Equivalent parallel capacitance is approximately 2 pF.

Dimensions: (dia) ⅝ by (length) 1¼ in (16, 32 mm).

Net Weight: ½ oz (15 grams).

Shipping Weight: 3 oz (85 grams).

Catalog Number	*Description*	*Price in USA*
1806-9602	**Type 1806-P2 10:1 Range Multiplier**	**$20.00**

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VIBRATION PICKUPS • 100 μF DECADE CAPACITOR • 900–2000 MHz OSCILLATOR • COAXIAL MICROWAVE NEWS

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Figure 1. ***(Left)*** **Vibration pickup with control box installed on Type 1551-C Sound-Level Meter.** ***(Above)*** **The three vibration pickups with their connecting cable. Left to right: Type 1560-P52, Type 1560-P53, and Type 1560-P54.**

VIBRATION MEASUREMENTS WITH THE SOUND-LEVEL METER

The standard sound-level meter can be adapted for the measurement of solid-borne vibrations by the substitution of a vibration pickup, or accelerometer, in place of the microphone. For use with General Radio sound-level meters, three vibration pickups are now available, offering a wide choice of characteristics.

Each pickup is offered, either by itself or in combination with a control box, which by means of electrical integrating networks converts the acceleration response of the pickup into velocity and displacement responses. Each combination, called a Vibration Pickup System, consists of pickup, control box, low-noise connecting cable, and convenient probes or fastening devices.

The control boxes are basically alike, but each type requires unique input and output circuits determined by the vibration-pickup characteristics. A three-position switch, labeled ACC, VEL, DISP, selects the characteristic desired. At each switch position the signal level is automatically adjusted to the correct calibration value.

VIBRATION-PICKUP CHARACTERISTICS

Table I lists the characteristics of the three Vibration Pickups and of their corresponding Vibration Pickup Systems.

Type 1560-P52 Vibration Pickup

This pickup has a low output impedance and is especially suited for the detection of low-frequency vibrations.

TABLE I

VIBRATION PICKUPS

Type Number	Type 1560-P52	Type 1560-P53	Type 1560-P54
Catalog Number	1560-9652	1560-9653	1560-9654
Sensitivity (mV/g), nominal	75	72	580
Temp Coeff of Sens (dB/°C)	0.06	<0.02	0.01
Resonant Frequency (c/s)	3200	28,000	5000
Capacitance (pF)	10,000	350	700
Temperature Range (°C)	0 to 75	− 18 to 120	− 18 to 120
Relative Humidity Range (%)	0 to 100	0 to 100	0 to 100
Cable Length (ft)	5 (1.55 m)	8 (2.5 m)	8 (2.5 m)
Dimensions (in)	1⅝ by 1 7/16 by 9/16	⅝ hex by 0.7	1 3/16 dia by 1 1/16
(mm)	42 by 37 by 15	15.5 by 18	31 by 27
Net Weight (oz)	1.6 (45 grams)	1.1 (31 grams)	3.1 (90 grams)
Price	**$100.00**	**$220.00**	**$160.00**

VIBRATION PICKUP SYSTEMS

(Used with Type 1551-B or Type 1551-C Sound-Level Meter)

Type Number	Type 1560-P11B	Type 1560-P13	Type 1560-P14
Catalog Number	1560-9922	1560-9613	1560-9614
Ranges of Measurement Rms Acceleration (in/s²)	0.1 to 39,000	0.3 to 390,000	0.01 to 3900
(m/s²)	0.002 to 1000	0.006 to 10,000	0.0002 to 100
(g†)	0.0002 to 100	0.0006 to 1000	0.00002 to 10
Rms Velocity (in/s)	0.001 to *	0.001 to 1000	0.0001 to *
(m/s)	0.00002 to *	0.00002 to 20	0.000002 to *
Rms Displacement (mils)	0.03 to *	0.03 to 30,000	0.003 to *
(mm)	0.0006 to *	0.0006 to 600	0.00006 to *
Frequency Range (see Figure 2)			
Net Weight of System (lb)	1¾ (0.8 kg)	1¾ (0.8 kg)	2(1 kg)
Shipping Weight (lb)	5 (2.3 kg)	5 (2.3 kg)	5 (2.3 kg)
Price	**$160.00**	**$290.00**	**$220.00**

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

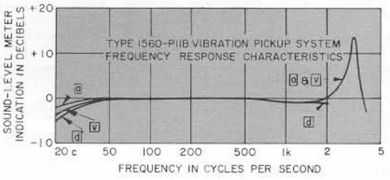
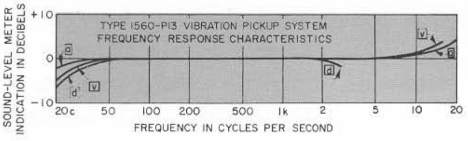
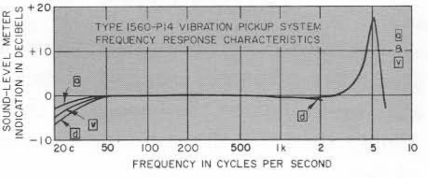


Figure 2. Response characteristics for constant applied (a) acceleration, (v) velocity, and (d) displacement.





It is supplied with the Type 1553 Vibration Meters for measurements down to 2 c/s. When the pickup is used on the Type 1560-P11B Vibration Pickup System, the 20-cycle low-frequency limit for acceleration measurements is set by the frequency response of the Type 1551-C Sound-Level Meter and for velocity and displacement by the integrating networks in the control box. Measurements of acceleration down to 2.5 c/s can be made if the Type 1564-A Sound and Vibration Analyzer is used in place of the sound-level meter. Velocity and displacement are easily calculated from the acceleration readings, when the frequency of the vibration is known.

Type 1560-P53 Vibration Pickup

From among the many excellent, small, lightweight accelerometers now available, this pickup has been chosen as best suited for vibration measurements over the complete audio range with GR instruments. It has (approximately) 10 times the resonant frequency, 20 times the output impedance, and the same output voltage as the Type 1560-P52. Owing to its high output impedance, this pickup requires the Type 1560-P40 Preamplifier for measurements down to 2 c/s with the Type 1553 Vibration Meter or to 2.5 c/s with the Type 1564-A Sound and Vibration Analyzer. Without the preamplifier, acceleration response will be down approximately 3 dB at 12 c/s.

The Type 1560-P13 Vibration Pickup System, in which this pickup is used, is capable of measurements down to 20 c/s with the Type 1551-C Sound-Level Meter. This combination is recommended for measurements to meet the requirements of Mil Std-740 (Ships).

Type 1560-P54 Vibration Pickup

This high-sensitivity pickup is a newly developed high-output, high-performance piezoelectric ceramic transducer. It has (approximately) 1.5 times the resonant frequency, 10 times the output, and 10 times the output impedance of the Type 1560-P52 Pickup. With its associated control box in the Type 1560-P14 Vibration Pickup System, it is intended for use with the Type 1551-C Sound-Level Meter. It is equally useful with the Type 1553 Vibration Meters and the Type 1564-A Sound and Vibration Analyzer. With these two instruments, the low-frequency response will be down about

3 dB at 6 c/s. With the TYPE 1560-P40 Preamplifier, the full range of the vibration meter and analyzer can be covered.

VIBRATION PICKUP SYSTEM CHARACTERISTICS

The curves of Figure 2 show the frequency-response characteristics of the three systems. In each case the response shown is the combined response of the pickup, its connecting cable, the associated control box, and the TYPE 1551-C Sound-Level Meter on 20-kc weighting switch position. Table II lists the characteristics of the three Vibration Pickup Systems so they can be readily compared.

DECIBELS OR VIBRATION QUANTITIES?

When a Vibration Pickup System is used in place of the microphone, the decibel readings of the sound-level meter can be converted to the corresponding vibration quantities, as above, or alternatively, the decibel scale can be assigned new reference levels. A data plate, see Figure 3, on the panel of the control box for each Vibration Pickup System lists the conversion factors to convert the dB reading to magnitudes of the vibration parameters. In addition, dB conversion charts are supplied in the operating instruction booklet, which relate any decibel reading of the sound-level meter to the vibration quantity being measured.

Some of the recent vibration specifications require answers in acceleration level, L_a (sometimes called adB), for acceleration measurements and velocity level, L_v (sometimes called vdB), for velocity measurements. There have been no standardized reference levels for these quantities, but some Navy specifications have commonly used 10^{-5} m/s² (10^{-3} cm/s²) for the L_a reference and 10^{-8} m/s (10^{-6} cm/s) for the L_v reference.

A new ASA Standard for Reference Quantities for Acoustical Measurements is now in process. It includes the two reference quantities above plus the

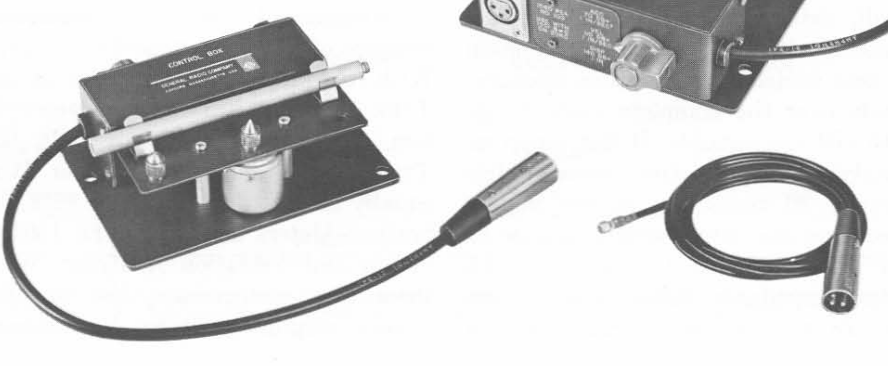


Figure 3. Two views of the control box, which attaches to the Type 1551-C Sound-Level Meter.

reference quantity of 10^{-10} m (10^{-8} cm) for displacement level, L_d.

When the Sound-Level Meter is used with any of the Vibration Pickup Systems, decibel readings can be easily translated to the proper vibration level in dB by adjustment of the internal calibration of the Sound-Level Meter for a −58.1 dB (re 1 volt/μbar) microphone and addition of the dB corrections listed in Table II.

TABLE II

Vibration Pickup System Type Number		*dB to be added to SLM* reading when control box switch is*		
	set at	ACC	VEL	DISP
	to get	L_a	L_v	L_d
	re	10^{-5}m/s²	10^{-8}m/s	10^{-10}m
1560-P11B		20	40	50
1560-P13		30	40	50
1560-P14		0	20	30

*Internal calibration set for −58.1 dB microphone (re 1 volt/μbar).

USE WITH TYPE 1565-A SOUND-LEVEL METER

All three pickups can be used with the Type 1565-A Sound-Level Meter. Since the sensitivity of the Type 1565-A is lower by 10:1 than that of the Type 1551-C Sound-Level Meter, it may be desirable to avoid the loss introduced by the control box. With the pickup connected directly to the sound-level-meter input, acceleration measurements can be made to 10 c/s, 25 c/s, and 20 c/s with the Types 1560-P52, -P53, and -P54 Vibration Pickups, respectively. The upper frequency limits of 1200 c/s and 1500 c/s are safely below the resonant frequencies of the Types 1560-P52 and -P54. Above 3000 c/s the response of the Type 1560-P53 will be modified by the C-weighting characteristic (the Type 1565-A does not have a flat-response position). The operating instructions for the Type 1565-A Sound-Level Meter include a table of meter readings (level in dB) versus acceleration in g for the Type 1560-P52 Vibration Pickup. The same table applies to the Type 1560-P53 Vibration Pickup. For the Type 1560-P54, the table can be used if 20 dB is added to the "Level in dB" column. Use of the control box will permit measurement of velocity and displacement as well as acceleration, but, owing to the lower sensitivity of the Type 1565-A Sound-Level Meter, minimum readings will be 10:1 (20 dB) higher than those possible with the Type 1551-C.

PICKUP FASTENING OR ATTACHMENT

Specifications for the three vibration measuring systems described apply when the pickup is fastened to the device to be measured in a rigid manner, so that it cannot move with respect to the surface to which it is attached. Probes or other simple mounting devices are supplied as conveniences to be used when survey-type measurements are required or the preferred stud mounting cannot be readily ac-

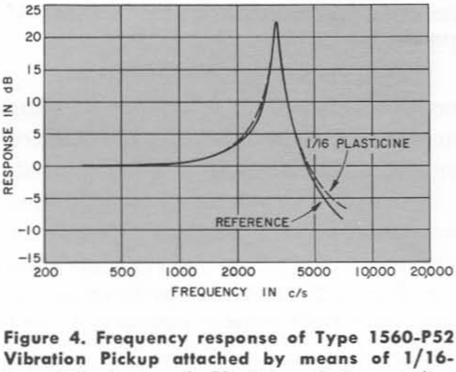


Figure 4. Frequency response of Type 1560-P52 Vibration Pickup attached by means of 1/16-inch-thick layer of Plasticine. Reference line shows response of pickup mounted directly on shaker.

Figure 5. Vibration Pickup with Type 1560-P35 Permanent-Magnet Clamp.

complished. When vibration measurements are made to meet specifications that require that the pickup be mounted by a stud or bolt, that is the way one must make the measurement.

Pickups can be fastened by many different methods but for greatest accuracy the fastening should be as direct and rigid as possible. If the pickup is to be fastened only temporarily, and if the acceleration is less than gravity and only low frequencies are present, simple methods of fastening are adequate. Plasticine or double-faced tape can be placed between the base of the pickup and a flat surface, at the desired point. If the surface is horizontal, flat, and smooth, the pickup may be wrung to the surface with a thin film of petroleum jelly or light silicone grease. Figure 4 shows the responses of a TYPE 1560-P52 Pickup fastened securely and by means of Plasticine.

On magnetic materials, the pickup may be fastened to a magnet and the magnet then attached to a flat surface on the device that is to be measured.

A small magnet clamp is supplied with the TYPE 1560-P13 System. A slightly larger clamp, TYPE 1560-P35 (see Figure 5), is available as an accessory for the Types 1560-P11B and 1560-P14 Systems. If the TYPE 1560-P53 Vibration Pickup is fastened to the magnet and the magnet attached to a smooth, flat surface with petroleum jelly or light silicone grease used to ensure close contact between all mating surfaces, the response of the TYPE 1560-P13 System is not significantly altered for frequencies up to 10 kc/s and accelerations up to 5 g. Figure 6 shows the response of a small shaker system measured with the TYPE 1560-P53 Pickup with and without the magnet clamp. Unless the mass of the pickup is many times smaller than the mass of the device being measured, the addition of the pickup will modify the response of the system. By the same token, adding the magnet will modify the response of the system still further. For the responses shown in Figure 6, the mass of the system, including shaker plus pickup and shaker plus pickup on magnet, was maintained constant.

At high accelerations simple fastenings are inadequate; a stud must be used to hold the pickup directly against the surface being measured. Even with the stud, petroleum jelly or silicone grease should be used to ensure close contact, without applying undue strain to the pickup.

To install the pickup permanently, where tapped holes for studs are not available, an adhesive such as dental cement, Eastman 910, or an epoxy ce-

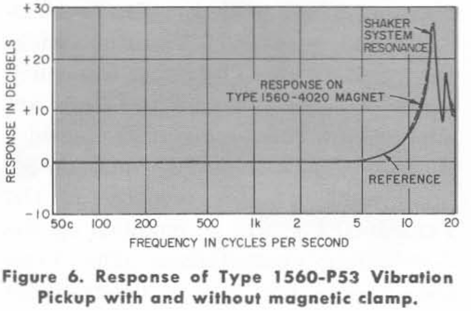


Figure 6. Response of Type 1560-P53 Vibration Pickup with and without magnetic clamp.

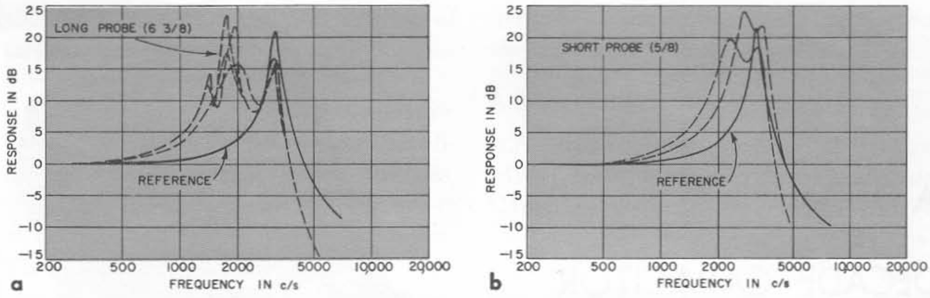


Figure 7. (a) Frequency response of Type 1560-P52 Vibration Pickup mounted on hand-held (6⅜-inch) probe. Several sample responses are shown. Reference line shows response of pickup mounted directly on shaker. (b) Frequency response of the Vibration Pickup mounted on hand-held short (⅝-inch) probe. Several sample responses are shown. Reference line shows response of pickup mounted directly on shaker.

ment should be used. For best results, use only a thin layer so that the elastic characteristics of the cement will not affect the behavior of the pickup.

Use of Probes

Probes and probe tips are supplied with the Types 1560-P11B and 1560-P14 Systems. These are supplied as a convenience to help in cases where flat smooth surfaces may not be available for proper mounting of the vibration pickup. A long probe will modify the pickup response appreciably. The primary resonance of the measuring system will be determined by the probe dimensions. For example, Figure 7 shows the response of the TYPE 1560-P52 Pickup mounted directly on a flat, smooth surface and hand held in contact with the surface through (a) a 6⅜-inch long and (b) a ⅝-inch long probe. Figure 8 shows the response obtained with a TYPE 1560-P53 Vibration Pickup mounted on a flat, smooth surface and then held in contact through a 6-inch long × ¼-inch diameter probe.

Unless the device being measured is massive, a hand-held probe may seriously alter the motion. Also, some vibration is transferred to the pickup by tremor of the hand. This vibration is made up mostly of components below 20 c/s so it is attenuated somewhat by the 20-cycle, low-frequency cutoff of these measuring systems. The observed peak-to-peak displacement from this source is in the order of 0.2 mil so that, even with care, low-level measurements are limited by this factor.

The hand-held probe is useful at frequencies below 1000 c/s if the vibrating object is large and has relatively large motion.

— ERVIN E. GROSS

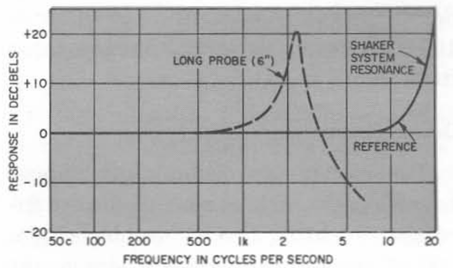
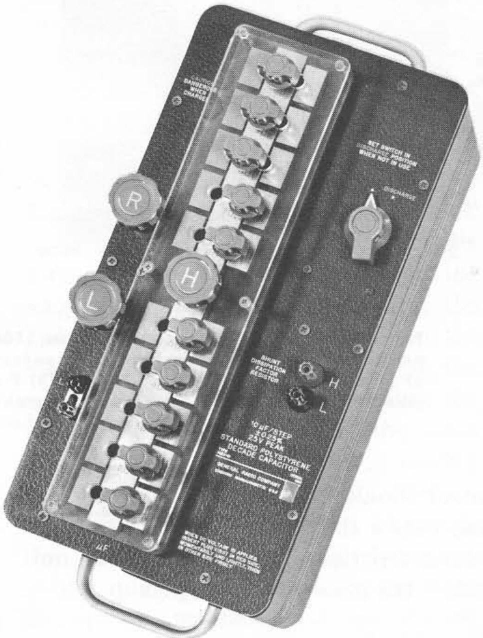


Figure 8. Frequency response of the Type 1560-P53 Vibration Pickup mounted on hand-held 6-inch long by ¼-inch diameter probe. Curve is smoothed average of several responses. Reference line shows response of Pickup mounted directly on shaker.

A 100-μF DECADE CAPACITOR



Performance and acceptance tests on high-capacitance electrolytic capacitors have created a need for high-capacitance standards against which the accuracy of the test equipment can be monitored. Following the introduction of the Type 1424-A Standard Polystyrene Decade Capacitor (10 μF) a few years ago, customer interest in a 100-μF decade developed, and a special unit was designed and built. Having thus proved the practicability of the basic design, we are now able to offer a 100-μF decade as a standard catalog item.

Design Factors

The effects of residual impedances become more serious as capacitance increases, creating design problems in a 100-μF decade that are not significant in a 10-μF unit. Some of these problems are:

Control of series loss outside the dielectric, that is, the resistance of the leads, switching means, and binding posts. One can reduce the resistance of leads and binding posts by making them of larger cross section, but reduction of the switching resistance requires more drastic treatment. In the 10-μF decade, the switch contacts were duplicated and paralleled to make the resistance loss negligible in comparison with the dielectric loss inherent in well made polystyrene capacitors. For the 100-μF decade the tapered-plug technique long used in accurate dc bridges and resistance boxes was adopted. The resistance of a connection made by the tapered plug wrung into its mating tapered socket (approximately 5.5° included angle) by its actuating T-handled knob is quite acceptably low, of the order of 50μΩ. All other joints in the internal electrical circuit are soft-soldered. The resistance of the external connections at the binding posts is minimized by the large contact areas and the use of large knobs so that high contact pressures can be obtained.

Control of residual series inductance. The geometrical locations and the dimensions of binding posts, bus, islands, studs and current-sheet connectors were chosen to minimize the inductance. The binding posts are located as near one edge of the instrument as practical. They are staggered with respect to one another so that wide low-inductance ribbons or strips can be run directly when connections are made to associated equipment. Although the instrument is considerably larger than the 10-μF decade, the total residual inductance is less than twice as large.

Maintenance of manageable size and weight. The 10-μF TYPE 1424-A weighs 16½ pounds. The thought of a decade weighing ten times as much is a little shattering. The only ready way to reduce size and weight is to use lower-voltage capacitors, and, therefore, the peak voltage rating has been reduced to 25 volts. This is not a serious limitation in use, since large standard capacitors are almost never required for use with high voltages applied, either ac or dc. The capacitor volume is only twice that of the 10-μF box.

Protection and dc energy storage. The reduction in voltage rating minimizes the danger from dc energy stored in the capacitor. The lower stored energy and the low voltage greatly reduce the shock hazard. If the metal components of the switching means were exposed, dropping metal pieces would be a hazard. A plexiglas cover plate protects against this contingency as well as serving as an insertion guide for the tapered plugs. Built-in current-limiting resistors are provided for limiting the charging and discharging current to a safe value when the capacitor is used on dc.

A Standard of *D* as well as of *C*

A major application for the TYPE 1425-A Standard Polystyrene Decade Capacitor is the calibration of bridges used for measuring capacitance and dissipation factor of electrolytic capacitors. A characteristic that makes polystyrene such a desirable dielectric is that its D is very low and is quite constant as a function of frequency. Electrolytic capacitors, on the other hand, have characteristically high D's. When the decade is to be used as a reference standard to check the calibration of electrolytic-capacitor-measuring bridges, it should be possible to increase its D to any desired degree, in order to check the dissipation factor accuracy of the bridge.

This can be accomplished by the addition of a known external resistor. Ideally, the resistor should be in *series* with the capacitor, since electrolytic capacitors are specified and usually measured in terms of series components.

A massive binding post is provided for the series connection. Unfortunately when low values of D are desired, the required series resistance may be very low, and suitable adjustable resistors may not be available. Even if they are, the problem of connecting a resistor of, say, one milliohm into a simple series circuit is formidable when lead-and-contact resistance is considered.

If the required series resistance is unmanageably low, the desired D value can be produced by a much larger, more practical value of resistance connected in parallel. A pair of conventional instrument binding posts (TYPE 938) is provided for such parallel connection.

When using the parallel connections, one must remember that the equivalent series capacitance of the combination is the parallel capacitance multiplied by $1 + D^2$. Thus, the series connection should be used whenever practical.

A few numerical examples will serve to illustrate the situation. Suppose, at 1000 cycles, one wishes to establish a *D* of 0.01 for 100 μF. The required series resistance is 0.0016 ohms, which is rather awkward. The parallel value on the other hand is 16 ohms, conveniently realized with a decade resistance box. For a *D* of 0.01 the difference between series and parallel capacitance is only 0.01%, and the use of the parallel resistor is clearly indicated. As another example, a *D* of 0.5 at 120 cycles, 50 μF requires about 26 ohms in series, again a practical value, and in this case the series connection is indicated.

The new TYPE 1425-A Standard Capacitor extends by one more decade the calibration capabilities of GR capacitance standards, which now cover the range from 10^{-3} picofarad to 100 microfarads, a formidable 10^{11} range.

— P. K. McELROY

SPECIFICATIONS

Total Capacitance: 100 μF.
Capacitance per Step: 10 μF.
Dielectric: Polystyrene.
Adjustment Accuracy at 1 kc/s: ±0.25%.
Certificate: A certificate is supplied giving measured values obtained by comparison, to a precision better than ±0.01%, with working standards whose absolute values are known to an accuracy better than ±0.05%, determined and maintained in terms of reference standards periodically measured by the National Bureau of Standards.
Stability: ±0.05%/year.
Dissipation Factor at 1 kc/s: <0.0004.
Insulation Resistance: $>10^6$ ΩF.
Voltage Recovery*: <0.1%.
Temperature Coefficient of Capacitance (typical) ppm/°C: −140.
Max Operating Temperature °C: 65.
Max Safe Voltage: 25 V, peak, below 10 kc/s.
Dimensions: Width 9⅜, height 19⅛, depth 8⅛ inches (240 by 195 by 205 mm), over-all.
Net Weight: 46½ lb (21.5 kg).
Shipping Weight: 67 lb (31 kg).

* Dielectric absorption.

Catalog Number	*Description*	*Price in USA*
1425-9701	**Type 1425-A Standard Polystyrene-Decade Dielectric Capacitor**	**$1400.00**

Hz or c/s?

In describing the new TYPE 1218-B Unit Oscillator we have used the abbreviation MHz for the unit of frequency, rather than Mc/s. The explanation is simple: the frequency dial is engraved in megahertz.

The International Electrotechnical Commission has recently recommended that hertz be the international unit of frequency, and the National Bureau of Standards has adopted it. The new standard on abbreviations of the Institute of Electrical and Electronic Engineers prefers Hz but allows the alternative of c/s.

At General Radio we shall use Hz on all new designs. Existing designs will continue to use c/s (or cps, kc, and Mc) until they are redesigned or otherwise superseded.

In the *Experimenter* and other General Radio publications, we shall use hertz except when discussing instruments on whose dials or panels the older units appear.

IMPROVED UHF OSCILLATOR

900 to 2000 MHz

A low-priced, high-powered, stable signal source covering better than an octave of uhf or "L band" has been a unique and popular member of the Unit rf oscillator family for some 10 years.[1] Additional convenience in use and greater stability of output are now offered in the completely redesigned TYPE 1218-B Unit Oscillator.

Compatible with the other oscillators in the family it heads, the new oscillator has a much lower profile than its predecessor. Seven inches high and 12 inches wide, it can be attached semi-permanently to any GR power supply of that height. If the power supply is a TYPE 1267 or 1269, both of which are 4 inches wide, the combination can be rack-mounted side by side. On the other hand, the TYPES 1263 and 1264 Power Supplies, which are 8 inches wide, mount above or below the oscillator for a total height of 14 inches in a 19-inch rack.[2]

[1] E. Karplus, "A 900–2000 Mc Unit Oscillator," *General Radio Experimenter*, February 1955.
[2] "Oscillator-Power-Supply Combinations for Frequencies from 0.5 Mc/s to 2 Gc/s," *General Radio Experimenter*, June 1965.

For convenience, particularly in rack assemblies, all three controls are on the front panel. Frequency is set by a vernier-drive knob, which makes 8 complete turns, and is indicated on a custom-calibrated dial to better than ±1%. The scale length of 10.5 inches was unchanged in the redesign. A logging scale has been added for precise interpolation or resetting of frequencies. The ΔF control operates an incremental tuning capacitor, which is considerably more effective and stable

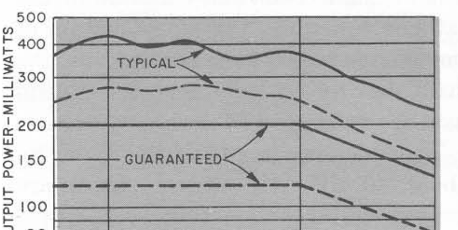


Figure 1.
Output power vs frequency.

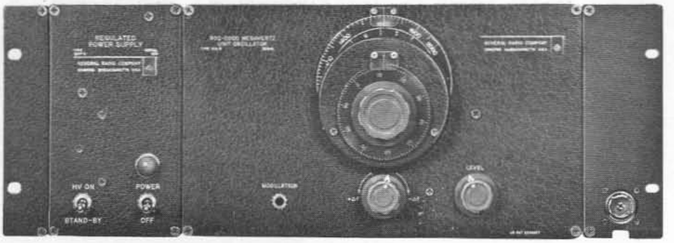


Figure 2. Panel view of the Type 1218-B7R, for rack mount.

than the variable grid resistor that it replaces. This control can be used to make adjustments as fine as 1 part per million, over a range of about 0.1%. The third control sets the output level between zero and maximum by rotation of the pickup loop. The redesign brought this control to the front and also "geared it down" so that settings as low as 30 dB below full output are easily made.

A pencil triode is used in a tuned-plate-tuned-cathode circuit (although plate, not grid, runs at dc ground potential). The plate resonator is a high-Q, quarter-wavelength, coaxial line with a contacting plunger. The output loop is mounted on the plunger and therefore maintains a position in the zone of highest magnetic-field intensity. The cathode is tuned by a curled three-quarter-wavelength line of unusual design. The rotary motion of the cathode tuner and the linear motion of the plate tuner are coupled to the main dial by an improved mechanism having negligible backlash.

The shielding has been improved by about 40 dB. All control shafts are nonconducting and act through waveguide-below-cutoff sleeves. Circuit connections are brought through the main casting wall through filters. Cathode and grid-voltage test points have been brought out so that monitoring or special-purpose modulation can be accomplished without disturbance to the shielded compartments.

The rear location of the locking GR874 output connector is convenient in many applications. In addition, the adaptor-panel set used for rack installation provides front mounting space for a similar connector to which the output is brought by a short coaxial cable. The guaranteed output power (shown in Figure 1) is now specified more precisely than before. The power available from a typical Type 1218-B compared to its predecessor is the same at most frequencies except where the older instrument had weak spots. These have been alleviated by improvements in the tuned circuits.

A substantial improvement in spectral purity of the output signal results from two measures. First, the cathode circuit has been isolated from the heater so that alternating current there does not modulate the oscillator appreciably. Second, the entire tuning assembly has been so mounted as to reduce the transmission of acoustic energy from the main casting to the tube, where modulation can result. The electrodes in the tube resonate mechanically at nearly 3 kHz, but the resultant frequency modulation at resonance is less than a very few parts per million at sound levels found in most laboratories.

In cw applications requiring the highest stability of frequency and amplitude, it is important to regulate both heater and plate supplies. Because the frequency is more sensitive to heater voltage changes than to proportional changes in the plate (or B+) circuit, the TYPE 1267-A Power Supply, which is fully regulated, is recommended for critical applications.

Modulation is facilitated by duplication of the usual plate-modulation jack on the front and behind the panel. A connector is also provided for direct connection of the TYPE 1264-A Modulating Power Supply (formerly possible only with adaptor cables). With that modulator, typical delay, rise, and fall times of square-wave or pulse modulation are about 1 microsecond. To obtain very constant output, cw or square wave, the TYPE 1263-B Amplitude-Regulating Power Supply should be used.

Applications for the TYPE 1218-B Unit Oscillator are widespread in laboratories and production facilities where uhf signals are handled. For example, it is an excellent, low-cost pump for a parametric amplifier. It may be the "local oscillator" in a heterodyne receiving or measuring system. It is recommended as a generator for the TYPE 900-LB Slotted Line in the 900-to-2000 MHz frequency range.

— R. W. HARLEY

SPECIFICATIONS

Frequency Range: 900 to 2000 MHz (0.9 to 2.0 GHz).

Frequency Calibration Accuracy: ±1%.

Warmup Frequency Drift: 0.1% approximate total warmup drift.

Frequency Control: A 4-inch dial with calibration in MHz over 290° (10½-inch scale length), with a slow-motion drive of about 8 turns. Supplemented by a logging scale of 800 divisions.

ΔF Control: 1.8 turns for approximately 0.1% total range.

Output Power (Into 50 Ω): 200 mW (0.9 to 1.5 GHz) guaranteed minimum, dropping linearly to 130 mW at 2.0 GHz, with TYPE 1269-A or 1203-B Power supply.

120 mW (0.9 to 1.5 GHz) guaranteed minimum, dropping linearly to 80 mW at 2.0 GHz, with TYPE 1267-A, 1264-A, or 1201-C Power Supply.

Output Connector: Locking type GR874, located at rear. Adaptors available for other connector systems.

Level Control: Full output to about 30-dB attenuation easily set by 200° rotation, uncalibrated.

Modulation: An external audio-frequency voltage for plate modulation can be introduced at the front-panel MODULATION jack. The impedance there is about 6,000 Ω; approximately 30 V, rms, is required for 30% amplitude modulation. For 400- and 1000-Hz modulation, the TYPE 1214-A Unit Oscillator is recommended.

Power Supply: Four types of power supplies are recommended; the choice depends on the intended application.

The TYPE 1267-A is fully regulated, for cw operation.

The TYPE 1269-A is unregulated, for maximum power, cw.

The TYPE 1263-B automatically controls the output level up to 2 V behind 50 Ω, cw or 1-kHz square-wave modulated.

The TYPE 1264-A provides full-power cw or modulated operation: 1-kHz square wave or pulse at externally determined duty ratio and frequency up to 100 kHz.

The oscillator is available in combination with each of these power supplies, for either bench or rack mount, as listed on page 16.

Tube: One 5675 pencil triode.

Mounting: The oscillator is housed in an aluminum casting with gray-wrinkle-finished shield covers on right and left ends and a front panel similarly finished.

Accessories Supplied: TYPE 874-R22LA Patch Cord, phone plug.

Other Accessories Available: GR874 coaxial elements.

Dimensions: Width 12, height 7⅝, depth 9 inches (320 by 205 by 240 mm), over-all.

Net Weight: 14 lb (6.5 kg).

Shipping Weight: 25 lb (11.5 kg).

Catalog Number	*Description*	*Price in USA*
1218-9702	**Type 1218-B Unit Oscillator**, only, Bench Mount	$465.00
0481-9642	**Type 481-P412 Rack-Adaptor Set**, for oscillator only	20.00

U.S. Patent Number 2,548,457.

OSCILLATOR – POWER-SUPPLY COMBINATIONS

These combinations include oscillator, power supply as listed, and accessory hardware for rack or bench mount, as specified.

PERFORMANCE (POWER SUPPLY TYPE)		*Maximum power; lowest cost* (1269-A)	*Ultimate cw stability; very low residual fm* (1267-A)	(1267-AQ18)	*Stable cw; 100% square-wave & pulse modulation; internal 1-kc square-wave* (1264-A)	*Amplitude-leveled output behind 50-Ω source impedance; metered output level; 1-kc square-wave modulation, or cw* (1263-B)
INPUT LINE VOLTAGE		105 to 125 V or 195 to 250 V	105 to 125 V	195 to 250 V	105 to 125 V or 210 to 250 V	105 to 125 V or 210 to 250 V
Bench Mount	*Catalog No.*	1218-9429	1218-9427	1218-9428	1218-9424	1218-9423
	Type	1218-B9	1218-B7	1218-B7Q18	1218-B4	1218-B3
	Price	**$540.00**	**$635.00**	**on request**	**$750.00**	**$890.00**
Rack Mount	*Catalog No.*	1218-9549	1218-9547	1218-9548	1218-9544	1218-9543
	Type	1218-B9R	1218-B7R	1218-B7RQ18	1218-B4R	1218-B3R
	Price	**$561.00**	**$656.00**	**on request**	**$774.00**	**$914.00**

COAXIAL MICROWAVE NEWS

A TUNABLE, ADJUSTABLE PROBE FOR SLOTTED-LINE MEASUREMENTS

Users of the TYPE 874-LBA Slotted Line who need a calibrated and more precise probe penetration adjustment and more precise tuning than is provided by a simple stub will find the TYPE 900-DP Probe Tuner a useful accessory. This is the same probe assembly that is supplied with the precision slotted line, TYPE 900-LB.

The probe penetration is adjusted by a micrometer drive and its position is indicated on an engraved knob. Tuning is performed by rotation of the probe-tuner barrel, which imparts

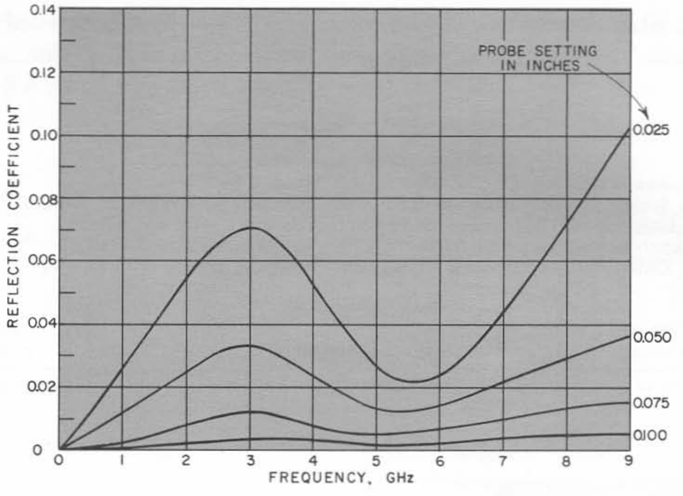


Figure 1. Typical probe reflections at four penetrations.

linear motion to the stub without rotation, and, in this case, the length of the stub in centimeters is shown on an engraved scale. Tuning is possible from 300 MHz to 9GHz, which encompasses the complete frequency range of the slotted line. A screw-on plastic cover is provided with each tuner to protect the probe tip when the probe tuner is not in use.

Since both the TYPE 874-LBA and the TYPE 900-LB Slotted Lines have their own diode- or bolometer-mount assemblies, the probe tuner does not contain a diode holder.

Probe penetration is an important factor in slotted-line measurements. A probe coupled too tightly into the slotted line can cause measurement errors when the source driving the slotted line is not matched. In this case, the probe reflects the incident wave back to the source; a second reflection occurs at the source and adds or subtracts to the incident wave as the slotted-line carriage is moved. The result is that minima and maxima are affected in both position and magnitude, and the VSWR measurement is in error. With the probe penetration clearly visible and directly readable, the chances for maladjustment of probe penetration are greatly reduced. It is usually much easier to decouple the probe than to match the source impedance.

Excessive probe penetration can also cause errors at the higher VSWR values, say above 10, because the loading effects are greater at the voltage maximum than at a minimum. The loading effects increase more and more as the VSWR is increased. Therefore, here again the easy readability feature removes any guesswork about probe penetration.

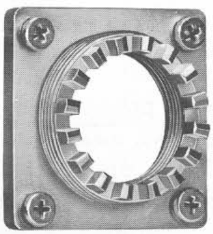
The probe reflection, as a function of frequency and distance to the slotted-line inner conductor (probe penetration), is shown in Figure 1.

A detailed instruction sheet is furnished with each probe tuner. It contains all the necessary installation instructions. A tuning graph is included, which indicates the correct setting for any frequency in the tuning range. A small ⅞-inch open-end wrench is provided for installation of the probe tuner on the slotted line, and a No. 2 Bristol wrench for scale adjustments.

SPECIFICATIONS

Frequency Range: 0.3 to 9 GHz.
Probe Depth Scale: Calibrated from 0.010 to 0.150 in., in intervals of 0.001 inch. One revolution of the knob moves the probe 0.025 inch.
Stub Tuner: Calibrated at intervals of 0.1 cm from 0 to 17 cm.
Dimensions: Length 11 in (280 mm), dia ⅞ in (23 mm), over-all, closed.
Net Weight: 8½ oz (245 g).
Shipping Weight: 3 lb (1.4 kg)

Catalog Number	*Description*	*Price in USA*
0900-9654	**Type 900-DP Probe Tuner**	**$75.00**



PANEL MOUNTING KIT FOR GR900 PRECISION COAXIAL CONNECTORS

The Type 900-PKM Panel Mounting Kit is a simple conversion kit for adapting a GR900 connector, or any component equipped with a GR900 connector, to panel mounting. This application includes adaptation of GR-900 connector devices as panel feed-through or "bulkhead" connectors.

The kit comprises one gear-ring assembly; four 4-40 screws, ½ inch long; four nuts and lockwashers; and a detailed instruction sheet.

A centering (gear) ring is modified to include a flange, as shown in Figure 1. It is installed directly on any GR900 connector after removal of the existing centering ring and locking nut.

The resulting panel connector does not contain a locking nut, since the locking nut on the mating connector is usually all that is needed. When two panel connectors are to be mated, a Type 900-L Air Line can be used.

Examples of applications of this kit are shown in Figures 1 to 4. Note that the flange mounted on the front face of the panel (Figure 2) provides the greatest accessibility and ease of connection. If necessary, the flange can be mounted behind the panel at the expense of accessibility and possibly appearance. Accessibility, in this case, is a matter of how much of the locking nut of the mated connector can be grasped during tightening. This recessed mounting configuration is shown in Figure 4.

Specific applications include: panel connector for frequency- or time-domain reflectometers or similar test sets, equipment modules, and rack-mounted assemblies where a feed-through from the rear to the front of the rack is required.

Over-all panel space required by the flange of the unit is $1\frac{3}{16}$ inches on each side.

Weights: Net, 1 oz (30 g); Shipping, 8 oz (230 g).

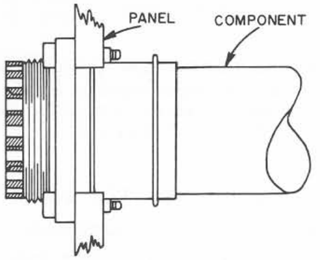


Figure 1. Panel connector mounted with air line.

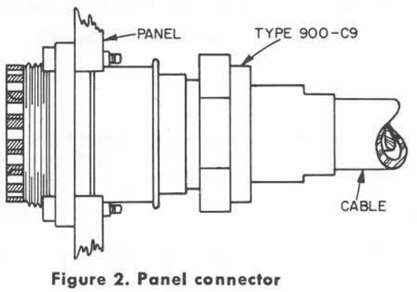


Figure 2. Panel connector mounted with coaxial cable.

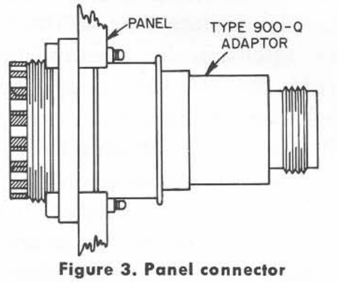


Figure 3. Panel connector mounted with a Type 900-Q Adaptor.

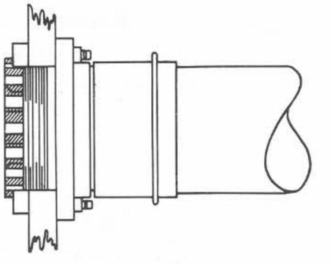


Figure 4. Panel connector mounted with flange behind panel.

Catalog Number	*Description*	*Price in USA*
0900-9498	**Type 900-PKM Panel Mounting Kit**	**$7.00**

GR874 COAXIAL CABLE CONNECTION

A very slight modification in the usual assembly procedure can improve the VSWR performance of ten GR874 coaxial connector types. Developed recently in General Radio's continual product-improvement program, this new technique can be applied to both panel-mount and patch-cord connectors, in two groupings, for use with RG-8 size cable. The connectors affected are listed in the table on page 20.

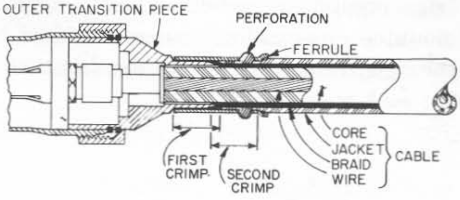
The new technique is of particular interest to those now using General Radio TYPE 874-TO8 and -TO58 Crimping Tools to fasten the connectors to the cable with a cylindrical metal ferrule.

Present practice calls for a slightly overlapping double crimp, utilizing the same diameter opening in the hex-shaped jaws of the crimping tool. The first crimp locks the cable braid between the ferrule and the knurled surface of the outer-transition piece of the connector. The second crimp holds the cable jacket firmly in place. (See figure at right.)

This second crimp is applied around the circular perforations on the ferrule. Jacket retention is accomplished by the cold flow of the jacket material through the perforations, which are distributed evenly around the ferrule.

The resulting squeeze on the cable can reduce braid diameter, thereby altering characteristic impedance at that point sufficiently to raise overall VSWR performance.

The new approach calls for use here of a larger crimp diameter, which avoids the discontinuity problem yet causes only a small reduction in jacket-retention capability. The result is a low-VSWR connector assembly with good jacket retention, unless subjected to severe pulling, twisting, or bending.



Section view of a GR874 connector attached to a coaxial cable. The larger-diameter second crimp still grips the jacket securely, without reducing the diameter of the braid.

The crimping tools offer an adequate selection of openings in their crimp dies to permit the diameter change.

— J. Zorzy

Connector Type No.	Cable Type No.	Ferrule Part No.	First Crimp (over braid)		Second Crimp (over jacket)	
			Tool	Die Size (inch)	Tool	Die Size (inch)
874-CA, -CLA, -PBA, -PLA, -PRLA	874-A2	5240-4026	TO-58	0.375	TO-8	0.389
874-C8A, -CL8A, -PB8A, -PL8A, -PRL8A	RG-8, RG-213, etc (single-braid only)	5240-4028	TO-8	0.389	TO-8	0.411

TYPE 1806-P MULTIPLIER

Omitted from the announcement in the *Experimenter* last month of the 10:1 Range Multiplier for the Type 1806-A Electronic Voltmeter was mention of the frequency characteristic Low-frequency roll-off of the Multiplier is less than 3% at 10 kc/s. It is useful, therefore, at frequencies from the top of the audio range up to where the inductance of connecting leads might begin to cause errors — at frequencies in the vicinity of 200 Mc/s. The addition of the multiplier has no appreciable effect upon the resonant frequency of the probe.

— J. J. Faran

the GENERAL RADIO
experimenter

VOLUME 39 NUMBER 8 AUGUST 1965

A MODERN, WIDE-RANGE, RC OSCILLATOR

the GENERAL RADIO
experimenter

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Figure 1. Panel view of the Type 1310-A Oscillator showing synchronization jack

A MODERN, WIDE-RANGE, RC OSCILLATOR

The Type 1310-A Oscillator brings the small size, mechanical ruggedness, and reliability of transistorized circuitry to a wide-range, general-purpose instrument. It offers substantial improvement in many oscillator characteristics, includes an entirely new frequency-synchronization feature, and yet maintains the high accuracy, infinite resolution of variable-capacitance tuning, high-output voltage, and other desirable features of older vacuum-tube designs — all at a reasonable cost.

> The introduction of the new Type 1310-A Oscillator continues the development of the modern two-feedback-path RC oscillator, invented by General Radio back in 1937. Another modern instrument that uses this circuit is the solid-state Type 1311-A Audio Oscillator[1].

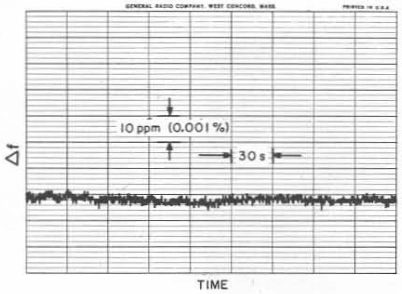
FREQUENCY

The unusually wide frequency range alone makes the Type 1310-A Oscillator a signal source of exceptional utility. The lower limit of 2 c/s covers the roll-off region of most ac-coupled circuits, and the upper limit of 2 Mc/s includes the important area around 1 Mc/s where many high-frequency measurements are made on components. A finely graduated, vernier-driven dial with ±2% accuracy makes for rapid yet precise setting of frequency. High-stability frequency-determining components in the oscillator and the low internal power dissipation result in a very stable output frequency. Drift during warm-up is typically below 0.1% at frequencies above 20 c/s.

OUTPUT

The output waveform has a high degree of purity. Harmonic distortion

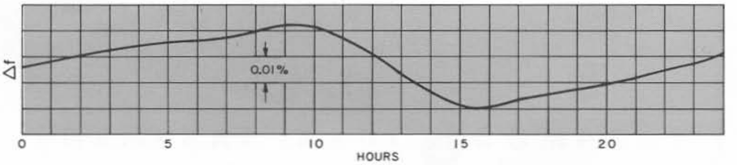
[1] R. G. Fulks, "High-Performance, Low-Cost Audio Oscillator, with Solid-State Circuitry," *General Radio Experimenter*, August-September 1962.



a

Figure 2. Typical frequency stability after warmup at 1 kc/s; (a) short term, (b) long term. Sampling time is 0.1 second (100 periods).

b



is low, less than 0.25% over most of the audio range. This low distortion is always obtainable, even at full output, because it remains constant regardless of the size of the linear load applied, including short circuit. This feature is particularly useful at higher frequencies where low impedances are required, as, for example, in 50-ohm systems. Hum is below 0.02% of the output regardless of the attenuator setting and is typically 0.005%. Noise at frequencies distant from a 1-kc fundamental, measured in a bandwidth of 5 c/s to 500 kc/s, is typically less than 0.02%. Noise close to the fundamental is low, as the spectrum analysis of a 1-kc output in Figure 4 shows. This low noise level permits amplitude modulation in magnetic recordings and inter-modulation products in any device to be measured to −90 dB with ease.

The 20-volt, open-circuit output behind 600 ohms is adjustable over approximately a 50-dB range by means of a constant-percentage-resolution attenuator. The output is essentially constant with frequency (Figure 5), a convenience for frequency-response

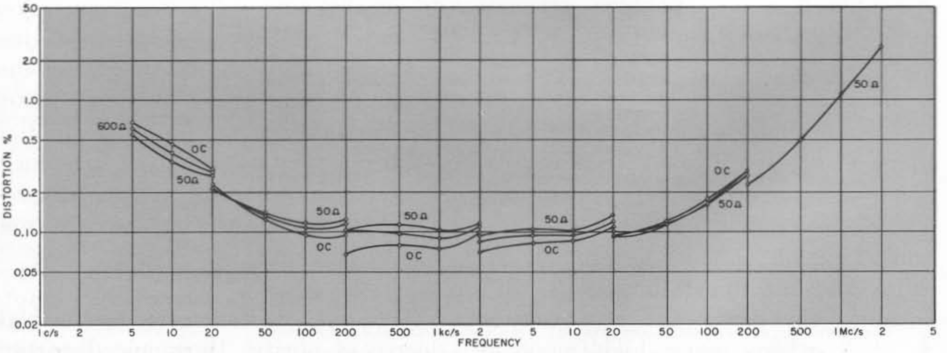


Figure 3. Measured harmonic distortion of a typical Type 1310-A Oscillator for 50-ohm and 600-ohm loads and open circuit. When the attenuator is used for open-circuit output voltages of five volts or less, the load seen by the oscillator is 600 ohms.

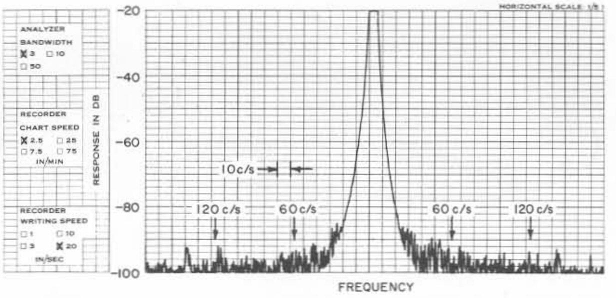


Figure 4. Spectrum analysis of 1-kc output. Type 1910-A Analyzer bandwidth is 3 c/s. Note absence of components at the line frequency and multiples.

measurements. Changes in the output within the audio range are imperceptible on the usual analog type of voltmeter.

SYNCHRONIZATION—INPUT

Provision is made for external synchronization, which is believed to be unique with General Radio oscillators. At a single-conductor, shielded telephone jack on the side of the instrument, an external signal can be introduced. Whenever the oscillator frequency is near to the introduced frequency, the oscillator locks in with the signal, and their frequencies will be identical. An input of one volt will keep the oscillator locked for changes of approximately ±3% in frequency of either the signal or the oscillator dial setting. The lock range and capture range are identical and are approximately proportional to the amplitude of the component of the signal to which the oscillator is locked. Sinusoidal inputs of up to ten volts may be used for locking ranges of up to 30 or 40 percent.

For small synchronizing signals, the output characteristics of the oscillator are essentially the same as when the oscillator is operating normally, and the output waveform is independent of the waveform fed in. Larger signals may increase the hum, noise, jitter, or distortion of the output above the specifications, if these components are present in the signal, but, in general, there will be a considerable improvement over the synchronizing signal.

By means of the frequency dial the oscillator output can be adjusted to differ in phase from the synchronizing signal by approximately ±75°.

One obvious application for the synchronizing capability is for locking one or more oscillators to a frequency standard. Because the oscillator is in essence phase locked to the standard, the long-term stability and accuracy will be identical with the standard. The short-term stability or jitter will be limited to that of the oscillator, which, as shown in Figure 2(a), is typically below 10 parts per million at 1 kc/s for a 0.1 second (100 period)

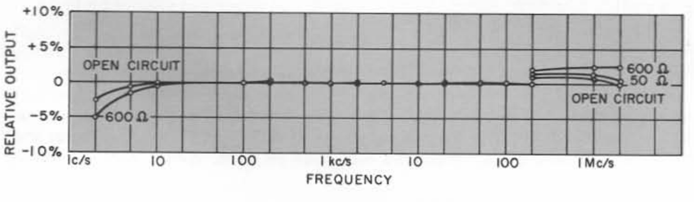


Figure 5. Typical output voltage-vs-frequency characteristics for various load impedances.

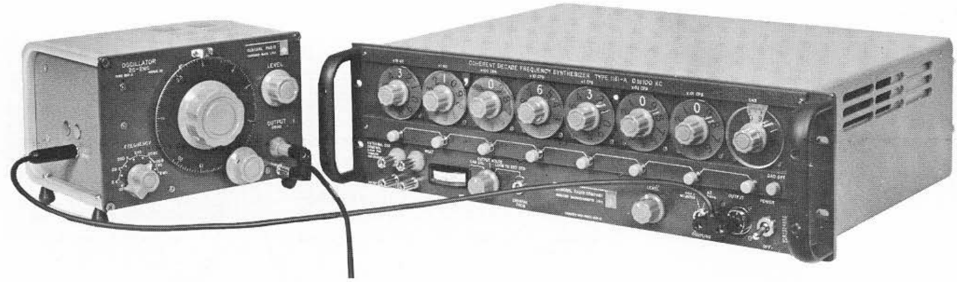
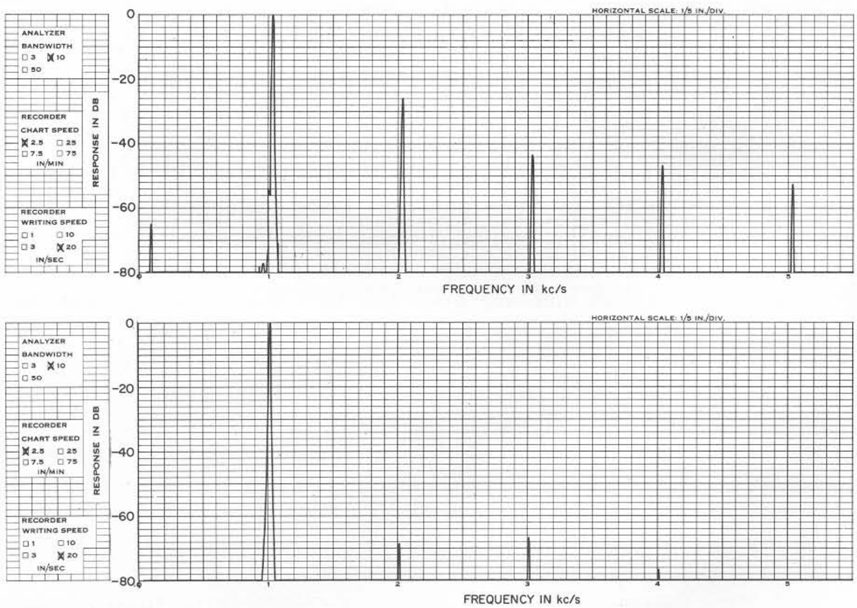


Figure 6. The Type 1310-A Oscillator with a Type 1161-A7C Synthesizer used as an adjustable high-accuracy, high-voltage, low-distortion source for a precision fm-deviation measurement. The output frequency, 31.063 kc/s, when used to modulate an fm generator produces a null in the carrier for a ±75.00-kc frequency deviation.

sampling time. The oscillator has all the characteristics of a narrow-band distribution amplifier: increasing voltage and power output, reducing hum and distortion, and isolating the standard from load changes with the additional advantage of automatic level control.

The oscillator can also be locked to the harmonics of a signal. This allows precise frequency multiplication of most sources since harmonics are usually present or can be easily generated. The accuracy and long-term stability of the submultiple source are maintained in the output, and the waveform is, of course, sinusoidal.

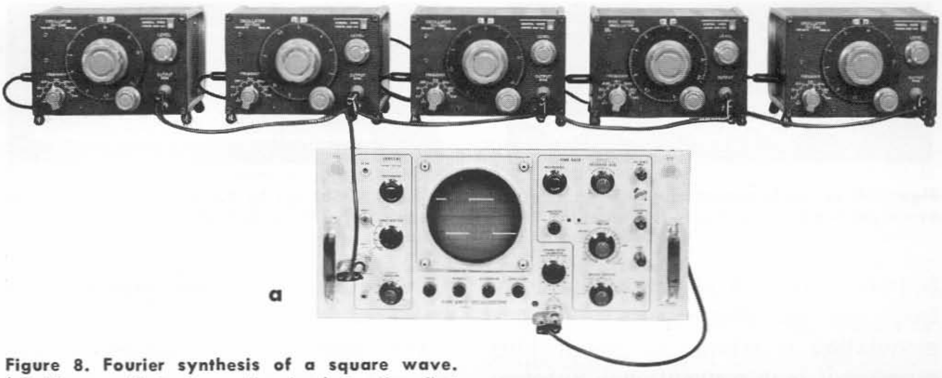
Even if the oscillator is not locked to a high precision standard, the ability to lock onto any signal can be very



a

b

Figure 7. (a) The spectrum of the output of a typical sinusoidal 1-kc standard frequency, derived by division from a crystal frequency standard. (b) The output spectrum of a Type 1310-A Oscillator that has been synchronized to the 1-kc standard of (a). Note the reduction in hum, noise, and distortion.



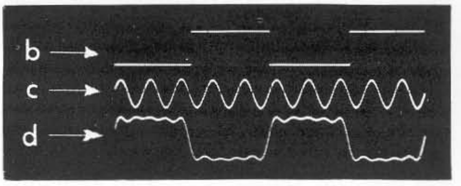


Figure 8. Fourier synthesis of a square wave. (a) Five oscillators synchronized to the first five odd-order harmonics of a square wave. The sinusoidal outputs of the oscillators are adjusted for phase coherence and summed in the ratio of their respective Fourier coefficients to make a Fourier approximation to the original square wave. (b) The original synchronizing square wave. (c) The coherent fifth harmonic. (d) The synthesized square wave.

useful. When measurements are to be made at the fundamental or harmonics of the power-line frequency, it is often desirable to lock the source to the line frequency in order to avoid beats. With the oscillator locked to the line or its harmonics, there will be no beat, and the phase can be adjusted to minimize other effects of pickup.

Although the short-term frequency stability, or jitter, of the synchronized oscillator output will not be less than that of the free-running oscillator, it can be better than that of the synchronizing source. In this respect, also, it behaves like a phase-locked oscillator[2] Or, to express it differently, the synchronized oscillator acts as a tracking narrow-band filter to reduce short-term instability. For example, Figure 9(a) is a plot of the cycle-to-cycle frequency of a jittery 10-cycle source versus time. Figure 9(b) shows the same measurement made on the output of a Type 1310-A Oscillator that has been synchronized to the source. Notice that the cycle-to-cycle change in frequency has been greatly reduced, yet the relatively long-term change of about 1% has been faithfully tracked. The ef-

[2] Harold T. McAleer, "A New Look at the Phase-Locked Oscillator," *Proceedings of the IRE*, Vol 47, pp 1137–1143; June, 1959. (GR Reprint No. A-79).

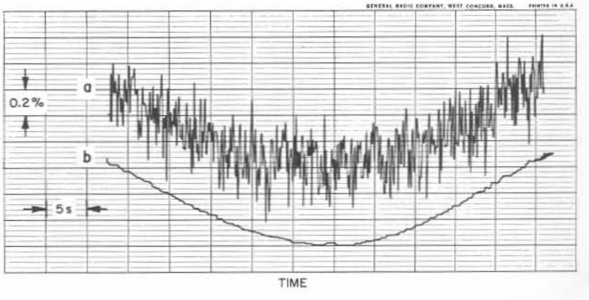


Figure 9. (a) Frequency of output of a drifting 10-cycle jittery source. (b) Output frequency of oscillator synchronized to source of (a). Note reduction in jitter and yet tracking of drift.

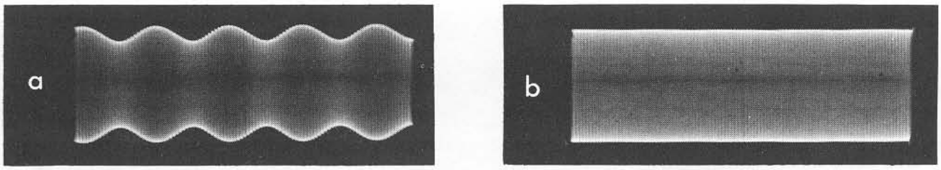


Figure 10. (a) 10-kc output of oscillator, amplitude modulated at 500 c/s by 9.5-kc signal fed into the synchronizing jack. (b) The reduction of the amplitude modulation in the output of an oscillator that has been locked to the a-m signal of (a).

fective bandwidth of the oscillator to frequency perturbation or frequency modulation is related to the locking range as it is in conventional, automatic-phase-controlled oscillators. Since the locking range is proportional to the synchronizing-signal amplitude, the effective bandwidth is also proportional to the amplitude. For example, if a one-volt signal is used to synchronize the oscillator at 100 kc/s giving a ±3% locking range, then the oscillator will have a 3-dB bandwidth of 3 kc/s to perturbations in frequency. Thus, frequency deviations in the 100-kc source at a 3-kc rate will be reduced by 3 dB in the output of the oscillator.

If the oscillator is operated outside the locking range, the signal fed into the synchronizing jack will beat with the oscillator frequency and produce an amplitude-modulated output as shown in Figure 10(a). The modulation will be approximately sinusoidal for modulation levels up to about 10%. Although using the TYPE 1310-A in this manner does not make it a versatile source of amplitude-modulated signals, it does provide a-m in the audio range where it is not normally obtainable, but nevertheless useful. For example, the modulated output can be used to measure the effects of incidental a-m on other measurements, and it provides a "wobbulated" source for reducing meter friction errors in ac measurements.

The synchronized oscillator can also be used to reduce amplitude modulation (Figure 10(b)). This again is a natural consequence of the oscillator's similarity to a high-Q filter. Any amplitude modulation on the synchronizing signal is reduced to the extent that the modulation sidebands fall outside the pass band of the oscillator.

SYNCHRONIZATION—OUTPUT

The synchronization jack serves as an output as well as an input. Approximately 0.8 volt behind 25 kilohms is available regardless of the setting of the output attenuator or the size of the output load. This output can be used to trigger an oscilloscope when the oscillator amplitude is often varied; frequent readjustment of the triggering level is thus eliminated. Also, a counter can be driven from the jack when a more precise measure of the frequency is desired. One side of this output is grounded, and the signal is 180° out-of-phase with the front-panel output, which makes possible a high-impedance output balanced to ground for driving push-pull circuits. The synchronization output will drive any size load without increasing the oscillator distortion. However, only high-impedance loads are recommended where the full frequency accuracy is required. A short circuit will decrease the frequency by 1 to 2 percent.

Because the synchronizing jack is simultaneously an input and an output, two or more oscillators can be synchronized by interconnection. Oscillators connected in this way will operate at the same frequency or multiples of it and can be adjusted to differ in phase by 180 ±75°.

TECHNICAL DESCRIPTION

The circuit is a capacitance-tuned Wien-bridge oscillator followed by a low-distortion, shortable amplifier and a constant-impedance, bridged-T attenuator. Figure 11 is a simplified diagram of the seven-transistor, one-Nuvistor circuit. A high-gain, wide-band amplifier is used for low distortion and noise and to achieve high input and low output impedances for use with the Wien bridge. This assures that the frequency of oscillation is dependent only upon the passive values of R and C of the bridge. Stable, low-temperature-coefficient, metal-film resistors are used on all but the lowest-frequency range, which uses glass-sealed, carbon resistors.

A negative-temperature-coefficient thermistor is used in the upper half of the negative-feedback divider of the bridge to keep the oscillator amplitude constant, rather than the more conventional positive-TC incandescent lamp in the lower half. This is in large part responsible for the flat frequency characteristic.

Changes in oscillator amplitude with frequency in any Wien-bridge oscillator may be caused by three major factors: (1) unbalance in the values of R for the different frequency ranges; (2) unbalance in C values as the oscillator frequency is varied across one range; and (3) change in the gain, phase and terminal impedances of the amplifier with frequency. These changes all affect the loop gain of the bridge-amplifier combination, and, to maintain stable oscillation, the amplitude-regulating mechanism must change the negative-feedback divider gain so that the over-all loop gain remains at unity. It is inherent in incandescent lamp-regulating circuits that the output level must change if the divider gain changes. This can be seen by reference to the E-I characteristics of Figure 12(a) where the subscripted components, voltages, and current correspond to those of Figure 11. The output voltage is E_3 or $E_1 + E_2$, and the gain of the negative feedback divider (R_1 and R_2) is $\frac{E_2}{E_3}$. It is apparent from Figure 12(a) that, regardless of the

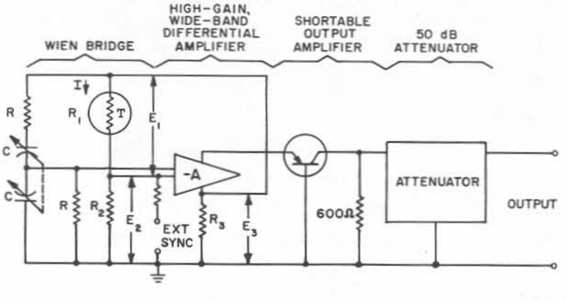


Figure 11. Simplified circuit diagram of Type 1310-A Oscillator.

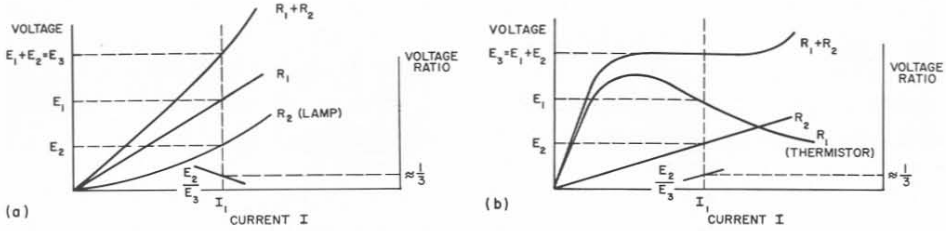


Figure 12. Voltage-current characteristic curves for amplitude-regulating divider of Wien bridge using (a) an incandescent lamp, (b) a thermistor.

actual slopes of the lines involved, for the ratio $\frac{E_2}{E_3}$ to change, the current through the divider must change, and, therefore, the output voltage, E_3, must also change.

Figure 12(b) shows equivalent E-I characteristics where a negative-temperature-coefficient thermistor is used, as in the TYPE 1310-A. In this case, the slope of the thermistor curve in the area of operation near I_1 has been made equal in magnitude to the slope of the R_2 line but opposite in sign. When the two characteristics are added to obtain the E_3 vs I characteristic, the result is approximately a horizontal line. Hence, the output voltage in the normal range of operation is independent of the current and, therefore, independent of the ratio $\frac{E_2}{E_3}$. The ratio $\frac{E_2}{E_3}$ is free to change to keep the loop gain constant at unity, and yet the output voltage, E_3, remains unchanged.

The grounded-base transistor stage following the oscillator translates the constant-voltage output of the oscillator into a constant-current source at the amplifier output, shunted by a 600-ohm internal load. It is the fact that the current is constant and, therefore, limited, which permits low-impedance loads, even a short circuit, to be driven without clipping. The circuit functions as follows: Voltage E_3 is maintained constant by the thermistor regulator, and, since R_3 is much smaller than the resistance of the bridge circuit, the current through R_3 is also maintained constant. This same constant current flows through the emitter and collector of the output transistor since the forward current gain of the transistor is almost unity. The high degree of isolation between emitter and collector of the grounded-base stage prevents changes of the load from being reflected back across R_3. The equivalent circuit of the output with the internal 600-ohm load shunting it is shown in Figure 13(a). Since the h_{ob} of the transistor is small compared with the load conductance, the more familiar equivalent circuit of Figure 13(b) is also correct.

The method used to synchronize the oscillator is commonly called injection

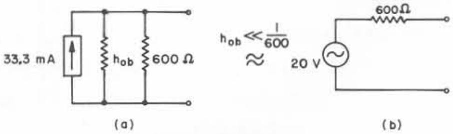


Figure 13. (a) Equivalent circuit of output systems (b) Thévenin equivalent approximation of (a) is conventional voltage source behind 600 ohms.

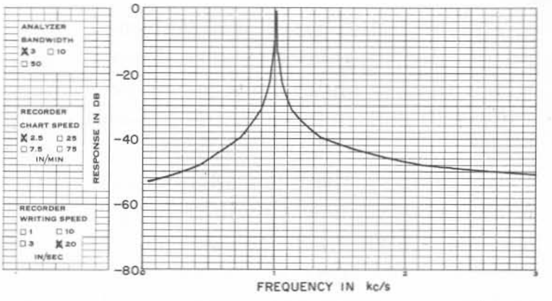


Figure 14. Plot of frequency response between synchronizing jack and oscillator output with dial set to 1 kc/s and with an input of 0.1 volt. Output level is constant at 1 kc/s regardless of the input voltage.

locking. This same mechanism causes some oscillators to beat with the power-line frequency or to lock to it. It is an old phenomenon, perhaps first observed between two pendulum clocks hanging on the same wall, and has been frequently discussed.[3,4,5,6]

The synchronizing signal is injected into the negative-feedback loop. For small signals, the transfer function between this point and the oscillator output is the closed-loop response of the oscillator. This results in a gain near the frequency of oscillation and rejection elsewhere. This rejection reduces the hum, noise, distortion, and both amplitude and frequency modulation in the synchronized output.

Figure 14 is a plot of the forward transfer response between the synchronizing jack and the output for a 0.1-volt input with the oscillator set at 1 kc/s. In the audio-frequency range this curve can be used to estimate the reduction in the output of components in the synchronizing signal. For example, if a one-volt signal that has 10% (0.1 volt) second-harmonic distortion is used to synchronize the oscillator, the second harmonic (2 kc) will be approximately 50 dB below the fundamental in the oscillator output, reducing distortion to 0.3%.

If the oscillator is locked to the same 1-kc signal with an amplitude of only 0.5 volt (0.05-volt second harmonic), then the second harmonic in the output will be 50 dB + 6 dB or 56 dB below the fundamental or only 0.15%. This illustrates the effective decrease in bandwidth as the synchronizing signal decreases. Thus, the smallest signal that will provide stable locking should be used to achieve the greatest rejection of unwanted frequencies.

Figure 15. Rack-mounted Type 1310-A Oscillator and Type 1396-A Tone-Burst Generator used to test amplifier overload characteristics. A behind-the-panel connection to the synchronization jack allows precise readout of frequency on the Type 1150-B Digital Frequency Meter.

[3] W. A. Edson, *Vacuum-Tube Oscillators*, John Wiley & Sons, Inc., New York, Chapter 13; 1953.
[4] P. R. Aigrain and E. M. Williams, "Pseudo-synchronization in Amplitude-Stabilized Oscillators," *Proceedings of the IRE*, Vol 36, pp 800–801; June, 1948.
[5] Robert Adler, "A Study of Locking Phenomena in Oscillators," *Proceedings of the IRE*, Vol 34, pp 351–357; June, 1946.
[6] Marcel J. E. Golay, "Normalized Equations of the Regenerative Oscillator — Noise, Phase Locking and Pulling," *Proceedings of the IEEE*, Vol 52, pp 1311–1330; November, 1964.

The oscillator has a self-contained, ac-operated, regulated power supply, which assures uniform operation even with ±10-volt changes in the 115-volt line.

In summary, the TYPE 1310-A Oscillator, by using new circuit techniques and modern transistorized design, provides a wide-range, high-output, general-purpose instrument useful in the many applications that require oscillators in electronics today. Its small size, light weight, and rugged construction make it a convenient source of ac signals, and its low distortion, noise, and hum, its flat-frequency characteristic, and its good frequency stability give outstanding performance.

In addition, owing to its unique synchronizing feature, this oscillator can often perform many of the functions of other laboratory instruments. It can serve as:

A tracking, narrow-band filter to reduce hum, noise, and distortion in a signal.

A source of amplitude-modulated signals.

An automatic-phase-controlled oscillator to reduce frequency modulation or jitter.

A single-frequency, leveling amplifier.

A phase-locked, sinusoidal-frequency multiplier.

A phase shifter.

A narrow-band, isolation amplifier.

— R. E. OWEN

Credits

The author gratefully acknowledges the contribution of R. G. Fulks who initiated the development.

SPECIFICATIONS

FREQUENCY

Range: 2 c/s to 2 Mc/s in 6 decade ranges; continuously adjustable, one-turn, high-resolution dial with 4¼:1 drive.
Accuracy: ±2% of reading.
Stability: Typical warmup drift, under 0.1%; typical drift after warmup, 0.001% short term (1 min), 0.03% long term (12 h); all at 1 kc/s.
Synchronization: Telephone jack provided for external phase-locking signal. Locking range is about ±3% for 1-V, rms, input reference signal. Frequency dial can be used for phase adjustment.

OUTPUT

Power: 160 mW into 600 Ω.
Voltage: Over 20 V, open circuit; continuously adjustable attenuator (approximately 50 dB).
Amplitude Stability: Typical drift after warmup, 0.02% short term (1 min), 1.0% long term (12 h); both at 1 kc/s.
Frequency Characteristic: ±2%, 20 c/s to 200 kc/s, open circuit or 600-Ω resistive load. (See Figure 5).
Impedance: Approximately 600 Ω.
Distortion: <0.25%, 50 c/s to 50 kc/s, with linear loads. **Hum:** <0.02% independent of attenuator setting.
Synchronization: High-impedance, constant-amplitude, 0.8-V, rms, output for use with oscilloscope, counter, or other oscillators.

GENERAL

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 400 c/s, 12 W.
Terminals: Two Type 938 Binding Posts, one grounded to panel.
Accessories Supplied: Type CAP-22 Power Cord, spare fuses.
Accessories Available: Type 1560-P95 Adaptor Cable (telephone plug to Type 274-M Double Plug) for connection to synchronizing jack.
Mounting: Convertible-bench cabinet.
Dimensions: Width 8¼, height 6, depth 8⅛ inches (210 by 155 by 210 mm), over-all.
Net Weight: 7¾ lb (3.6 kg).
Shipping Weight: 10 lb (4.6 kg).

Catalog Number	*Description*	*Price in USA*
1310-9701	**Type 1310-A Oscillator**	**$295.00**
1560-9695	**Type 1560-P95 Adaptor Cable**	**3.00**

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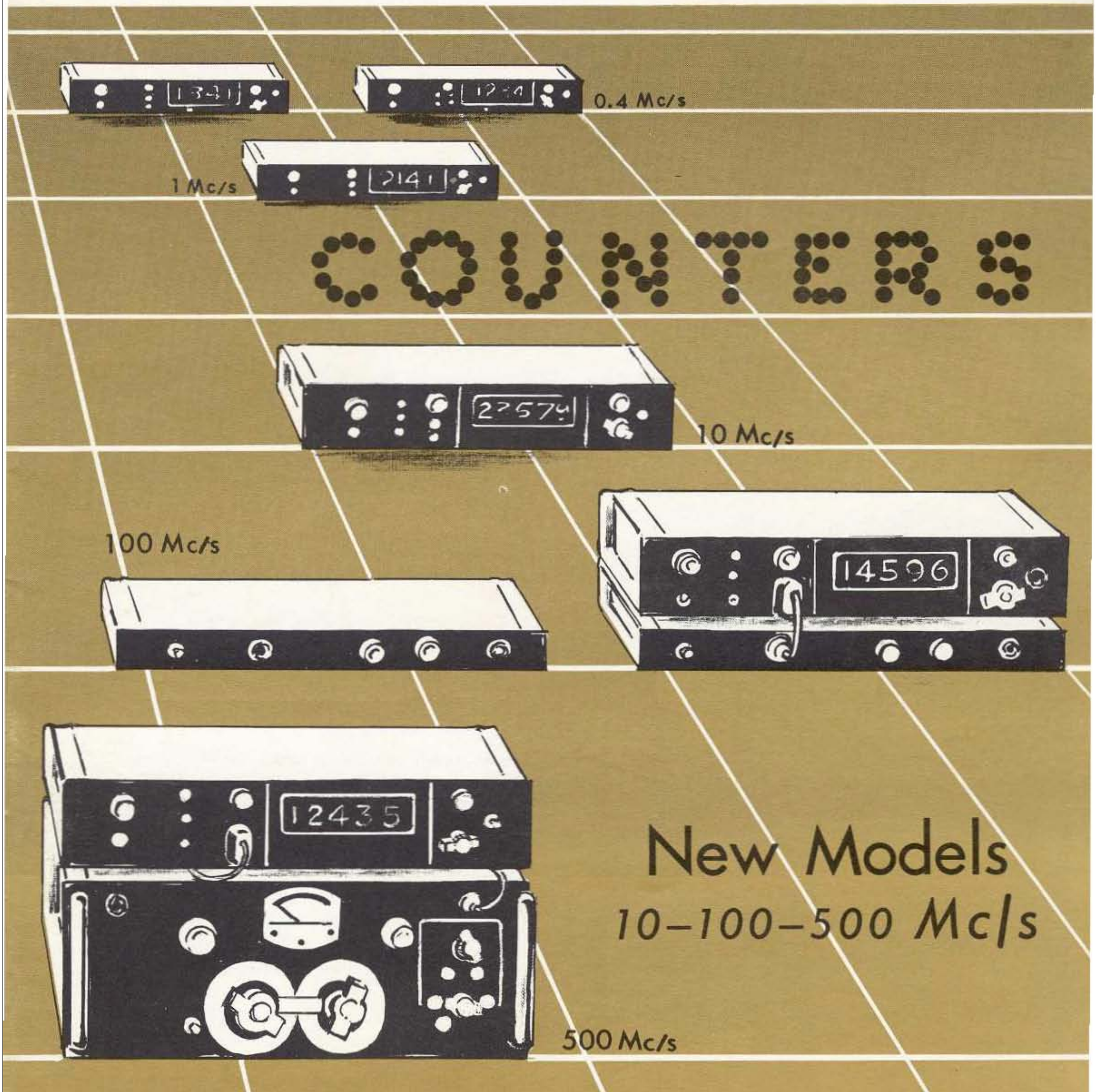
the GENERAL RADIO
experimenter

50th ANNIVERSARY

VOLUME 39 NO 9 SEPTEMBER 1965



also in this issue:

DIGITAL-TO-GRAPHIC RECORDING ASSEMBLY

NMR MEASUREMENTS

the GENERAL RADIO
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10-Mc SOLID-STATE COUNTER

In this issue of the *Experimenter* we describe several additions to our line of frequency meters: an inexpensive 10-Mc counter, a unique 100-Mc decade scaler, and 100-Mc and 500-Mc frequency measuring assemblies.

Accessory instruments for our counters—range-extension scalers, heterodyne converters, and data-recording instruments—have been designed as independent, self-contained equipment, usable not only with our counters but with other instruments for a variety of measurements. This "add-a-unit" philosophy has enabled us to design optimum instruments for a given task, unhampered by power-supply restrictions or artificial packaging constaints.

The Type 1153-A Digital Frequency Meter shown in Figure 1 is the newest member of GR's 1150 series of counters. In addition to extending the frequency range to 10 Mc/s, it introduces several new features that make frequency measuring easier and more accurate: a higher stability time-base oscillator, a full set of input controls, an automatic decimal point, and "spill" indication. The upper limit of the frequency range can be extended to 100 Mc/s by means of a decade scaler (Type 1156-A*) and to 500 Mc/s with a frequency converter (Type 1133-A†).

Time-Base Oscillator

The time-base oscillator uses a 200-kc, GT-cut, room-temperature quartz bar, which has a very low and uniform temperature coefficient and therefore maintains constant frequency without the fluctuations that would be caused by on-off cycling of a crystal oven. While not significant in lower-frequency counters, this cycling would be objectionable in a 10-Mc unit, and particularly in the 500-Mc combination, because of the increased resolution. In most laboratory and industrial environments, ambient temperatures change by less than one degree C over a five-to-ten-minute period. Under these conditions, with the long thermal time constant provided by the cabinet and crystal mount, the time-base frequency varies so slightly that short-term fre-

* See pages 6 and 12.
† See page 13.

Figure 1. Panel view of the Type 1153-AP Digital Frequency Meter.

quency-difference measurements can be made typically to a precision of a few parts in 10^8. (The temperature coefficient of the crystal is less than 5 parts/10^8 per degree.) Common measurements of this kind include oscillator warmup drift and frequency shift caused by such factors as shock, adjustment of trimming components, component replacements (or repositioning), and load changes.

For more exacting measurements, the time base can be locked to an external 100-kc standard-frequency source, such as the TYPE 1115-B Standard-Frequency Oscillator. Procedures for checking or calibrating the time-base oscillator are described in detail in the operating instructions.

Input Circuits

The input-circuit controls make it possible to minimize the effects of noise and to establish optimum trigger conditions for complex waveforms, pulses, and signals with large dc components; but they need only minor adjustment or no adjustment at all for such simple waveforms as sine waves and square waves. The input attenuator (IMPEDANCE) selects a sensitivity of either 0.1 volt or 1.0 volt, peak-to-peak.*

* See Appendix, page 14, for a discussion of sensitivity specifications for counters.

The TRIGGER LEVEL control adjusts the voltage level at which the input circuits trigger to form the pulse that is counted. The input coupling can be set to either AC or DC. For sine waves, the IMPEDANCE switch is usually set for maximum sensitivity (0.1 volt, peak-to-peak) and the coupling switch to AC to block any dc component. When the input is greater than about 2.5 volts, peak-to-peak (≅0.9 volt, rms), the signal is larger than the range of the trigger-level control, and the counter will operate properly at any setting of that control. If the input is greater than 25 volts, peak-to-peak (9 volts, rms), the counter will operate properly regardless of the settings of both controls.

The input circuit has been designed to work well, even on brief pulses, and is specified for pulses of 15-nanosecond and 30-nanosecond duration.

Control of Sensitivity and Trigger Points

A sensitivity of 0.1 volt, peak-to-peak, is fine for measuring low-level signals but can cause errors on large signals that contain noise pulses greater than 0.1 volt. To decrease the sensitivity for large signals, the input attenuator is switched to change the sensitivity from 0.1 to 1 volt.

The trigger-level control effectively shifts the hysteresis region (V_0 to V_1)

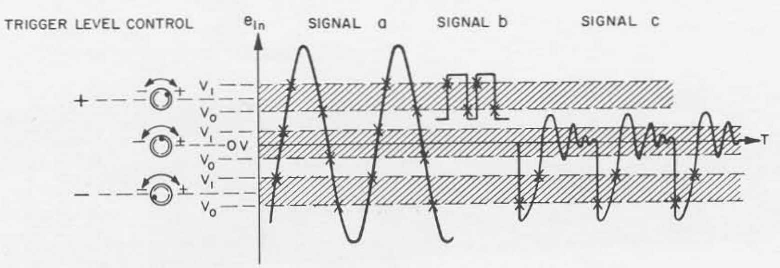


Figure 2. The trigger-level control adjusts the input trigger point. The control settings and the corresponding trigger points are shown for three types of input signals.

with respect to OV as shown in Figure 2. This allows triggering at different points on the waveform (Signal 1), proper triggering on waveforms with a dc component (Signal 2), and triggering in a noise-free region of the waveform (Signal 3). The effective range of the level control is about ±10 times the setting of the sensitivity control (i.e., sensitivity at 0.1 volt, peak-to-peak, range of level control is ± 1 volt).

A small-amplitude signal (0.1 volt, peak-to-peak) with a large dc component (20 volts) can not be measured without removal of the dc component. The ac position of the coupling switch is provided for this purpose.

Decimal Point and Spill Lamp

The spill lamp, which indicates that the register capacity has been exceeded, is actuated by a flip-flop that is triggered by the carry pulse of the last counting decade. Its purpose is to remind the operator that there are one or more digits to the left of the number displayed.

The decimal point is automatically positioned by the COUNTING TIME switch to indicate c/s, kc/s, and Mc/s.

Readout and Resolution

The five-digit readout indicators are bright, incandescent-lamp units designed for maximum legibility. Counting-time controls vary the resolution of the readout over a 1000-to-1 range so that any five digits of interest are displayed, depending upon the degree of precision desired.

—S. BENTZEN

—D. S. NIXON, JR.

SPECIFICATIONS

INPUT

Frequency: Dc to 10 Mc/s.

Accuracy: ±1 count ± time-base stability.

Sensitivity: 0.1 V, p-to-p, (30 mV, rms), at 100 kΩ and 50 pF; 1.0 V, p-to-p, (0.3 V, rms) at 1MΩ and 20 pF. For brief pulses, 0.1 V at 100 kΩ and >30-ns duration; 0.2 V at 100 kΩ and >15 ns; 1.0 V at 1 MΩ and >30 ns; 2.0 V at 1 MΩ and >15 ns. Max allowable input is ±400 V (at 1 MΩ).

Counting Interval: 0.01, 0.1, 1, or 10 s, extendible by multiplier switch, or as set manually.

Input Trigger: Ac or dc coupled. Trigger-level range is ±1 V at 0.1-V sensitivity, ±10 V at 1-V sensitivity. Trigger-level drift is typically 0.05 V, p-to-p, at 0.1-V sensitivity, 0.5 V, at 1-V sensitivity, from 0°C to 50°C.

Self Test: TEST position of measurement switch disconnects input and applies 100 kc/s to check all functions.

TIME BASE	*Stability*
100 kc/s, internal or external. Internal frequency derived from 200-kc, GT-cut, room temperature crystal; adjustment provided, adjusted to within 1 ppm when shipped.	**Cycling:** None **Temp Effects:** < 6 ppm, 0 to 50°C ambient rise; < ±0.1 ppm per °C, 20° to 30°C ambient rise. **Aging:** < 0.1 ppm per week.

DISPLAY 5-digit, in-line readout with decimal point and spill lamp, incandescent-lamp operated. Display time of 0.16, 0.32, 0.64, 1.28, 2.56, 5.12, 10.24 seconds, or infinity.

GENERAL

Input Terminals: TYPE 938 Binding Posts, ¾-inch spacing.

Rear-Mounted Connectors

Time-Base Output: 100 kc/s, 4 V, p-to-p, behind 2 kΩ.

External Time-Base Input: 100 kc/s at 1 V, p-to-p, into 1 kΩ.

Auxiliary Connector: Inputs — reset, start-stop. Outputs — carry pulse from last decade, print command, zero set, 100 kc/s, +20-V test point.

Photoelectric Pickoff Input Connector: 3-terminal telephone jack with +20 V dc and connection to main input.

Data-Output Connector (Type 1153-AP only): 10-line decimal for each digit — one wire binary 1 (+14-V level) and nine wires binary 0 (0 to +4-V level); source impedance 2.4 kΩ; +20-V power; ground; and print-command pulse.

Operating Temperature: 0° to +50°C.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 70 W.

Accessories Supplied: TYPE CAP-22 Power Cord, 8 replacement incandescent lamps, spare fuses.

Accessories Available: Type 1536-A Photoelectric Pickoff, Type 1133-A Frequency Converter and Type 1153-P1 Frequency Multiplier to extend range to 500 Mc/s, Type 1156-A Decade Scaler to extend range to 100 Mc/s. For Type 1153-AP only — Type 1136-A Digital-to-Analog Converter, Type 1137-A Data Printer, Type 1510-A Digital-to-Graphic Recording Assembly.

Mounting: Rack-Bench cabinet.

Dimensions: Bench model — width 19, height 3⅞, depth 12½ inches (485 by 99 by 320 mm); rack model — panel 19 by 3½ inches (485 by 89 mm), depth behind panel 11⅝ inches (298 mm).

Net Weight: 20 lb (9.5 kg).

Shipping Weight: 28 lb (13 kg).

Catalog Number	*Description*	*Price in USA*
1153-9801	**Type 1153-A Digital Frequency Meter,** Bench Model	**$1495.00**
1153-9811	**Type 1153-A Digital Frequency Meter,** Rack Model	**1495.00**
1153-9871	**Type 1153-AP Digital Frequency Meter,** with data output, Bench Model	**1550.00**
1153-9981	**Type 1153-AP Digital Frequency Meter,** with data output, Rack Model	**1550.00**
1153-9601	**Type 1153-P1 Frequency Multiplier**	**70.00**

100-Mc DECADE SCALER

Figure 1. Panel view of the 100-Mc Decade Scaler.

The Type 1156-A Decade Scaler shown in Figure 1 is a digital 10:1 scaler with its own power supply, output amplifier, trigger circuits, input amplifier, and input controls. The input circuit and controls will handle a wide variety of signals from dc to 100 Mc/s. The output amplifier provides a high-level signal adequate to drive counters without further amplification.

A major use of the scaler is to extend the frequency-measurement range of counters by a factor of 10. Thus, 10-Mc counters can measure frequencies to 100 Mc/s, 1-Mc counters to 10 Mc/s. Two scalers can be cascaded to extend the range of 1-Mc counters to 100 Mc/s, etc. The range of analog frequency meters such as the GR Type 1142-A Frequency Meter and Discriminator can be extended in the same manner.

Use with Counters

The scaler output signal is adequate to drive any counter over its entire range. The input sensitivity of some vacuum-tube counters is no better than 1 volt, rms, and the input is shunted by as much as 40 pF. The Type 1156-A Scaler, however, will deliver to these counters, through a patch cord, at least 1 volt, rms, even at 10 Mc/s (100-Mc scaler input). Newer counters and lower-frequency counters have better sensitivity and will be well over-driven. Figures 2 and 3 show output waveforms.

The combination of counter and scaler counts by tens instead of by units. To read the frequency being measured one mentally shifts the decimal point in the counter display one place to the right. The fractional accuracy of the measurement, however, is not affected

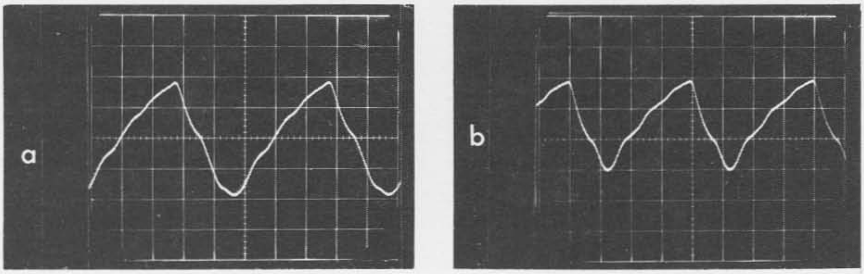
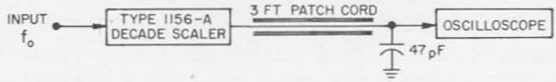


Figure 2. Scaler output waveforms (a) 10 Mc/s (100-Mc input); (b) 12.5 Mc/s (125-Mc input). Vertical scale is 1 V/cm. Measurement setup is shown at right.



by the use of the scaler. It is strictly a function of the counter and is usually specified as ±1 count ± crystal-oscillator stability, where the ±1 count is actually ±1 unit in the least significant digit displayed on the counter. The scaler offers a means of increasing the upper frequency limit of existing 10-Mc counters by a factor of 10. Its usefulness to update existing counter designs has been recognized by a few manufacturers, who have supplied plug-ins that fit only their own counters.

The Type 1156-A Decade Scaler is a completely independent instrument *and will work with any counter*.

Use with the Analog Frequency Meter

The GR Type 1142-A Frequency Meter and Discriminator is an analog-type frequency meter, which measures frequency from 3 c/s to 1.5 Mc/s with an over-all accuracy of ±0.2%. It can be used with a recorder to produce time records of frequency change or drift. Its highly linear discriminator, when used with an external voltmeter, can measure fm deviation. With a wave analyzer it can measure individual components of incidental fm.

When this frequency meter is used with the scaler, its range is extended to 15 Mc/s or, with two scalers, to 100 Mc/s, and the fractional accuracy of measurement is unchanged (+0.2% of the frequency measured).

When the combination is used as a discriminator, the fm deviation at the input to the scaler is 10 times the fm deviation measured at the terminals

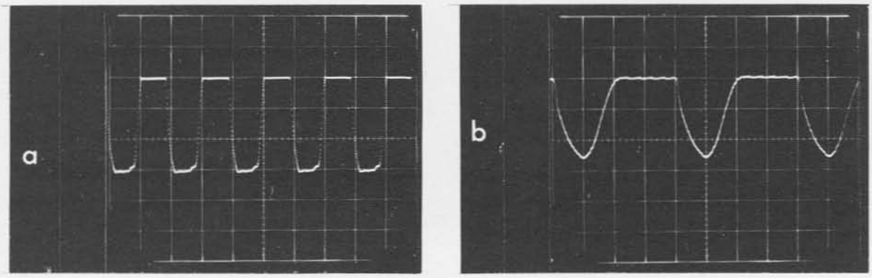


Figure 3. Output into 50 ohms. (a) 5 Mc/s (50-Mc input); (b) 12.5 Mc/s (125-Mc input). Vertical scale is 0.5 V/cm.

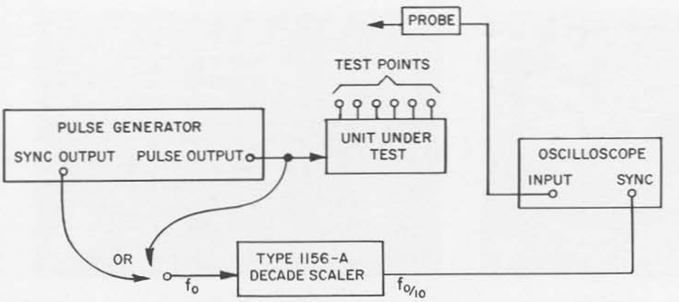


Figure 4. Oscilloscope synchronizing setup for testing decade scalers and frequency dividers.

of the frequency meter. Thus the carrier and the fm deviation are both scaled by a factor of 10. The frequency at which the signal is modulated is not affected by the scaler, and the residual fm noise introduced by the scaler is negligible. The residual noise of the combination is more than 100 dB below full output of the frequency meter.

Synchronizing Oscilloscopes

Another use of the TYPE 1156-A Decade Scaler is the synchronization of an oscilloscope for the observation of waveforms in scalers and other frequency dividers. With the scope sweep synchronized directly with the input to the device under test, as shown in Figure 4, waveforms at test points can be observed in their proper time relationship to the input signal, malfunction and failure points can be detected, and the usable ranges of operating parameters can be determined.

DESCRIPTION

Figure 5 is a block diagram of the TYPE 1156-A Decade Scaler. The 50-ohm input circuit is designed for low VSWR. The input connector is a GR874 Locking Connector. The input attenuator (sensitivity control) consists of a resistive ladder network mounted between a ground plane and a switch wafer. The input and output connections of the attenuator are made with ground-plane configurations that minimize reflections at the input terminal. When the sensitivity switch is in the 0.1-volt position, the attenuator acts only as a 50-ohm load, and the input is connected directly to the input amplifier. A 500-ohm position is also provided.

A two-transistor, dc-coupled input amplifier provides gain and buffers the input connector from switching transients generated by the Schmitt circuits that follow.

The Schmitt circuits use conventional emitter-coupling with Zener diodes for dc translation.

The scale of 5 is a unique circuit first described by Rudolph Englemann[1]. It

[1] Rudolph Englemann, "Bi-quinary Scaling: Accuracy and Simplicity at 500 Mc," *Electronics*, p 34, November 15, 1963.

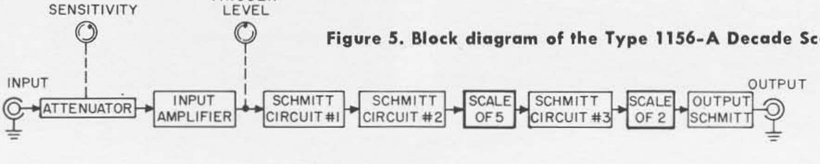


Figure 5. Block diagram of the Type 1156-A Decade Scaler.

Figure 6. Tektronix oscilloscope probe (foreground) can be plugged directly into the scaler. The scaler input and output terminals can be mounted either on the panel or at the rear. Cover plates are provided for the panel when rear connections are used.

consists of five bi-stable Schmitt circuits serially connected to form a ring counter. This ring differs from most counting circuits; it does not require pulses but operates on the transitions of the input waveform. The Schmitt-circuit propagation delay and the stray capacitance of the output transistor of each stage provide the required interstage storage or memory. No additional energy-storage elements need be added.

The scale of 2 is an emitter-coupled flip-flop, with inductive memory, and is driven from a pulse generated by Schmitt No. 3. The output of the flip-flop drives the output Schmitt circuit, which provides at least 1 volt, peak-to-peak, into 50 ohms at the output connector. This output is approximately square wave from dc to 10 Mc/s for an input to the scaler from dc to 100 Mc/s.

Input Characteristics

The 50-ohm input impedance has a VSWR of less than 1.1 up to 100 Mc/s and causes a reflection of less than 10% when a 0.4-nanosecond rise-time pulse is applied. The scaler input can be used as a 50-ohm cable termination or as a 50-ohm load up to ½-watt dissipation.

The Tektronix oscilloscope probes for use at a 50-ohm impedance level, such as the TYPES P6026, P6034, and P6035, can be used with this scaler. They are equipped with GR874 Connectors, so that no adaptors are necessary. See Figure 6.

The input sensitivity of the scaler is specified at 100 Mc/s as 0.1 volt, peak-to-peak, or 35 millivolts, rms, for a sine wave. It is generally even better at lower frequencies; Figure 7 shows the actual sensitivity of a typical instrument as a function of frequency for a sine wave input.

It is often necessary to measure the repetition rate of a signal composed of very brief pulses. To determine the sensitivity of the scaler to signals of this kind, a pinch-off diode and a clipping line were used to generate pulses at 105 Mc/s. These signals, shown in Figure 8, trigger the scaler reliably. For

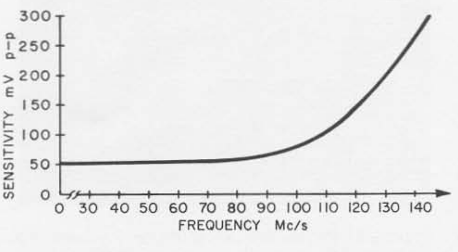


Figure 7. Scaler sensitivity vs frequency. The scaler will operate reliably over a temperature range of 0 to 50°C with an input frequency of at least 125 Mc/s and a sensitivity of better than 300 mV, peak-to-peak.

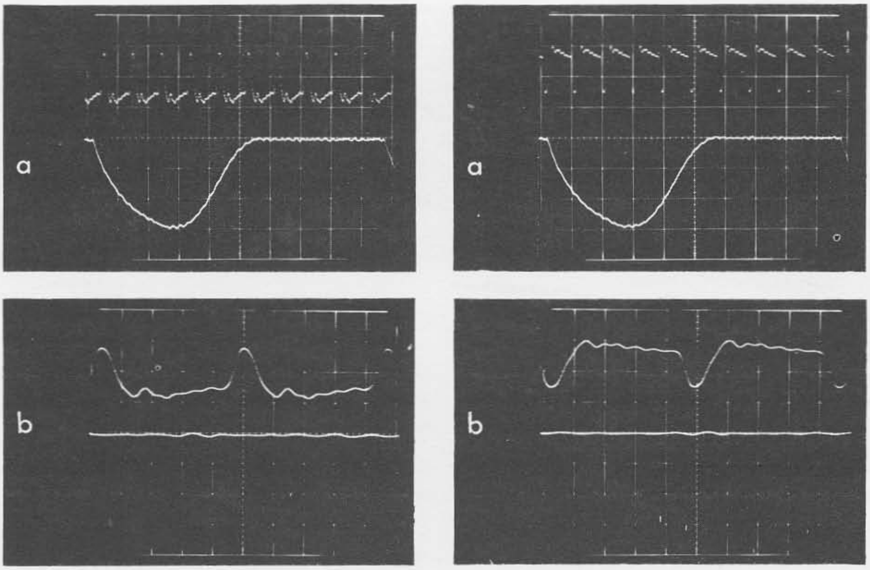


Figure 8. Operation on brief pulses at 105 Mc/s. Positive pulses at left, negative at right. Upper trace shows input; vertical scale is 0.1 V/cm. Lower trace shows output into 50 ohms; vertical scale is 0.5 V/cm. For (a), horizontal scale is 10 ns/cm; for (b), 2 ns/cm.

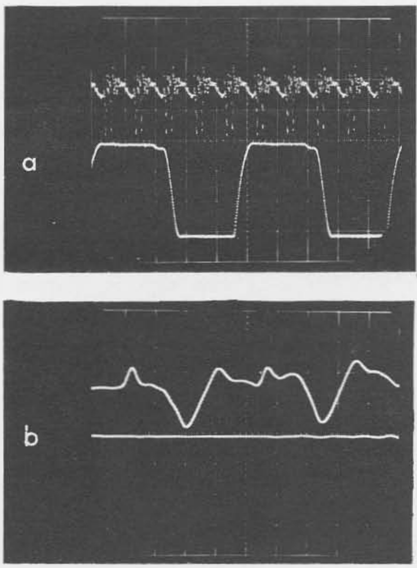


Figure 9. Resolution of pulse pairs occuring at a 20-Mc rate. Upper trace shows input; vertical scale is 0.1 V/cm. Lower trace shows 4-Mc output into 50 ohms; vertical scale is 0.5 V/cm. For (a), horizontal scale is 50 ns/cm, for (b), 2 ns/cm.

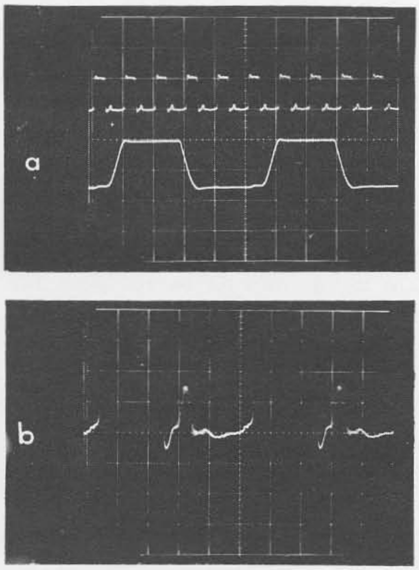


Figure 10. Resolution of pulse pairs when first pulse has 10 times the amplitude and 4 times the duration of the second pulse. For (a), upper trace shows input, lower trace output; vertical, 1 V/cm; horizontal, 50 ns/cm. (b), input signal expanded to show smaller pulse; vertical scale is 0.1 V/cm; horizontal, 10 ns/cm.

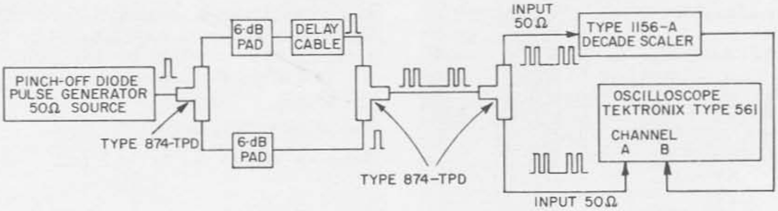


Figure 11. Test setup for Figure 9.

reliable triggering on briefer pulses, however, the amplitude must be larger.

Pulse-Pair Resolution and Operation with Random Inputs

The input circuits of the Type 1156-A Decade Scaler are direct coupled straight through to the trigger circuits and operate well even with pulse trains of random amplitude and duration. Figure 9, for instance, shows input and output signals when the scaler counts pairs of pulses. The pairs occur at a 20-Mc rate, and the pulses in each pair are separated by about 10 nanoseconds. Note the large amount of base-line noise on this signal. The trigger-level control is adjusted so that the scaler triggers only on the pulses.

Figure 10 shows another train of pulse pairs. Here, the first pulse has about 10 times the amplitude of the second pulse and about four times the duration. This is a somewhat more severe test of the input circuits. It checks the operation with pulses of different amplitude, duration, and repetition rate and shows that the amplifier and trigger circuits do not change their bias conditions because of amplifier nonlinearity and stray inductance and capacitance. Figures 11 and 12 show the setups used to make these tests.

— D. S. Nixon, Jr.

SPECIFICATIONS

Frequency	*Impedance*	*Remarks*
INPUT Dc to 100 Mc/s	50 or 500 Ω	VSWR: 1.1 max at 100 Mc/s (50 Ω). Reflection: 10% max with 0.4-ns step (50 Ω).
OUTPUT Dc to 10 Mc/s	250 Ω	Approximately square-wave output, 20 mA; 1 V into 50 Ω, over 5 V open circuit, all p-to-p.

Sensitivity: 0.1, 0.2, 0.5, and 1 V, p-to-p, at 50 Ω; 1 V, p-to-p, at 500 Ω. Maximum input is 20 times sensitivity or ½ W, whichever is smaller.

NOTE: With an input of 0.3 V, p-to-p, at 50 Ω, the scaler will operate reliably at frequencies up to at least 125 Mc/s.

GENERAL

Operating Temperature: 0 to 50°C.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 15 W.

Terminals: GR874 Locking Connectors. For connection to other types of coaxial connectors, use locking adaptors, which lock securely in place, yet are easily removed.

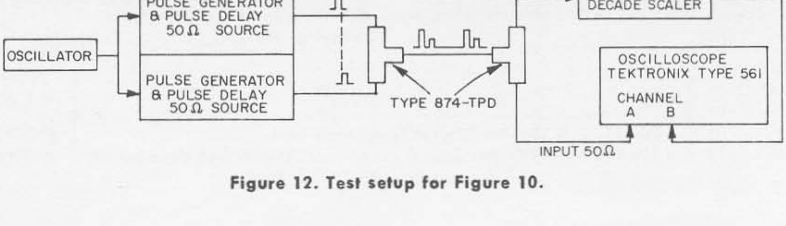


Figure 12. Test setup for Figure 10.

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

Accessories Available: TYPE 874-K Coupling Capacitor for ac coupling to input or output connectors. For output connection to TYPE 1142-A Frequency Meter and Discriminator, use TYPE 874-R34 Patch Cord.

Mounting: Rack-Bench cabinet.

Dimensions: Bench model — width 19, height 2⅛, depth 12¼ inches (485 by 54 by 315 mm); rack model — panel 19 by 1¾ inches (485 by 45 mm), depth behind panel 11⁵⁄₁₆ inches (288 mm).

Net Weight: 10¾ lb (4.9 kg).

Shipping Weight: 25 lb (11.5 kg).

Catalog Number	*Description*	*Price in USA*
1156-9801	**Type 1156-A Decade Scaler,** Bench Model	**$490.00**
1156-9811	**Type 1156-A Decade Scaler,** Rack Model	**490.00**

US Patent No. 2,548,457

100-Mc DIGITAL FREQUENCY METER

This direct-counting, dc-to-100-Mc Digital Frequency Meter is a combination of completely independent instruments — the 10-Mc Counter (TYPE 1153-A) and the 100-Mc decade scaler (TYPE 1156-A) described elsewhere in this issue. The two instruments are assembled and shipped as a unit. The special short patch cord shown connecting the counter and the scaler is included.

The frequency at the input is 10 times the frequency measured by the counter. A mental shift of the decimal point one place to the right gives the frequency at the input to the scaler. The accuracy of the measurement is unaffected by the scaler and is still ± 1 count ± crystal-oscillator stability. The ±1 count is in the least significant digit displayed on the counter. Sensitivity and other input specifications are identical with those for TYPE 1156-A Decade Scaler, page 6.

SPECIFICATIONS

Range: dc to 100 Mc/s.

Power Required: 100 to 125 or 210 to 250 V, 50 to 60 c/s, 85 W.

Accessories Supplied: Power cord, spare fuses, patch cord, hardware for rack mount.

Input Terminal: GR874 Coaxial Connector (locking type); use TYPE 874-Q Adaptors to connect to other coaxial types.

Data-Output Connector (-AP model only): 10-line decimal for each digit — one wire binary 1 (+ 14-V level) and nine wires binary 0 (0 to +4-V level); source impedance 2.4 kΩ; +20-V power; ground; and print-command pulse.

Dimensions: Width 19, height 11¼, depth 12½ inches (485 by 150 by 320 mm).

Net Weight: 46 lb (21 kg).

Shipping Weight: 61 lb (28 kg).

Catalog Number	*Description*	*Price in USA*
1144-9701	**Type 1144-A 100-Mc Digital Frequency Meter**	**$1995.00**
1144-9829	**Type 1144-AP 100-Mc Digital Frequency Meter,** with data output	**2050.00**

US Patent No. 2,548,457

500-Mc FREQUENCY-MEASURING ASSEMBLY

The TYPE 1143-A Frequency-Measuring Assembly is a combination of the previously described TYPE 1153-A Digital Frequency Meter and a heterodyne converter, the TYPE 1133-A Frequency Converter[1]. A frequency multiplier, which multiplies the 100-kc standard frequency output of the counter to the 5-Mc reference frequency required by the converter, is included. This assembly will measure frequencies to 500 Mc/s with simplicity and with a sensitivity and optional selectivity not available elsewhere.

In the converter the input frequency is heterodyned against a 10-Mc multiple of the counter's time-base-oscillator frequency and the less-than-10-Mc difference frequency is applied to the counter. In-line numerals indicate directly the heterodyne reference frequency to be added to the counter reading, and a panel meter indicates proper input and output level. Level adjusting controls are provided.

The converter can be operated in one of two modes: a wide-band mode for simplified measurement of clean signals of greater than 100-millivolt, rms, level; and a narrow-band mode for measurement of noisy signals of greater than 10-millivolt level. In the narrow-band mode a tuned amplifier is switched into the system to provide selectivity and increased sensitivity. Panel lights indicate proper control settings.

In this assembly, ruggedness and lasting reliability accompany several unique features — high sensitivity, optional selectivity, and simple operation — to produce an instrument of outstanding performance for frequency measurement to 500 Mc/s.

[1] H. T. McAleer, "A New Converter for Frequency Measurements to 500 Mc," *General Radio Experimenter*, December, 1962.

SPECIFICATIONS

Range: dc to 500 Mc/s.
Sensitivity: Better than 10 mV, rms, on narrow band (above 100 kc/s); better than 100 mV on wide band.
Data-Output Connector: 10-line decimal for each digit — one wire binary 1 (+14-V level) and nine wires binary 0 (0 to +4-V level); source impedance 2.4 kΩ; +20-V power; ground; and print-command pulse.
Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 140 W.
Input Terminal: GR874 Coaxial Connector; use TYPE 874-Q Adaptors to connect to other coaxial types.
Accessories Supplied: Patch cords for interconnection, spare fuses, hardware for rack mount.
Dimensions: Width 19, height 11¼, depth 19 inches (485 by 290 by 485 mm).
Net Weight: 54 lb (24.5 kg).
Shipping Weight: 84 lb (39 kg).

Catalog Number	*Description*	*Price in USA*
1143-9701	**Type 1143-A Frequency-Measuring Assembly**	**$3090.00**
1143-9829	**Type 1143-AP Frequency-Measuring Assembly,** with data output	**$3145.00**

US Patent No. 2,548,457

APPENDIX

COUNTER INPUT CIRCUITS AND SENSITIVITY SPECIFICATIONS

Why does GR specify the input sensitivity of its counters in volts peak-to-peak instead of rms? This is a question often asked by those who are not familiar with the operation of counter input circuits. Those who are lucky enough to be making frequency measurements of large amplitude, clean sine waves don't need to know. For those whose lot it is to deal with all sorts of waveforms, the answer will be apparent from the following discussion.

The input circuits of digital frequency meters, period meters, and time-interval meters all operate on the same basic principle. They must transform the input waveform, regardless of shape and amplitude, into a pulse with a fixed amplitude and transition time. To do this requires a switching circuit of some kind. The most common ones are Schmitt circuits and tunnel diodes.

The output of a switching circuit has two states, a high state whenever the instantaneous value of the input voltage is above a certain level (V_1 in Figure 1), and a low state whenever the instantaneous input voltage is below a certain level (V_0).

V_1 and V_0 are sometimes called the set and reset voltages, or the trigger voltages, of the switching circuit. V_1 is larger than V_0, and the region between V_1 and V_9 is often called the hysteresis region. If the input voltage is below V_0 (output in low state) and is then raised to V_1, the circuit will switch to the high state. Even though the input voltage swings above and below V_1, the circuit will not switch again until the input goes below V_0. Therefore, a signal applied to the circuit must be greater than $V_1 - V_0$ and must be applied so that it goes above V_1 and goes below V_0 during each cycle for the circuit to change state each cycle. Figure 1 shows several different inputs to the switching circuit and their corresponding outputs. Note that the output is in the high state whenever the input signal exceeds V_1 and in the low state whenever the input is less than V_0. Note also that the amplitude of the output waveform is constant but that the duration of the output pulse is a function of the input signal. Since the internal counting circuits are actuated by a pulse of fixed duration and amplitude, a pulse shaper follows the switching circuit to establish the duration. It operates from either the rising or the falling edge of the output.

Input signals 1, 2, and 3 will all operate the counter properly. Signal 1 is, however, of minimum usable amplitude. Therefore, the sensitivity of the circuit is a peak-to-peak voltage of $V_1 - V_0$ volts, which is determined by the design of the switching circuit. If an instrument is to accept signals of less than $V_1 - V_0$, an amplifier must be used between the input connector and the switching circuit. The amplifier in the Type 1153-A Counter provides an effective $V_1 - V_0$ of 0.1 volt at the input terminals, thus, a sensitivity specification of 0.1 volt, peak-to-peak. This, of course, applies to input signals of any shape and has nothing to do with the rms and average values of the input signal.

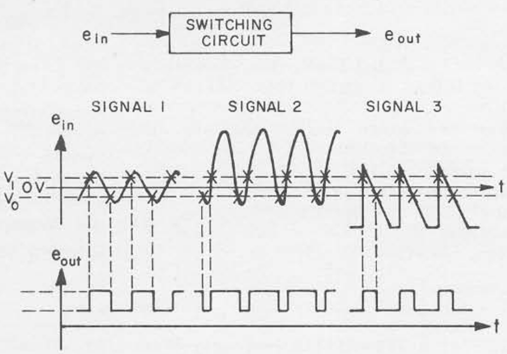


Figure 1. Switching-circuit input trigger points and corresponding output signals for three different input signals.

TYPE 1510-A DIGITAL-TO-GRAPHIC RECORDING ASSEMBLY

This convenient assembly of the Type 1136-A Digital-to-Analog Converter and the Type 1521-B Graphic Level Recorder will operate from the output of General Radio digital instruments to produce a strip-chart record that is the analog of the digital data as a function of time. It is equally usable with other digital equipment that is coded for 1-2-4-2, 1-2-2-4, or 1-2-4-8 output.

Shipped assembled, as shown, with 10 rolls of chart paper and input cable. Rack-mount hardware also supplied.

Catalog Number	*Description*	*Use**	*Price in USA*
1510-9401	**Type 1510-A Digital-to-Graphic Recording Assembly** (60-cycle operation)	For use with Types 1143-AP, 1144-AP, 1150-BP, -BPH, 1151-AP, 1153-AP Counters	**$1855.00**
1510-9571	**Type 1510-AQ1 Digital-to-Graphic Recording Assembly** (50-cycle operation)		**on request**
1510-9402	**Type 1510-A Digital-to-Graphic Recording Assembly** (60-cycle operation)	For use with Type 1680-A Automatic Capacitance Bridge Assembly	**$1725.00**
1510-9572	**Type 1510-AQ1 Digital-to-Graphic Recording Assembly** (50-cycle operation)		**on request**

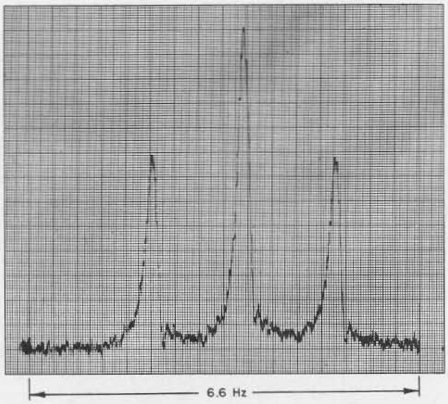
*Converters and cables for use with other digital instruments are available on special order. Write for information.

NMR MEASUREMENTS WITH THE FREQUENCY SYNTHESIZER

The General Radio Type 1161-A4C Coherent Decade Frequency Synthesizer has found unique use in the field of nuclear magnetic resonance at Mellon Institute of Industrial Research, Pittsburgh.

In nuclear magnetic resonance, a strong uniform magnetic field is applied to the sample. The sample is then excited by an rf field from a coil oriented around the sample. At Mellon an rf carrier near 60 MHz is first modulated by 1.0 kHz to produce a side band at 60.001 MHz. This side band is then phase-locked to a known resonance of the sample. Other resonances of interest lie between 60.0 and 60.001 MHz, and they can be stimulated by additional amplitude modulation of the 60-MHz carrier. The detected resonances are extremely narrow, typically 0.1 to 0.2 Hz wide, and several of these may appear in a 10-Hz band.

To measure these side bands, it is most convenient to use a slowly swept oscillator as the modulating source and to display the resonances on an X-Y recorder. The swept source, however, must be stable to 0.01 Hz or better during the sweep interval (typically 10



Typical plot obtained by the modulation method. Sample is CF_3CF_2COOH.

minutes) in order to produce sharply defined peaks on the recorder.

Physicists at the Institute have found the GR 1161-A4C Synthesizer to meet these demanding requirements. A variable dc source is used to control the continuously adjustable decade through a 5- or 10-Hz band. Because of the synthesizer's extreme stability, one can calibrate the recorder by peaking the synthesizer to an arbitrary resonance and measuring the output frequency on a digital counter. Even a 10-second counting interval can be used since this synthesizer will remain on the peak for extended periods of time. This method of calibration is not possible with conventional oscillators because of their relative instability.

Although frequency synthesizers have been widely used in studies of nuclear magnetic resonance, they ordinarily are used directly at the high frequency (in this case, 60 MHz). The modulation method has many advantages. It does not require extreme stability in the applied magnetic field, thus allowing more time for the taking of data. It also permits the use of a less expensive, lower-frequency synthesizer.

—D. L. Woodward

Credits: We gratefully acknowledge the cooperation of Dr. A. A. Bothner-By, of the Mellon Institute, who supplied the information on which this brief article is based. — Editor

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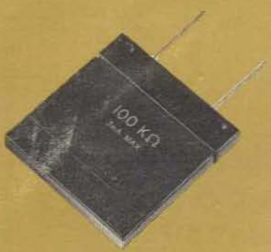
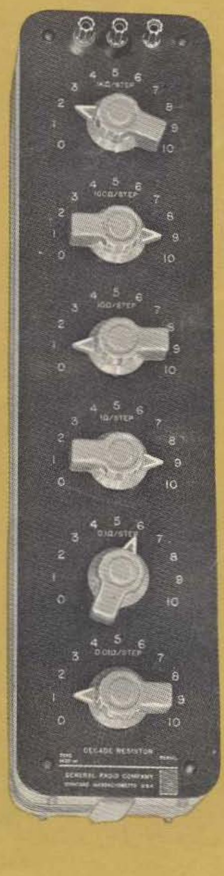


STABLE RESISTANCE STANDARDS

COMPACT, LOW-COST DECADES



INCREASED ACCURACY

in this issue:

RESISTANCE STANDARDS • DECADE RESISTORS • COAXIAL MICROWAVE NEWS

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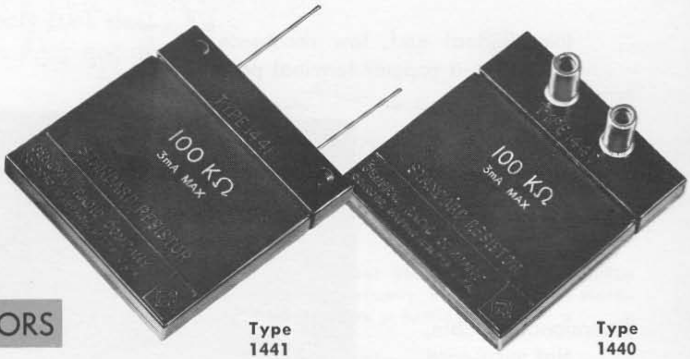
NEW STANDARD RESISTORS



Type 1441 Type 1440

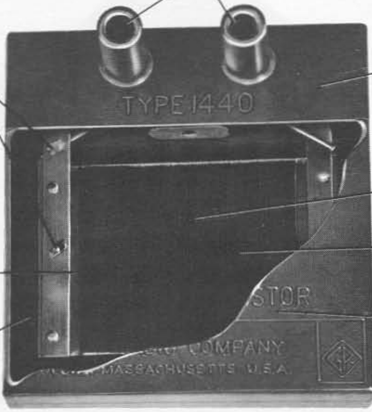
An important objective of our development program for precision resistors has been the design of a resistor unit of high stability for use both as a resistance standard and as a circuit component where ordinary commercial resistors are inadequate. Requirements for such a resistor are:

1. extreme stability
2. high accuracy (close to nominal value)
3. good frequency characteristics
4. low temperature coefficient
5. low thermal emf to copper
6. reasonable size with reasonable power rating
7. moderate price

These requirements are met in the new Types 1440 and 1441 Standard Resistors, shown above. These two types use identical resistance units but have different packages to suit the two distinctly different applications.

To obtain high stability, many improved techniques were necessary. First, the units are wound under low tension to avoid unnecessary stresses and wire deformation that would result in future relaxations and cause resistance drift. To do this, we had to build new winding machines with special tension-regulating devices, because no adequate machines were available. After the resistor is wound and welded to the copper terminals, it is artificially aged by repeated temperature cycling to remove stresses. Then the units are welded to the molded-in terminals on the head of the case and adjusted to value. A new abrasion adjustment technique permits extremely fine final adjustment without introducing harmful additional stresses in the wire.

After adjustment, the resistors are encased, filled with a special low-moisture oil, and sealed. All precision resistors must be sealed to avoid chemical reactions with moisture and other components of air. The more common way of sealing is to dip the resistors



* Reg. trademark of W. B. Driver Co.

Figure 1. Cutaway view of the standard resistor, showing construction.

in a rigid or semi-rigid coating. However, any such coating restricts the expansion and contraction of the wire, and stresses develop in the wire. Such coatings are always slightly porous and, if too brittle, are also subject to small cracks, which result in gradual resistance changes, particularly under humid conditions. The use of a sealed, oil-filled case removes these two causes of long-term drift.

After sealing, the units are measured and observed for at least three months and then go through a final inspection where any units that show unusual behavior are eliminated.

Table I shows the average drift for the first year. As is to be expected with wire-wound resistors, these units all show a reduced rate of drift as they age, so that drift during their second year is less.

TABLE I.
AVERAGE DRIFT FOR FIRST YEAR

1 MΩ	100 kΩ	10 kΩ	1 kΩ	100 Ω	10 Ω	1 Ω
7 ppm	6 ppm	2 ppm	3 ppm	8 ppm	8 ppm	10 ppm

Good frequency characteristics are inherent in these units because they are wound on thin mica cards. The inductance of all units is reduced because the wire forms a flat coil with low cross-sectional area. The lower-resistance units, in which inductance is more critical, use the Ayrton-Perry winding, which cancels the magnetic field to a great degree. A plastic (non-conducting) container was chosen to reduce capacitance. Our specifications include the values of residual inductances (for low-resistance values) and capacitances and approximate frequencies at which the effective series and parallel values of resistance will change by 0.1%.

The resistance wire used has a low temperature coefficient and a low thermal emf to copper. A low thermal emf is further ensured by copper terminals on the resistor itself and on the case. The units are shaped to have a relatively large surface-to-volume ratio in order to dissipate one watt without permanent change in resistance. For high-accuracy measurements, only 0.01 watt should be used to avoid a temperature rise.

Applications

The TYPE 1440 Standard Resistor is intended for use as a laboratory or production standard for calibrating resistance measuring devices, for substitution measurements, and for incorporation in temporary measurement setups. It has gold-plated, copper, jack-top terminal posts and removable, gold-plated banana plugs, both on standard ¾-inch spacing. With the banana plug in place, there are four terminals available for making highest accuracy measurements on the low-resistance units by means of a Kelvin Bridge.

A calibration label is attached, which gives an initial calibration to ± 20 ppm against standards whose values are known typically to ±10 ppm as determined by the National Bureau of Standards. The date of calibration and a serial number are given, and room is provided for future calibration entries. The resistors can be immersed in oil without damage to this label.

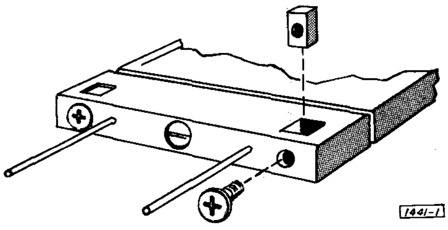


Figure 2. Type 1441 Standard Resistor can be mounted either vertically or horizontally. Hardware is furnished.

The TYPE 1441 resistors are intended for use in equipment requiring resistors of the highest stability. These units have No. 16 tinned copper leads and include hardware for vertical as well as horizontal mounting. Connection to the leads are made ½ inch from the case for calibration measurements on low-resistance units. See Figure 2.

One of the main reasons for developing these resistors was to give us a better precision resistor for use in our own precision instruments. Other equipment manufacturers will find them useful, as will anyone building his own laboratory or production measurement devices.

— W. J. BASTANIER

[redacted]

Accuracy: ±0.01% for all units except those of 1 Ω, which are ±0.02%. This accuracy is guaranteed for our standard warranty period of two years, unless the resistor has been damaged by excessive current. Measurements on the low-resistance TYPE 1440 units should be made with a four-terminal connection and on the TYPE 1441's at ½ inch from the case. All measurements at 23°C.

Calibration Accuracy: TYPE 1440 Resistors are calibrated by comparison, to a precision of ±20 ppm, with working standards whose absolute values are known typically to ±10 ppm as determined and measured in terms of reference standards periodically measured by the National Bureau of Standards. The measured deviation from nominal value, at 23°C and 0.01 watt, is entered on the label on the reverse side of the resistor.

Stability: ±30 ppm per year.

Temperature Coefficient (Max): ±10 ppm/°C for resistances above 10 Ω; ±20 ppm/°C for 10 Ω and below.

Power Rating: 1 W. The corresponding current is indicated on the resistor and in the table below. This dissipation will cause a temperature rise of approximately 25°C and a resulting temporary resistance change due to the temperature coefficient. If this rating is exceeded, permanent changes may result.

Residual Impedances: Approximate shunt capacitance (2-terminal measurement), TYPE 1440, 2.5 pF; TYPE 1441, 1.5 pF; less for 3-terminal measurement. Typical series inductance, see price table.

Approximate Frequency Characteristic: See table.

Terminals: TYPE 1440 — gold-plated, jack-top, copper binding posts (¾-in spacing) with banana plugs that are removable and can be replaced by 6-32 screws for installation of soldering lugs. TYPE 1441 — #16 tinned-copper-wire leads, 1⅛ in. long on 1⅛ in. spacing.

Dimensions (less terminals): Type 1440 — width 2¼, height 2½, depth ⅜ inches (58, 64, 10 mm); TYPE 1441 — width 2¼, height 2⁵⁄₁₆, depth ⅜ inches (58, 59, 10 mm).

Net Weight: TYPE 1440, 2 oz (60 g); TYPE 1441, 1½ oz (45 g).

Shipping Weight: TYPE 1440, 10 oz (0.3 kg); TYPE 1441, 10 oz (0.3 kg).

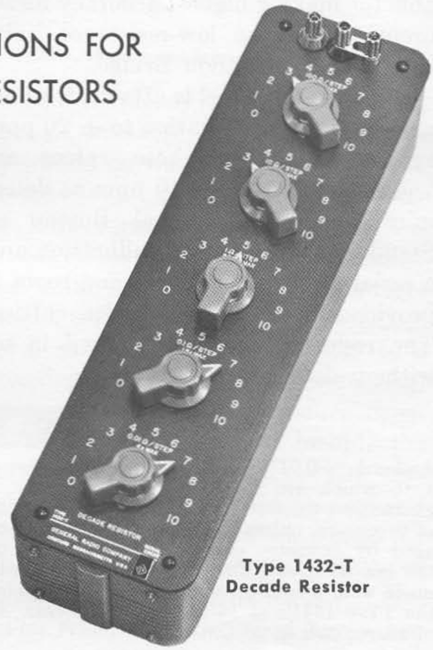
Resistance	*Max Current*	*Typical Inductance*	*Approx Frequency for 0.1% Resistance Change* Series R	Parallel R	*Type 1440* Catalog Number	Price in USA	*Type 1441* Catalog Number	Price in USA
1 Ω	1.0 A	0.12 μH	300 kc/s	30 kc/s	1440-9601	**$10.50**	1441-9601	**$ 6.50**
10 Ω	310 mA	0.13 μH	1 Mc/s	300 kc/s	1440-9611	**10.50**	1441-9611	**6.50**
100 Ω	100 mA	0.20 μH	3 Mc/s	1 Mc/s	1440-9621	**10.50**	1441-9621	**6.50**
1 kΩ	30 mA	2.5 μH	2 Mc/s	1 Mc/s	1440-9631	**10.50**	1441-9631	**6.50**
10 kΩ	10 mA	—	200 kc/s	1 Mc/s	1440-9641	**10.50**	1441-9641	**6.50**
100 kΩ	3 mA	—	20 kc/s	100 kc/s	1440-9651	**12.50**	1441-9651	**8.50**
1 MΩ	1 mA	—	2 kc/s	10 kc/s	1440-9661	**21.50**	1441-9661	**17.50**

When ordering, please specify catalog number, type number and name, resistance value, and price. Any other resistance value between 0.1 Ω and 1 MΩ can be supplied. Please ask for a quotation.

IMPROVED SPECIFICATIONS FOR THE 1432 DECADE RESISTORS

Our general program for developing improved resistors has resulted in more accurate and stable resistors for use in decade boxes as well as in the extremely stable TYPES 1440 and 1441 Standard Resistors described above. New winding, coating, heat-treating, and adjustment procedures have made possible a new two-year warranty of 0.025% for steps of 100 ohms and higher in the popular TYPE 1432 Decade Resistor and TYPE 510 Decade-Resistance Unit.

We want to emphasize that this specification is for a full two years after date of shipment. As discussed elsewhere (see page 12), we feel that this is the information that is most useful to the decade-box user who usually wants to know that his decade is better than some stated accuracy and will remain that way. We also want to point out that we feel that this new specification remains conservative. Our records show that we could have improved our specifications without actually improving the stability of the resistors and still have a reasonably low rate of returned boxes under our warranty. However, we feel that our customers have developed, over the years, a high confidence in the specifications of our



Type 1432-T Decade Resistor

impedance standards of all types, and we want to be very careful not to destroy this confidence by specifying our units too closely. Therefore, we waited until we had made definite improvements in our resistance units to ensure that a closer tolerance would still be a conservative specification.

In the small percentage of decade resistors that have been returned because they were out of tolerance, the difficulty has often occured in the 10-ohms-per-step decade. For a number of reasons, this resistor has been a particularly awkward value to make. The new boxes use 10-ohm units of a new design that has been tested under extreme conditions and has proved to hold its specifications as well as resistors of other values.

Another important improvement in the new decades is the reduced zero resistance, which is now typically 1 milliohm per dial. This is made possible by the use of a silver overlay on the switch contact studs in all positions where the switch resistance affects either the resistance accuracy or the zero resistance. This overlay not only improves the initial zero resistance but it also is much less susceptible to long-term contamination, which was occasionally a problem with the older boxes if they were left for some time in a humid or corrosive environment. Long-term tests in a variety of gas mixtures discolored the new contacts in some cases but made negligible change in their contact resistance.

A third improvement is the use of a solid-copper alloy for the body of the binding posts. This feature is particularly important for low-level dc applications, where the thermal emf from copper wire to a binding post of another metal could result in appreciable errors. These new binding posts are gold-plated to avoid corrosion, and this also distinguishes the new decade boxes from the older models. Actually, the new switch contacts and resistor units have been in use for some time, but, officially, the new specifications apply only to units with gold-plated binding posts.

With the introduction of the new Type 1434 series of decade resistors (see page 8) our customers now have a choice between two series of resistance boxes. The new, less expensive units are recommended primarily for circuit design work and other applications where the utmost in accuracy is not required. We recommend the improved Type 1432 resistors for applications where a decade box is used as an adjustable resistance standard, or where additional accuracy in the decade could improve accuracy of a measurements system.

[redacted]

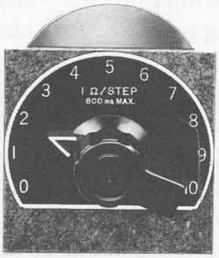
(For complete specifications, see Catalog S, pp 203 and 204.)

Long-Term Accuracy: See table at right. Our general two-year warranty applies to these tolerances unless the unit is damaged by excessive current. Tolerance shown applies to both resistance increments and total resistance after correction for zero resistance.

Zero Resistance: 1 mΩ per dial at dc; 40 mΩ per dial at 1 Mc/s; proportional to square root of frequency at all frequencies above 100 kc/s.

Resistance Per Step (ΔR) *Ohms*	*Long-Term Accuracy*
0.01	±2%
0.1	±0.5%
1	±0.15%
10	±0.05%
100	±0.025%
1000	±0.025%
10,000	±0.025%
100,000	±0.025%
1,000,000	±0.025%

Catalog Number		Total Ohms	Multiple of	No. of Dials	Price in USA
1432-9721	**Type 1432-U**	111.1	0.01 ohm	4	**$ 98.00**
1432-9711	**Type 1432-K**	1111	0.1	4	**102.00**
1432-9710	**Type 1432-J**	11,110	1	4	**110.00**
1432-9712	**Type 1432-L**	111,100	10	4	**116.00**
1432-9717	**Type 1432-Q**	1,111,000	100	4	**127.00**
1432-9720	**Type 1432-T**	1111.1	0.01	5	**124.00**
1432-9714	**Type 1432-N**	11,111	0.1	5	**128.00**
1423-9713	**Type 1432-M**	111,110	1	5	**139.00**
1432-9716	**Type 1432-P**	1,111,100	10	5	**154.00**
1432-9725	**Type 1432-Y**	11,111,000	100	5	**229.00**
1432-9723	**Type 1432-W**	11,111.1	0.01	6	**158.00**
1432-9724	**Type 1432-X**	111,111	0.1	6	**165.00**
1432-9702	**Type 1432-B**	1,111,110	1	6	**185.00**
1432-9726	**Type 1432-Z**	11,111,100	10	6	**262.00**



Type 510-B
Decade-Resistance Unit

Catalog Number		Total Resistance Ohms	Price in USA
0510-9806	**Type 510-AA**	0.1	**$19.50**
0510-9701	**Type 510-A**	1	**15.00**
0510-9702	**Type 510-B**	10	**21.50**
0510-9703	**Type 510-C**	100	**23.50**
0510-9704	**Type 510-D**	1000	**24.00**
0510-9705	**Type 510-E**	10,000	**24.00**
0510-9706	**Type 510-F**	100,000	**27.00**
0510-9707	**Type 510-G**	1,000,000	**35.00**
0510-9708	**Type 510-H**	10,000,000	**98.00**
0510-9604	**Type 510-P4**	Switch only	**11.00**
0510-9511	**Type 510-P4L**	Switch only	**12.00**

A NEW LINE OF INEXPENSIVE DECADE-RESISTANCE BOXES

As the accuracies of decade resistors increase with the state of the art it is almost inevitable that decade-box prices increase also, as a result of the additional procedures necessary to achieve this better accuracy and its required stability. However, it is apparent that many decade-box applications do not require extreme accuracy. One such application would be in the determination of resistor values in the design of electronic circuits. For this and many other uses 0.05% accuracy is sufficient, and such features as lower cost, smaller

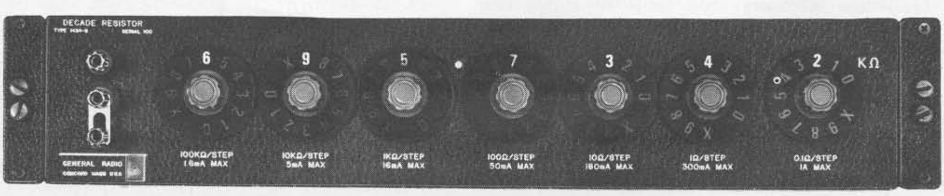


Figure 1. (*right*) **Type 1434-QC Decade Resistor includes a continuously variable 100-ohm element (extreme right-hand dial).** (*below*) **The 7-dial Type 1434-G Decade Resistor can be used on the bench or in a rack. Photograph shows box with rack-mount hardware attached.**

size, and increased readability are more welcome improvements than a closer tolerance.

The new TYPE 1434 Decade Resistors were designed for these applications. They are small and light in weight for convenient use on the designer's bench, and they have a bold in-line readout that is easily interpreted. In addition to three conventional five-digit boxes, two somewhat-different models are offered. One of these, with four digits plus a 100-ohm rheostat, should be particularly useful in circuit-design work, for it has a maximum setting of over a megohm with a resolution of better than one ohm. This is adequate for simulating most resistors used in low-power transistor circuitry.

The larger, seven-dial box goes to over a megohm with 0.1-ohm steps. The panel is relay-rack height (3½ inches) and with supplied hardware forms a neat rack-mounted unit. It also has provision for rear connections so that in a relay-rack it can be wired into systems without wires visible from the panel.

The cost of these boxes is low compared with that of similar units, not

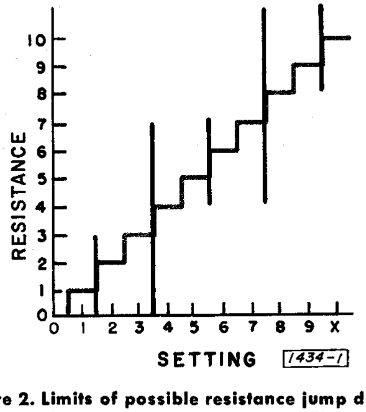


Figure 2. Limits of possible resistance jump during switching for a 1-2-4-4 combination. The system of Figure 3 avoids these jumps.

because the resistors are of lower quality but because fewer resistors are used. The resistors are similar to those used in our precision boxes (see page 6) but only six units per decade are used, instead of the usual ten.

Anyone familiar with the simplest binary logic could design a decade with only four resistors, and most capacitance and inductance decades are designed this way. However, if only four components per decade are used, there has to be some switching irregularity. For example, in a series 1-2-4-4 scheme it is impossible to switch out the 1 and 2 units and switch in the 4 unit at exactly the same time. The total resistance will jump during the switching process to a value below 3 ohms or to a value above 4 ohms. The limits of possible switching jump are shown in Figure 2. Such a situation is tolerable in capacitance and inductance boxes, but in many resistance-box applications an unexpected jump in resistance value might cause damage to an electronic component. This could happen, for instance, if such a decade resistor were being used to set the bias level on a power transistor operating near its rating.

The six-resistor scheme used has none of these switching jumps and therefore acts as if ten resistors were used. Basically, the method is that of Behr and Tarpley[1], but modern switches have made the practical realization of the scheme much simpler than that of their original description in which some of the resistors had to change physical position. In this scheme six resistors are used, each with a value of two units of resistance. Five of these

[1] Behr and Tarpley, *Proceedings of the IRE*, Vol 20, 1101 (1932).

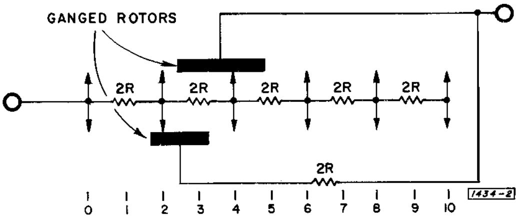


Figure 3. Diagram of the switching system used for the 6-resistor decade. Switch position shown is 3R.

are connected in series and give the even values. The sixth resistor is used to get the odd values by shunting one of the other five, as shown in Figure 3. To avoid a resistance jump the sixth resistor is put in place before it is used.

A minor limitation to this scheme is the slightly reduced maximum current specification. Because the resistor units have the same power rating as do those used in our TYPE 1432 boxes, but have twice the resistance value, the maximum current is reduced by $1/\sqrt{2}$*. We feel that this limitation is unimportant because most modern solid-state circuitry dissipates such very little power.

To ensure long life and low zero-resistance, solid-silver switch rotors and contacts are used, all switching functions are duplicated, and, in the zero position, the switching is repeated four times in parallel. While the resulting "zero resistance" specification is not so good as it is for the new TYPE 1432 Decade Resistors, which use an improved version of the TYPE 510 Decade Switch (see page 6), it is at least as good as that of former versions of this switch (2 milliohms/dial).

Decade boxes in the 1434 series are limited to those using decades with steps of 0.1 ohm to steps of 100 kilohms. Lower-resistance steps are possible, but the need for them is relatively rare, and such units are more satisfactory with the TYPE 510 switch, which is used in the TYPE 1432 Decade Resistors. One-megohm-per-step units are also less popular, and the saving in cost through the use of six resistors disappears, because the cost depends largely on the amount of wire used and would actually be higher for the six-resistor scheme, which uses a total of 12 megohms. We recommend that the TYPE 1432 Decade Resistors be used when these very-low and very-high ranges are required.

We recommend these new boxes for general use when the utmost in accuracy and low zero-resistance are not required and when the resistance range is limited to 0.1 ohm to 1 megohm. They have the important advantages of reduced size and low cost over our TYPE 1432 boxes and other similar units.

— HENRY P. HALL

* The rating of the 0.1-ohm-per-step and 1.0-ohm-per-step decades is reduced slightly more.

Long-Term Accuracy: See Table 1. Our general two-year warranty applies to these tolerances unless the resistor is damaged by excessive current. Tolerance shown applies to both resistance increments and total resistance after correction for zero resistance.

Zero Resistance: Approximately 2 mΩ per dial at low frequencies except for the TYPE 1434-QC for which it is approximately 30 mΩ.

Maximum Current: See table; these values also appear on the panel of each decade box. When this maximum current is passed through a decade, the temporary change in value will be less than the accuracy specification. Currents appreciably higher than this will cause permanent changes.

TABLE I

Total Resistance of Decade	*Resistance Per Step*	*Long-Term Accuracy**	*Max Current*
1 Ω	0.1 Ω	±2.0%	1 A
10 Ω	1.0 Ω	±0.25%	0.3 A
100 Ω	10 Ω	±0.07%	160 mA
1 kΩ	100 Ω	±0.05%	50 mA
10 kΩ	1 kΩ	±0.05%	16 mA
100 kΩ	10 kΩ	±0.05%	5 mA
1 MΩ	100 kΩ	±0.05%	1.6 mA
100-Ω Rheostat**	1 Ω/div	±1 Ω	200 mA

* At low currents and low frequencies.
** Used in Type 1434-QC.

Temperature Coefficient: Less than ±10 ppm/°C at room temperature, except for the low-valued units where the 0.4%/°C temperature coefficient of the zero resistance must be added.

Frequency Characteristics: Generally similar to those of the Type 1432 Decade Resistors.

Switches: Multiple, solid-silver-alloy switches are used to obtain low and stable zero resistance.

Terminals: Jack-top binding posts (Type 938-A) on standard ¾-inch spacing. A shield terminal is also provided. The Type 1434-G has lug connections accessible from the rear.

Mounting: All types except the Type 1434-G are in small cabinets for bench use. The Type 1434-G is also designed for bench use but, with the addition of mounting hardware, becomes a 3½-in high, 19-in relay-rack unit.

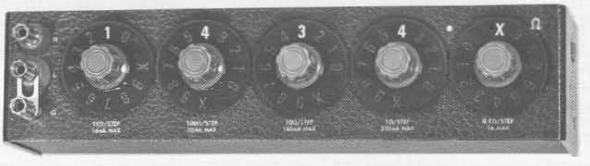
Dimensions: Type 1434-M, N, P, QC — width 11⅝, height 2¾, depth 4¼ inches (298, 70, 110 mm); Type 1434-G (bench) — width 17$^{5}/_{16}$, height 3½, depth 5 inches (442, 89, 130 mm); Type 1434-G (rack) — width 19, height 3½, depth behind panel, 3½ inches (485, 89, 89 mm)

Net Weight: Type 1434-M, N, P, QC, 3 lb (1.4 kg); Type 1434-G, 6 lb (2.8 kg).

Shipping Weight: Type 1434-M, N, P, QC, 4 lb (1.9 kg); Type 1434-G, 7 lb (3.2 kg).

Catalog Number	*Description*	*Total Resistance*	*Resistance Per Step*	*Number of Decades*	*Price in USA*
1434-9714	**Type 1434-N Decade Resistor**	11,111	0.1 Ω	5	$ 99.00
1434-9713	**Type 1434-M Decade Resistor**	111,110	1.0 Ω	5	109.00
1434-9716	**Type 1434-P Decade Resistor**	1,111,100	10 Ω	5	113.00
1434-9576	**Type 1434-QC Decade Resistor**	1,111,105	1 Ω/div	4+rheostat	101.00
1434-9707	**Type 1434-G Decade Resistor**	1,111,111	0.1 Ω	7	155.00

X IS 10



On our new Type 1434 Decade Resistors, as on several other of our new instruments that have a digital readout, we have adopted the convention of using an **X** to denote a 10. Thanks to the Romans, we have a couple of thousand years precedent for this use even though X-is-10-tialism is a rather modern philosophy.

This convention is most useful. For example, most decade boxes have always included a 10 setting in order to facilitate adjustments near a setting of any "round" number. Consider the number of adjustments necessary to go from 49999 to 50000 if the maximum value on each dial were 9. If the last digit went to 10, only one dial would have to be adjusted. However, if the readout is in line, as is now popular, this would result in successive readings of 49999 and 499910, which is wrong by a factor of 10. Clearly, some other symbol, such as **X**, is required to denote 10 to avoid adding the extra digit.

Some practice is required to convert numbers using the **X** into conventional numbers. We suggest that data be taken just as it appears on the readout and conversion carried out later. This not only avoids making mistakes that cannot be checked later but also records the exact dial setting, which may be important in precision work.

DECADE-RESISTOR ACCURACY SPECIFICATIONS

General Radio welcomes, and is participating in, the efforts to produce industry standards for the writing of specifications for decade boxes and related devices. In the meantime the prospective purchaser is faced with comparing the published specifications of different manufacturers and soon begins to suspect that, although the same words are being used, the meanings of the words are not necessarily the same.

Many different terms are used to express the accuracy of decade resistors. Among them are "initial accuracy," "accuracy of adjustment," "calibration accuracy," and just plain "accuracy." We have chosen the term "long-term accuracy" because we feel that this is the specification that is most informative and useful.

In most applications the user of a decade resistance box doesn't want to look at a correction chart (as he might for a single standard resistor) and then to calculate the corrected value for any setting. Also he is not particularly interested in what the accuracy was before the box was shipped to him, and the simple, unmodified term "accuracy" leads to the question of "for how long". Instead, he would like to pick up a decade box and have high confidence that it is within a given tolerance.

By the adjective "long-term" we mean two things. First, GR decade boxes, like all GR instruments, are sold under a two-year warranty. If a decade box is returned because it is outside specifications (without evidence of overload or other abuse) within two years, we will repair and readjust it at no charge*. Secondly, our experience indicates that our decade boxes will hold their specification for many more years, because wire-wound resistors almost always exhibit their greatest changes early in their life. Therefore, if the accuracy of a decade resistor is conservatively rated for a two-year warranty, it probably will be within this specification for many more years.

Obviously, the conditions of measurement have to be explained, and our wording of the specification paragraphs is an attempt to clarify these conditions.

The accuracy we refer to is the accuracy of the resistance difference between any arbitrary setting and the zero setting. It is necessary to take this difference not only because of the residual "zero resistance" of the decade box (a maximum value is specified) but also because of the resistance of any external connecting leads, which, in most cases, will be much larger. The accuracy statement also applies to each separate resistor so that the difference between any two settings on a given dial is accurate to the stated tolerance. This accuracy refers to measurements made at room temperature (23°C), at low power, and at dc or a low frequency. The effects of ambient temperature, applied power, and frequency are given elsewhere in the specification and should be added to the accuracy tolerance to obtain the tolerance under any specific condition.

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* Subject to the conditions stated in our standard warranty.

COAXIAL MICROWAVE NEWS

14-dB (5×) ATTENUATOR

A calibrated fixed attenuator is a convenient device for accurate voltage division in measurement or test systems. In pulse work, moreover, it is important that the division be accomplished without deterioration in rise-time performance.

A recent addition to the GR874 coaxial attenuator line that very nicely meets this criterion in the TYPE 874-G14, a 14-dB unit that gives a 5× voltage division. It rounds out the line in the 10:1, 5:1, and 2:1 division ratios popular with oscilloscope and other pulse-equipment users.

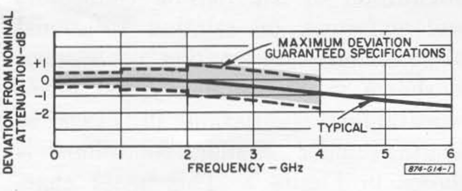


Figure 1. Attenuation vs frequency.

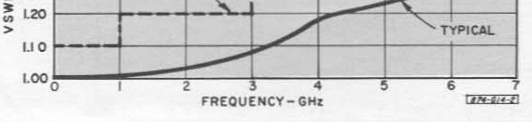
Like the familiar TYPE 874-G6 (2×) and TYPE 874-G20 (10×) Attenuators, it is a 50-ohm T-network fitted with the GR874 Coaxial Connectors. The network elements are carbon-film resistors, for superior performance in handling high-power pulses, and resistance values are held to within ±1%.

As can be seen from Figure 1, the frequency response of attenuation is quite flat. This fact, coupled with the low-VSWR obtainable through the use of the GR874 Connector (as shown in Figure 2), makes these units attractive for pulse applications all the way up to the fractional-nanosecond-rise-time category.

Another important use of attenuators is found in coaxial systems for measuring power, impedance, and VSWR. Attenuators are used to match generator and detector to the 50-ohm line impedance and to isolate the generator from the measuring circuit to prevent changes in load from reacting upon the amplitude and frequency of the generator.

— J. ZORZY

Figure 2. Voltage-standing-wave ratio vs frequency.



Catalog Number	*Description*	*Price in USA*
0874-9560	**Type 874-G14 14-dB (5X) Fixed Attenuator**	**$30.00**

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

TYPE 874-BBL CONNECTOR

A few years ago a locking version of the GR874 Connector, fully compatible with the nonlocking connector yet retaining the hermaphrodite feature, was introduced to provide an electrically and mechanically stable connection and to minimize leakage. While retaining all these characteristics, the TYPE 874-BBL Connector, the latest addition to the GR874 connector series, has a lower VSWR over an extended frequency range, with improved reliability and repeatability of connection.

The TYPE 874-BBL Connector, shown above, replaces the TYPE 874-BL connector for use on rigid 50-ohm air lines. Dimensionally the same, it can be distinguished by a grey (vs clear) bead support and an inner conductor with coated threads. Typical VSWR performance of the TYPE 874-BBL Connector over the 0- to 9-GHz range is shown in Figure 1.

The extended frequency range and improved performance are a direct result of two factors. First, the new polystyrene-bead support is specially compensated. The second improvement factor is the new inner-conductor locking arrangement, achieved by addition of a coating of lead-tin on the 8-32 thread of the connector inner conductor. When the connector inner conductor is threaded into the air-line inner conductor, the coating acts as a semipliable filler. It produces a very reliable electrical contact with a mechanical lock (of about 4 inch-pounds of torque) that prevents loosening of the inner-conductor joint.

Typical VSWR repeatability when the connector junction is repeatedly made and broken, for direct and 180° relative orientation of the mating connectors and extremes of relative rotational play between the mating connectors, is shown in Figure 2. Typical phase repeatability (variation in electrical length) under similar conditions is shown in Figure 3. This latter characteristic is of principal importance in phase-measuring systems, including phased-array radar systems, when disconnection and reconnection of connector junctions in the phase-information paths must be made.

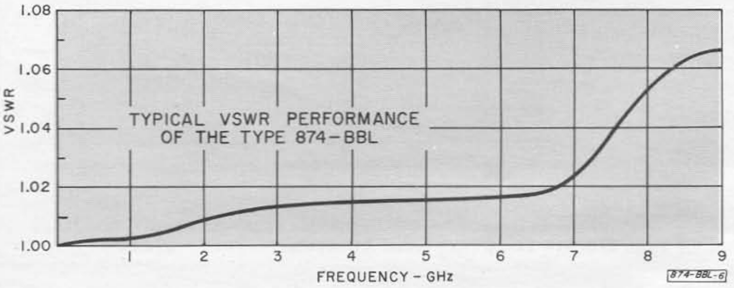


Figure 1. Plot of VSWR vs frequency for a typical mated pair of Type 874-BBL Coaxial Connectors.

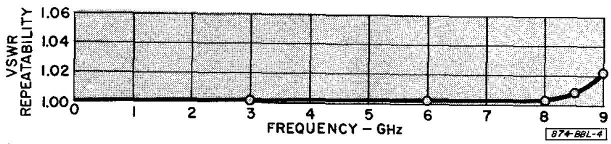


Figure 2. Repeatability, as a function of frequency, of the VSWR when the connection is repeatedly made and broken, for direct and 180° relative orientation of the connectors.

GR874 Connectors are used widely on fast-rise-time pulse equipment, including time-domain reflectometers. In those applications, where it is important that reflections from the connectors be small, the TYPE 874-BBL Connectors are recommended. Figure 4 shows a recording of a time-domain reflectometer display for a pair of TYPE 874-BBL Connectors inserted between two air-line sections that are equipped with GR900 Precision Coaxial Connectors.

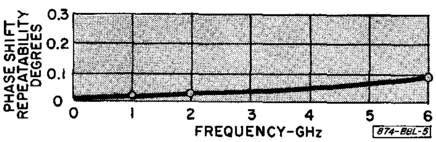


Figure 3. Phase-shift repeatability under same conditions.

Required dimensions for the air-line outer and inner conductors, for proper mounting of the connector, are shown in Figure 5. Two significant changes (vs the TYPE 874-BL) have been made in the preparation of the inner conductor. The 0.162-inch diameter step is needed to achieve the electrical performance indicated. The 0.141-inch diameter is required for proper mechanical fit between the connector inner conductor and the air-line inner conductor.

— T. E. MACKENZIE

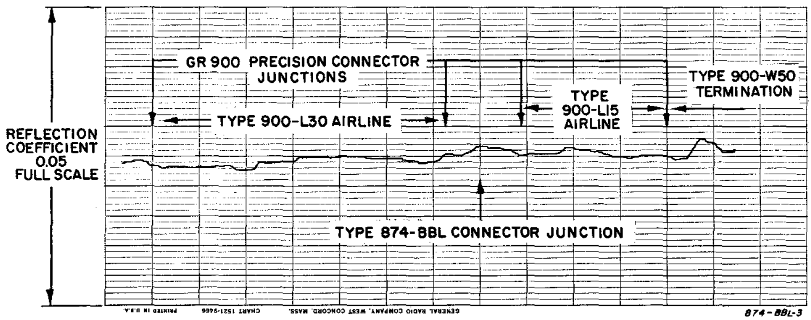
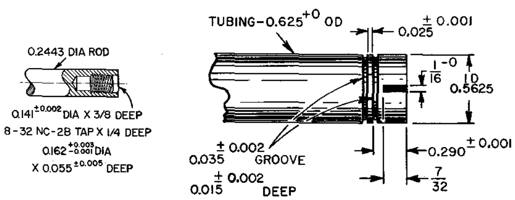


Figure 4. Time-domain reflectometer record for a pair of Type 874-BBL Coaxial Connectors inserted between two air-line sections equipped with GR900 Precision Coaxial Connectors.

Figure 5. Installation dimensions for Type 874-BBL Coaxial Connector. Ends of pieces should be flush, within $^{+0}_{-0.004}$ inch. Allow minimum of 0.531 inch of unobstructed tubing to permit mounting of locking nut. All dimensions are in inches.



Catalog Number	*Description*	*Price in USA*
0874-9403	**Type 874-BBL Connector, locking**	**$3.25**

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

This new, 16-page, illustrated booklet describes some of many ways that the GR Variac® adjustable autotransformer is used in laboratories, factories, and educational institutions — for plastic molding, stage lighting, vacuum coating, distillation, packaging, speed control, electrical testing, and temperature control. Free on request — write for your copy today.

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VOLUME 39 NOS 11 & 12 NOVEMBER-DECEMBER 1965

THE GR FAMILY OF SYNTHESIZERS IS GROWING....

in this issue:

12-MC COHERENT DECADE FREQUENCY SYNTHESIZER

COAXIAL MICROWAVE NEWS

MEASUREMENT BRIEFS

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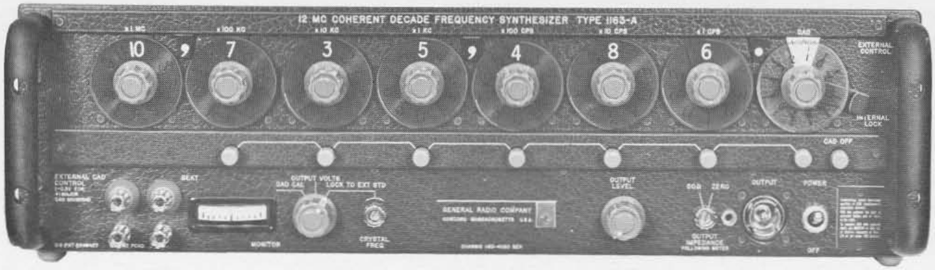
Figure 1. Panel view of the 12-Mc Synthesizer. Note the similarity to the 0.1-Mc and 1-Mc models shown above.



12-MC COHERENT DECADE FREQUENCY SYNTHESIZER

The GR family of frequency synthesizers now welcomes a new member, the 12-Mc TYPE 1163-A. Like its older brothers[1] it uses modular construction, which allows one to order at minimum cost the degree of resolution needed for one's application and also to add increased resolution later, if needed. Other features, common to the 1160 family, include 2-volt output, in-line readout, provision for sweeping, programmable options,[2] and ac or battery operation.

The TYPE 1163-A Coherent Decade Frequency Synthesizer, first displayed at the IEEE Show in March, is now in production. Using the same principles proved in the earlier instruments of the series,[1] it produces coherently synthesized sine-wave frequencies up to 12 Mc/s, selectable in 1-cycle steps. A continuous interpolation dial calibrated in 0.01-cycle divisions improves the resolution by at least two significant figures.

In appearance, the Type 1163-A closely resembles the TYPES 1161-A (100 kc/s , top frequency) and 1162-A (1 Mc/s), as illustrated in Figure 1. Like them, it is a frequency-coherent, beat-frequency oscillator, in which the two frequencies heterodyned to produce any chosen final output frequency are derived from a single, self-contained, 5-Mc, master crystal oscillator. Figure 2 shows in simplified form the basic principles of operation of all three types.

The final output of the TYPE 1163-A is at the difference frequency between

[1] Atherton Noyes, Jr., "Coherent Decade Frequency Synthesizers," *General Radio Experimenter*, September 1964.

[2] G. H. Lohrer, "Remote Programming for GR Synthesizers," *General Radio Experimenter*, May 1965.

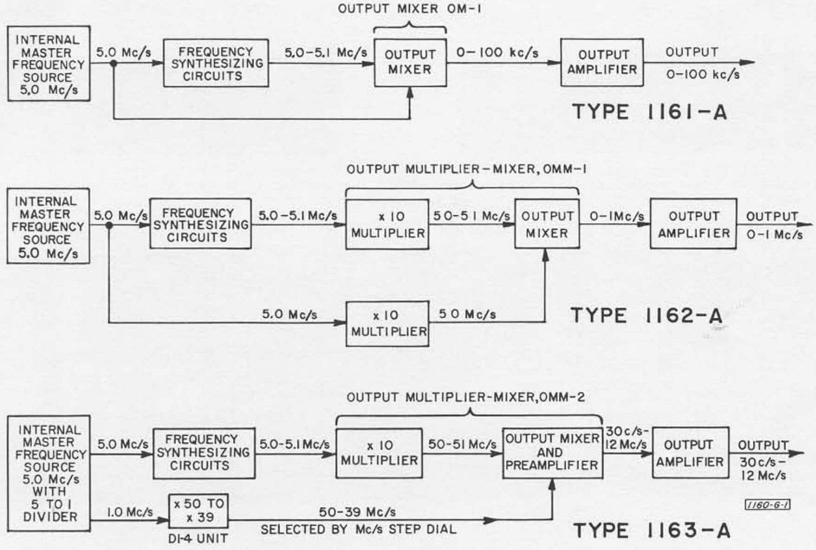


Figure 2. Block diagrams of the three GR synthesizers. All operate on the same principles and use interchangeable modules.

a signal synthesized anywhere in a continuous band from 50 to 51 Mc/s and a second signal generated, at 1.0-Mc increments, between 50 and 39 Mc/s, inclusive. The synthesized frequency between 50 and 51 Mc/s is produced in exactly the same way as in the 1-Mc Synthesizer[1], and all plug-in modules used in the direct synthesis of the 5- to 5.1-Mc band are identical and are readily interchangeable in synthesizers of all three types.

Two new modules are used in the 12-Mc Synthesizer — the Type 1163-DI-4 Digit-Insertion Unit, which develops steps of 1 Mc/s, and a new mixer, the Type 1163-OMM-2 Output Multiplier-Mixer.

The digit module generates the 1-Mc series from 50 to 39 Mc/s and has 12 positions, 0 through 11. Although it is is similar in size to the basic DI-1, the two are not interchangeable.

The mixer accepts at one end the 5/5.1-Mc synthesized signal from the DI-1 and CAD train; its second input, at 50 to 39 Mc/s as selected by the DI-4 dial, is mixed with a signal between 50 and 51 Mc/s produced in the unit by multiplication of the 5/5.1-Mc input by ten. It is noteworthy that the slight departure from the strict decimal system in the DI-4 unit — 12 numbered settings instead of 10 — gives a very useful extension beyond the normal 10-Mc decade limit, without the necessity for an additional digit unit.

Since the DI-4 performs an entirely different electrical function from any of the DI-1 units, the CAD cannot "replace" it in frequency, and, hence, no CAD pushbutton is provided for this position.

At the upper end of the output-frequency range the ratio of frequencies

[1] *Ibid.*
[2] *Ibid.*

applied to the output mixer is not so favorable to the suppression of spurious-frequency mixing products as it is in the lower-frequency synthesizers, and a low-level, more nearly square-law mixer is required. This mixer is followed by a broadband preamplifier (30 c/s to 12 Mc/s) and the final output amplifier.

The chassis of the TYPE 1163-A Synthesizer is superficially the same as that used in both the TYPE 1161-A and the TYPE 1162-A Synthesizers but differs in minor particulars. The two chassis are not interchangeable.

Except that there is no direct-coupled output provided, the operating controls and techniques are identical with those of the other members of the GR synthesizer family.

Continuously Adjustable Decade (CAD)

The Continuously Adjustable Decade (CAD) can replace any chosen group of DI-1 units in exactly the same way[1] as in the other instruments for search, sweep-frequency, or phase-tracking applications, and provisions for monitoring the CAD deviation from replaced dialed digits are identical. By means of the monitoring circuits, one can set the CAD precisely to three, or even more, significant figures, in terms of the digit dials.

Up to four DI-1 Digit-Insertion Units and the CAD can be omitted from any instrument, if not needed for the intended application, at a saving in initial cost, yet can be installed at any time. The rapid and easy interchange of modules between synthesizers also makes possible the transfer of digit units between instruments to suit the needs of the moment. All modules except the DI-4 Digit-Insertion Unit and the OMM-2 Mixer are identical with corresponding plug-in units in the other GR synthesizers and interchangeable with them.

Remote Programming

The RDI-1 Unit[2] can be plugged into any or all DI-1 digit stations in the TYPE 1163-A, just as in the other members of the family, wherever remote programming is required. At the present time a remotely programmable version of the DI-4 is not available.

Output Impedance Control

The screwdriver-operated switch near the output connection, which in the TYPE 1161-A/1162-A chassis selects between ac and dc output coupling, is used in the TYPE 1163-A to set the value of output impedance, after the point monitored by the panel voltmeter, at either 50 ohms or zero. When an impedance match to a 50-ohm load is not required, a voltage adjustable up to at least 2 volts, rms, will be delivered to a load of 50 ohms or higher when the switch is in the zero-ohm position. At the 50-ohm setting, 2 volts, rms, are available behind a 50-ohm matching resistor. The range of the output level control is at least 30 dB without instability of setting.

Receptacles at the Rear*

In this synthesizer, three BNC connectors are mounted at the rear of the instrument to give access to the synthesizer OUTPUT, the EXT CAD CONTROL input circuits, and the CAD deviation-

[1] *Ibid.*
[2] *Ibid.*

* The rear receptacles noted here are also incorporated in all current-production TYPES 1161-A and 1162-A Synthesizers.

monitoring BEAT terminals on the front panel. One additional subminiature receptacle, identified as 5/5.1 Mc/s REFERENCE, also is installed. This connects to the output of the pushbutton-replaced group of DI-1 units (group with dial illumination extinguished) for use in certain specialized applications.

At subminiature receptacles, which appear at the rear of the deck, other useful frequencies are available (see Specifications).

— ATHERTON NOYES, JR.

ACKNOWLEDGEMENTS

The present three GR synthesizers are the result of the combined efforts of G. H. Lohrer, C. C. Evans, W. F. Byers, and the author. In the TYPE 1163-A the primary responsibility for the new modules, the DI-4 and the OMM-2, was carried by Evans, who worked out an ingenious application of sampling techniques to the generation of the DI-4 output frequencies. Lohrer also contributed substantially to the new design, particularly in the output amplifier and mixer. Supporting effort by many other members of the General Radio organization, while well recognized and appreciated, has been too widespread to permit individual mention.

— A. N., Jr.

SPECIFICATIONS

Frequency Range: 30 c/s to 12 Mc/s.
Smallest Digital Step: 1 c/s.
Smallest Direct-Calibrated CAD Increment: 0.01 c/s.
Max Bandwidth Controllable by CAD: 1 Mc/s.
Spurious Frequency Outputs: Harmonic, < -34 dB; non-harmonic, < -60 dB.
Synthesizer Output: 0 to 2 V, metered, behind 50 Ω. 0 to 2 V, metered at output receptacle after low impedance.
Output-Frequency Characteristic: $\pm$ 1.5 db, max, 50 c/s to 12 Mc/s; 50-Ω load.
Output Terminals (at front-panel binding posts and at rear BNC connectors): Synthesizer OUTPUT, EXTERNAL CAD CONTROL, and BEAT.
Other Outputs (at rear connectors): 100 kc/s and 5 Mc/s (0.5 V, rms, min, across 50 Ω); 39 to 50 Mc/s in 1-Mc steps, 50 to 51 Mc/s, 5 to 5.1 Mc/s, 42 Mc/s (0.1 V min across 1 kΩ).
Operating Temperature Range: 0 to 50° C.
Internal Freqency Standard: Room-temperature, quartz-crystal oscillator. Temperature coefficient of frequency is typically less than 2×10^{-7}/°C from 20°C to 50°C. A front-panel frequency adjustment is provided. Crystal can easily be phase locked to an external standard.
Lock Signal Input from external standard (if used): 0.25 V, rms, to 5 V, rms, 5 Mc/s, or any submultiple down to 100 kc/s. Input impedance is approximately 1 kΩ for low-level signals; drops to approximately 50 Ω effective at high level.
Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 400 c/s, 55 W; or 20 to 28 V, dc, 1.8 A.
Accessories Supplied: TYPE 874-R22LA Coaxial Patch Cord, Bridging Unit (maintenance substitute for DI), Panel Insert for use with Bridging Unit, TYPE CAP-22 3-wire Power Cord, spare dial lamps and fuses.
Terminals: Locking GR874 coaxial, TYPE 938 Binding Posts, BNC, and miniature coaxial.
Cabinet: Rack-bench; end frames for bench mount and fittings for rack mount are included.
Dimensions: Bench model — width 19, height 5¼, depth 15½ inches (485 by 135 by 395 mm); rack model — width 19, height 5¼, depth behind panel 13 inches (485 by 135 by 330 mm).
Net Weight: 38 lb (17.5 kg).
Shipping Weight: 45 lb (20.5 kg).

MANUAL OPERATION

Catalog No.	*Type*	*Units Included*	*Price in USA*
1163-9597	**1163-A7C**	7 DI Units+CAD	**$5600.00**
1163-9596	**1163-A6C**	6 DI Units+CAD	**5160.00**
1163-9595	**1163-A5C**	5 DI Units+CAD	**4720.00**
1163-9594	**1163-A4C**	4 DI Units+CAD	**4280.00**
1163-9593	**1163-A3C**	3 DI Units+CAD	**3840.00**
1163-9417	**1163-A7**	7 DI Units	**5100.00**
1163-9416	**1163-A6**	6 DI Units	**4660.00**
1163-9415	**1163-A5**	5 DI Units	**4220.00**
1163-9414	**1163-A4**	4 DI Units	**3780.00**
1163-9413	**1163-A3**	3 DI Units	**3340.00**

REMOTE/MANUAL OPERATION

Catalog No.	*Type*	*Units Included*	*Price in USA*
1163-9527	**1163-AR7C**	1 DI+6 RDI Units+CAD	**$6110.00**
1163-9526	**1163-AR6C**	1 DI+5 RDI Units+CAD	**5585.00**
1163-9525	**1163-AR5C**	1 DI+4 RDI Units+CAD	**5060.00**
1163-9524	**1163-AR4C**	1 DI+3 RDI Units+CAD	**4535.00**
1163-9523	**1163-AR3C**	1 DI+2 RDI Units+CAD	**4010.00**
1163-9507	**1163-AR7**	1 DI+6 RDI Units	**5610.00**
1163-9506	**1163-AR6**	1 DI+5 RDI Units	**5085.00**
1163-9505	**1163-AR5**	1 DI+4 RDI Units	**4560.00**
1163-9504	**1163-AR4**	1 DI+3 RDI Units	**4035.00**
1163-9503	**1163-AR3**	1 DI+2 RDI Units	**3510.00**

THE GR SERIES OF SYNTHESIZERS

The presently available GR synthesizers, TYPES 1161-A, 1162-A and 1163-A, have digital frequency selection up to top frequencies of 100 kc/s, 1 Mc/s and 12 Mc/s, respectively. Each instrument, when fully equipped, has seven dials adjustable in digit steps and an eighth dial adjustable continuously. Since the maximum number of digit dials is fixed, it follows that the smallest available digit step increases in size as the available top frequency increases. Thus, the TYPE 1161-A has digit steps as small as 0.01 c/s, and the corresponding values for the TYPES 1162-A and 1163-A are 0.1 c/s and 1 c/s, respectively. For any application, therefore, the finest resolution can be obtained with the lowest-frequency model capable of covering the required range.

Also, the TYPE 1161-A has, in principle, ten times better phase stability and ten times smaller nonharmonic spurious outputs than the other two, as will be seen in the accompanying table of specifications. The TYPES 1162-A and 1163-A are nominally equal in these respects, so a choice between them can, in most cases, be made on the basis of range and resolution only.

The modular construction with interchangeable plug-in units yields a further advantage, which may influence the choice of synthesizers.

The TYPE 1161-A and the TYPE 1162-A can be transformed, each into the other, inexpensively, by the use of conversion kits comprising, principally, the output mixer modules. The 1160-3040 conversion kit ($295.00) will change a TYPE 1161-A into an 1162-A; for the reverse transformation, kit 1160-3030 is used ($155.00).

	Type 1161-A	**Type 1162-A**	**Type 1163-A**
Frequency Range:	0-100 kc/s	0-1 Mc/s	30 c/s-12 Mc/s
Smallest Digital Step:	0.01 c/s	0.1 c/s	1 c/s
Smallest Direct-Calibrated CAD Increments (A7C-models only):	0.0001 c/s	0.001 c/s	0.01 c/s
Max Bandwidth Controllable by CAD:	100 kc/s	1 Mc/s	1 Mc/s
RD1-1 Units may be used in:	All digit positions		All except 1-Mc step position
Spurious Frequency Outputs: Harmonic (at max output):	<−40 dB	<−40 dB	<−34 dB
Nonharmonic:	<−80 dB	<−60 dB	<−60 dB

COAXIAL MICROWAVE NEWS

• POWER DIVIDERS • TERMINATIONS • TIME-DOMAIN APPLICATIONS

The improved locking version of the GR874 basic connector, TYPE 874-BBL[1], now used on GR Coaxial Elements, has opened the way to broader frequency coverage and improved performance. Elements equipped with the new locking connector have a lower VSWR than formerly, over the extended frequency range of 0 to 9 GHz, with greater reliability and repeatability of connection. These elements are well suited for use in both frequency- and time-domain applications. The new locking connector is fully compatible mechanically with the earlier model, the TYPE 874-BL, and with the nonlocking, quick-disconnect, TYPE 874-B Connector.

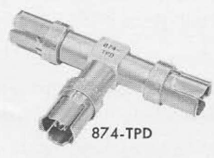
The GR874 series of coaxial elements continues to offer high performance-per-dollar for a wide range of coaxial measurements. Low-VSWR plug and jack adaptors from the GR874 series to other coaxial connector types, both plug and jack, have broadened the scope of this series of elements to include almost all the popular 50-ohm connectors.

Two new elements using the -BBL Connector are a power divider and an improved 50-ohm termination. Both are also available in non-locking versions.

[1] "TYPE 874-BBL Connector," *General Radio Experimenter*, October 1965.


874-TPDL

TYPES 874-TPDL and -TPD POWER DIVIDERS


874-TPD

Each of the TYPES 874-TPDL (locking) and -TPD (nonlocking) Power Dividers comprises a three-port coaxial tee that, throughout the frequency range, is nominally matched at any port when the remaining ports are terminated in 50.0-ohm loads. The broadband match is obtained by the use of three 16.67-ohm series resistors, one in each leg of the tee, and by careful compensation of the resistor surroundings. Figure 1 is a schematic diagram of the Power Divider. The insertion loss between any two ports, when the third port is connected to a matched termination, is nominally 6 dB.

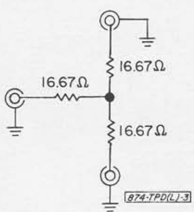


Figure 1. Simplified schematic of Power Divider.

These dividers utilize 1%, deposited-carbon-film resistors that combine high stability with high peak-power capac-

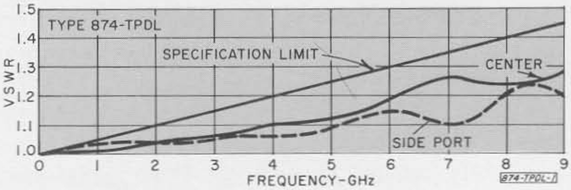
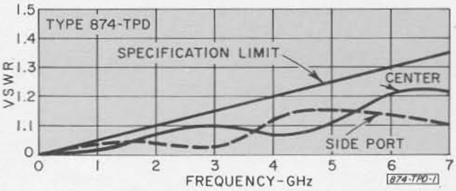


Figure 2. Typical VSWR characteristics.



ity. The film temperature coefficient is the order of −200 to −220 ppm/°C. The VSWR specifications (see Figure 2) provide a linear rise in VSWR with frequency at both the center and side ports of the tee.

Owing to the inherent symmetry, when the power divider is driven from the center port into equal loads, the output signals at the side ports are very nearly equal in amplitude and phase. Figure 3 shows the typical inequality of output signals in decibels.

The insertion loss between the center port and a sideport, with a matched source and matched load, deviates somewhat from 6 dB with increasing frequency owing to the distributed-impedance effects of the resistors at higher frequencies. Figure 4 shows the typical insertion loss for both types.

General Applications

The Type 874-TPDL/-TPD Dividers are used to split a signal into two approximately equal parts, with a minimum of reflections introduced in the process. When the divider is used to split the output of a nominally 50-ohm source between two 50-ohm loads, each load will be driven at a level 6 dB below the source output. Very little of the source signal is reflected at the power-divider input owing to the low input VSWR. Any signals reflected from the loads are isolated, by the 6-dB insertion loss of the power divider, from each other and from the source. Re-reflections at the divider outputs are small, again owing to the low divider standing-wave ratio.

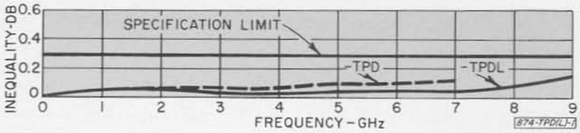


Figure 3. Typical inequality of output signals at side ports.

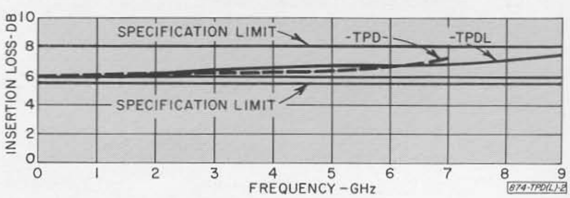


Figure 4. Typical insertion loss between center and side ports.

These dividers are also used (usually in conjunction with some additional isolation devices such as GR874 Attenuators) to combine two signals. In this case, the two source signals are isolated from each other by the divider insertion loss and any additional padding. The sum of the two applied signals appears at the common port of the divider.

Applications are found in antenna-feed systems, in dual-channel insertion-loss or phase-measuring systems, and in pulse systems. The applications to the last area are discussed in greater detail on page 12.

SPECIFICATIONS

TYPE 874-TPDL POWER DIVIDER

Frequency Range: dc to 9 GHz.
Characteristic Impedance: 50 Ω, nominal.
VSWR (at any port when remaining ports are terminated in matched 50-Ω loads): Less than $1.00 + 0.05 \times f_{GHz}$ to 9 GHz.
Inequality of Power Division (symmetrically fed): Less than 0.3 dB.
Phase Difference between Outputs (symmetrically fed): 0°, nominal.
Insertion Loss (between any two ports when remaining port is terminated in a matched 50-Ω load): 6 dB, nominal.
Insertion Loss (input to each output, symmetrically fed): $6.0 \begin{smallmatrix} +2.0 \\ -0.5 \end{smallmatrix}$ dB.
Dc Resistance (at any port, when remaining ports are terminated in 50.00-Ω resistors): 50.00 ± 0.25 Ω (0.5%).
Maximum Input Power: 2 W, continuous.
Dimensions: Width 4, height 2⅝, depth 1$\frac{1}{16}$ inches (105 by 60 by 27 mm).
Net Weight: 6 ounces (170 grams).

Catalog Number	*Description*	*Price in USA*
0874-9913	**Type 874-TPDL Power Divider**	**$73.00**

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

TYPE 874-TPD POWER DIVIDER

Same as Type 874-TPDL, except:
Frequency Range: 0 to 7 GHz.
VSWR (at any port when remaining ports are terminated in matched 50-Ω loads): $1.00 + 0.05 \times f_{GHz}$ to 7 GHz.
Dimensions: Width 4, height 2⅝, depth $\frac{13}{16}$ inches (105 by 60 by 20 mm).
Net Weight: 5 ounces (145 grams).

Catalog Number	*Description*	*Price in USA*
0874-9912	**Type 874-TPD Power Divider**	**$70.00**

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

TYPES 874-W50BL and -W50B 50-OHM TERMINATIONS

New 50-ohm terminations, the Types 874-W50BL and −W50B, now replace the Types 874-W50L and −W50. In these new terminations the design of the resistor surroundings has been improved,[2] and the Type 874-W50BL is equipped with the new Type 874-BBL Connector.

Figure 5 shows the VSWR specification, as well as the performance of a

[2] MacKenzie, T. E., "Recent Advances in the Design of Precision Coaxial Standards and Components," *1965 IEEE Convention Record*, Part 5, Session 67, p 190.

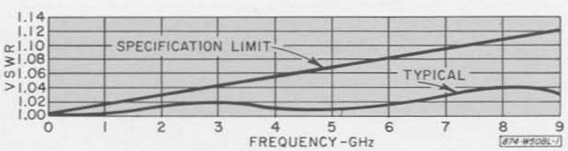


Figure 5. Type 874-W50BL Termination VSWR.

typical unit, for the TYPE 874-W50BL; Figure 6 shows similar curves for the TYPE 874-W50B, which is equipped with the non-locking connector, TYPE 874-B.

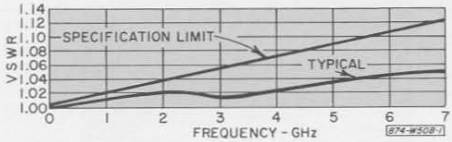


Figure 6. Type 874-W50B Termination VSWR.

The terminating element used in both units is a highly stable, deposited-metal-film resistor with a dc resistance of 50.0 ohms ±0.3% and a temperature coefficient of less than 150 ppm/°C. The change in resistance and VSWR versus heating due to incident power is negligible up to 1 watt. The resistors can dissipate up to 5 watts incident power without permanent change of characteristics.

General Applications

The TYPE 874-W50BL/-W50B Terminations are used as standards in the calibration of bridges, slotted lines, and reflectometers and as reference terminations in measurements of multiport networks. They are well suited for use with the TYPE 874-LBA Slotted Line as a termination for impedance measurements of multiport networks equipped with GR874 Connectors. Through the use of GR874 Adaptors, these terminations can be used as dummy loads in other line sizes. Their use in time-domain applications is discussed below.

SPECIFICATIONS

TYPE 874-W50BL 50-OHM TERMINATION

Frequency Range: dc to 9 GHz.
VSWR: Less than $1.005 + 0.013 \times f_{GHz}$.
Dc Resistance: 50.0 ohms ±0.5%.
Maximum Power: 2 watts, continuous (1 watt with negligible change in resistance and VSWR; 5 watts without damage).
Dimensions: Length, 2¼ inches (57 mm); maximum diameter, 1$\frac{1}{16}$ inches (27 mm).
Net Weight: 3 ounces (85 grams).

Catalog Number	*Description*	*Price in USA*
0874-9955	**Type 874-W50BL 50-ohm Termination**	**$24.00**

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

TYPE 874-W50B 50-OHM TERMINATION

Same as Type 874-W50BL, except:
Frequency Range: dc to 7 GHz.
VSWR: less than $1.005 + 0.017 \times f_{GHz}$.
Dimensions: Length, 2¼ inches (57 mm); maximum diameter, $\frac{13}{16}$ inch (20 mm).
Net Weight: 2½ ounces (70 grams).

Catalog Number	*Description*	*Price in USA*
0874-9954	**Type 874-W50B 50-ohm Termination**	**$23.00**

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

TIME-DOMAIN APPLICATIONS OF COAXIAL ELEMENTS

The GR874 series of coaxial elements — connectors, air lines, tees, terminations, etc, are widely used in pulse-system measurements. In these time-domain applications they offer high performance at low cost, and their hermaphroditic-mating and quick-disconnect features help to save both time and money.

With the advent of fast-rise-time, gigahertz-pulse generators and sampling oscilloscopes, emphasis has been put on the high-frequency performance of coaxial elements. Here again the

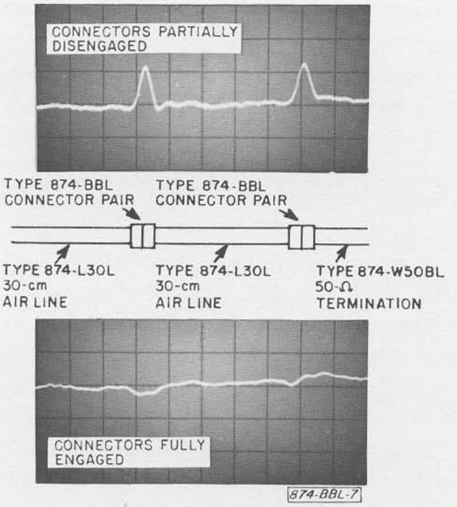


Figure 7. Time-domain reflectometer traces. Vertical scale: Reflection coefficient = 0.005/cm. (Z_0, normalized to 50 ohms, 1%/cm.) Horizontal scale: 6 cm of line/cm.

broad line of GR874 coaxial elements provides the required performance characteristics.

Bandwidth and pulse rise-time are related approximately by $bw = 0.35/rt$. Thus, the typical fast pulse characterized by a 100-ps rise-time corresponds to a bandwidth of about 3500 MHz. To keep pulse distortion and reflection low, it is necessary to keep the VSWR of the associated coaxial circuitry low over the full bandwidth of the pulse. The new GR874 Coaxial Elements meet this need. For example, the Type 874-TPDL Power Divider introduces a VSWR of less than 1.18 up to 3500 MHz while the Type 874-W50BL Termination VSWR is less than 1.05 up to 3500 MHz.

The advantages of GR874 elements for handling fast-rise-time pulses are further illustrated by time-domain reflectometer traces.

Figure 7 shows time-domain reflectometer traces of two Type 874-L30L Air Lines connected in series and terminated in a Type 874-W50BL. All connectors are the new Type 874-BBL Locking Connectors. To obtain the upper trace, the connector joints were partially disengaged in order to pin point their locations. For the lower trace, the connectors were fully engaged; characteristic impedance variations throughout the air line, connector, and termination sections are less than 0.5%.

Sampling Oscilloscope

Reflectometer

Figure 8 illustrates the use of the Type 874-TPDL/-TPD Power Divider in time-domain reflectometry instrumentation built around a sampling scope.[3,4,5] The power divider transforms the pulse generator into a nearly matched source, thereby reducing troublesome re-reflections, even in the presence of large reflections from the unknown.

The air line provides time isolation between the source and the unknown impedance reference. The characteristic impedance of the Type 874-L Air Lines

[3] Long, Gordon D., "Pulse Reflections Pin Down Discontinuities," *Electronic Design*, May 10, 1963, pp 62–66.
[4] Noel, D. R., "Subnanosecond Instrumentation," *IEEE Student Journal*, January 1964, pp 27–32.
[5] Application Note 62, "Time-Domain Reflectometry," Hewlett-Packard Company, 1964.

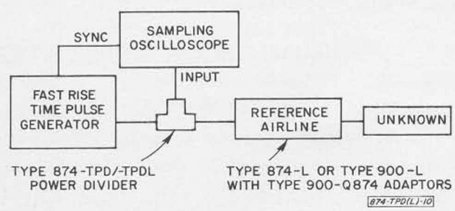


Figure 8. Use of the Type 874-TPDL/-TPD Power Divider in time-domain reflectometry instrumentation built around a sampling oscilloscope.

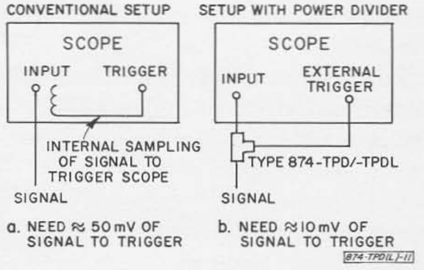


Figure 9. Use of the Type 874-TPDL/-TPD Power Divider to increase the sensitivity of sampling oscilloscopes.

is 50.0 ohms ±0.4%. The characteristic impedance of the Type 900-L Air Line, which can be used with Type 900-Q874 Adaptors to the GR874 line size, is 50.0 ohms ±0.065%.

Type 874-W50BL/-W50B Terminations keep reflections low at the output ports of multiport unknowns.

Trigger

Sampling-oscilloscope sensitivity can often be increased by a factor of five if a power divider is used in the signal-input line. The performance improvement is brought about by external division of the signal to increase the trigger input. Thus, a representative sampling oscilloscope that requires a 50-millivolt signal to provide 5 millivolts of trigger internally can trigger equally reliably on input signals of only 10 millivolts, when the power divider is used. Figure 9 shows this principle.

Pulser Accessories

The repetition rate of most fractional nanosecond-rise-time pulse generators can be extended from several hundred hertz to the region of several hundred megahertz by cascaded power dividers. As shown in Figure 10, power dividers can be cascaded to fractionize the original pulse, and additional dividers can be used to recombine the resulting signal, after suitable delays, into a train

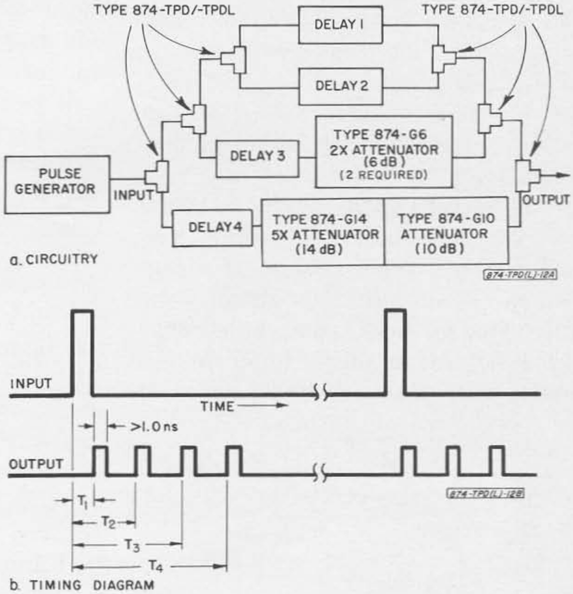


Figure 10. Cascaded power dividers used to construct a pulse burst, which effectively raises the repetition rate of a subnanosecond-rise-time pulse generator to several hundred megahertz.

of pulses, adjustably spaced in times T_1 through T_4.

This application envisions as a pulse generator one that consists of a 50-ohm charge line operated with a mercury-wetted reed switch.

GR874 Air Lines can be used for minute delays (up to 1 ns), and GR874 Attenuators are available to achieve compensatory losses, where required, for pulse bursts of uniform amplitude.

The Type 874-G6 (6 dB or 2×) Attenuator bears the most convenient relation to the insertion loss in the divider.

Patch cords, ells, adaptors, and other elements needed to complete the system are available.

— Thomas E. MacKenzie

Credits

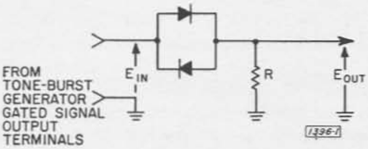
The writer gratefully acknowledges the contributions of time-domain applications of the GR874 elements provided by J. K. Skilling and D. S. Nixon, Jr. of the GR engineering staff.

MEASUREMENT BRIEFS

A Note on the Tone-Burst Generator Reduction of Gate Feedthrough

Some users of the Type 1396-A Tone-Burst Generator may require a ratio of open- to closed-gate signal greater than the 40 dB we specify (43 dB typical). It is not possible to modify the design of the instrument in this respect without sacrificing switching-noise suppression and gate speed (maximum frequency).

Addition of the circuit shown below, however, can reduce the feedthrough by introducing a small amount of distortion in the output. This circuit is an attenuator for small voltages (less than ±1 volt), and it passes other voltage levels with little attenuation. Since feedthrough is in the ±1-volt range, it is attenuated, but the desired signal (assumed at maximum level of ±7 volts) has only a small amount of distortion near the zero crossings. This distortion looks much like crossover distortion and may be quite acceptable in some applications.



With germanium diodes, 1N455-type, and a value of R of 1.0 kilohm, the feedthrough varies from −55 dB at 500 kc/s to −58 at 20 kc/s and below. With silicon diodes, 1N459A-type, and a value of R of 10 kilohms, the feedthrough drops to −63 dB at 500 kc/s, −77 dB at 20 kc/s, and less than −80 dB at 2 kc/s and below. The silicon diodes, however, introduce more distortion than the germanium diodes. By the addition of bias sources in series with the silicon diodes it should be possible to effect a compromise between distortion and attenuation of feedthrough.

— J. K. Skilling

Instrument Note on Frequency Converter

The TYPE 1133-A Frequency Converter[1] extends the range of 10-Mc counters to 500 Mc/s. Originally designed for use with GR counters, it can also be operated with counters of other manufacture. Details of this use are discussed in a recently published Instrument Note, free on request. Ask for IN-106.

[1] H. T. McAleer, "A New Converter for Frequency Measurements to 500 Mc," *General Radio Experimenter*, December, 1962.

Capacitance Change Measures Strain in Fibers

A recent article[1] in *The Review of Scientific Instruments* describes a new testing device for inorganic whiskers and other fine fibers, developed by the Laboratory for Physical Science of P. R. Mallory and Company at Burlington, Mass. The fiber-holding device replaces one pan of an analytical balance. Measurable stress can be applied by weight in the other pan. Flat electrodes on the holder form the plates of a capacitor, whose capacitance changes with changes in length of the fiber under test.

The capacitance change is measured with a GR TYPE 1615-A Capacitance Bridge, which is capable of detecting a change of 1×10^{-17} F.

[1] R. H. Kelsey and R. H. Krock, "Microfiber Stress-Strain Apparatus," *The Review of Scientific Instruments*, 36, 7, July 1965, pp 1031–1034.

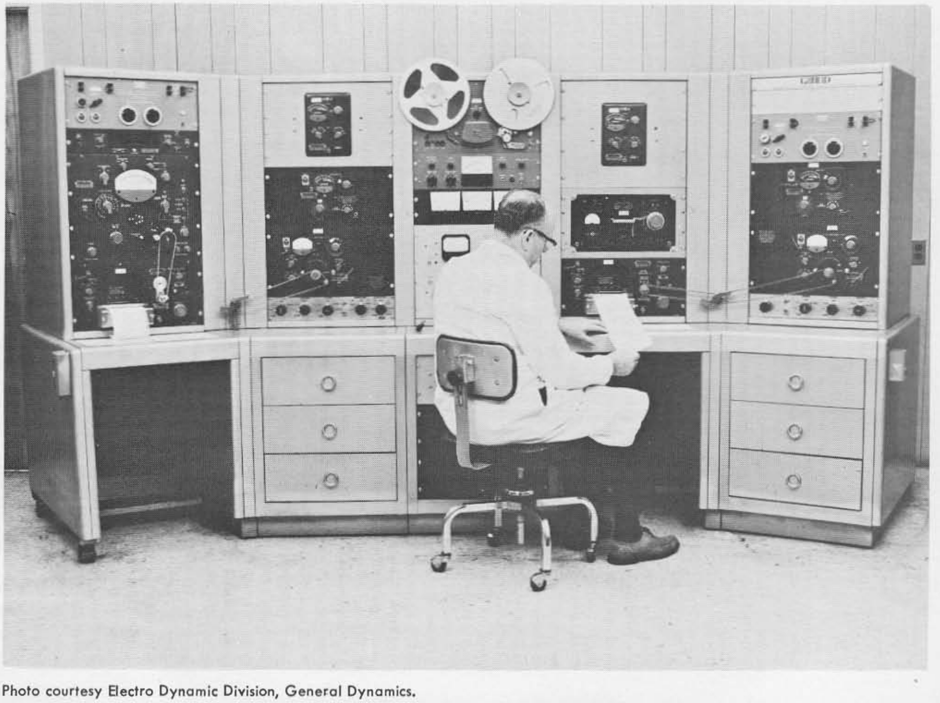
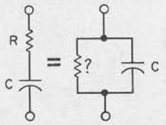


Photo courtesy Electro Dynamic Division, General Dynamics.

In this console, used in tests on motor-generator sets, GR sound-level meters, analyzers, and recorders measure air-borne sound and automatically record the frequency spectra of structure-borne vibrations. Electro Dynamic at Avenel, N. J., manufactures heavy electrically operated equipment, including ac and dc motors, generators, blowers and fans, frequency converters, and HERF machines.

OUR ABACUS SLIPPED A COLUMN



The less-than-perfect arithmetic on page 12 of our July issue has recently been called to our attention. We had hoped it would be overlooked. Mr. P. K. McElroy, author of the article in question, cannot be held responsible, since he retired from the General Radio Engineering Staff a full six months before the article was published, and, further, these figures were not in his original article. For the record, however, an editorial apology to him and a published correction are in order. Thus—to Mr. McElroy, our regrets for having, by implication, attributed to him the faulty calculations, and, for the record, these are the ohms:

0.0016 ohm should be 0.016 ohm

16 ohm should be 160 ohm

26 ohms should be 13 ohms.

Fortunately for the unidentified toiler who perpetrated these errors, the corrections in no way alter the conclusions drawn in the article.

GENERAL RADIO COMPANY EXTENDS TO ALL EXPERIMENTER READERS ITS BEST WISHES FOR A HAPPY AND PROSPEROUS 1966

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