the GENERAL RADIO Experimenter

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TO

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EXPERIMENTER

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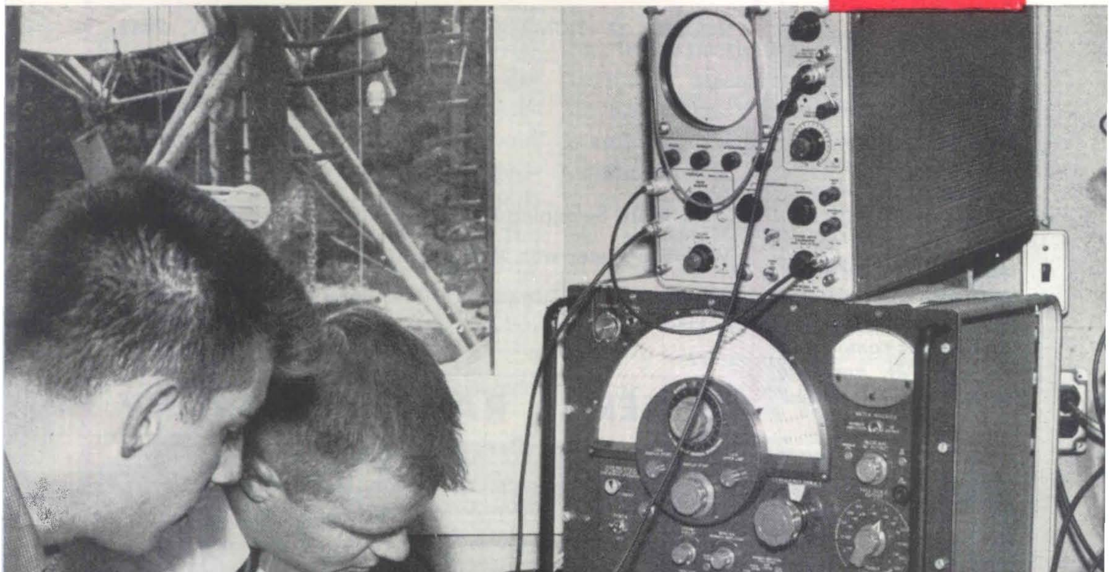
EXPERIMENTER



VOLUME 37 No. 1 JANUARY, 1963

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Standard Sweep-Frequency Generator

Vibration Meter in Metric Units

Single-Pulse Trigger

THE GENERAL RADIO

EXPERIMENTER

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COVER

Engineers at Tapetone Electronics Laboratories, manufacturers of frequency converters for ham radio and for telemetry, are shown with the Type 1025-A Standard Sweep-Frequency Generator in aligning a converter. In this application, the stability and versatility of the generator save time and assure accurate alignment.

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GENERAL RADIO COMPANY (OVERSEAS), ZURICH, SWITZERLAND
REPRESENTATIVES IN PRINCIPAL OVERSEAS COUNTRIES

A STANDARD SWEEPING-FREQUENCY SIGNAL GENERATOR

The General Radio Company has for many years manufactured standard-signal generators, the word standard denoting that certain characteristics (usually the frequency, amplitude, and modulation) of the output signal provided are accurately indicated, or standardized. With the introduction of the TYPE 1025-A Standard Sweep-Frequency Generator, the *standard* concept has been extended to the sweeping-frequency signal generator.

This generator has been designed to be as universally applicable as possible, but is particularly useful for sweep-frequency measurements on wide-band devices where a multiplicity of adjustments must be set to secure the desired characteristics.

In this instrument, the frequency of the sinusoidal output is varied in a smooth, continuous manner over a frequency band in repetitive cycles by means of a motor-driven tuning capacitor. By this means, the amplitude response of a network or device as a func-

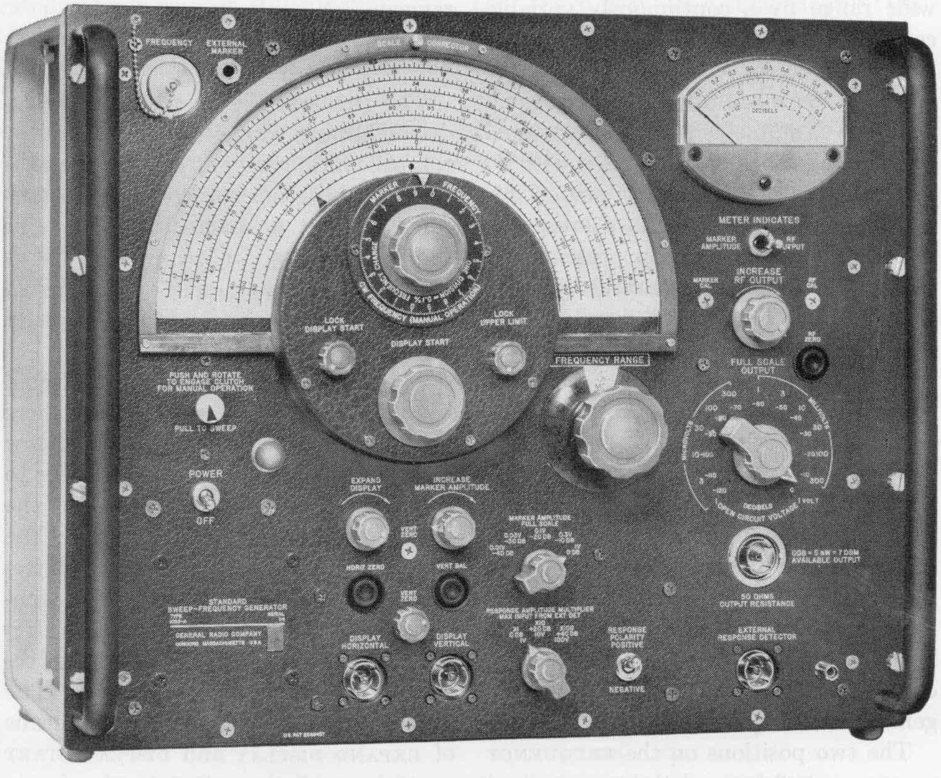

Figure 1. Panel view of Type 1025-A Standard Sweep-Frequency Generator.

tion of frequency can be displayed automatically on an oscilloscope. A synchronously varying horizontal deflection is provided for the oscilloscope. The large dial on the instrument indicates the frequency of a manually positioned marker on the display. The amplitude of the marker is adjustable and is monitored by a panel meter, thus providing complete frequency and amplitude calibration of the displayed response.

An automatic amplitude-control circuit holds the rf output behind an accurate 50-ohm resistance at a manually preset level, independent of frequency, line voltage, and load variation. The rf output level is accurately indicated by the panel meter and is adjustable over a wide range by a continuously variable control and step attenuator.

The generator can also be quickly switched to cw operation, in which function it is as stable as a non-swept signal generator, so that it can be used with an external digital frequency meter for really precise measurements of a response after a preliminary sweep presentation shows that such detailed measurements are justified. This is not possible with the usual sweep generator, so that often both a sweep generator and a cw signal generator are necessary.

Frequency Ranges

The oscillator coils for the various frequency ranges are mounted on a 12-sector turret which is designed to permit individual sectors to be readily replaced for special ranges. The instrument is normally supplied with ten octave ranges covering from 0.7 to 230 Mc with generous overlaps.

The two positions on the FREQUENCY RANGE control beyond the ten required for 0.7 to 230 Mc are normally supplied with bandspread sectors of 400 to 500 kc and 10.7 ± 0.3 Mc. Additional bandspreads can be had at the sacrifice of general-coverage ranges up to the 12-sector capacity of the turret. The bandspread ranges have an essentially linear frequency distribution on the display, while the octave ranges have a logarithmic distribution. In order to make use of a single pre-calibrated multi-scale dial, the available bandspreads have been quantized to fit a zero center ±30 scale, a zero center ±100 scale, and a 40 to 50 scale. For the general-coverage octave ranges there are four nearly logarithmic scales which are used for 0.4 to 80 Mc and two quasi-logarithmic scales for the 65- to 140-Mc and 100- to 230-Mc ranges.

Automatic Sweeping

The frequency is swept by a motor-driven tuning capacitor. The capacitor rotates continuously at 1200 rpm and is balanced both mechanically and electrically, so that no balancing weights or sliding contacts are required. This is accomplished by a split-stator design with the rotor plates divided equally about the axis of rotation.

The entire frequency range selected is swept in 1/45 of a second, and there are 20 sweeps per second. The oscillator output is blanked off between sweeps to permit the capacitor to return to the low-frequency end of the range; the sweeping is always from low to high frequencies. A sawtooth voltage is generated in synchronism with the frequency sweeping for horizontal deflection of a cathode-ray oscilloscope. The entire range is swept, but, by means of EXPAND DISPLAY and DISPLAY START controls, as little as one-tenth of any octave range can be set to occupy the full screen width of the display oscilloscope. Where additional resolution is required, bandspread ranges can be provided on special order covering as little as 5% in frequency for the full-range sweep, and this, too, can be reduced by expansion of the display to one-tenth of the full range.

Manual and Slow-Speed Sweeping

In addition to the normal sweep mode of operation, the sweep motor can be stopped and a clutch engaged to connect the marker control and frequency indicator directly to the tuning capacitor for manual control of the frequency. In this mode, the frequency indicated on the dial is the cw frequency generated. The generator still functions as a sweep generator since a dial potentiometer provides a display sweep voltage proportional to frequency-indicator travel. In fact, the dial potentiometer is arranged to duplicate operation in the normal sweep mode, so that the DISPLAY START and DISPLAY EXPANSION controls continue to function. Thus, an XY plotter can be connected to replace the oscilloscope used with the high-speed sweep, and a plot of the response obtained by slow rotation of the frequency knob.

The manual drive provides a test method for determining whether the automatic sweeping speed is excessive for the device under test and, if it is, for plotting the true response. In addition, two dial drives are available, and can be attached to the dial in place of the manual-drive knob. The TYPE 908-P2 Synchronous Dial Drive is used for slow-speed sweeping (10 seconds to sweep the full range of the dial) for display on an oscilloscope with a long-persistence phosphor. The TYPE 908-P3 Dial Drive provides a single sweep (1¼ minutes) for use with an XY plotter.

Marker Generation

The heart of this instrument, which makes it unique among sweeping generators, is the system used to provide

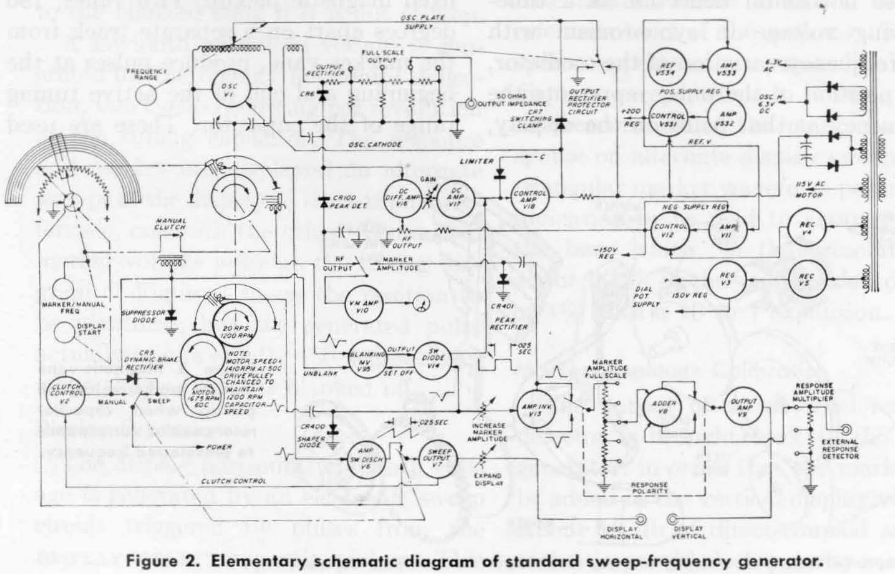

Figure 2. Elementary schematic diagram of standard sweep-frequency generator.

frequency markers in the normal sweep mode of operation. Figure 2 is an elementary schematic. The angular position of the variable capacitor can obviously be calibrated in terms of frequency generated for any particular range. The position of the capacitor is used as an indication of frequency, but in the sweep mode it is done instantaneously. Figure 3 is a cutaway drawing showing how this is accomplished. The capacitor drive drum carries a thin iron vane, which generates a pulse as it passes a magnetic pickup device. The pickup's angular position is indicated on a dial and can be adjusted to coincide with the capacitor vane at any position of the capacitor within its active range. For each setting of the marker pickup dial, the pulse generated occurs at a particular position of the tuning capacitor and consequently at a particular frequency. The dial therefore can be calibrated in frequency existing at the instant the pulse occurs. If this pulse is displayed as a vertical deflection on an oscilloscope whose horizontal deflection is a time-varying voltage in synchronism with the frequency variation of the oscillator, the position of the pulse represents the frequency at that point on the display, regardless of any nonlinearities that may be present in the display horizontal deflection.

Since the response is presented as a vertical deflection on the display, the superposition of the marker could distort the picture. To avoid this, we take advantage of the fact that the tuning capacitor is useful for only 180 degrees of its range. Figure 4 is a timing diagram showing the relationship of events in the sweep cycle.

The oscillator is blanked off for the second 180 degrees of capacitor rotation and, since the rotating capacitor with its drive drum is a very good flywheel, the angular speed of the second 180 degrees is the same as that of the first 180 degrees of rotation. Consequently, the time relationships in the two half-revolutions are identical for all practical purposes. The marker vane is positioned 180 degrees from the position to be identified, so that the marker is generated while the oscillator is blanked off. The blanking is controlled by pulses from a fixed magnetic pickup. Two vanes, 180 degrees apart on a separate track from the marker vane, produce pulses at the beginning and end of the active tuning range of the capacitor. These are used

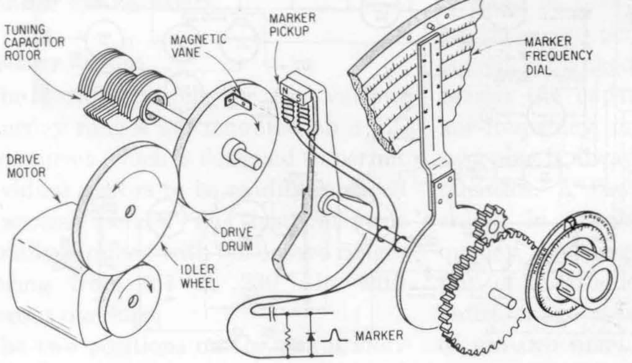

Figure 3. Magnetic vane induces marker voltage in pickup when capacitor rotor position corresponds to preselected frequency.

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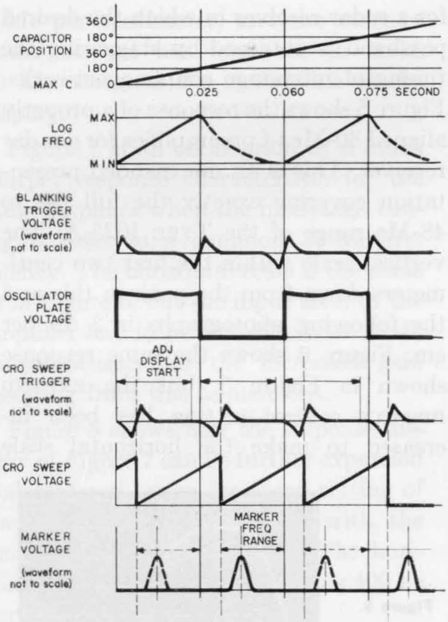


Figure 4.
Timing diagram of one complete sweep cycle.

to complement a bi-stable blanking multivibrator. The proper phasing of the blanking is obtained by use of the marker pulse to set the multivibrator to the blanked state if it is out of step.

A sawtooth waveform voltage is generated for the display horizontal deflection, two cycles occurring per revolution of the tuning capacitor. The response and marker are displayed on alternate sweeps of the display so there is no interference, one with the other. The dotted marker-voltage pulse on the timing diagram of Figure 4 shows the position to be identified, but the generated pulse actually occurs exactly 180 degrees later while the oscillator is blanked off.

Display Expansion

The display horizontal sawtooth voltage is generated by an electronic sweep circuit triggered by pulses from the DISPLAY START magnetic pickup. This pickup operates with the same rotating vanes used for the blanking, and thus two equally-spaced pulses are produced per revolution of the tuning capacitor. The angular position of the pickup can be varied by the DISPLAY START control to set the point at which the display sawtooth starts. This, in conjunction with the EXPAND DISPLAY control, permits any part of a frequency range to be expanded on the display. About 10 to 1 is the practical limit of expansion, so that 1/10 of any tuning range can be made to occupy full scale of this display. This requires a 10-volt full-scale display horizontal sensitivity, since the maximum peak-to-peak amplitude of the sawtooth is 100 volts. The start of the sawtooth is clamped to zero, so that with a direct-coupled oscilloscope the start of the display remains fixed and the excess voltage deflects the trace-off scale to the right. The base width of the marker is less than 1% of the unexpanded display, and, since it occurs when the oscillator is blanked off, the base line on which it sets is the zero reference level of the response. The response appears as a separate line on the display, except when it is zero, owing to presentation of the marker and response on alternate display sweeps. The triangular marker waveform permits the indication to be read to about 1/10 of the base width, so that resolution is about 0.1% of the unexpanded display or 1% with a 10 to 1 expansion.

Marker-Amplitude Calibration

The output of an external response detector is brought back to the signal generator, in order that the marker can be added to the vertical display voltage. About 18 db of direct-coupled amplification is provided. A polarity-reversing switch permits a right-side-up display with a response detector of either output polarity. Step attenuators and the metering of the adjustable marker amplitude provide means of calibrating the vertical scale of the display.

Detector

When the device under test includes a detector, its dc output can be fed directly into the EXTERNAL RESPONSE DETECTOR terminals of the generator.

Where there is no built-in detector, the Type 1025-P1 Detector Probe, supplied with the generator, will be found satisfactory for most uses. Its high input impedance imposes no appreciable load on the device under test.

For 50-ohm systems, the Type 874-VQ Voltmeter Detector and Type 874-WM 50-ohm Termination are recommended.

Generator Output Calibration

The rf output voltage is provided as a true zero-impedance generator voltage in series with an accurate 50-ohm resistance. The maximum value of the voltage is one volt and is adjustable down to a fraction of one microvolt by means of a 10-db-per-step attenuator and a continuously adjustable output control. The output is indicated on a meter with a multiplying factor determined by the attenuator setting. A db calibration relative to the one-volt output is provided in addition to a voltage calibration.

Applications

One of the important fields of application for this generator is, as pointed out previously, in measurements on wide-band devices where many adjustments are necessary to get the desired response. A good example of this use is in the alignment of a wide-band i-f amplifier for a radar receiver in which the desired passband is obtained by staggering the tuning of interstage coupling networks. Figure 5 shows the response of a properly aligned 30-Mc i-f preamplifier for a radar receiver. This is an unexpanded presentation covering exactly the full 24- to 48-Mc range of the Type 1025-A. The vertical scale within the first two centimeters down from the peak in this and the following photographs is 2 db per cm. Figure 6 shows the same response shown in Figure 5, but the EXPAND DISPLAY control setting has been increased to make the horizontal scale

Figure 5.

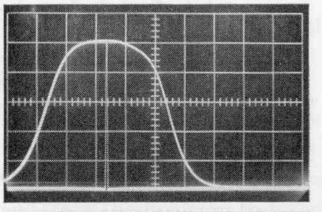


Figure 6.

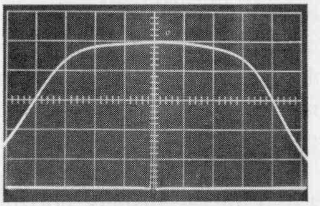


Figure 7.

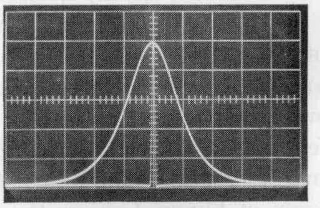
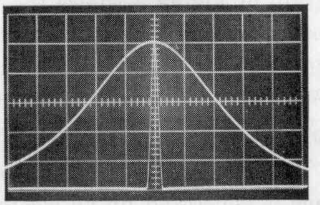


Figure 8.



Figures 5-8.
Response characteristics of 30-Mc i-f amplifier for various alignment and sweep conditions (see text).

1 Mc per centimeter, and the DISPLAY START control has been set to make 30 Mc occur on the center line of the display.

Figure 7 is an oscillogram of a much sharper response characteristic for the same amplifier when the interstage tuning is reset to a common 30-Mc frequency. The horizontal scale is the same as in Figure 6, but the input level to the amplifier had to be reduced about 20 db to compensate for the increased gain resulting from this adjustment.

Figure 8 shows how the response display of Figure 7 can be further expanded and centered by an increased setting of the EXPAND DISPLAY control with the DISPLAY START control reset. The horizontal scale in this photograph is 400 kc per centimeter.

In all these oscillograms the marker is at 30 Mc, but it may be used to calibrate both horizontal and vertical scales of the display. Incidentally, the amplifier whose characteristics are shown was designed to work from a 300-ohm source shunted by a 10-pf capacitance, representing the output impedance of the crystal-diode-microwave mixer in the radar receiver. A dummy network, consisting of a 250-ohm series resistor in a TYPE 874-X Insertion Unit with a 10-pf capacitor across the output connector, can be quickly assembled to provide the proper source impedance for testing this amplifier. Similarly, other impedances may be provided for testing devices requiring source impedances differing from the 50-ohm output of the generator.

— W. F. BYERS

CREDITS

The design and development of the TYPE 1025-A Standard Sweep-Frequency Generator was carried out by W. F. Byers, supported by E. Karplus, Group Leader; E. Favre, designer; D. Foss, production engineering; W. Montague, design drafting; and W. Poté, test engineering; plus many others in Engineering who contributed to the details of the design.

— EDITOR

SPECIFICATIONS

FREQUENCY

Range: 0.7 to 230 Mc in 10 ranges (0.7 to 1.4, 1.3 to 2.6, 2.4 to 4.8, 4 to 8, 7 to 14, 13 to 26, 24 to 48, 40 to 80, 65 to 140, and 100 to 230 Mc) and bandspread ranges of 400 to 500 kc and 10.7 ± 0.3 Mc.

Alternate range sectors can be substituted in the range-selector turret. Those presently available are: 0.4 to 0.8 Mc, 2 ± 0.1 Mc, 2.8 ± 0.1 Mc, 4 to 5 Mc, 16 ± 0.3 Mc, and 40 to 50 Mc. Special bandspread ranges can be provided according to the following schedule:

Specified Center Frequency	*Bandwidth*
Between 0.4 and 0.5 Mc	±0.01 Mc
0.45 and 1.6 Mc	±0.03 Mc
1.4 and 5 Mc	±0.1 Mc
4.5 and 16 Mc	±0.3 Mc

Control: 11-inch semicircular dial; scales are logarithmic for octave ranges up to 80 Mc, quasi-logarithmic between 65 and 230 Mc, essentially linear for all bandspread ranges. Slow-motion vernier drive dial is provided. One division on the vernier dial represents approximately 0.1% frequency difference on the octave frequency ranges.

Calibration Accuracy: At output voltages less than 0.3 volt, frequency is indicated to within ±0.5% when scale corrector is set to bring dial to index line. At output voltages above 0.3 volt, an external load on the output can produce frequency changes as large as ±0.5%. With an external frequency meter, scale corrector can be used to bring dial into agreement, for frequency resolution within ±0.1%.

Drift: Not greater than 0.3% for five hours after one-hour warmup.

Sweeping Rate: Frequency is swept from low-frequency end to high-frequency end of range in 22.2 milliseconds 20 times per second. Output is blanked off for return sweep.

Sawtooth Sweep Voltage: Adjustable in amplitude up to 100 volts, peak-to-peak. Also adjustable in starting point in the frequency range.

Marker: Internally generated marker of half-sinusoidal waveform is adjustable in amplitude from 3 millivolts to 1 volt; response amplitude multiplier effectively extends range up to 100 volts. Amplitude is indicated to an accuracy of ±10%.

RF OUTPUT

Voltage: Adjustable from 0.3 microvolt to 1

SPECIFICATIONS (*Continued*)

volt behind 50 ohms (−123 to 7 dbm power into 50 ohms).

Over-all Voltage Accuracy: ±14% up to 100 Mc, due to maximum voltmeter and attenuator errors listed below. Above 100 Mc, harmonics may add additional error of ±3%.

Voltmeter Error: 2% + 2% of full scale.

Attenuator Error: 1% per step to maximum of 6%.

Stability: Output is held at preset level to within ±1% (0.1 db) up to 100 Mc and within ±3% (0.25 db) up to 230 Mc. Changes due to line-voltage variations and range switching will not exceed ±3% (0.25 db). A TYPE 874-R22A Patch Cord will reduce output 5% (0.4 db) at 230 Mc.

Impedance: 50 ohms resistive with a vswr of less than 1.01 at the panel jack. With a TYPE 874-R22A Patch Cord, vswr at the output of the cable will be less than 1.1 over the frequency range.

Leakage: External rf field produces negligible interference with measurements down to the lowest levels provided by the generator.

RESPONSE AMPLIFIER

Maximum Input Voltage: 1, 10, or 100 volts as selected by the response-amplifier multiplier switch. Noise level is less than 1 millivolt peak-to-peak referred to the input at the ×1 (1 v) position of the multiplier switch, 10 millivolts at the ×10 (10 v) position, and 100 millivolts at the ×100 (100 v) position.

Input Impedance: 1 megohm in parallel with 30 to 45 pf.

Gain: Dc amplification between external response input connector and vertical display output connector is ×8 (18 db) at the ×1 position of the multiplier, ×0.8 at the ×10 multiplier position, and ×0.08 at the ×100 multiplier position.

Bandwidth: Greater than 10 kc. Sufficient for passing all details of any response that can be resolved at the maximum sweep rate of the generator.

Polarity: A polarity-reversing switch is provided to give a positive display vertical output voltage with either positive or negative inputs from the external response detector.

DISPLAY OUTPUT VOLTAGES

Vertical: Up to +8 volts into 100-kilohm load, consisting of marker plus response to be displayed.

Horizontal: Up to +100 volts dc or sawtooth peak into 100-kilohm load.

GENERAL

Frequency Output Voltage: 0.1 to 0.3 volt behind 50 ohms for operating external frequency meter or external marker generator.

External Marker Input Voltage: 1 volt peak-to-peak into 50 kilohms. Birdie-type markers can be applied which are controlled in amplitude and added to the response displayed.

Power Requirements: 105 to 125 (or 210 to 250) volts, 60 (or 50) cps. Maximum input power is 145 watts.

Terminals: Recessed TYPE 874 Locking Connectors, except for EXTERNAL MARKER input connector, which is a standard phone jack.

Accessories Supplied: TYPE 1025-P1 Detector Probe, three TYPE 874-R22A Patch Cords, three TYPE 874-R33 Patch Cords, three TYPE 874-C58A Cable Connectors, six TYPE 838-B Alligator Clips, TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: TYPE 874-VQ Voltmeter Detector, TYPE 874-WM 50-ohm Termination, TYPES 908-P2 and -P3 Synchronous Dial Drives, locking adaptors to all standard coaxial connectors.

Cabinet: Aluminum, with aluminum panel, in both relay-rack and bench models.

Dimensions: Bench model — width 19, height 16, depth 13¾ (485 by 410 by 350 mm), over-all; rack model — panel, width 19, height 15¾ inches (485 by 400 mm), depth behind panel, 11⅛ inches (290 mm).

Net Weight: 73 pounds (34 kg.)

Shipping Weight: 108 pounds (50 kg), approximately.

TYPE 1025-P1 DETECTOR PROBE (supplied with instrument)

Input Impedance: 1.5 pf, in parallel with 25 kilohms up to 10 Mc decreasing to 6 kilohms at 250 Mc.

Maximum RF Voltage: 3 volts rms.

Frequency Characteristic: Flat within 5% (0.4 db) from 0.4 to 250 Mc.

Output Polarity: Positive.

Transfer Characteristic: Dc output voltage equals the rms rf voltage above 0.5-volt input; essentially square-law characteristic below 50 millivolts rms rf input.

Fall Time: Less than 150 μsec, sufficiently short to follow all details of any response that can be resolved at the maximum sweep rate of the TYPE 1025-A.

Type		*Code Number*	*Price*
1025-AM	**Standard Sweep-Frequency Generator, Bench Model**	1025-9801	**$3250.00**
1025-AR	**Standard Sweep-Frequency Generator, Rack Model**	1025-9811	**3250.00**

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

VIBRATION METER WITH METRIC CALIBRATION

To meet the requirements of those who prefer to use the metric system, the TYPE 1553 Vibration Meter[1] can now be supplied with a metric calibration. The TYPE 1553-A Vibration Meter which is calibrated in mils displacement, in/sec velocity, in/sec^2 acceleration, and in/sec^3 jerk, is still available. A new model, the TYPE 1553-AK is direct reading in mm displacement, m/sec velocity, m/sec^2 acceleration, and m/sec^3 jerk.

Both instruments will be supplied with the new TYPE 1560-P52 PZT Ceramic Vibration Pickup.[2] The basic frequency response is now 2-2000 cps with the full 2-20,000 cps band available for acceleration measurements with auxiliary wide-range pickups. Other than the difference in units and numbers appearing on the FUNCTION and METER FULL SCALE dials, the specifications for the two instruments are identical. Tabulated below are the ranges and corresponding units for the two instruments.

In the table below MIN refers to 1/10 full-scale reading on the meter with scale selector switch in the most sensitive position (max clockwise). MAX refers to full-scale reading on the meter with the scale selector switch in the least sensitive position. (This is determined by rotation of the scale selector knob counterclockwise as far as possible before CAL appears in the METER FULL SCALE window or before the knob pointer is at CAL engraved on the panel.)

— E. E. GROSS

[1]E. E. Gross, "Type 1553-A Vibration Meter," *General Radio Experimenter*, 35, 11, November, 1962.

[2]E. E. Gross, "New PZT Ceramic Vibration Pickup and Control Box for Vibration Measurements," *General Radio Experimenter*, 36, 11, November, 1962.

TYPE NO.	QUANTITY	PK TO PK INDICATION MIN	PK TO PK INDICATION MAX	AVE INDICATION MIN	AVE INDICATION MAX	UNITS	FREQUENCY RANGE (cps)
1553-A	Acceleration	0.3	300,000	0.1	100,000	in/sec^2	2-2000
1553-AK	Acceleration	0.01	10,000	0.003	3,000	m/sec^2	2-2000
1553-A	Velocity	0.03	30,000	0.01	10,000	in/sec	2-2000
1553-AK	Velocity	0.001	1,000	0.0003	300	m/sec	2-2000
1553-A	Displacement	3	300,000	1	300,000	mils	2-2000
1553-AK	Displacement	0.1	10,000	0.03	10,000	mm	2-2000
1553-A	Displacement	0.03	30,000	0.01	10,000	mils	20-2000
1553-AK	Displacement	0.001	1,000	0.0003	300	mm	20-2000
1553-A	Jerk	30	300,000	10	300,000	in/sec^3	2-20
1553-AK	Jerk	1	10,000	0.3	10,000	m/sec^3	2-20

Type		*Code Number*	*Price*
1553-AK	**Vibration Meter** (Metric Units).............	1553-9817	**$740.00**

U. S. Patent No. 2,966,257

A SINGLE-PULSE TRIGGER FOR THE TYPE 1217-B UNIT PULSE GENERATOR

When the new Type 1217-B Unit Pulse Generator[1] was in design, we considered adding a panel pushbutton to permit a single pulse to be produced manually. There are some serious disadvantages to a panel-mounted pushbutton; it may be hard to reach, and even if it can be reached it may be awkward and tiresome to push. A more comfortable method, and one which is more economical for users who do not need manual operation, is to make the pushbutton a hand-held device; hence the Type 1217-P2 Single-Pulse Trigger.

The trigger assembly consists of a Microswitch, battery, and bounce filter. The circuit arrangement applies a clean dc pulse (normally negative-going) to the input terminals of the Type 1217-B Unit Pulse Generator, which is set up to accept a negative-going external trigger. It will produce its single output pulse when the button is released. When the trigger input plug is reversed, a pulse will be produced when the button is first pushed.

There are myriad applications for a pulse generator which will produce a single pulse upon manual command. For example, in design of complex systems that are intended to operate at any high repetitive rates, it is often desired to cycle them slowly (to permit voltages to be read, for example). With a manual system the user can rapidly skip unwanted conditions, and then slow down and stop at the desired condition. The pushbutton, which in no way alters the pulse specifications of the generator, will also permit a pulse of given duration and amplitude to be injected into a working system at random times, thus approximating a controlled noise impulse.

[1] R. W. Frank, "More and Better Pulses from the Unit Pulse Generator," *General Radio Experimenter*, 36, 1 & 2, January-February, 1962.

SPECIFICATIONS

Pulse Output Amplitude: −1.2 to −1.5 volts depending on battery used, behind 200 kilohms.

Upon switch closure: Rise to zero volts in approximately 0.02 second.

Upon switch opening: Fall to between −1.2 and −1.5 volts in approximately 0.02 second with output terminals open-circuited.

Battery: 1.5-volt penlite cell.

Battery Life: Shelf life of battery used.

Weight: 6 ounces (0.2 kg).

Dimensions: Diameter 1¼, length 4½ inches (32 by 115 mm), over-all.

Type		*Code Number*	*Price*
1217-P2	**Single-Pulse Trigger**	1217-9602	**$25.00**

General Radio Company

PRINTED IN U.S.A.

THE GENERAL RADIO
EXPERIMENTER

A RADICALLY NEW COAXIAL CONNECTOR FOR HIGH-PRECISION MEASUREMENTS

For many years the accuracy of coaxial VSWR measurements has been limited to a few percent by the deficiencies of coaxial connectors. With the introduction of the Type 900 line of coaxial measuring equipment, the limit is lowered by an order of magnitude, and VSWR measurements can be made to an accuracy of a few tenths of one percent. The principal factor in this substantial improvement is the Type 900 Precision Coaxial Connector, with excellent repeatability and VSWR below 1.004 to 3 Gc and 1.01 to 9 Gc. Without such a precision connector, highly accurate measuring equipment was not only impossible to design but also not worth designing, since any improvements would be obscured by the connector deficiencies. The development of the Type 900 Connector has overcome these problems and a line of precision coaxial instruments and components has been developed.

(Continued on page 2.)

VOLUME 37 Nos. 2 & 3 FEBRUARY-MARCH, 1963

IN THIS ISSUE

A RADICALLY NEW COAXIAL CONNECTOR

(Continued from page 1)

These instruments and components can also be used to advantage for measurements on systems fitted with other types of connectors through the use of adaptors. The errors introduced by these adaptors are small compared to the errors and uncertainties in the characteristics of most other connectors.

Design Objectives

The design objectives of the Type 900 Connector program were:

(1) Each connector must mate with every other and be self-contained, with no male or female parts or loose parts, such as bullets.

(2) Characteristic impedance must be 50 ohms ± 0.1%.

(3) Connector VSWR must be better than 1.01 up to 9 Gc.

(4) Connector VSWR must be repeatable to within 0.1%.

(5) The connector must include an insulating bead support for the center conductor.

(6) All current-carrying surfaces must be of silver or a silver alloy for low loss and low contact resistance.

(7) The leakage of energy from the connector must be lower than that from any other available connector.

(8) The electrical length must be a convenient, integral number of millimeters.

(9) VSWR-guaranteed limits must be established and each connector checked against these limits up to the cut-off frequency of the air line.

The over-all objective, then, was to design a connector far better than any existing type and to manufacture it at reasonable cost. For example, the design tolerance on characteristic impedance was set at ±0.1%, and this dictated tolerances on the diameters of the inner and outer conductors of ±100 and ±200 microinches, respectively. Once this design objective was frozen, then extensive production engineering was required to find relatively economical methods of manufacture to such close tolerances.

Description

The Type 900 Connector is intended for use on rigid air-dielectric, 9/16-inch, 50-ohm coaxial transmission line (principal dimensions: 0.5625 inch and 0.24425 inch). The connector (Figure 1) consists of (1) a solid silver-alloy inner conductor and spring contact, (2) a solid coin-silver outer conductor, stainless-steel centering gear ring, and locking nut, and (3) a solid Teflon bead support. The connector is attached to the air line by a coupling nut and retaining

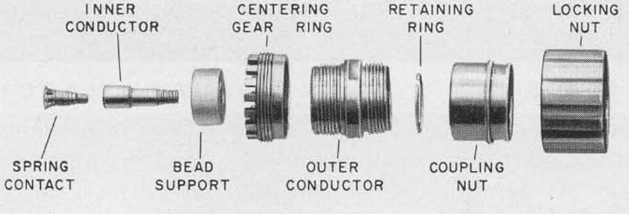


Figure 1. Exploded view of the Type 900-BT Precision Coaxial Connector.

ring on the outer conductor; the inner conductor is threaded into an 8-32 tapped hole in the center conductor of the air line. Silver is used extensively throughout the connector, and all silver parts are plated with a few microinches of gold to keep them from tarnishing.

Mating Surfaces

When two of these connectors are mated, the centering gear rings interlock and overlap in order to center each of the connectors with respect to the other, and also to provide indexing in one of 16 possible positions. The outer conductors have solid coin-silver flange-type surfaces, which are butted tightly together by the pressure of the locking nut. Only one of the locking nuts is necessary for the connection; the unused one is backed off into a storage position. The over-all diameter of the mated pair is only 1-1/16 inches.

The front surfaces of the inner conductors are recessed by 0.001 inch with respect to the surfaces of the outer conductors to insure that the outer conductors will always meet first. Inner conductor contact is made by a spring-contact assembly, which projects slightly beyond the surface of the outer conductors until the connector is mated (see Figure 2). The spring-contact assembly consists of six solid silver-alloy segments, independently sprung. Upon mating, these contacts are forced back and spread, making wiping contact both with one another and with the inside surface of the inner conductor. This method of mating inner conductors avoids the disadvantages of slots placed in the electric field, and it does not affect the diameter of the inner conductor. Only one spring contact is necessary for a good electrical connection; the spring

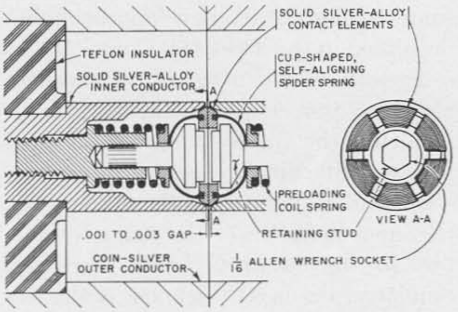


Figure 2. Cross-section view of the connector showing contact surfaces of two mated inner conductors.

contact will mate just as well with a flat surface.

When two connectors are mated, the conductors meet in the center of the connection, and this provides a very convenient electrical reference plane. (For instance, a reference short circuit consists of simply a disc, whose electrical position coincides exactly with the centerline of the mated pair.)

The outer conductors are held in alignment to within 0.001 inch by the centering gear rings and form a continuous tube through the centerline of the joint. In this respect, the connection is as precise as that formed by the junction of two waveguide flanges of the type used in precision waveguide standards. Unlike waveguides, however, the mating surfaces are protected from accidental damage by the teeth of the gear ring, which extend well beyond these surfaces. If the surface of the outer conductor is damaged or soiled, the gear ring and the spring contact can be removed without disassembling the connector, and the mating surface can be lightly lapped to restore it to its original condition.

Bead Support

An essential part of any generally useful coaxial connector is the bead support, and this part usually is the most troublesome to design. A new approach has been used in the TYPE 900 Connector, in order to take advantage of the excellent electrical properties of Teflon without incurring the disadvantages associated with its difficult mechanical properties. The bead is made slightly larger than the inner diameter of the outer conductor, so that a press fit is necessary. Similarly, the bead thickness is slightly oversized, and the hole for the inner conductor undersized, so that the bead finally assumes the dimensions of the metal parts rather than its original dimensions. The faces of the bead are undercut to compensate for discontinuity capacitances at the interface. The depth of these undercuts is used to keep bead weight within close tolerance. Weight has been found to have a first-order effect on VSWR, while minor variations in dielectric constant or mechanical dimensions with weight held constant have only a second-order effect. As further advantages, the press-fit Teflon bead holds the inner and outer conductors together in a rigid assembly and keeps dirt and moisture from entering the line or component.

The electrical performance of the bead support determines the performance of the connector. The type of bead used in this connector was described by M. Ebisch[1], and it appears to give perfect results up to and above the cut-off frequency of the air line. The characteristic impedance inside the bead is exactly 50 ohms. Both the inner and outer conductors are stepped to accommodate the bead, for it has been found that the bead end capacitance is thus minimized. The effect of the remaining end capacitance is compensated by removal of some of the dielectric from both faces of the bead. As a result, the VSWR of a single bead support of this type can be held to less than 1.001 up to 9 Gc. The performance of the connector is theoretically equal to that of a beadless connector, and the only limitations are those imposed by manufacturing tolerances.

Performance

VSWR

The most important characteristic of a precision connector is, of course, its VSWR; that is, the extent to which it introduces reflections into an otherwise matched transmission line. Figure 3 shows the VSWR test specifications that each connector pair must meet (1.001 + 0.001 f_{Gc}), as well as an average characteristic. Connector VSWR is measured at six frequencies up to 9 Gc. Since it is impossible to say how much each connector contributes to the VSWR of the pair, the test limits for the pair are used as the catalog specification for a single connector. Since the VSWR of these connectors is well below 1.01 over the entire frequency range, several new techniques and new instruments had to be developed to measure such low values of VSWR. For example, a substitution method of measuring the VSWR of pre-

[1] M. Ebisch, "Coaxial Measurement-Line Inserts of High Precision for the Frequency Range 1–13 Gc," *Frequenz*, February 1959, Vol 13, No 2, pp 52–56.

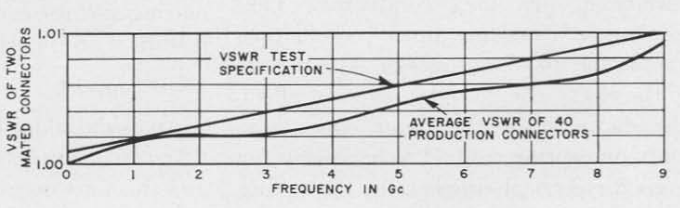


Figure 3. Type 900 Connector VSWR vs frequency. All connectors must meet the test specification shown.

cision connectors[2,3] was devised to distinguish the VSWR of the connectors from the residual VSWR's in the slotted line and termination. In this method the basic standard is a short length of rigid air line whose characteristic impedance can be accurately calculated. A slotted-line recording system was developed, which made possible the measurement of VSWR's as small as 1.0005 by a substitution method. The chart record of such a measurement is shown in Figure 4; the full-scale value of VSWR can be adjusted continuously from 1.20 to 1.008.

Repeatability

Another very important characteristic of a precision connector is repeatability, that is, the consistency of measured value as the connection is broken and remade in different orientations. The repeatability of the butt joint of the outer conductors is virtually perfect as long as the faces are kept reasonably clean and free from nicks or scratches. The connection of the inner conductors repeats to within ±0.03% up to 9 Gc, owing mainly to the action of the spring contacts, which maintain a good connection even when there is some misalignment, without transmitting torque or bending moments across the joint. This is important because the two inner conductors are rarely perfectly centered with respect to the outer conductors, so that, as two connectors are mated in different orientations, the alignment of the two inner conductors changes. The misalignment itself is not so important as the stresses and strains introduced when "bullets" are used to force the center conductors into alignment. A chart record of a repeatability run is shown in Figure 5; between each line the joint was broken, rotated 45 degrees, and remade. The total spread is less than ±0.02%.

Leakage

The leakage of energy from a coaxial connector can be of great importance in measurements at low levels, or when large amounts of attenuation are present in the system. For example, energy could be lost at the input connector of an

[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*, November 1961, Vol MTT-9, No 6, pp 524–528.

[3] A. E. Sanderson, "An Accurate Substitution Method of Measuring the VSWR of Coaxial Connectors," *The Microwave Journal*, January 1962, Vol 5, No 1, pp 69–73.

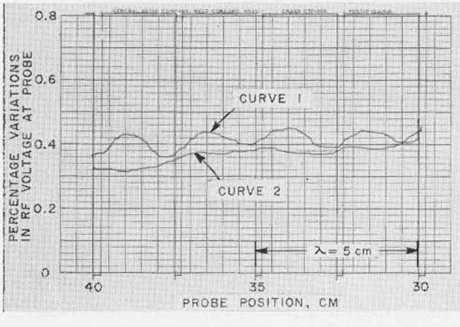


Figure 4. Chart record of the measurement of the minimum detectable VSWR. Curve 1 shows a peak-to-valley voltage variation of 0.05%, corresponding to a VSWR of 1.0005. Curve 2 shows for comparison a "flat" line, VSWR = 1.0000. The frequency is 6 Gc.

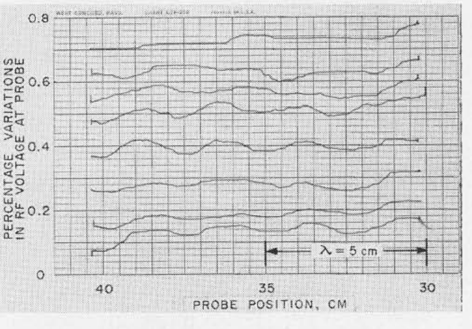


Figure 5. Repeatability of the Type 900 Connector at 6 Gc. Between each pair of lines on the chart, the connection was broken, rotated 45°, and remade. The spread in measured VSWR's is less than ±0.02%.

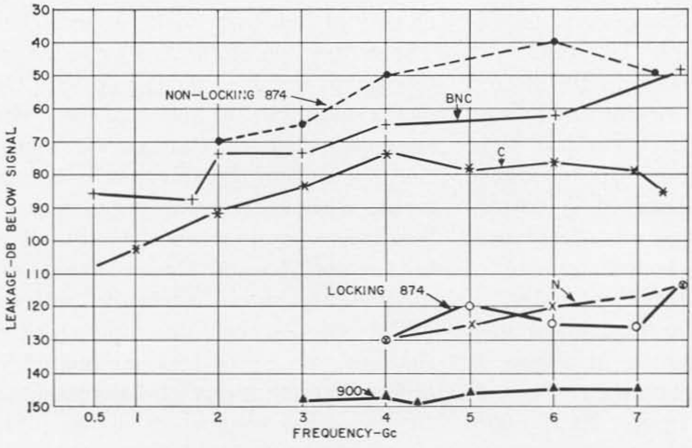


Figure 6. Leakage of coaxial connectors as a function of frequency.

attenuator and recovered at the output connector, causing an erroneous indication of attenuation. The leakage of the Type 900 Connector is compared with that of other types of connectors in Figure 6, and is lower than that of any other commonly used coaxial connector.[4] This is due to the triple shielding action of (1) the butt contact of the outer conductors, (2) the interlocking and overlapping of the centering gear rings, and (3) the outer locking nut.

Insertion Loss, Electrical Length, and DC Resistance

The insertion loss or attenuation of the Type 900 Connector is minimized by the use of Teflon for the bead and solid silver alloys for both the inner and outer conductors (silver-plated surfaces are relatively poor conductors in contrast to these alloys). The insertion loss of a mated pair depends on frequency, according to the following approximate formula:

$$\text{Loss} = \sqrt{f_{Gc}} \times 0.002 \text{ db.}$$

[4] J. Zorzy and R. F. Muehlberger, "RF Leakage Characteristics of Popular Coaxial Cables and Connectors, 500 Mc to 7.5 Gc," *The Microwave Journal*, November, 1961, pp 80-86.

This is virtually the same as the loss in an equivalent length of silver, air-dielectric transmission line.

The electrical length of a pair of Type 900 Connectors is 3.50 cm and is virtually independent of frequency. The dc resistance of a mated pair is typically 0.4 milliohm for the inner conductors, and 0.04 milliohm for the outer conductors.

Conclusion

The Type 900 line of coaxial equipment includes many instruments and components either now available or in development. Among those soon to be announced are a precision slotted line, a slotted-line recording system, and various terminations, air-line sections, and adaptors.

During the past three years, prototypes of the Type 900 Connector have been used at General Radio and at other research laboratories. This extensive field testing has proved that the theoretical excellence of this connector design has been realized in a stable, practical connector.

— A. E. Sanderson

SPECIFICATIONS

Frequency Range: DC to 9 Gc.

VSWR: Less than $1.001 + 0.001 \times f_{Gc}$ per connector. (Connectors are tested by pairs, and this figure is used as the test limit for a *pair* of connectors.)

Repeatability: Within 0.05%.

Leakage: Better than 130 db below signal level.

Insertion Loss: Less than $0.003 \sqrt{f_{Gc}}$ db per pair.

Electrical Length: 3.500 ±0.005 cm per pair.

DC Contact Resistance: Inner conductor, less than 0.5 milliohm; outer conductor, less than 0.07 milliohm.

Dimensions: Length of one connector, 1-3/16 inches (31 mm); maximum diameter, 1-1/16 inches (27 mm).

Net Weight: 2 ounces (60 grams).

Type		*Code Number*	*Price*
900-BT	**Precision Coaxial Connector**	0900-9405	**$35.00**

MEASUREMENT OF DIELECTRIC PROPERTIES OF PLASTIC TENSILE SPECIMENS

By LAWRENCE C. LYNNWORTH*

Avco Research and Advanced Development Division
Wilmington, Massachusetts

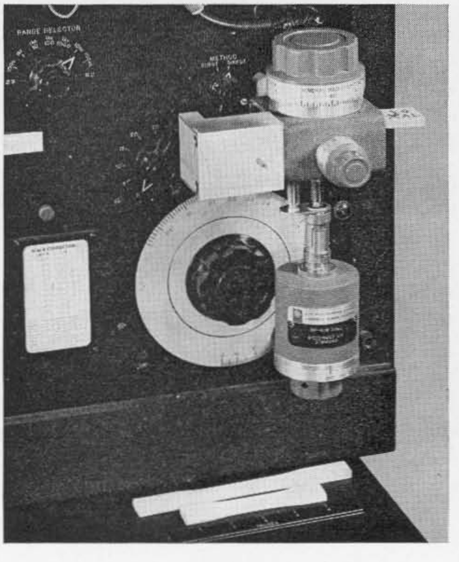
Introduction

New research and production-line applications for instruments of calibration-laboratory caliber are being motivated by reliability requirements for aerospace materials. These requirements, and the corresponding need for electrical measurements, may be explained as follows:

The tensile properties of metals, ceramics, and plastics exhibit considerable variability. Plastics, in particular, show variations attributable to composition nonuniformity, porosity, degree of cure, anisotropy, cracks or foreign inclusions, and absorbed moisture. In view of this observed variability, a nondestructive means of predicting the tensile properties of plastics is desirable. Prediction of properties becomes especially important in aerospace applications where safety factors are minimum.

One approach to the problem of predicting the tensile properties of variable plastics lies in the correlation of dielectric properties to the above-mentioned factors that influence mechanical properties. These correlations have been reported in the literature and occasionally

Figure 1. Standard tensile bar in dielectric sample holder. Pin in jig acts as stop for shorter specimen.



*Now with Parametrics, Inc., Waltham, Mass.

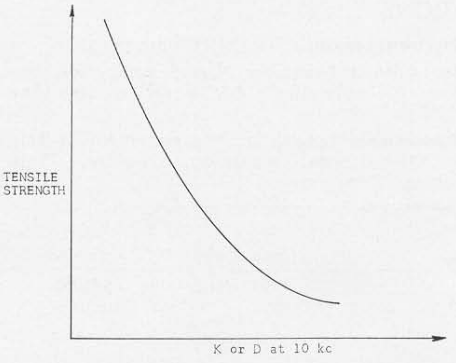


Figure 2. Hypothetical inverse relation when water absorption reduces tensile strength of a hygroscopic plastic.

provide the basis for quality-control procedures.[1–8] For example, absorbed water weakens plastic, while increasing its dielectric constant K and dissipation factor D. Therefore, measurement of K or D indicates water content, from which reduction in strength may be predicted.

In this note a fast and simple means of determining the degree of correlation between dielectric and tensile properties is described.

Discussion

In Figure 1, a tensile bar is centered in a General Radio Dielectric Sample Holder, Type 1690-A. The tensile bar conforms to the dimensions recommended in ASTM D638-61T; i.e., the gage length is two inches. This is fortunate, because the sample holder (see ASTM D150-59T) accordingly samples only the gage length.

The unorthodox removal of the side doors has not yet caused measurement difficulty, as was verified by tests on the Teflon specimens in the foreground. In an electrically noisy environment, however, shielding would be required.

Since the specimen is one-quarter inch thick, but the gage area is only about one square inch, $C = \epsilon_r \epsilon_0 A/d$ is usually between one and ten pf. Therefore, a shunt capacitor is required, such as Variable Air Capacitor, Type 874-VC, to bring the capacity up to the range of the Capacitance-Measuring Assembly, Type 1610.

Procedure

In practice, to determine whether a useful correlation exists between dielectric and tensile properties, a tensile bar, after suitable environmental conditioning, is wiped dry, centered in the sample holder, and C_x and D_x are determined at 10 kc, for example. The bar is removed and is ready for tensile testing, with less than one minute added to the interval between pretest environment and tensile test.

When more than one factor is suspected of influencing tensile properties (for example, moisture absorption *and* resin-hardener ratio), it may be necessary to use two or more test frequencies.

Results

For a hypothetical case, wherein moisture absorption reduces tensile strength and is the only variable present, correlation is illustrated in Figure 2.

Figure 3. Closeup of probe and slabs.

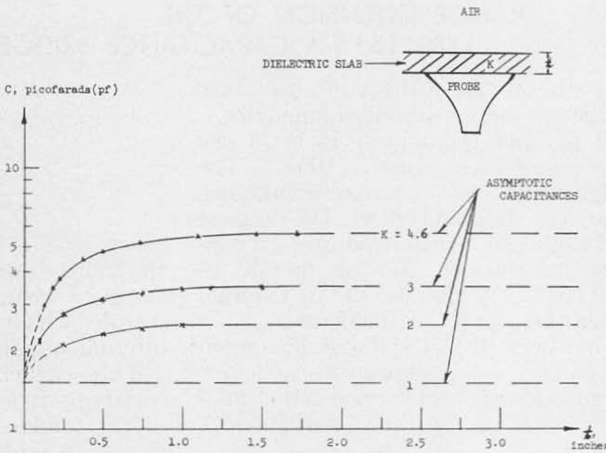


Figure 4.
Capacitance *vs* thickness of air-baked dielectric slab.

Quality Control on Production Line

Once a correlation has been established, tensile properties may be predicted on the actual production part by using an electrode arrangement designed or calibrated to yield K and D. One useful configuration consists of concentric electrodes (Figure 3). Other shapes, such as contoured or elongated probes, are of course possible.

It may be mentioned that even if probe geometry is not amenable to mathematical analysis, measurement of K and D is still simple, since probe calibration by slabs of standard dielectric materials is straightforward (Figure 4).

Conclusions

As capacitance and dissipation-factor measurements become increasingly sensitive over a range of frequencies, correlation of dielectric and physical properties may provide the basis for quality-control procedures and for new and interesting applications for instruments that may have been occasionally confined to the calibration laboratory. The Type 1690-A Dielectric Sample Holder has been used satisfactorily with ASTM D638 tensile bars, and may also be suitable for testing tensile samples of thin plastic sheeting (ASTM D882-61T) or nonrigid plastics (ASTM D412-61T).

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[1] A. R. Von Hippel (ed.), *Dielectric Materials and Applications*, 311, Technology Press of M.I.T., Cambridge, Mass., and Wiley, New York (1954).

[2] J. Vitins, "Dielectric Properties and Moisture Content Determination in Paper," *Tappi 43*, 4, 318 (April 1960).

[3] H. W. Gebele, "Moisture Measurements in Industry," *IRE Trans. Industrial Electronics, IE-9* 1, 7 (May 1962).

[4] J. A. Wickett, Jr., "Moisture Measurement and Control—an Increasingly Exact Technique," *Chemical Processing 25*, 15, 20 (September 10, 1962).

[5] B. W. Thomas et al, "Dielectric Constant Continuous Analyzers in Petroleum Refining," *Ind. Eng. Chem. 48*, 1990 (1956).

[6] R. F. Wall, "Analysis and Control by Dielectric Constant," *Ind. Eng. Chem. 50*, 69A (June 1958).

[7] R. J. Ward and E. G. Bobalek, "Some Correlations Between Thermal, Electrical, and Mechanical Properties of Alkyd-Epoxy Copolymer Adhesives," *American Chemical Society, Div. of Organic Coatings and Plastics Chemistry, Papers Presented at the Atlantic City Meeting, 22*, 2, 236 (September 1962).

[8] L. C. Lynnworth, "Inspection of Material Uniformity and Thickness Using Dielectric Measurements," to be presented at Fourth International Conference on Nondestructive Testing, London, September 1963.

RANGE EXTENSION OF THE TYPE 1615-A CAPACITANCE BRIDGE

In the Type 1615-A Capacitance Bridge the largest standard capacitor is 1000 pf, and the largest ratio in the transformer ratio arms is 1000:1. The bridge can, therefore, measure unknown capacitors up to 1.11110 μf. The range of the bridge can be extended upward continuously through another decade to 11.11110 μf by the use of an external standard capacitor of 10,000 pf.

The Type 1615-P1 Range-Extension Capacitor is a 10,000-pf mica capacitor, designed for easy connection and adjustment to extend the range of the bridge to 11 μf.

The bridge has EXT STANDARD terminals to which this capacitor can be connected and an eleven-position rotary switch, which connects the capacitor to the transformer taps to provide the same steps of adjustment in the external decade which the levers provide for internal standards.

This capacitor is not a calibrated standard. It is to be adjusted in terms of the standards in the bridge, by means of its variable trimmer capacitor, for either two- or three-terminal operation.

Dimensions: Diameter 3-1/16 by length 4⅞ inches (78 by 125 mm).

Net Weight: 1 pound (0.5 kg).

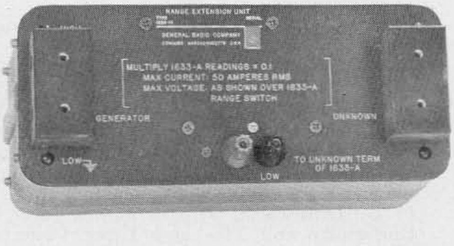
Type		*Code Number*	*Price*
1615-P1	**Range-Extension Capacitor**	1615-9601	**$35.00**

TYPE 1633-P1 RANGE-EXTENSION UNIT

The Type 1633-P1 Range-Extension Unit can be used with the Type 1633-A Incremental-Inductance Bridge to extend the current ratings to 50 amperes. It connects a 250-watt, 0.1-ohm resistor in parallel with one of the bridge arms.

High-current terminals capable of accommodating leads up to 1/4 inch in diameter are provided on the range-extension unit for the generator and unknown. A cable is furnished for connection to the bridge.

When the range-extension unit is connected, the operation of the bridge is unchanged, but only the *a*, *b*, and *c* ranges can be used. Bridge readings must be multiplied by 0.1. The upper limit of measurement is 100 mh up to 120 cps and 10 mh up to 1 kc.



The use of the Type 1633-P1 Range-Extension Unit at frequencies up to 400 cps can cause up to 1% additional error in the bridge readings. Correction can be made for the larger error occurring at higher frequencies. The temperature coefficient of the resistor is less than 20 ppm per degree Centigrade.

Any current up to 30 amperes continuous, or 50 amperes intermittent, ac or dc, can be used. Continuous operation at 50 amperes without forced-air cooling is not recommended.

Dimensions: Width 10½, height 4¼, depth 5 inches (270 by 110 by 130 mm).

Net Weight: 5¼ pounds (2.4 kg).

Type		*Code Number*	*Price*
1633-P1	**Range-Extension Unit**	1633-9601	**$125.00**

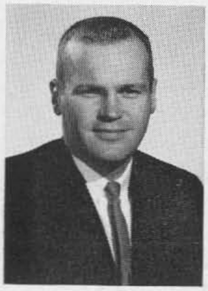
PERSONNEL CHANGES at our Sales Engineering Offices

Gerald Lett

Richard Rogers

Richard G. Rogers, now at our New England Office, will be devoting full time to calling upon our customers in the Boston and southern New England areas.

Gerald L. Lett was assigned to our Washington Office, in November 1962.



Crawford Law

Richard Eskeland

Richard K. Eskeland has recently joined the staff of our Metropolitan New York Office. He will be calling on our customers in the northern New Jersey area.

Crawford E. Law has been at our Syracuse Office since October 1962. He will be visiting customers in New York State west of Syracuse.

INSTRUMENTATION IN ISRAEL

The First International Electronics, Nucleonics, Control and Scientific Instrumentation Exhibit in Israel was held at Tel Aviv, November 7 through 16, 1962. Some 5000 representatives of science, engineering, and industry in Israel came to see the latest equipment displayed by 16 manufacturers, including General Radio, whose booth is shown in the photographs below.

(*Left*) Mr. R. Danziger of Eastronics, Ltd., General Radio representatives in Israel, demonstrates GR instruments to Mr. I. Ben Menachem, Postmaster General of Israel. (*Right*) Colonel M. Kashty, Deputy Director General, Israel Ministry of Defense, watches a demonstration of the Strobotac® electronic stroboscope by Peter Macalka of General Radio Company (Overseas).

THE GENERAL RADIO

EXPERIMENTER

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EXPERIMENTER
VOLUME 37 NOS. 4&5 APRIL—MAY 1963

ABSOLUTE CALIBRATION OF PZT MICROPHONES

Reciprocity techniques[1,2,3,4,5] have long been recognized as the preferred means of determining the absolute pressure calibration of microphones. By these methods the sensitivity, defined in terms of voltage output per unit of acoustic pressure, is determined from the measurement of voltage ratios, mechanical dimensions, and electrical impedance. The techniques have been refined over a period of years to the point where agreement between laboratories to 0.1 db or better, on stable microphones, is consistently obtained. These values represent the best available measure of microphone sensitivity in the present state of the art. Such accuracies are not easily realized, however, and are in fact obtained only by meticulously careful laboratory work, together with a fair amount of calculation. An hour or more is normally allowed to obtain reliable results at a single frequency.

[1]W. R. MacLean, "Absolute Measurement of Sound Without a Primary Standard," *Journal of the Acoustical Society of America*, 12, 140–146 (1940).

[2]R. K. Cook, "Absolute Pressure Calibration of Microphones," *Journal of Research*, National Bureau of Standards, 25, 489–505 (1940); also *Journal of the Acoustical Society of America*, 12, 415–420 (1941).

[3]L. L. Beranek, *Acoustic Measurements*, Sec. 4.2, John Wiley & Sons, Inc. (1949).

[4]A. L. DiMattia and F. M. Weiner, "On the Absolute Pressure Calibration of Condenser Microphones by the Reciprocity Method," *Journal of the Acoustical Society of America*, 18, 341–344 (1946).

[5]American Standard Method for the Pressure Calibration of Laboratory Standard Pressure Microphones, Z24.4–1949.

Figure 1. The Type 1559-A Microphone Reciprocity Calibrator is supplied in a Flip-Tilt case for convenient bench use. A relay-rack model is also available.

CONTENTS OF THIS ISSUE

A new General Radio development, the Type 1559-A Microphone Reciprocity Calibrator, reduces the reciprocity measurement to a matter of routine for General Radio piezoelectric microphones. The instrument is portable, and the measurement technique is so simplified that a measurement at any one frequency can be made in a minute or so. Before important measurements are undertaken, field checks of microphone sensitivity can be made with this calibrator to an accuracy comparable to that hitherto obtainable only in the best standardizing laboratories.

Basic Principles *(see also page 3)*

In addition to the transducer to be calibrated, the reciprocity technique requires two other transducers, one of which is reciprocal,[*6,7] and an acoustic cavity. One transducer is used as a sound source which excites the remaining two transducers (microphones) with a sound pressure. The ratio of the open-circuit voltages of the two microphones equals the ratio of the microphone sensitivities. If the two microphones are then coupled together by a known acoustic impedance (the cavity) and the reciprocal microphone is driven as a sound source, the ratio of the open-circuit voltage of the second microphone to the driving current of the first microphone can be theoretically related to the product of the microphone sensitivities. The two relationships, one for the *ratio* of microphone sensitivities and one for the *product* of microphone sensitivities, can then be solved for the sensitivity of either microphone. The acoustic impedance[8] of the cavity is the independent calculable quantity in terms of which microphone sensitivity is established.

A Unique Device

The uniqueness of the Type 1559-A Microphone Reciprocity Calibrator rests on the following design features:

(1) The transducer used to determine the ratio of sensitivities is in the form of a piezoelectric ring[†] which makes up the cavity wall, thereby eliminating the need for physically interchanging the location of microphones during the course of the measurement. Electrical excitation of the ring produces a uniform sound pressure throughout the cavity. This fact, plus the symmetry that results from the use of a transducer in the form of an encompassing cylinder together with a reversible transducer identical to the microphone being measured, makes the coupler usable over a wide frequency range.

(2) A switch is used to connect the circuits for the required operations without the need for physically interchanging the transducers.

(*continued on page 4*)

* In a reciprocal device, the ratio of response to excitation is unchanged if the points of excitation and observation are interchanged, provided that the terminal conditions remain the same.

6 Lord Rayleigh, *The Theory of Sound*, Vol II, 108, Macmillan and Company, Ltd. (1877).

7 S. Ballantine, "Reciprocity in Electromagnetic, Mechanical, Acoustical and Interconnected Systems," *Proceedings of the IRE*, 17, 929–951 (1929).

† A similar and independent development has been recently reported: see "Pressure Calibration of Measuring Microphones by the Reciprocity Method," *Soviet Physics Acoustics*, 26, 2, Oct-Dec 1960, p 246.

8 P. M. Morse, *Vibration and Sound*, Chapter 6, McGraw Hill (1936).

THEORY, OPERATION, AND READOUT

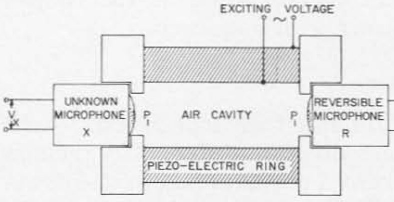


Figure 2a. Conditions for Step 1.

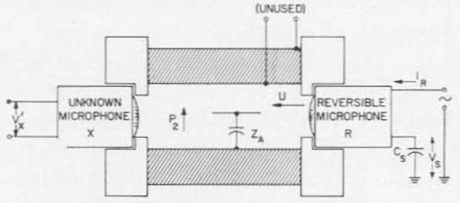


Figure 2b. Conditions for Step 2.

STEP 1 — Both microphones are excited by the same sound pressure, P_1. Their open-circuit voltages V_R and V_X are proportional to their sensitivities, M_R and M_X. Then

$$\frac{M_R}{M_X} = \frac{V_R}{V_X} \quad (1)$$

STEP 2 — The reversible microphone is driven by a current, I_R, producing a volume velocity of sound, $U = I_R M_R$, in the cavity, whose acoustic impedance is Z_A. This, in turn, produces a sound pressure, $P_2 = U_2 Z_A$ at the unknown microphone, which generates a voltage, $V'_X = P_2 M_X$.

Then,

$$M_R M_X = \frac{V'_X}{I_R Z_A} \quad (2)$$

Combining (1) and (2),

$$M^2_X = \frac{1}{Z_A} \cdot \frac{V_X}{V_R} \cdot \frac{V'_X}{I_R}$$

The impedance, Z_A, is calculated, and all the other quantities are measured. $\frac{V_X}{V_R}$ comes from step 1; I_R is measured in terms of the voltage across a polystyrene capacitor in the current path, $I_R = V_s \omega C_s$; V'_X is measured directly.

$$Z_A = \frac{\gamma P_o}{\omega V_c}$$

where:

γ is the ratio of specific heat of air at constant pressure to that at constant volume

P_o = atmospheric pressure

V_c = cavity volume

The two ω-terms cancel, and

$$M_X = \sqrt{\frac{V_c}{\gamma P_o C_S} \cdot \frac{V_X}{V_R} \cdot \frac{V'_X}{V_S}} = \sqrt{k\left(\frac{1}{P_o}\right) \cdot \frac{V_X}{V_R} \cdot \frac{V'_X}{V_S}} \quad (3)$$

Then M_X in db =

$$10\left[\log\frac{k}{P_o} + \log V_X - \log V_R + \log V'_X - \log V_S\right] \quad (4)$$

This computation is carried out on a simple analog computer consisting of a function switch and an attenuator that includes a logarithmic potentiometer, shown in Figure 3. The first term is taken care of by an initial setting of the answer dial in terms of barometric pressure. Voltages are measured by a substitution method, and voltage ratios appear as differences in the attenuator settings necessary to produce a constant detector reading. The function switch, in addition to controlling generator, detector, and transducer connections, actuates the brake to hold the answer dial stationary while the attenuator is set to correspond to the amplitude of the numerator voltages in (3), then re-engages the dial for the setting of the denominator voltages. Thus, attenuator setting differences in db are transferred to the answer dial during steps in the computation. The final result, i.e., the sensitivity of microphone X, is read from the computer dial in db *re* 1v/μbar.

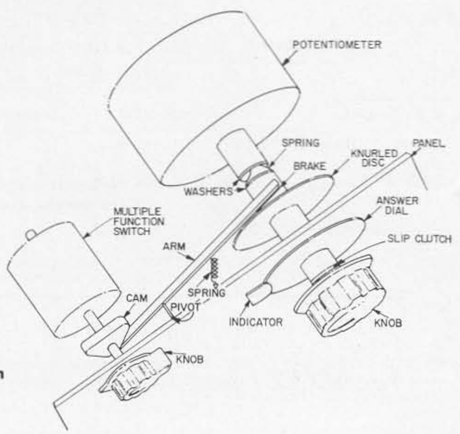


Figure 3. Switching and computer mechanism in elementary form.

(3) A standard capacitor is used to measure the driving current of the reciprocal transducer.[9]

(4) The necessary calculations are performed by a simple dial-type analog computer coupled to the switch (see Figure 3). The voltages that result from the acoustical transfers are duplicated with an electrical network that includes a logarithmic potentiometer. The angular positions of the potentiometer shaft are proportional to the logarithms of the voltages to be measured, and these shaft positions are transferred to the answer dial in such a way that the necessary multiplications and divisions are accomplished in a manner analogous to the use of a slide rule.

(5) The closed coupler reciprocity technique normally yields the pressure response of a microphone, but the American Standards Association Specification for General Purpose Sound-Level Meters S1.4-1961 requires a microphone which has a flat random-incidence (diffuse-field) response. In this calibrator, the deviation of the coupler from a simple acoustical element with increasing frequency is empirically matched to the correction between the random-incidence response and the pressure response. The calibration is then effectively in terms of a diffuse-sound field, which is the environment to which a sound-level-meter microphone is most commonly exposed. Figure 4 shows the degree to which the random-incidence correction matches the deviation of the coupler impedance with frequency.

[9] A. K. Nielson, "A Simplified Technique for the Pressure Calibration of Condenser Microphones by the Reciprocity Method," *Acoustica*, Vol 2 #3, 112–118 (1952).

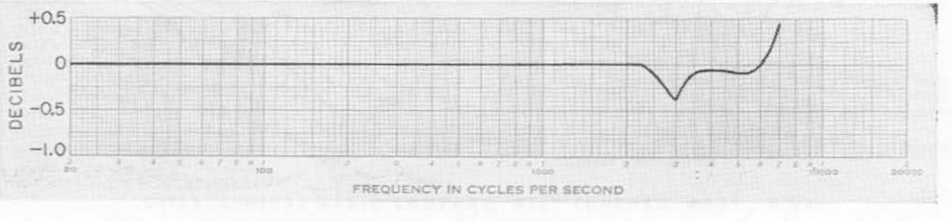
Procedure

To calibrate a microphone one inserts the microphone into the cavity, clamps it in place, and connects it to the instrument. Then one sets a reference to the barometric pressure and proceeds to make four dial settings. At the completion of the fourth setting, the random-incidence (diffuse-field) microphone sensitivity in db *re* lv/μbar is read directly from a dial on the instrument panel to an accuracy which varies from 0.2 db at low frequencies to 0.7 db at 7 kc.

The Calibration, Absolute and Traceable

The Type 1599-A Microphone Reciprocity Calibrator is a primary and accurate calibrator of General Radio Company's PZT microphones below 1 kc, while above 1 kc (where the dimensions of the cavity become comparable with the wavelengths of the sound) it is direct reading in the random-incidence (diffuse field) response of the microphones. The calibration of a Type 1560-P3 PZT Microphone by use of this instrument depends on the measurement of length (volume of the cavity) and electrical impedance (capacitance and resistance), and is thus "traceable" to NBS calibrations of those units. An independent cross-check is also possible by comparison with an NBS calibrated 640-AA microphone, as shown later.

Figure 4. Average deviation between calibration by the Type 1559-A Microphone Reciprocity Calibrator and calibration at random incidence.



A Standard Source

The Type 1559-A Microphone Reciprocity Calibrator can also be used as a precision acoustic source for setting the reference level of a sound measurement system. When the instrument is to be used as a precision source, the sensitivity of a microphone must first be determined by the procedure outlined above. This sensitivity is used as a reference to set the driving current for the reversible transducer. For a given input voltage a known sound-pressure level will then be produced in the cavity. A sound-measurement system connected to the output of the microphone can then be set to indicate this known level.

Comparison with Standard Microphone

This technique for producing a known sound level in the cavity can also be used to compare the sensitivity of a General Radio Type 1560-P3 PZT Microphone to that of a Western Electric 640-AA Laboratory Standard Microphone or to calibrate a sound-measuring system that uses such a microphone. After the Type 1559-A Microphone Reciprocity Calibrator is set to produce a known sound field as above, the Type 1560-P3 PZT Microphone is replaced by the 640-AA microphone with the adaptor sleeve furnished with the calibrator. The sound level in the cavity is then measured by the 640-AA microphone and its associated measurement system, and the system calibration can be set according to the known level. Or, if the sensitivity of the 640-AA is known and the electrical response of the associated system is known, one can then compare the sound level measured with the 640-AA and that produced in the cavity. When this is done, the primary calibration of a Type 1560-P3 PZT Microphone made with a Type 1559-A Microphone Reciprocity Calibrator has been compared to the National Bureau of Standards calibration of a 640-AA microphone, and the agreement is better than 0.2 db for frequencies below 1 kc.

Generator and Detector

The accessories required are a generator and a detector. The Type 1311-A Audio Oscillator, which supplies 10 fixed frequencies between 50 and 5000 cps, is recommended. For continuously adjustable frequencies, either the Type 1210-C Unit R-C Oscillator or the Type 1304-B Beat-Frequency Audio Generator can be used. For recording applications or for fixed installations, the latter is preferable. The detector can be either the Type 1551-C Sound-Level Meter or the Type 1558-A Octave-Band Noise Analyzer, usually the instrument whose microphone is to be calibrated.

Applications

Use of the Type 1559-A Microphone Reciprocity Calibrator effectively eliminates instrument error from sound-level measurements; the observer can then concentrate his attention on the acoustical factors, such as environment and microphone placement. Hitherto, one could readily calibrate the electrical part of a sound-measuring system, but the calibration of the microphone was restricted to a check on the microphone's sensitivity at a single frequency. A complete calibration of the microphone could be made only at a qualified laboratory.

The need for proved accuracy, including calibration of the microphone, in the field of sound-level measurements, is illustrated by a noise specification such as MIL-E-22842 (Ships), which is referenced to MIL-STD-740 (Ships). The latter specification requires that the microphone used in the sound-measuring system be calibrated every six months. With both the supplier and the purchaser performing noise measurements according to the specifications, accuracy of calibration will be an important factor in the rapid and economical elimination of any discrepancies between the respective measurements.

The manufacture and purchase of equipment to a particular noise specification is not restricted to military applications. Some examples are: (1) The air-moving industry which has specifications on the noise levels that may be generated by fans, blowers, etc.; (2) communities with ordinances restricting the maximum noise level produced by trucks and other vehicles; and (3) airports that have limits on the noise level produced by aircraft using their facilities. Industrial hygienists require proof of the calibration accuracy of their sound-level measuring equipment. In general, requirements for sound-measuring equipment are becoming more stringent because users demand correlation of measurements taken at different locations and consistency of measurements taken at different times.

Simple to operate, direct reading, and accurate, this calibrator provides a reliable and consistent means of standardizing sound measurements.

— Basil A. Bonk

SPECIFICATIONS

MICROPHONE CALIBRATOR

Microphones: This instrument will calibrate the Type 1560-P3 and -P4 PZT Microphones, currently used on the Type 1551-C Sound-Level Meter and the Type 1558-A Octave-Band Noise Analyzer, respectively; also the Type 1560-P1 (Rochelle Salt) Microphone, used on the older Type 1551-B Sound-Level Meter.

Range: Direct reading for microphone sensitivities between −55 db and −65 db *re* 1 volt/μbar.

Frequency Range: 20 to 8000 cps.

Accuracy: ±0.2 db ± (0.1 db × frequency in kc) up to 2.5 kc, ±0.7 db above 2.5 kc to 7 kc, when reference is set to actual barometric pressure.

PRECISION ACOUSTICAL SOURCE

Frequency Range: 20 to 8000 cps.

Output: 92 db *re* 0.0002 μbar for excitation of 50 volts.

Accuracy: At 92 db, ±0.1 db + error in determining microphone sensitivity.

SOUND-LEVEL CALIBRATOR

Frequency Range: 20 to 2000 cps.

Output: 92 db *re* 0.0002 μbar for excitation of 50 volts.

Accuracy: ±0.7 db at standard atmospheric pressure.

GENERAL

Maximum Safe Input Voltage: 50 volts behind 600 ohms.

Accessories Required: Generator and detector. Generator to supply 5 volts or more into a 2000-pf load, and 2.5 volts or more into a 600-ohm load. Lower voltage can be used, with a resultant lowering of signal-to-ambient-noise ratio. The Type 1304-B Beat-Frequency Audio Generator, the Type 1210-C Unit R-C Oscillator, and the Type 1311-A Audio Oscillator are recommended. The Type 1551-B or -C Sound-Level Meter or the Type 1558-AP Octave-Band Noise Analyzer is recommended for the detector.

Accessories Supplied: Cables for connection to generator and detector; adaptor sleeve for 640-AA microphone.

Cabinet: Flip-Tilt; relay-rack model also is available.

Dimensions: Portable model, case closed — width 10, height 8, depth 7½ inches (255 by 205 by 190 mm), over-all; rack model — panel 19 by 10½ inches (485 by 270 mm), depth behind panel 5 inches (130 mm).

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

Shipping Weight: Portable model, 22 pounds (10 kg); rack model, 29 pounds (13.5 kg).

Type		*Code Number*	*Price*
1559-A	**Microphone Reciprocity Calibrator,** Portable Model	1559-9701	**$475.00**
1559-9820	**Microphone Reciprocity Calibrator,** Rack Model . . .	1559-9820	**475.00**

Patent Applied For.

Note: The relay-rack model of this instrument makes use of an adaptor panel of the type described (for the Type 1650-A Impedance Bridge) on page 7 of the November, 1962, issue of the *Experimenter*. This method of rack mounting is used for all GR Flip-Tilt cases.

TYPE 1120-AB FREQUENCY STANDARD

Emergency power equipment, which assures continuity of service despite interruption of normal power service, is now incorporated in a new assembly of standard-frequency equipment, the TYPE 1120-AB Frequency Standard. The individual standard-frequency instruments, which have been described previously,[1] are:

TYPE 1113-A STANDARD-FREQUENCY OSCILLATOR
TYPE 1114-A FREQUENCY DIVIDER
TYPE 1103-B SYNCRONOMETER® TIME COMPARATOR

The additional units, which provide emergency power, are:

TYPE 1116-B EMERGENCY POWER SUPPLY
TYPE 1268-A AUTOMATIC BATTERY CHARGER
TYPE 1268-P1 BATTERY DRAWER
TYPE 1268-9602 BATTERY

The entire assembly is housed in a floor-type cabinet rack, as shown in Figure 1.

Standard-Frequency Oscillator

The performance of the TYPE 1113-A Standard-Frequency Oscillator has amply justified the original evaluations[1] of its over-all stability. The one-year drift record of a typical unit is shown in Figure 2. Note that the drift rate at the end of a year has diminished to less than one part in 10^9 per month, or better than 3 parts in 10^{11} per day.

[1] R. W. Frank, F. D. Lewis, and H. P. Stratemeyer, "The New GR Frequency Standard," *General Radio Experimenter*, 35, 4, April 1961.

Of particular interest is the spectrum plot of Figure 3, which indicates a high degree of short-term stability, that is,

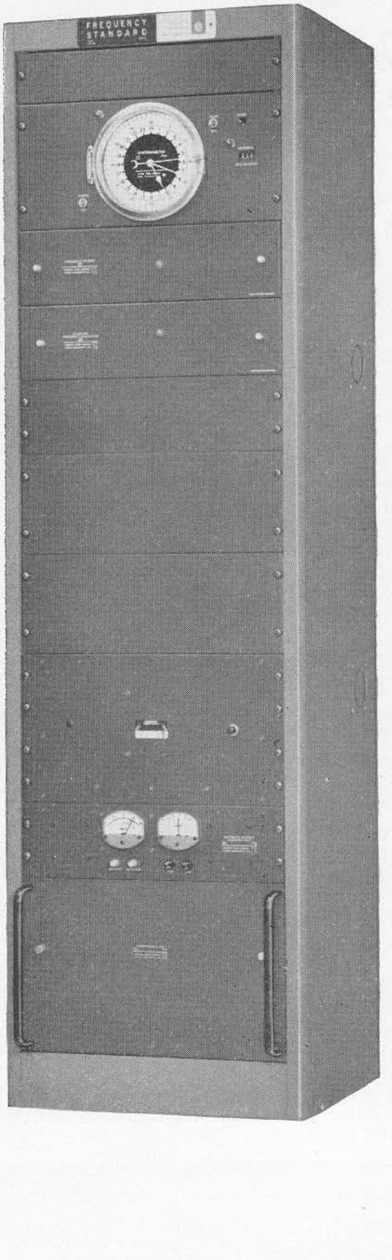


Figure 1. View of the Type 1120-AB Frequency Standard.

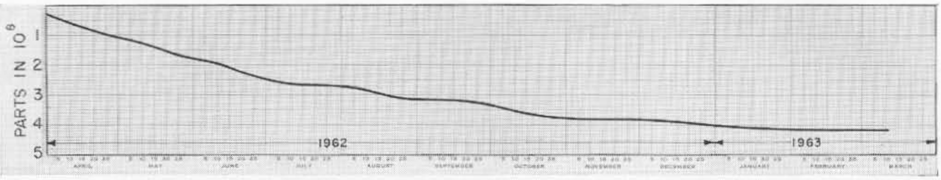


Figure 2. Typical long-term frequency drift of Type 1113-A Standard-Frequency Oscillator.

a very low level of fm noise. Note that this spectrum is that of the oscillator frequency multiplied up to 23,900 Mc, and so it includes not only oscillator instabilities, but also any noise that might be contributed by the multipliers.

Frequency Divider

The Type 1114-A Frequency Divider[1] divides the 5-megacycle crystal frequency to produce sine-wave output frequencies at 1 Mc, 100 kc, 10 kc, 1 kc, and 100 cps, as well as square waves at 100 kc and 10 kc. The divider circuits are designed for low jitter (about 0.5 nsec over-all from 5 Mc to 100 cps) and are all "fail-safe," that is, they have no output in the absence of an input signal.

Time Comparator

The Type 1103-B Syncronometer® time comparator[1] provides a calibration against standard time by comparison with radio time signals. Such comparisons can be made to about 0.1 millisecond. Radio propagation time varies up to ±0.1 millisecond, making over-all accuracy of comparison approximately ±0.2 millisecond. A frequency calibration accuracy of $\pm 1 \times 10^{-9}$ is possible over a 48-hour interval. This unit provides an additional fail-safe feature since even momentary failure of the driving frequency will stop the clock, which will not restart of itself when the drive reappears.

[1] *Loc. cit.*

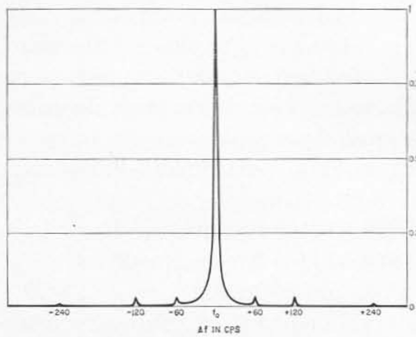


Figure 3. Spectrum of the Type 1113-A Standard-Frequency Oscillator as measured at 23,900 Mc by the National Bureau of Standards.

SPECIFICATIONS

Output Frequencies: 5 Mc, 1 Mc, 100 kc, 10 kc, 1 kc, 100 cps; additional plug-in units for the Type 1114-A Frequency Divider are available to produce output at 400 cps and 60 cps.

Power Requirements: 105 to 125 (or 210 to 250) volts, 50 to 60 cps, 370 watts.

Dimensions: Width 22, height 76½, depth 18½ inches (560 by 1950 by 470 mm).

Net Weight: 475 pounds (220 kg).

Shipping Weight: 645 pounds (300 kg).

Type		*Code Number*	*Price*
1120-AB	**Frequency Standard**	1120-9430	**$5200.00**

Note: Other frequency-standard combinations available include the Type 1120-A, which has the same output frequencies as the -AB model, but without emergency power equipment, and the Type 1120-AH, which furnishes, in addition, frequencies of 10, 100, and 1000 Mc (also without emergency power equipment). All component units are available separately and special assemblies can be devised to meet individual requirements.

EMERGENCY POWER SUPPLY

The TYPE 1116-B Emergency Power Supply is a combination inverter and switching device, designed for use with a 28- to 32-volt storage battery. Upon failure of the power line, the vibrator-type inverter is automatically connected to the battery supply, the power-input terminals of the frequency standard are transferred to the inverter output, and a front-panel lamp glows to indicate emergency operation. This changeover occurs when the line voltage falls below 105 (or 210) volts; the return to line operation takes place at a level between 108 and 113 (or 216 and 226) volts.

The switching is accomplished so rapidly that no interruption occurs in the operation of the frequency standard. The transfer takes place in less than two cycles of the power-line frequency.

On resumption of the power-line service, the standard is automatically switched back to the line, and the inverter is disconnected from the battery.

Switching is accomplished by fast-acting relays and solid-state diodes.

Automatic Battery Charger

The TYPE 1268-A Automatic Battery Charger is designed to maintain at optimum charge condition a 24-cell nickel-cadmium battery to provide emergency power for the TYPE 1116-B Emergency Power Supply.

As soon as line voltage is restored after power failure, a constant current charge of about 4 amperes is applied to the battery. After 6 hours of this charge, a timer changes the operating mode to constant voltage. This float voltage maintains the battery at optimum charge regardless of the trickle-charge current required. Under these conditions the voltage across the battery is about 34 volts. Meters are provided for battery voltage and current.

Battery Drawer

This unit is a relay-rack-mounted drawer capable of housing the 24-cell battery. Ball-bearing slides and quick-release fasteners provide easy access for battery maintenance. Stainless steel is used for the battery holder to insure chemical resistance against the alkaline electrolyte of the nickel-cadmium battery.

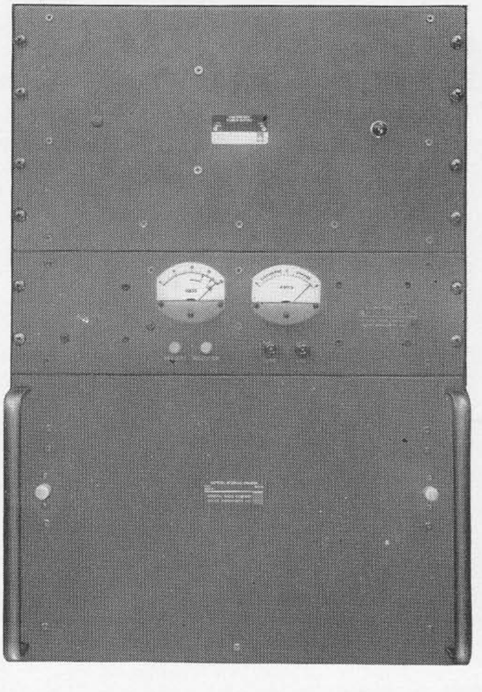


Figure 4. View of the emergency power supply equipment. From top, Type 1116-B Emergency Power Supply, Type 1268-A Automatic Battery Charger, Type 1268-P1 Battery Drawer.

Battery

This 24-cell nickel-cadmium battery is shipped directly from the manufacturer's plant. Its capacity is sufficient to operate the frequency standard for at least 3½ hours.

SPECIFICATIONS

TYPE 1116-B EMERGENCY POWER SUPPLY

Input: 115/230 v, 50–60 cps from power line. 28–32 v, 4.3–3.2 amp from battery (when operating Type 1120-AB Frequency Standard).

Output: 115 v, nominal, 60 cps, 180 watts continuous maximum rating.

Operational Range: Battery cuts in when line voltage falls below 105 v and cuts out when restored line voltage reaches a threshold value between 108 and 113 v.

Accessories Supplied: Type CAP-22 Power Cord (2); spare power line fuses (2).

Accessories Required: 28-, 30-, or 32-v battery and cables.

Accessories Available: Type 1268-A Automatic Battery Charger; Type 1268-P1 Battery Drawer; Type 1268-9602 Battery.

Cabinet: Relay-rack.

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

Net Weight: 58½ pounds (26.6 kg).

TYPE 1268-A AUTOMATIC BATTERY CHARGER

Constant-Current Charge: 6 hours at 4 amperes, nominal.

Trickle Charge: 33.8 volts ± 2% is maintained at the battery.

Power Required: 105 to 130 (or 210 to 260) volts, 60 cps, 240 watts maximum.

Ambient Temperature Range: 0 to 50 C.

Cabinet: Rack-bench.

Dimensions: Bench model — width 19, height 5¼, depth 11¾ inches (485 by 135 by 300 mm), over-all; rack model — panel 19 by 5¼ inches (485 by 135 mm), depth behind panel 11 inches (280 mm).

Net Weight: 29½ pounds (13.5 kg).

Shipping Weight: 50 pounds (23 kg).

TYPE 1268-P1 BATTERY DRAWER

Cabinet: Relay-rack.

Dimensions: Panel 19 by 12¼ inches (485 by 314 mm), depth behind panel 19 inches (485 mm); interior, battery compartment floor, 16¼ by 14¾ inches (415 by 375 mm), height 10¾ inches (275 mm).

Net Weight: Less battery, 25 pounds (11.5 kg).

Shipping Weight: Less battery, 35 pounds (16 kg).

TYPE 1268-9602 BATTERY

Type: Nickel-cadmium.

Voltage: 28 volts dc, nominal.

Ampere-Hours: 15 ampere-hours. At 4.3 to 3.2 amperes required by Type 1116-B Emergency Power Supply, batteries will run at least 3½ hours.

Net Weight: 90 pounds (41 kg), approximately. Battery shipped direct from supplier.

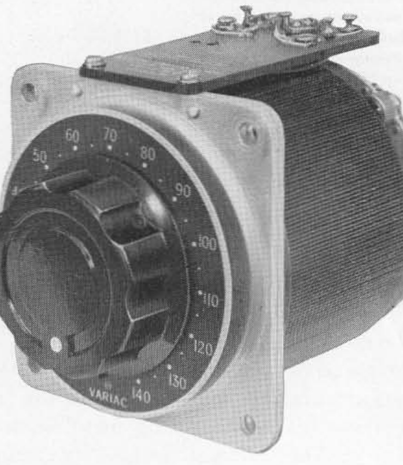
Type		*Code Number*	*Price*
1116-B	**Emergency Power Supply**	1116-9702	**$450.00**
1268-AM	**Automatic Battery Charger,** Bench Model	1268-9801	**450.00**
1268-AR	**Automatic Battery Charger,** Rack Model	1268-9811	**450.00**
1268-P1	**Battery Drawer,** less battery	1268-9601	**195.00**
1268-9602	**Battery**	1268-9602	**250.00**

COMING EXHIBITS

General Radio instruments will be on display at these meetings and exhibits during the month of May. Our engineers will be on hand to welcome you and to answer your questions.

Date	*Sponsor or Title*	*Location*
May 6–10	National Industrial Production Show of Canada	Exhibition Park, Toronto
May 6–10	American Industrial Hygiene Conference	Sheraton-Gibson Hotel, Cincinnati
May 15–18	Acoustical Society of America	Hotel New Yorker, New York
May 20–23	Design Engineering Show	Coliseum, New York

MORE WATTS PER DOLLAR WITH THE NEW W8 VARIAC® AUTOTRANSFORMER



VARIAC® autotransformers, TYPES W8 and W8L, offer increased ratings and increased volt-amperes per dollar, yet occupy the same panel space as the popular TYPE W5. They differ dimensionally from the TYPE W5 in but one respect, an increase in back-of-panel depth of one-half inch. They embody all the features common to the General Radio "W" line of VARIAC autotransformers, and are currently available as basic models only, without cases.

We feel that these two new units will serve a useful purpose by meeting a demand for more power in a limited space. Their increase in volt-amperes-per-dollar is a built-in bonus.

SPECIFICATIONS

Type	W8	W8L*
Input Volts	120	120
Output Volts	0–120 0–140	0–120
Line Frequency	50-60 cps	60 cps
Rated Amperes	8.5	10

Type	W8	W8L*
Max Amperes	11	13
Rated KVA	1.32	1.56
Code Number	3038-5110	3058-5110
Price	**$21.00**	**$21.00**
Volt-Amperes/$	62.9	74.3

* Note that the Type W8L cannot be operated at line frequencies lower than 60 cps, and that it cannot be used to obtain overvoltage.

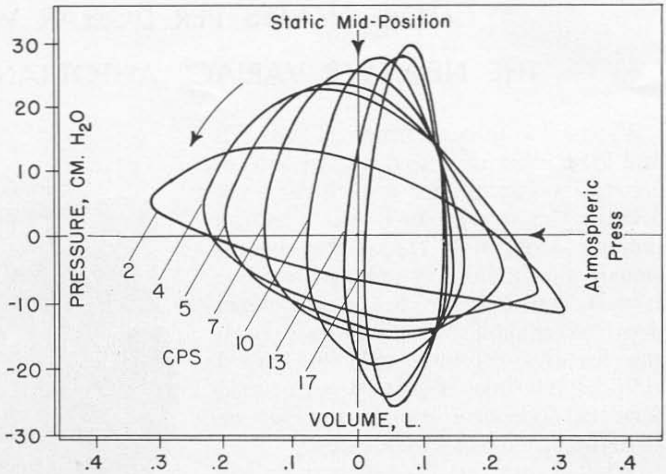
AC THEORY AND THE HUMAN CHEST

The GR TYPE 1305-A Low-Frequency Oscillator was featured in an unusual demonstration last September at the XXII International Congress of Physiological Sciences at Leiden. In the exhibit, entitled "Interpretation of the Respiratory Pressure-Volume Lissajous Figures," the oscillator was used to produce, on a dual-beam oscilloscope, Lissajous loops analogous to pressure-volume and pressure-volume flow in the human chest. The input data were taken from actual experiments performed on animals and human beings, part of a long-term program conducted by Drs. Wayland E. Hull and E. Croft Long at Duke University Medical Center.

The electrical analog of the human chest is an interesting example of the use of analogous systems to explain natural phenomena. The human chest and lungs are here visualized as a series circuit, containing capacitance (compliance of lung tissues and rib cage), inductance

Figure 1. Pressure-volume Lissajous patterns at frequencies indicated. System is asymmetrical at lower frequencies and resonant, in this particular case, at about 10 cycles/sec as seen from vertical loop indicating 90 degrees of phase shift. Data from anesthetized dog.

(by permission of the *Journal of Applied Physiology*)



(the massive or inertant character of the tissues), and resistance (opposition to air flow). The breathing rate is frequency, the normal frequency being about 20 cycles per minute. By the use of an iron-lung-type respirator, breathing rates up to 20 cps can be produced in anesthetized animals. Thus, if pressure is held constant at all frequencies, a frequency-impedance relation can be determined. Similarly, the volume of air moved by the system can be studied as a function of frequency. The alternating pressure supplied in the test is made to approximate a sine wave, so that much of elementary ac theory can be applied in this biological system.

The resonant frequency of both animal and human chests is of the order of 5 cps, and many animals, including dogs, pant at that frequency. To the physiologist, this implies that the maximum air flow is available to cool the mouth, tongue, and air passages for the minimum expenditure of energy.

The relation of volume and pressure in connection with distention of lung and thorax is of especial interest to physicians. Several chest diseases are seen to involve changes in chest "capacitance" or "resistance." Beyond the considerations of chest and lung research lie the exciting possibilities of explaining other biological phenomena by electrical analog.

Our thanks to Dr. E. C. Long and Dr. W. E. Hull of Duke for permission to publish this brief abstract. Those interested in a more complete discussion are referred to *American Journal of Applied Physiology*, 16:439–443, 1961 and 17:609–612, 1962.

Drs. Hull and Long have been actively interested in the use of analogous systems to explain biological phenomena and hope that this approach may stimulate electrical engineering graduates to recognize that biological science offers them the opportunity for work at a truly professional level.

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THE GENERAL RADIO

EXPERIMENTER

VOLUME 37 No. 6 JUNE, 1963

IN THIS ISSUE

New

Digital Time and Frequency Meter
Solid-State Data Printer
Ferrite Isolators

THE GENERAL RADIO

EXPERIMENTER

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Type 1151-AP Counter measures period of output signal from a Type 1311-A Audio Oscillator. A Type 1137-A Data Printer provides a permanent record.

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GENERAL RADIO COMPANY (OVERSEAS), ZURICH, SWITZERLAND
REPRESENTATIVES IN PRINCIPAL OVERSEAS COUNTRIES

ZERO TO 300 kc
WITH FIVE-DIGIT ACCURACY

The new TYPE 1151-A Digital Time and Frequency Meter is a more sophisticated brother of the TYPE 1150-A Digital Frequency Meter previously announced.[1] It does not replace the TYPE 1150-A, but it does extend the range of precision frequency measurement to low frequencies, where a simple counting frequency meter is inefficient. Low frequencies are determined rapidly and accurately by measurement of their periods or decimal multiples of the period. Measurement of higher frequencies is accomplished in the usual fashion, by the counting of zero-crossings per unit time, but an altogether new and highly efficient program is used. Provision is also made for frequency-ratio and multiple-interval measurements in addition to the usual totalizing or accumulative counting functions.

The input circuit includes the controls necessary for measurement of pulsed and low-frequency signals — trigger level, slope polarity, and ac or dc coupling.

The new counter is available in two versions, the standard model, TYPE 1151-A, and the TYPE 1151-AP* which can be used to drive auxiliary equipment — like the TYPE 1137-A Data Printer described elsewhere in this issue.†

The other elements of the TYPE 1151-A counter are similar to the TYPE 1150-A introduced a year ago. Counting decades, quartz-reference oscillator, power supplies, and package are substantially the same.

THE COUNTER PROGRAM

The program of the TYPE 1151-A is as efficient as a program can be made for a counter without storage. It is more complex than the elementary program of the TYPE 1150-A Digital Frequency Meter, less so than the highly efficient program of the TYPE 1130-A Digital Time and Frequency Meter with its storage system.[2]

Since the two useful intervals are those for counting and display, it is obviously desirable to minimize the zero interval that occurs between the

[1]R. W. Frank and J. K. Skilling, "A Five-Digit Solid-State Counter for Frequency Measurements to 220 kc," *General Radio Experimenter*, 36, 4, April, 1962.

*The TYPE 1150-AP Digital Frequency Meter is also now available.

†See page 9.

[2]R. W. Frank and H. T. McAleer, "A Frequency Counter with a Memory and with Built-In Reliability," *General Radio Experimenter* 35, 5, May, 1961.

Figure 1. View of the Type 1151-A Digital Time and Frequency Meter.

end of the display interval and the start of the next counting interval. This has been done in the new counter, whose frequency-measurement program is shown in block form in Figure 2.

The time-base of the TYPE 1151-A counter is, like the ring counting decades previously described,[1] an innovation. This counter uses two identical binary scale-of-1000 dividers to control the counting gate duration and to produce variable display time. Since these dividers are aperiodic devices they can be used to produce multiple-period gating in decimal steps. These binary scaling devices cost less than many solid-state monostable dividers and are more reliable. They also make possible a more efficient program.

[1] *Loc. cit.*

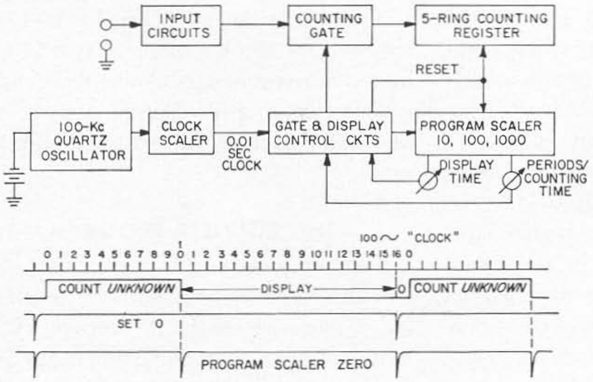


Figure 2. Elementary block diagram of the counter when used for frequency measurements. The program scaler determines the crystal-controlled counting time and the display time.

In a first scale-of-1000 divider, the 100-kc signal from the oscillator is reduced to 100 cps to supply clock pulses to operate the program. Assume that the counting register has just been cleared and the program scaler set to zero by a reset pulse. The next 100-cycle clock pulse will cause the main gate to open and the program scaler to advance 1 count. The program scaler is coded to count 10, 100, or 1000 clock pulses by the PERIODS/COUNTING TIME switch. When the appropriate number of clock pulses have been counted, the signal from the scaler closes the main gate. But the scaler's job is not finished. Upon main-gate closure, the scaler is reset and again begins to accumulate clock pulses. If, for example, a display interval of around 0.3 second is desired, the DISPLAY TIME switch set to its second position will terminate the display interval after $32(2^5)$ clock pulses have been accumulated. The program scaler operates in a pure binary fashion to count out 16, 32, 64, 128, 256, 512, and 1024 clock pulses corresponding to display time ranging from 0.16 to 10.24 seconds.*

At the conclusion of the display interval, the next clock pulse generates the reset pulse, and the very next clock pulse, 1/100 second later, will open the counting gate to begin a new measurement. The maximum "time out" for reset is 1/100 second, regardless of the gate time. Note that this program is what might be termed fully synchronous since all three intervals, counting, display, and reset, are continuously under control of the 100-cycle clock.

Figure 3 shows the rearrangement of the basic circuit blocks for period measurement.

Here, the input circuits produce their one pulse per cycle for the program, and the 100-kc oscillator pulses are passed through the counting gate to be accumulated in the register. Periods and their multiples are therefore measured in a minimum time increment of 10 μsec.

Let us assume, as with our previous example, that a reset pulse has just been produced. The next pulse from the input circuits will open the main gate and start the counting of the input pulses in the program scaler. If the scaler is not in the circuit, a single period will open and close the gate. If the PERIODS/COUNTING-TIME switch is set at 10, ten pulses must be counted before the gate closes, etc. Upon gate closure, the program scaler is reset to zero, and, as before, the pulses from the 100-cycle clock become

*This display interval has the same precision as the gate interval. This is incidental; unfortunately, no one has yet found a good use for it.

its input signal. A binary sequence of 100-cycle clock pulses is now counted to establish the display interval. The signal from the scaler via the display-time switch initiates the reset pulse, and we are back where we started from. The next pulse from the input circuits will again open the counting gate.

The program for frequency-ratio measurement is exactly like that for multiple-period measurement, shown in Figure 3. The 100-kc oscillator which provided the precision clock for period measurements is simply replaced with a second, simple, set of input circuits. Suppose a signal of 10 cps is impressed on the main input terminals (with the MEASUREMENT switch set to PERIOD). The counting register will display its period as 10,000 (tens of μsec). If the MEASUREMENT switch is now placed in RATIO position and a 100-kc signal is admitted, the register will still read 10,000, now the ratio of frequency B to frequency A. If the periods multiplier is set at 10, the reading is 10 B/A, etc.

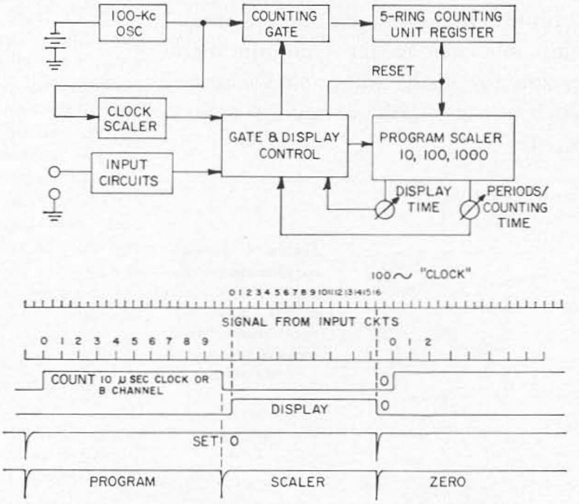


Figure 3. Elementary block and timing diagram of the counter when used for period measurement. The program scaler determines the number of periods measured and the display time.

INPUT CIRCUITS

The ideal digital frequency meter would be an automatic measuring instrument, to which one could connect a signal of any kind (no matter how weak, distorted, or noisy) and always get the correct answer. Furthermore, this perfect device should not burden the signal source with a load, either conductive, reactive, or radiational. While obviously never realized, this ideal is, nevertheless, the designer's objective. Input circuits should require an absolute minimum of adjustments and operator attention, should load the circuit under test as little as possible, and should radiate practically nothing. The input circuits of the TYPE 1151-A Digital Time and Frequency Meter are, we believe, the best available — almost without regard to cost.

To achieve the desired level of performance, the new counter has four input controls and switches (in contrast to the simple TYPE 1150, which had none). With these, one can choose:

(1) AC or dc coupling

(2) Zero-crossing slope for triggering

(3) Triggering level over a narrow range

(4) Higher sensitivity — 0.1 volt at 100-kilohm input resistance or, conversely, 1 volt into 1.0 megohm. (In other words, the input sensitivity is 1 microampere.)

While this flexibility is contrary to the ideal of automation, it does permit the counter to operate more successfully in noisy environments. Let us examine these input circuits to see what they can do.

Figure 4 is a simplified schematic of these circuits. It is not entirely new, but is a "transistorization" of an amplitude comparator designed for another instrument.[3] The circuit has the input characteristics of a Schmitt circuit, but has better common mode rejection for such things as variations in such power-supply voltage, temperature, etc.

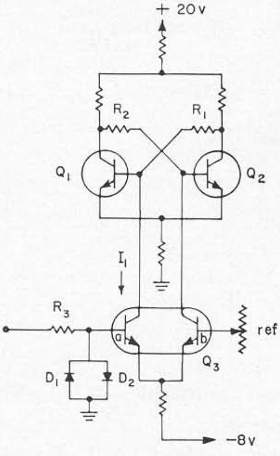


Figure 4. Elementary schematic diagram of the input-circuit amplitude comparator. Sensitivity is one microampere.

The pair of symmetrically connected transistors (Q_1, Q_2) forms a bistable switching circuit. A differential amplifier (Q_3), connected in the base circuits of the flip-flop transistors, modulates their base current with the input signal and causes switching at the signal rate. This differential-amplifier transistor is crucial to the circuit performance. It is a double silicon, planar, epitaxial unit with 20% gain (h_{fe}) balance, and less than 10 nanoamperes leakage.

The circuit operates in the following manner: Assume current balance in the differential amplifier and suppose that Q_1 is on. Q_1's low collector voltage, combined with the current passing the right side of the differential transistor, will keep Q_2 shut off and Q_2's collector voltage high. The higher current in R_3 to the base of Q_1 will, even in the presence of the equal current from the left side of the differential amplifier, keep Q_1 on. Now, suppose that the collector current of Q_{3a} (the left side of the differential pair) is decreased, owing to the presence of an input signal. The collector current of Q_1 will decrease and eventually would decrease sufficiently to permit Q_2 to go on. But, when Q_2 starts on, it begins to turn Q_1 off, and the circuit switches to the opposite state at a rate determined only by the gain-bandwidth product of Q_1 and Q_2. Remember, Q_3 helped Q_2 to go on in the first place and its other side was, at the same time, helping Q_1 to go off. But now the signal of Q_1 itself is keeping Q_2 on even when Q_3 is again at balance. Before the circuit can switch back to its original state, the current will have to be reversed in Q_3 to help Q_1 to go on. The amount by which the base current of Q_3 must be varied through the balance point to cause switching is the current sensitivity or "hysteresis" of the circuit. For the TYPE 1151-A Digital Time and Frequency Meter, this quantity is one microampere.

The input resistance at the base of Q_3 is low, but only one microampere is required to switch the circuit. One volt will cause switching when applied to the megohm resistor (R_3), and with 100 kilohms a tenth-volt is adequate. Input polarity is easily selected by simple interchange of the signal and reference. At one-megohm input impedance, this circuit typically has an input dc drift (the switching point) of less than 1 mv/°C with temperature, most of which is h_{fe} unbalance of Q_1 and Q_2 with temperature. The silicon diodes D_1 and D_2 are used to prevent saturation of high-beta transistors at elevated temperatures.

[3] R. W. Frank, "How to Kill Time — Accurately," *General Radio Experimenter*, 32, 19, December, 1958.

NOISE

The drifts in the operating point of the input switching circuit are a matter of concern, since they constitute a form of noise. This noise, which is due to thermal time constants, is very low in frequency and will only be significant when long periods are being measured, and then only during violent temperature changes.

Thermal drift is just one of the "noises" that detract from performance and which must be minimized in the in-

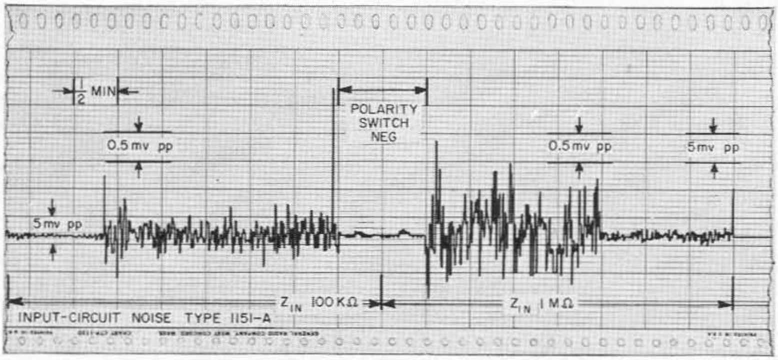


Figure 5. Analog recording of a continuous period measurement of a precise signal. The fluctuations of the curve indicate the counter's internal noise — less than 5 millivolts, peak-to-peak.

put circuits of a low-frequency counter. The specification for accuracy of a period measuring device always reads "±1 count ± time base accuracy ± error due to S/N of input signal." Often the counter manufacturer chooses to ignore the counter's own input-circuit noise. H. T. McAleer in a recent article in this publication[4] has discussed the effects of noises of all sorts on the accuracy of the measurements made by counters. Here we will repeat only the basic equation. When the input signal is a sine wave and triggering occurs on zero crossings, the error made in a period measurement due to input noise is:

$$(\text{error})\ \% = \pm \frac{1}{\pi} \frac{V_n}{V_s} \times 100$$

Where:

V_n = peak effective noise voltage
V_s = peak signal voltage

In this counter the equivalent input noise is less than 5 millivolts, peak-to-peak. In the best input circuit the irreducible input noise would be that in the input resistor and possibly the input transistor. In most counters, the noise is not random but is a relatively coherent signal, consisting of various signals produced within the counter. In the TYPE 1151-A counter, a lot of attention has been given to minimizing these noises.

Figure 5 is a recording showing fluctuations in the measured period of a low frequency (3 cps) signal. The period of this signal (a positive sawtooth) is precise, and its own noise is very low. The curve was obtained using a new storage-type digital-to-analog converter soon to be announced.

APPLICATIONS

A digital frequency meter is, as the name so clearly implies, an automatic instrument for the accurate measurement of frequency. It has two advantages over any other means of frequency measurement. First, it is accurate — as accurate, ultimately, as its reference oscillator (since provision is made for an external 100-kc precision source to control the gate time, accuracy is not necessarily limited to the accuracy of the built-in oscillator). Second, since the measurement is automatic and the result is displayed by big, bright, in-line indicators, the measurement can be made

[4] H. T. McAleer, "Digits Can Lie," *General Radio Experimenter*, 34, 12, December, 1962.

by unskilled people. The Type 1151-A Digital Time and Frequency Meter extends the range of accurate measurement to the frequencies where direct counting of the unknown is too time consuming.

The ratio channel is useful for direct-reading industrial measurements. A jack is provided at the rear for connection to the Type 1536-A Photoelectric Pick-off for measurements of rotational speed. By application of two input signals to the A and B channels, the counter can be made direct reading in any dimensional system, as ft/sec, rpm, gallons/-min, etc.

With appropriate transducers and terminal equipment the counter can indicate, and with the Type 1137 Data Printer can record, any measurement, as, for instance,

Units per anything
Force — weight — strain — pressure
Flow-rate
Velocity, linear or rotational
Voltage, current, resistance, via a voltage-to-frequency converter.

— R. W. Frank

SPECIFICATIONS

Frequency Measurement:
Range — DC to 300 kc.
Sensitivity — 0.1 volt, peak-to-peak, at 100 kilohms or 1 volt, peak-to-peak, at 1 megohm (1 microampere), switch-selected.
Counting Interval — 10 milliseconds to 10 seconds, extendible by multiplier switch.
Accuracy — ±1 count ± crystal-oscillator stability.

Period Measurement:
Range — DC to 20 kc.
Number of Periods — 1, 10, 100, or 1000.
Sensitivity — 0.1 volt at 100 kilohms or 1 volt, peak-to-peak, at 1 megohm (1 microampere), switch-selected.
Accuracy — ±1 count ± time base accuracy ± noise errors.
Input Noise — 5 millivolts equivalent open-circuit input noise at 1 megohm, less at 100 kilohms.
Counted Frequency — 100 kc.

Ratio Measurement:
Range — B/A, 10 B/A, 100 B/A, or 1000 B/A.
Frequency Range — A input, dc to 20 kc; B input, dc to 300 kc.
B Input — 1 volt peak-to-peak, 100 kilohms.

Display: 5-digit, in-line Numerik register, incandescent-lamp operated.

Display Time: 0.16, 0.32, 0.64, 1.28, 2.56, 5.12, or 10.24 seconds, switch-selected.

Input Impedance: 1 megohm shunted by 50 pf or 100 kilohms shunted by 500 pf, switch-selected.

Input Trigger Level: ±1 volt at 0.1-volt sensitivity; ±10 volts at 1-volt sensitivity.

Input Trigger Slope: AC or dc coupled, positive- or negative-going.

Crystal-Oscillator Stability:
Short-Term — Better than ½ part per million.
Cycling — Less than counter resolution.
Temperature Effects — Less than 2½ parts per million for rise of 0 to 50 C ambient.
Warmup — Within 1 part per million after 15 minutes.
Aging — Less than 1 part per million per week after four weeks, decreasing thereafter.

Crystal Frequency Accuracy: The frequency is within 10 parts per million when shipped. Frequency adjustment is provided.

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

Accessories Supplied: Type CAP-22 Power Cord, eight replacement incandescent lamps, spare fuses.

Accessories Available: Type 1136-A Digital-to-Analog Converter and Type 1137-A Data Printer operate from output of Type 1151-AP model.

Cabinet: Rack-bench.

Dimensions: Bench model — width 19, height 3⅞, depth 12½ inches (485 by 99 by 320 mm), over-all; rack model — panel 19 by 3½ inches (485 by 90 mm), depth behind panel 12¾ inches (328 mm).

Net Weight: 19 pounds (9 kg).

Shipping Weight: 22 pounds (10 kg).

Type		*Code Number*	*Price*
1151-AM	**Digital Time and Frequency Meter**, Bench Model . .	1151-9801	**$1195.00**
1151-AR	**Digital Time and Frequency Meter**, Rack Model . . .	1151-9811	**1195.00**
1151-APM	**Digital Time and Frequency Meter** (with output for printer or D/A converter), Bench Model	1151-9871	**1250.00**
1151-APR	**Digital Time and Frequency Meter** (with output for printer or D/A converter), Rack Model	1151-9981	**1250.00**

SOLID-STATE DATA PRINTER

Decimal-coded information can be reduced to a permanent, printed record through the use of a digital printer. For use with General Radio digital time and frequency meters, there is now available the TYPE 1137-A Data Printer, a precise, compact, and economical device, which is manufactured for the General Radio Company by Beckman Instruments, of Richmond, California. By fast parallel entry of 4-line BCD or 10-line code inputs, it can print at a rate of 3 lines per second with up to 12 digits per line.

The printer is equipped with plug-in solid-state code modules (see Figure 1) to control each digit column; a 4-line module which accepts 1-2-2-4, 1-2-4-8, or 1-2-4-2 coding; or a 10-line module which accepts either 10-line or 4-line data. Each printer contains the required quantity and type of code modules to operate with the intended digital instrument. Since the capacity of the printer is 12 columns, however, additional plug-in modules of either type are available for printing other data in the unused columns.

The digital information can be recorded in predetermined digit-columns and groups. The input cable provides a separate plug for each code module, so that input data can be programmed to specific digit-columns. In addition, the digital information can be separated into groups by application of a column-suppression signal to the code module

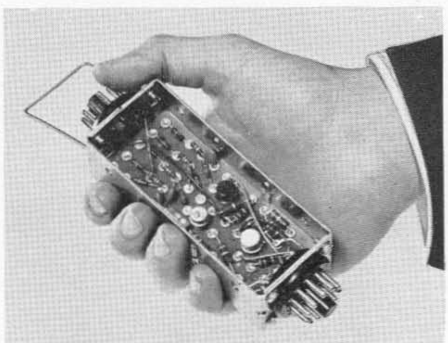


Figure 1. Multipurpose plug-in code modules with individual input connectors allow complete freedom for composing a desired printing format.

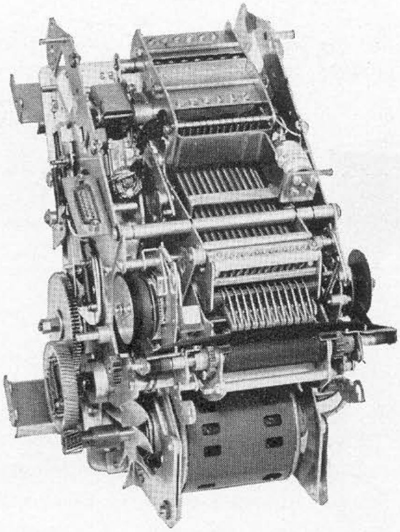


Figure 2. Compact, time-proven Burroughs printing mechanism is designed for continuous-duty operation with a minimum of maintenance.

of the digit-column in which a space is desired. Unplugging the appropriate code module will also accomplish this.

A two-color ribbon can be automatically or manually controlled to print black or red on standard 2¼-inch roll tape. This is a convenient means for indicating off-limit readings or readouts from different input sources.

The Type 1137-A Data Printer has a number of outstanding design features, which ensure optimum performance with a minimum of maintenance. Through the use of solid-state circuits and the absence of power-consuming keyboard actuators, over-all power requirements have been minimized. The extended front panel affords an unobstructed view of each line immediately after printing, and a useful flat surface for writing on the paper tape.

The solid-state code modules have convenient handles for quick removal from the top rear of the printer. To facilitate trouble-shooting or maintenance, the control circuit chassis is mounted vertically as an integral part of one of the side gussets.

The printing mechanism is a reliable Burroughs "10-key" tabulator, shown in Figure 2, which is designed for fast parallel-entry operation. Listing keys and intermediate keyboard have been replaced by small pawl-magnet devices, each of which controls an individual 0-to-9 type bar. This eliminates the need for complex mechanical linkages usually incorporated in digital printers. The stop-pawls and armatures (see Fig-

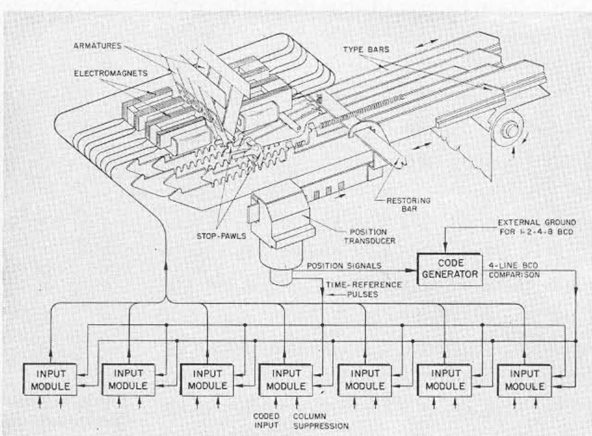


Figure 3. During the printing cycle the type bars move from "0" through "9", and the position transducer and code generator produce binary-coded voltages. When these voltages coincide with the input signals, the input modules transmit pulses to drop the stop pawls and hold the type bars until the cycle is completed.

ure 3) are reset mechanically; thus the associated electromagnets require only a minimum of power to hold their respective armatures in the actuated position. Each electromagnet is provided with an electrical suppressor. This — plus the use of an induction motor operated continuously — helps to minimize radiated electrical interference.

In place of the usual sliding-contact commutators or stepping switches, a single-position transducer and code generator are used to translate each position of the type bars into binary-coded voltages. These voltages are compared with the input signals in the plug-in code modules. Whenever the input code coincides with the internal type position code, a pulse is generated which releases the particular stop-pawl to lock the type bar in the proper digit position. This position-decoding process continues from "0" through "9" until all type bars are properly indexed. The platen is then mechanically engaged and shifted upward toward the in-line type, printing the correct digits on the paper tape.

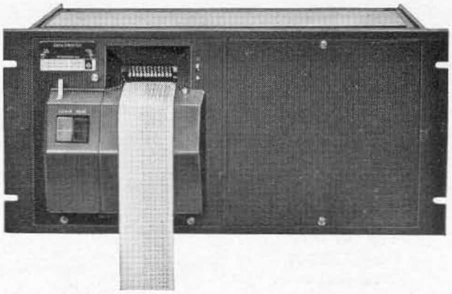


Figure 4. View of the Type 1137-A Data Printer, Rack Mounted.

This compact printer is available in either a portable cabinet for bench use, as shown on page 9, or a relay-rack adaptor cabinet, as shown in Figure 4. The printer occupies only half the panel space of the relay-rack adaptor cabinet, leaving adjacent space for associated equipment.

A cable is supplied with the printer for direct connection to the companion instrument.

— H. T. McAleer

SPECIFICATIONS

Capacity: 12 columns.

Digits: 0 through 9 or blank (column suppression).

Printing Rate: 3 lines per second maximum.

Accuracy: Identical to input.

Input:

Logic Levels —

Source Resistance	*Binary 0*	*Binary 1*
100 kilohms	−8 to −50 v	0 to +50 v
2 megohms	−12 to −50 v	0 to +50 v

Code — 10-line code (one wire is binary 1, eight wires binary 0) or four-line BCD (1-2-2-4, 1-2-4-8, or 1-2-4-2) input.

Resistance — Approximately 10 megohms for minus input, 200 kilohms for plus input.

Internal Ground: Isolated from chassis. May be biased to ±100 volts.

Color-Control:

Manual — Two-position lever selects red or black print-out.

Remote — Red, binary 1 or open circuit; black, binary 0. Input resistance approximately 2 megohms.

Column Suppression: Single line grounded for each column suppressed (3 milliamperes maximum, +10 volts open circuit).

Print Command: Change from binary 1 to binary 0. Binary 0, 100 milliseconds minimum after print command; binary 1, 15 milliseconds minimum before next print command. Source resistance 1 megohm maximum.

Inhibit Reset Output: Occurs within 50 milliseconds after print command; 200 milliseconds maximum duration.

Printing Ribbon: 7/16-inch two-color adding-machine ribbon.

Paper: Standard 2¼-inch roll tape.

Power Requirements: Types 1137-9731, 1137-9732, 1137-9735, and 1137-9736 — 115 volts, 60 cps, 45 watts. Types 1137-9733, 1137-9734, 1137-9737, and 1137-9738 — 230 volts, 50 cps, 45 watts.

Accessories Supplied: Cable assembly for connection to counter, spare fuses.

Accessory Available: Types 1137-9604 and 1137-9605 Plug-In Code Modules.

Cabinet: Rack and portable models available.

SPECIFICATIONS (Cont.)

Dimensions: Rack model — width 19, height 8¾, depth 15¼ inches (485 by 225 by 390 mm), over-all; portable model — width 9, height 10, depth 16½ inches (230 by 255 by 420 mm), over-all.

Net Weight: Rack model, 45 pounds (20.5 kg); portable model, 35 pounds (16.0 kg).

Shipping Weight: Rack model, 55 pounds (25.0 kg); portable model, 45 pounds (20.5 kg).

	Type		*Code Number*	*Price†*
For use with Type 1130-A Counter*	**1137-9731**	**Data Printer,** Portable Model (115 v, 60 cps)	1137-9731	**$1675.00**
	1137-9732	**Data Printer,** Rack Model (115 v, 60 cps)	1137-9732	**1725.00**
	1137-9733	**Data Printer,** Portable Model (230 v, 50 cps)	1137-9733	**1700.00**
	1137-9734	**Data Printer,** Rack Model (230 v, 50 cps)	1137-9734	**1750.00**
For use with Types 1150-AP and 1151-AP Counters	**1137-9735**	**Data Printer,** Portable Model (115 v, 60 cps)	1137-9735	**1350.00**
	1137-9736	**Data Printer,** Rack Model (115 v, 60 cps)	1137-9736	**1400.00**
	1137-9737	**Data Printer,** Portable Model (230 v, 50 cps)	1137-9737	**1375.00**
	1137-9738	**Data Printer,** Rack Model (230 v, 50 cps)	1137-9738	**1425.00**
	1137-9604	**Plug-In Four-Line Code Module**	1137-9604	**55.00**
	1137-9605	**Plug-In 10-Line Code Module**	1137-9605	**75.00**

*Type 1130-A counters shipped before February 1963 require minor modification. A modification kit is included with these printers. †Prices applicable for sales in U.S.A. and Canada only.

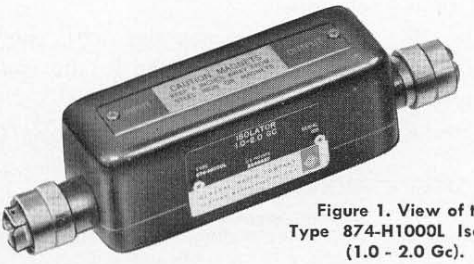


Figure 1. View of the Type 874-H1000L Isolator (1.0 - 2.0 Gc).

NEW FERRITE ISOLATORS

Ferrite isolators are basically one-way transmission devices. An rf signal applied at one port of an isolator is attenuated very little in passing through the isolator to the second port. However, a signal applied at the second port of the isolator is substantially attenuated in passing through the isolator to the first port.

When an isolator is inserted between a signal source and a load, the energy from the source is transmitted to the load with very little loss, but, owing to the high attenuation in the reverse direction, the undesirable effects of changes in load conditions on the source amplitude and frequency are substantially reduced. The isolator thus offers the distinct advantage of low insertion loss over the ordinary attenuator pad. As a result higher system sensitivities (or levels) can be achieved for a given source power.

DESCRIPTION

Coaxial ferrite isolators are now available that offer high performance characteristics over relatively wide frequency

TABLE I

Type	Frequency Range	Isolation	Insertion Loss	Can Be Used With These GR Oscillators
874-H500L	0.5 to 1 Gc	10 to 15 db	0.5 to 1.5 db	1209-C, -CL, 1361-A, 1021-AU
874-H1000L	1 to 2 Gc	10 to 15 db	0.5 to 1 db	1218-A
874-H2000L	2 to 4 Gc	20 to 25 db	0.5 to 1 db	1220-A, 1360-A

bands, as shown in Figure 2 and Table I. They can actually be used over considerably wider frequency ranges than their rated 2-to-1 bands with some deterioration in performance. They are equipped with locking Type 874 Connectors and will handle up to 5 watts cw power.

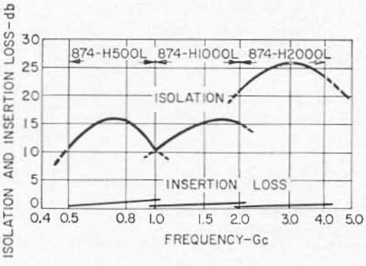


Figure 2. Average isolation and insertion-loss characteristics of several isolators.

THEORY OF OPERATION

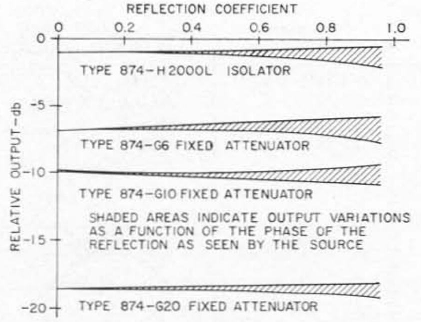
The isolators described here are based on the phenomenon of resonance-absorption. Their isolation characteristics depend on the absorption of energy that occurs at ferromagnetic resonance. To achieve this resonance, a ferrite material is placed in a region where the field is circularly polarized, and the ferrite is transversely magnetized by an external, static magnetic field. The resonance occurs when the strength of the external static field is such that the precession rate of the ferrite electron-spin axes caused by the static field is approximately equal to the frequency of the circularly polarized field. (The circularly polarized field is created in the coaxial isolator by placing dielectric material asymmetrically between the outer and inner conductors.)

When a signal is applied at one port of an isolator, the sense of rotation of the circularly polarized field generated by the dielectric is opposite to the direction of electron precession in the ferrite, and there is little interaction between the ferrite and the applied field. When the signal is applied to the other port of the isolator, the rotation of the field is in the same direction as the precession; the field is strongly coupled to the ferrite electrons, and a large amount of energy is dissipated in the ferrite.

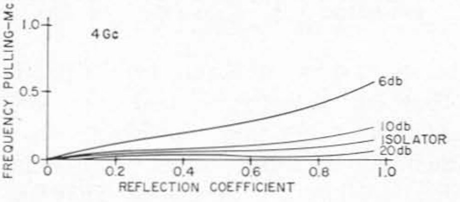
REFLECTIONS AND RF SOURCES

When an rf oscillator feeds a load directly, reflections from the load on arriving back at the source can influence the source output power and frequency. When the frequency of operation and the load conditions are fixed, the reflections, unless they are very large, do not usually affect the stability of the source output.

When changes are made in the load conditions, as for instance, when the load is an adjustable attenuator in an attenuation-measuring system, or when various loads or a sliding short circuit is connected to an impedance-measuring system, the change in load reflections can cause changes in the amplitude and frequency of the source. Similarly, when the source frequency is varied with fixed load conditions, the reflections (as observed from the source) change in amplitude and phase and affect the amplitude



Isolator *vs* fixed attenuators at 4 Gc, controlling output variations (Figure 3, *left*) and frequency pulling (Figure 4, *below*) of rf source (Type 1360-A Microwave Oscillator).



and frequency of the source. In either case, an isolator between the source and the load will improve the source stability.

The output impedance of an rf source is usually not 50 ohms. Many applications, however, require a matched source. Here the isolator can convert the effective source output impedance to 50 ohms over broad frequency ranges without tuning and with a minimum of power loss.

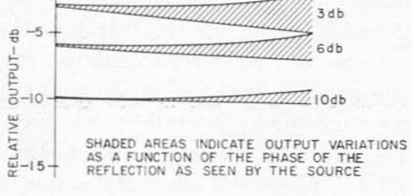
ISOLATORS VERSUS ATTENUATOR PADS

Figures 3 and 4 show the advantages of the isolator over the fixed attenuator pad. The data were taken with a General Radio Type 1360-A Microwave Oscillator operating at 4.0 Gc. Loads whose reflection coefficients vary from 0 up to approximately 1.0 were used, and their phases relative to the source were varied by means of a line stretcher between the source and the load. The isolator used was a Type 874-H2000L that, at 4.0 Gc, had an insertion loss of 0.9 db and an isolation of 24 db. Three Type 874-G Fixed Attenuators of 6, 10, and 20 db, respectively, were used for comparison. The shaded areas in Figure 3 show the variations in output at any given reflection coefficient as the phase of the reflected wave is varied through 180 degrees.

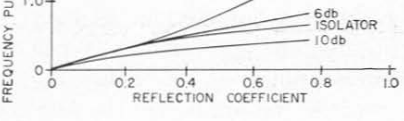
Figure 4 shows the frequency-pulling effects on the oscillator as a function of load reflection coefficient. Note that the isolator is better than the 10-db pad in controlling the frequency-pulling effects.

Additional data taken with a Type 1218-A Unit Oscillator operating at 1.5 Gc and a Type 874-H1000L Isolator (insertion loss of 0.9 db and isolation of 13 db) are presented in Figures 5 and 6.

Similar performance will be obtained with other types of oscillators. Triode, transistor, klystron, backward-wave, magnetron, and other oscillators having tightly coupled output circuits are subject to similar instabilities, and the use



Isolator *vs* fixed attenuators at 1.5 Gc, controlling output variations (Figure 5, *left*) and frequency pulling (Figure 6, *below*) of rf source (Type 1218-A Unit Oscillator).



of an isolator as opposed to an attenuator pad is equally advantageous with all types of sources.

APPLICATIONS

Attenuation Measurements

In the measurement of attenuators, filters, and other devices where attenuation may be high, it is usually important that the device under measurement be working between matched source and load. In addition, it is usually necessary to use all available power in order to attain sufficient sensitivity in the regions of high attenuation. Here the use of an isolator between the source and the device under test offers distinct advantages.

On the detector side, an isolator provides a match over more than a 2-to-1 frequency band while introducing a comparatively negligible loss in transmission. Neither tuners nor attenuator pads meet both these conditions.

Slotted-Line Measurements

In a slotted-line measurement system in which a tightly coupled, unmatched rf source is used, changes in frequency with changes in the impedance of the unknown connected can cause errors. For example, if the position of the desired reference plane is determined by the positions of voltage minima with the unknown and with a short- or open-circuit termination connected, a change in frequency will cause an error in the position of the reference plane. Similar errors can occur when a sliding short circuit is used. In systems in which sensitivity is a limitation, for instance, when very large VSWR's are measured, the use of an isolator in place of an attenuator can result in an improvement in measurement accuracy.

General

These isolators can also be used:

To match a detector to a 50-ohm line over a broad frequency band without tuning and without a significant reduction in sensitivity.

To improve the source amplitude stability in both fixed and sweep-frequency systems that require an amplitude-regulated rf output.

In a heterodyne detector to reduce the level of the local-oscillator signal appearing at the detector terminals by 10 to 20 db.

Wherever source output stability, impedance match, or minimum loss is an important consideration.

— T. E. MacKenzie

SPECIFICATIONS

Type	*Frequency Range — Gc*	*Insertion Loss db — Max*	*Isolation db — Min*	*VSWR Max*	*CW Power Watts — Max*	*Length*		*Net Weight*	
						Inches	*Millimeters*	*Pounds*	*Kilograms*
874-H500L	0.5 to 1	1.5	10	1.20	5	10¾	275	4	1.8
874-H1000L	1 to 2	1.0	10	1.15	5	7¾	200	1½	0.7
874-H2000L	2 to 4	1.0	20	1.18	5	8¼	210	2	0.9

Type		*Code Number*	*Price*
874-H500L	**Isolator**	0874-9581	**$550.00**
874-H1000L	**Isolator**	0874-9583	**325.00**
874-H2000L	**Isolator**	0874-9585	**275.00**

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

General Radio Exhibit in Tokyo

General Radio was proud to be one of the firms taking part in the opening exhibit at the new U.S. Trade Center in Tokyo. The exhibit, featuring industrial instruments and laboratory apparatus from 58 U.S. firms, ran from April 2 to 26, and attracted some 10,000 visitors, including Undersecretary of Commerce Franklin D. Roosevelt, Jr., and U.S. Ambassador to Japan E. O. Reischauer.

The GR exhibit was presented by our representative in Japan, the Midoriya Electric Company, of Tokyo.

General Radio at new U.S. Trade Center in Tokyo, as seen by U.S. Undersecretary of Commerce Franklin D. Roosevelt, Jr., with representatives of Midoriya Electric. From left to right, the Messrs. Nagakura, Sales Engineer; Kuroha, President; FDR, Jr.; Sekido, Import Division Manager; and Ishizawa, Manager, Instrument Sales Section.

Personnel Changes at our Sales Engineering Offices

Ronald F. Mossman was recently transferred to the Toronto Office, after nearly a year at our plant in West Concord.

Harold Stevens joined the staff of our Los Angeles Office in March, 1963. His territory will include metropolitan Los Angeles plus the military installations in the Mojave Desert region of California.

Ronald Mossman

Harold Stevens

General Radio Company

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THE GENERAL RADIO

EXPERIMENTER

VOLUME 37 No. 7 JULY, 1963

HIGHER ACCURACY, HIGHER FREQUENCIES WITH NEW ELECTRONIC VOLTMETER

The TYPE 1806-A Electronic Voltmeter (Figure 1) is a completely new instrument, superseding the TYPE 1800-B Vacuum-Tube Voltmeter. In this design we have been able not only to improve the performance substantially but also to make the instrument much more convenient to use. The new voltmeter embodies the following features:

Improved Performance

Improved accuracy — the basic accuracy is ±2% *of indication.*

Better frequency response — the probe is usable up to 1500 Mc for voltage measurements.

Wider voltage range — up to 1500 volts, both ac and dc, can be measured without external voltage dividers.

Figure 1. View of the Type 1806-A Electronic Voltmeter — portable model, in Flip-Tilt case.

CONTENTS OF THIS ISSUE

Stability — both zero stability and long-term calibration stability have been improved.

Increased Convenience

There are only four ranges, each covering a span of 10 to 1; the number of times the operator must turn the range selector switch is greatly reduced.

A single scale serves for all voltage readings (except on the lowest ac range).

Logarithmic scale on the meter gives constant-percentage resolution and readability.

New small probe is much easier to connect to modern small circuit components.

An ohmmeter is included for convenient resistance measurements.

The Flip-Tilt case permits tilting the meter for error-free antiparallax readability from almost any angle.

Alternate model is also available for relay-rack mounting.

Storage for the probe and its cable is provided inside the cabinet.

Improved circuits, new components, and modern mechanical design have all contributed to these performance characteristics and convenience features.

DESCRIPTION

Figure 2 is a simplified schematic of the Type 1806-A Electronic Voltmeter. The instrument is basically a high-quality dc amplifier, which is used directly for dc voltage measurements. There is included, for measurement of ac voltage, a diode probe, which rectifies the ac signal and whose output is measured by the same dc amplifier. The dc amplifier is also used in ohmmeter operation to measure the voltage drop across the unknown resistor in a voltage-divider-type ohmmeter.

DC Circuit

The dc amplifier is a balanced circuit, which functions as a pair of cathode followers, driving the meter circuit from cathode to cathode. There are two important operating parameters of a circuit of this type, the open-circuit voltage gain and the output resistance. The gain directly controls the calibration of the voltmeter; the output resistance appears directly in series with the meter and affects the calibration mainly on the most sensitive ranges. Both of these parameters, therefore, must be stabilized if the voltmeter is to retain its calibration. Owing to the use of a novel circuit, the voltage gain is extremely stable and the output impedance is so low that its variations are negligible.

Each "cathode follower" is made up of two vacuum tubes and one transistor, so connected as to operate much nearer to the ideal than is possible with one tube alone.

The first tube is operated as a simple cathode follower, and the transistor and the second tube comprise a circuit, suggested by Henry P. Hall, of the General Radio Company, which possesses a number of desirable characteristics. First of all, the input impedance (at the emitter) is extremely high, being approximately equal to the collector resistor in value. This means that the gain of the first tube is very closely equal to $\mu/(\mu + 1)$, a term which is substantially invariant during the lifetime of the tube. The gain of the transistor-tube circuit, being highly stabilized by feedback, differs from unity by only a few parts per million, so that the voltage gain of the entire circuit is quite independent of the gradual decrease in transconductance that occurs as the tubes age.

Secondly, the output impedance of the Hall circuit is less than one ohm, owing to the high gain enclosed in its feedback loop and, consequently, the variation in output impedance with tube aging is completely negligible (the lowest total resistance in the meter branch is 1500 ohms). In fact, the substitution of tubes of different types (but having the same base connections) for the second tube in this circuit produced no discernible change in calibration and only very slight changes in zero setting. We confidently predict that this instrument will not need recalibration of its dc ranges during the two-year warranty period and perhaps never during the lifetime of the instrument (barring catastrophic tube or component failure).

DC Zero Stability

An additional advantage of this circuit is its extremely good zero stability, which results from the completely balanced circuit arrangement and the use of regulated heater voltages on all tubes.

Open-Grid Operation

Range switching of the dc-voltmeter circuit is accomplished by changes in the resistance in series with the meter. Since the input voltage limit of the electronic circuit is 150 volts, an internal voltage divider is used on the 1500-volt range. Its total resistance is 100 megohms, and it can be connected or not on the other three ranges to serve as the input grid leak. With the 100-megohm resistance switched out by means of the screwdriver-type control on the front panel, measurements of dc voltage on circuits having source resistance of up to 100 or 1000 megohms are possible. The zero can be adjusted to compensate for the voltage offset due to grid current. The first tube is operated at reduced heater voltage and low plate current to keep the grid current less than 10^{-10} amperes.

Current Measurements

External resistances can be connected across the input terminals for the measurement of direct currents. For example, with a one-megohm resistor connected

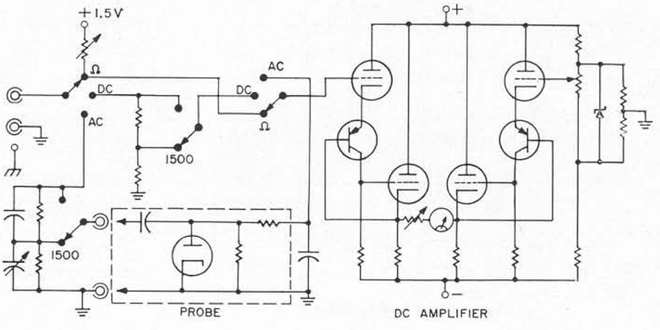


Figure 2. Simplified schematic diagram of the Type 1806-A Electronic Voltmeter.

as an external shunt (and with the 100-megohm resistance switched out), the meter on the most sensitive range corresponds to 1.5 microamperes full scale, and the smallest division corresponds to 5 nanoamperes. With a shunt of 10 megohms, these numbers become 0.15 microampere and 0.5 nanoampere, respectively. On these ranges the leakage currents of silicon transistors can be easily measured.

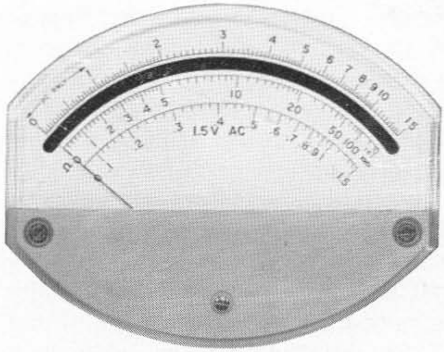


Figure 3. The meter scale. Note that all dc voltages and all ac voltages above 1.5 volts are read on a single scale.

Meter

The meter movement used in this new voltmeter is supplied by the Precision Meter Division of Minneapolis-Honeywell and was suggested and developed for General Radio by the late Roscoe Ammon. Starting at zero, the deflection characteristic is linear up to 1/10 full-scale current, and then is logarithmic the rest of the way, as shown in Figure 3.

This deflection characteristic has a number of important advantages. First, the meter can be adjusted to perform with such high accuracy that we have been able to specify a basic accuracy for the voltmeter of 2% of *actual reading*. A comparison of actual operating accuracy against that of a linear meter rated in terms of percentage of full scale will illustrate how striking is the improvement. As shown in Figure 4, on a linear meter rated at 2% of full scale, the reading at a point one-third of full scale is subject to an error of 2% of full scale or 6% of the reading. This new voltmeter rated at 2% of reading is, therefore, as much as three times as accurate as a conventional voltmeter rated at 2% of full scale.

Second, this deflection characteristic allows ranges to be switched by factors of ten; thus the number of times it is necessary to operate the range switch is greatly reduced. By far the greatest advantage of ten-to-one range switching, however, is that, with the exception of the lowest ac range, all voltage read-

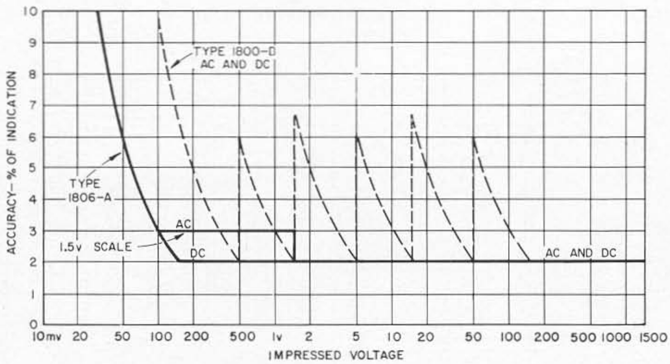


Figure 4. Accuracy as a function of scale reading for the Type 1806-A Electronic Voltmeter, compared with that of its predecessor, the Type 1800-B, whose accuracy was 2% of full scale.

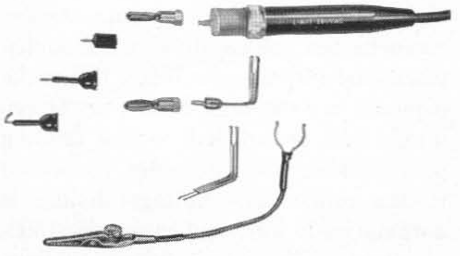


Figure 5. The ac probe and its accessory tips and ground clips.

ings are made on *one* scale. This eliminates what is probably the greatest source of error on most multiscale voltmeters, that of the operator inadvertently reading the wrong scale.

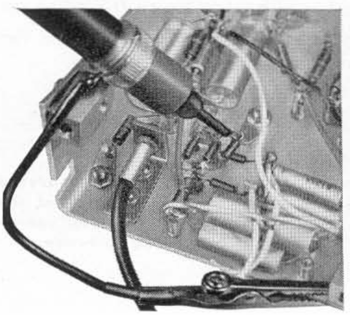
Third, because of the expansion of the scale at the low end of this meter, the deflection sensitivity down-scale is that of a linear meter having three times the sensitivity of this one, i.e., on the 1.5-volt dc range, the low end of the scale is as easy to read as that of a linear meter of 0.5 volt full scale. On this meter, on the 1.5-volt range, the smallest scale division is 5 millivolts!

AC Probe

Substantial improvements have been made in the performance and convenience of the ac probe. The diode is one of the small ceramic types developed by the General Electric Company. Its small size not only keeps the inductance low, giving the probe a resonant frequency higher than 3000 Mc, but has permitted a substantially smaller over-all size than existing probes of this type. Figure 5 shows the probe together with its accessory tips and ground clips. Figure 6 shows a number of different ways in which these accessories can be combined. Because the probe is small, and because of the versatility of these accessories, high-frequency measurements can be easily made even at points in modern miniaturized circuits.

Use at UHF

Above several hundred megacycles per second it is necessary to use the probe in a closed coaxial system to avoid connection errors. An accessory Tee Connector, Type 1806-P1, is available for bridging the probe across a coaxial line. It replaces the probe cap, as shown in Figure 7. It is equipped with General Radio Type 874 Locking Connectors and is compensated so that the disturbance in a smooth line resulting from the introduction of the probe and tee connector is a minimum. The voltage-standing-wave ratio of the tee connector and probe in a 50-ohm system is less than 1.10 at frequencies below 1000 Mc and typically does not exceed 1.2 at frequencies below 1500 Mc. The voltage indication is subject to error at high frequen-



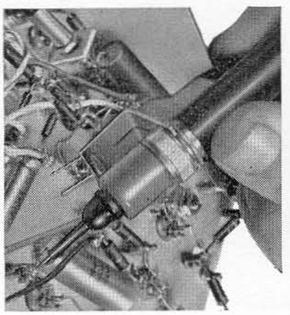
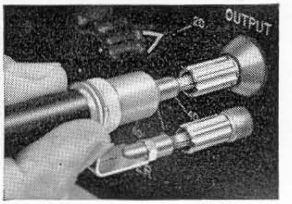


Figure 6. Various methods of using the probe with different combinations of the tips and ground clips.



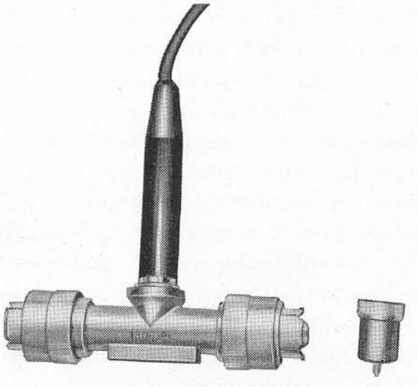


Figure 7. The probe with cap removed and the tee connector screwed on for ultra-high-frequency measurements.

cies from several sources: the resonance of the probe, transit time in the diode, and, to a slight extent, the compensation included in the tee connector. The typical magnitude of the error of voltage indication is shown in Figure 8. The error is a function of voltage level, because the effect of transit time depends upon the magnitude of the input voltage. This graph shows the difference (in decibels) between the voltage indication of the meter and the voltage measured at a low-VSWR 50-ohm termination on the same line. The specification on accuracy is that the error will not exceed 3 db for frequencies less than 1500 Mc.

High Voltages

For the measurement of ac voltages above 150 (the limitation imposed by the peak-inverse-voltage rating of the high-frequency diode), a capacitance-compensated voltage divider is included inside the instrument. When the probe is placed in its storage socket, ac voltage inputs can be applied to the binding posts, which are internally connected to the probe. The voltage divider is automatically switched in on the 1500-volt range. The upper frequency limit for ac signals applied to the binding posts in this manner is 500 kc.

Ohmmeter

For the measurement of resistance, the voltmeter is converted into an ohmmeter by the addition of a set of range-selector resistors connected to a regulated power supply. The ohmmeter is of the customary voltage-divider type. The use of a regulated power supply obviates the necessity for a full-scale adjuster on the panel of the instrument. The ohmmeter operates from a 1.5-volt source — a compromise between a voltage that is high enough to give stable operation of the dc voltmeter circuit and low enough to prevent burnout of sensitive devices. The maximum available power from the ohmmeter circuit is 16 milliwatts and the maximum short-circuit current is 43 milliamperes.

The wide-range logarithmic scale on the meter necessitates only four ranges, having center-scale values of 10 ohms, 1 kilohm, 100 kilohms, and 10 megohms. The scale is calibrated from 0.2 ohm on the lowest range to 1000 megohms on the highest.

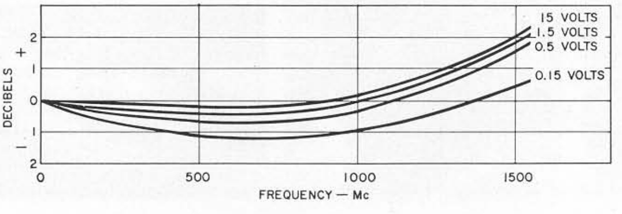


Figure 8. Typical high-frequency response characteristics of the probe and tee connector operating in a 50-ohm system.

Because of the high accuracy of the meter, the dc amplifier, and the ohmmeter circuit, we have conservatively rated the accuracy of the ohmmeter as $\pm 5\%$ of indicated resistance value, from 1 to 10 on the scale, decreasing to $\pm 10\%$ at 100 on the scale. For comparison of two resistances of approximately the same value, much smaller percentage differences can be observed. The wide range, absence of full-scale adjustment, and zero stability of this ohmmeter make it an extremely useful addition to the voltmeter.

External Description

The Type 1806-A Electronic Voltmeter is shown in Figure 1. This instrument is mounted in the by-now familiar Flip-Tilt case pioneered by General Radio. This case permits the instrument to be tilted so that the meter can be read without parallax from almost any angle. Figure 9 shows several possible attitudes for this voltmeter and illustrates the wide latitude that one has in

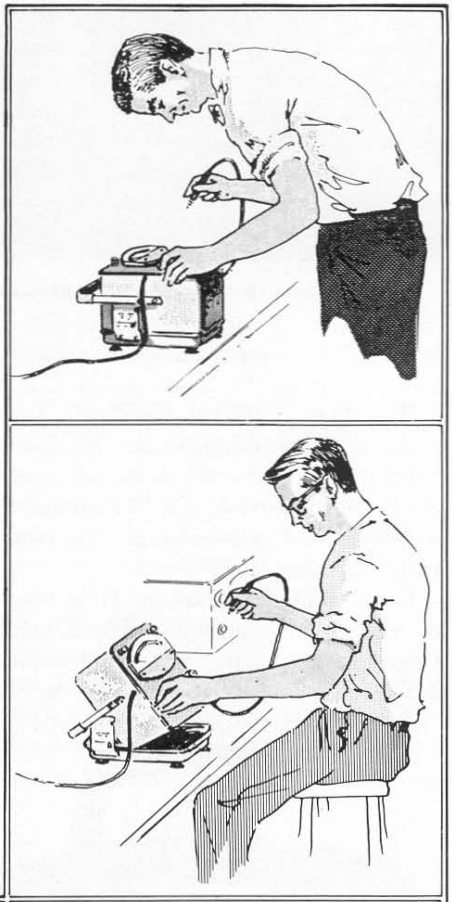
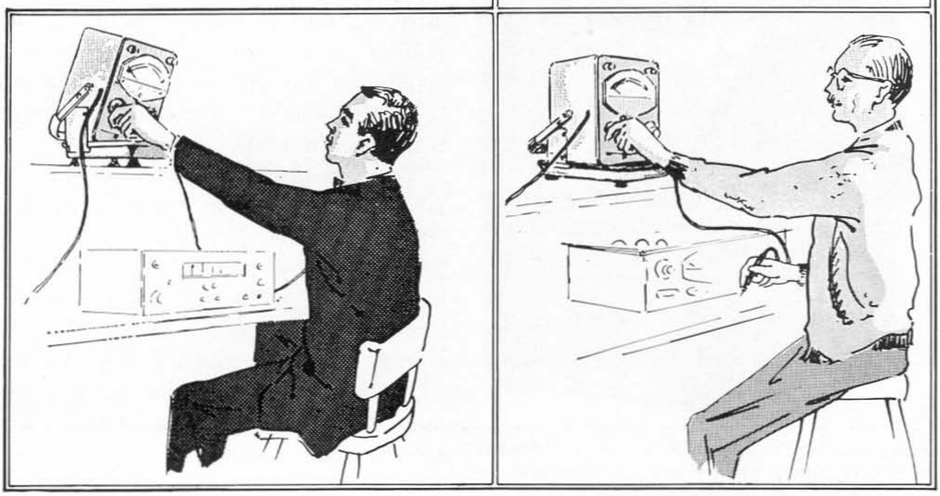


Figure 9. Various methods of placing the Flip-Tilt case for convenience in reading the meter.



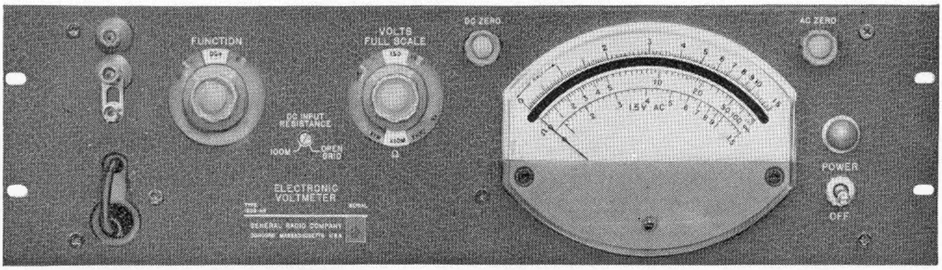


Figure 10. View of the Type 1806-AR Electronic Voltmeter for relay-rack mounting.

setting it up for convenience and accuracy in reading.

The Type 1806-AR Electronic Voltmeter is shown in Figure 10. This instrument contains the same electrical circuits as the Type 1806-A, but is mounted in a cabinet designed especially for relay-rack mounting.

In these photographs the large, easy-to-read meter is clearly visible. The arc length of the outer scale is 6 inches, which contributes considerably to the readability. The probe is visible in Figure 1, and at the lower right-hand corner of the panel is the storage socket for it. The probe cable can be stored in an internal reel and pulled out or pushed in as necessary. When the cover is closed, the power cord, which is permanently attached, can be wrapped around the large rubber feet, as shown in Figure 11.

Figure 11. The Type 1806-A Electronic Voltmeter with cover closed and the power cord around the rubber feet for storage or transporting.

Another unusual convenience feature of this voltmeter is that the range-selector switch turns in the same direction as the desired motion of the pointer on the meter. This is most easily seen on the ohmmeter, where, if the pointer is near zero, the range knob should be turned clockwise to bring the pointer clockwise, nearer to center scale. Similarly, on voltage measurements, if the pointer is off scale, the range knob should be turned counterclockwise to bring the pointer counterclockwise until it is again on scale.

This new design embodies several important advances: in performance, increased accuracy, wider ranges, and greatly improved stability; in convenience, the Flip-Tilt case, the ten-to-one range switching, the new small probe with storage provision, and the large meter.

These features combine to produce unusual simplicity of operation and accuracy of measurement.

— James J. Faran, Jr.

SPECIFICATIONS

DC VOLTMETER

Voltage Range: Four ranges, 1.5, 15, 150, and 1500 volts, full scale, positive or negative. Minimum reading is 0.005 volt.

Input Resistance: 100 megohms, ±5%; also "open grid" on all but the 1500-volt range. Grid current is less than 10^{-10} amperes.

Accuracy: ±2% of indicated value from one-tenth of full scale to full scale; ±0.2% of full scale from one-tenth of full scale to zero. Scale is logarithmic from one-tenth of full scale to full scale, permitting constant-percentage readability over that range.

AC VOLTMETER

Voltage Range: Four ranges, 1.5, 15, 150, and 1500 volts, full scale. Minimum reading on most sensitive range is 0.1 volt.

Input Impedance: Probe, approximately 25 megohms in parallel with 2 pf. Voltages above 150 use an internal voltage divider, and input impedance is 25 megohms in parallel with 30 pf.

Accuracy: At 400 cps, ±2% of indicated value from 1.5 volts to 1500 volts; ±3% of indicated value from 0.1 volt to 1.5 volts.

Waveform Error: On the higher ac-voltage ranges, the instrument operates as a peak voltmeter, calibrated to read rms values of a sine wave or 0.707 of the peak value of a complex wave. On distorted waveforms the percentage deviation of the reading from the rms value may be as large as the percentage of harmonics present. On the lowest range the instrument approaches rms operation.

Frequency Range: Low-frequency roll-off is less than 3% at 20 cps. Probe resonant frequency is above 3000 Mc. Above several hundred megacycles per second, probe should be used in a 50-ohm coaxial system with the accessory tee connector. The error is then less than ±3 db below 1500 Mc, and VSWR of the tee connector and probe is less than 1.1 below 1000 Mc. Total error, which for low voltages is a function of the input voltage level because of transit-time effects, is shown in the accompanying plot. Above 150 volts with internal voltage divider there is an additional error of not more than ±2% for frequencies below 500 kc.

OHMMETER

Range: 0.2 ohm to 1000 megohms in four ranges with center scale values of 10 ohms, 1 kilohm, 100 kilohms, and 10 megohms.

Test Voltage: The dc test voltage is positive with respect to ground and never exceeds 1.5 volts. The maximum current (which is delivered to a short circuit on the lowest resistance range) is approximately 43 ma. The maximum available power from the ohmmeter circuit is 16 mw.

Accuracy: ±5% of indicated value from 1 to 10 on scale, approaching ±10% of indicated value at 100 on scale.

GENERAL

Power Requirements: 105 to 125 (or 210 to 250) volts, 50 to 400 cps, 20 watts, approximately. The case is grounded by the third wire in the power cord. The voltmeter circuit can be disconnected from the case and operated as much as 300 volts dc off ground. The low input terminal remains by-passed to the case.

Probe Storage: A socket and reel store both probe and cable.

Accessories Supplied: Spare fuses, CAP-22 Power Cord (on -AR only), an assortment of probe tips for various types of connections.

Cabinet: Portable model, Flip-Tilt case. Rack model on 19-inch panel.

Dimensions: Portable model, case closed — 7½ by 8½ by 11½ inches (190 by 220 by 295 mm), over-all; rack model — panel 19 by 5¼ inches (485 by 135 mm), depth behind panel 9¼ inches (235 mm).

Net Weight: Approximately 10 pounds (4.6 kg).

Shipping Weight: Approximately 16 pounds (7.5 kg).

Type		*Code Number*	*Price*
1806-A	**Electronic Voltmeter, Portable Model**	1806-9701	**$490.00**
1806-AR	**Electronic Voltmeter, Rack Model**	1806-9811	**490.00**
1806-P1	**Tee Connector**	1806-9601	**35.00**

Vacation Closing

During the weeks of July 22 and July 29, our Manufacturing Department will be closed for vacation.

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

REDESIGNED MEGOHMMETER SIMPLIFIES INSULATION RESISTANCE MEASUREMENT

Users of the TYPE 1862-B Megohmmeter[1] who were kind enough to return questionnaires describing their use of the instrument and their suggestions as to how it could be improved will be pleased to know that they have had a hand in redesigning this popular instrument to make what should be an even more satisfactory unit. The new TYPE 1862-C, shown in Figure 1, has incorporated most of the ideas suggested and a couple we thought up ourselves. However, we could not add everything asked for, because we felt (and users agreed) that the small size and modest cost of the instrument were among its important features.

The most noticeable change is in the packaging. The new model is housed in the Flip-Tilt case, which has won wide approval, particularly for its ability to support the instrument with its panel at

[1]A. G. Bousquet, "New Model of Megohmmeter Has Two Test Voltages," *General Radio Experimenter*, 29, 9, December, 1954.

Figure 1. View of the Type 1862-C Megohmmeter.

almost any angle. Correct viewing angle is important for any instrument whose output is a meter reading. The Flip-Tilt case is especially versatile in this respect* and offers as well the added features of easy portability and protection for both transit and storage. Prominent also in the appearance is the large panel meter, the new GR design with its maximum-length, open scale. Further, for easy reading and interpolation, the movement is reversed, so that resistance values increase from left to right.

A new feature is the separate, 3-position DISCHARGE-CHARGE-MEASURE toggle switch. This is important for those who use the instrument to make repetitive measurements on a given range. With the older instrument, the MULTIPLIER switch had to be used for discharging, and, if the measurements were made on a high resistance range, this resulted in a lot of switch rotating for each measurement. The DISCHARGE position on the MULTIPLIER switch is still provided.

The voltage is removed from the unknown terminals if either switch is set to DISCHARGE. An indicator lamp, located near the measurement terminals, is lit when the test voltage is applied. The lamp, which is especially bright when 500 volts are applied, provides a warning to the operator, for, although the instrument current itself is not dangerous, a charged capacitor on the terminals is dangerous and could be lethal.

One change repeatedly asked for was the new, 100-volt test voltage, which is a standard for many measurements. This replaces the 50 volts provided on the older instrument. The accuracy is the same for both 100 and 500 volts, in contrast to the poorer accuracy on the 50-volt range of the older model. Internal changes include the use of semiconductor rectifiers and a "premium" tube in the meter circuit, whose low grid current improves the stability of measurements of very high resistances.

Our survey indicated that over 80% of the instruments were used for insulation resistance measurements, and the rest were used to measure volume and surface resistivity or high-valued resistors. The insulation resistance measurements were on cables, capacitors (leakage), transformers, connectors, relays, printed circuits, motors, and switches. With the new model these measurements can be made with even more ease than in the past.

— H. P. HALL

* For details, see page 7.

SPECIFICATIONS

Range: 0.5 to 2,000,000 megohms at 500 volts and to 200,000 megohms at 100 volts. There are six decade steps selected by a multiplier switch.

Scale: Each resistance scale up to 500,000 megohms utilizes 90% of the meter scale. Center-scale values are 1, 10, 100, 1000, 10,000, and 100,000 megohms for 500-volt operation.

Accuracy: From ±3% at the low-resistance end of each decade to ±12% (accuracy to which the scale can be read) at the high-resistance end up to 50,000 megohms. There can be an additional ±2% error at the top decade.

Voltage on Unknown: 100 or 500 volts, as selected by switch on front panel. Indicator lamp is lighted when voltage is applied. Current available limited to safe value. Voltage across unknown is 500 volts ± 10 volts, or it is 100 volts ± 4 volts. This voltage source is regulated for operation from 105- to 125- (or 210- to 250-) volt lines.

Terminals: Unknown, ground, and guard terminals. All but the ground terminals are insulated. The voltage is removed from the terminals in the DISCHARGE position of either switch.

Calibration: Switch position is provided for standardizing the calibration at 500 volts.

Power Requirements: 105 to 125 (or 210 to 250) volts, 40 to 60 cps, 25 watts. Instrument will operate satisfactorily on power-supply frequencies up to 400 cps.

SPECIFICATIONS (Cont.)

Accessories Supplied: Spare fuses, two color-coded test leads.

Cabinet: Flip-Tilt; relay-rack model also is available.

Dimensions: Portable model, case closed — width 11½, height 8¼, depth 7½ inches (295 by 210 by 190 mm), over-all; rack model — panel 19 by 5¼ inches (485 by 135 mm); depth behind panel 5 inches (130 mm).

Net Weight: Portable model, 9 pounds (4.1 kg); rack model, 10 pounds (4.6 kg).

Shipping Weight: Portable model, 16 pounds (7.5 kg); rack model, 23 pounds (10.5 kg).

Type		*Code Number*	*Price*
1862-C	**Megohmmeter,** Portable Model	1862-9703	**$310.00**
1862-9844	**Megohmmeter,** Rack Model	1862-9844	**310.00**

WESCON-1963 — August 20-23

Cow Palace, San Francisco

We look forward with pleasure to welcoming *Experimenter* readers to the General Radio exhibit at Wescon. Many new instruments will be on display. Several of these have been described in recent issues of the *Experimenter*. Others are shown for the first time and will be described in forthcoming issues.

Type 1900-A Wave Analyzer — A new narrow-band analyzer, 20 to 50,000 cps, with 3 bandwidths — 3, 10, and 50 cps.

Type 1564-A Sound and Vibration Analyzer — 2.5 to 25,000 cps, 1/3- and 1/10-octave bands, all-solid-state circuitry, line or battery power.

Type 1308-A Audio Oscillator and Power Amplifier — 20 to 20,000 cps, 200-watt output up to 1 kc, low distortion, good regulation, metered output, solid-state circuitry.

Counters — Type 1130-A with Type 1133-A Range-Extension Unit (*Experimenter*, February-March, 1963); **Type 1150-A** (*Experimenter*, April 1962); **Type 1151-A** (*Experimenter*, April-May, 1963); **Type 1137-A Data Printer** (*Experimenter*, April-May, 1963); **Type 1136-A Digital-to-Analog Converter; Type 1521-A Graphic Level Recorder.**

Type 1025-A Standard Sweep-Frequency Generator (*Experimenter*, January, 1963).

Type 1806-A Electronic Voltmeter (this issue).

Type 900 Precision Coaxial Connectors (*Experimenter*, February-March, 1963).

Type 1531-P2, -P3 Stroboscope Accessories.

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A HIGHLY STABLE REFERENCE STANDARD CAPACITOR

The transfer of the high accuracy of measurements at the National Bureau of Standards to other laboratories requires standards of correspondingly high stability. For example, NBS now calibrates capacitance standards of 1000 pf at 1000 cps with an accuracy better than $\pm 0.002\%$ or ± 20 ppm (parts per million). But, whenever a capacitor calibrated at NBS is moved to another laboratory, the uncertainty of the calibration is increased by the possible changes in capacitance when the capacitor is transferred to and measured at the new location. Capacitance changes of the order of 20 ppm can occur in most capacitors for several reasons.

SOURCES OF INSTABILITY

Mechanical Shock

Perhaps the most obvious source of change is mechanical displacement of the capacitor plates, resulting from vibration or shock in transport or in handling. Most capacitors must be handled with particular care to keep such changes below 20 ppm. Even with no handling at all, a capacitor sitting on a shelf can change in capacitance with time, because any strains left in

Figure 1. View of the 1000-pf capacitor removed from its cabinet and sealed container, showing the construction of the plate stack.

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the capacitor materials at the time of construction can change with age and thus change plate area or separation.

Temperature

Capacitance change also results from temperature change, not only because the dimensions are changed by mechanical expansion but also because the permittivity, particularly of solid dielectric materials, varies with temperature. Typical standard capacitors with air dielectric and plates of brass or aluminum have temperature coefficients of capacitance of the order of 16 to 22 ppm/°C, while the coefficient of a mica capacitor is of the order of 40 ppm/°C. Uncertainties of the order of 20 ppm can therefore result from temperature changes of only one degree. In order to apply corrections to reduce these uncertainties, accurate knowledge of both capacitor temperature and temperature coefficient is required.

Atmospheric Pressure and Humidity

Changes of capacitance with atmospheric pressure and humidity are less familiar because the effects are usually negligible. However, in an air-dielectric capacitor that is not hermetically sealed, the density of the air dielectric between capacitor plates will change with temperature and with atmospheric pressure. The resulting change in capacitance is about −2 ppm/°C at room temperature and +18 ppm per inch of mercury pressure change. Since the atmospheric pressure and density decrease with altitude, if such an unsealed capacitor is moved from Washington near sea level to the mile-high altitude of Boulder, Colorado, the capacitance will decrease by the no-longer-inconsiderable order of 100 ppm. If water vapor is present in the air, the dielectric constant is increased, and the capacitance increase with atmospheric humidity is approximately 2 ppm per percent relative humidity. Water that condenses on capacitor plates or soaks into solid dielectrics causes capacitance changes that are usually larger and less predictable.

Hysteresis

Another deficiency, which appears in most capacitors when parts per million become important, is that of hysteresis in the relation between capacitance and temperature. When a capacitor is subjected to relatively large temperature changes, such as those that can result from shipment, the capacitance at room temperature may have a different value after the capacitor has been hot than it has after being cold, as shown in Figure 2. In this example, the capacitor may start at the capacitance, C_{RH}, at room temperature, T_R, increase to the capacitance, C_H, when heated, and re-

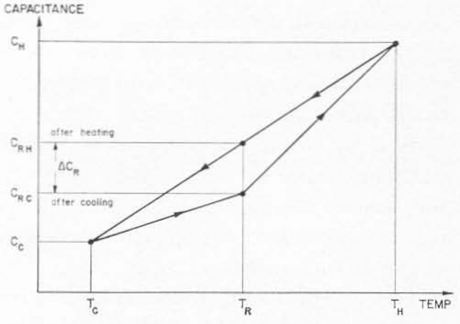


Figure 2. Capacitance *vs* temperature diagram showing hysteresis.

turn to C_{RH} when cooled to room temperature. This cycle can be retraced as long as the capacitor does not go much below room temperature. However, when the capacitor is cooled to the low temperature, T_C, and returned to room temperature, the capacitance at room temperature has a new value, C_{RC}, lower than the initial C_{RH}. Again, the cold cycle can be retraced from C_{RC} to C_C if the capacitor does not go far above room temperature. When the capacitor at C_{RC} is heated to T_H and then cooled to room temperature, the capacitance may return to the initial value, C_{RH}. Uncertainties of the order of 20 ppm can occur in capacitors that have such hysteresis unless: (1) large temperature variations can be avoided; (2) corrections can be made from a known characteristic curve; or (3) the capacitor can be run through a hot cycle before each calibration to put it at a known point in the cycle, such as C_{RH}. The source of such hysteresis is friction in the mechanical structure, which restricts the motion resulting from the thermal stresses. In most mechanical structures the hysteresis cycle is not so simple or so retraceable as assumed in this example.

Voltage and Frequency

Additional sources of capacitance change are variations in voltage and in frequency. Changes of capacitance no greater than a few ppm can be expected in standard air capacitors with voltages in the usual measurement range below, say, 100 volts. In silvered-mica capacitors, such as the TYPE 1409, changes from 10 to 200 ppm may occur for voltage changes from 1 to 100 volts. Such changes usually result from small isolated sections of the silver film that connect to the main body of film and add capacitance as the applied voltage increases. The magnitude of the change varies widely from capacitor to capacitor, depending upon the quality of the silver film. When foil electrodes are used instead of silvered mica, the changes with voltage decrease to the order of a few ppm.

In both air and mica capacitors the rate of change of capacitance with frequency is generally small enough to require no unusual frequency stability to keep the capacitance uncertainty small. Only when the frequency of measurement approaches the resonance frequency of the capacitor does accuracy of frequency become important, so that standard frequencies are required.

NBS Calibration of Type 1404 Capacitors

A report of calibration of the direct capacitance of these capacitors can be obtained from the National Bureau of Standards. After July 1, 1963, the accuracy of the report is ±20 ppm. The fee (Item 201.105a in Test Fee Schedule) is $35.00. For further information please write: Mr. Chester Peterson, Chief, Resistance and Reactance Section, Electricity Division, NBS, Washington 25, D.C.; or Frank D. Weaver, Acting Chief, Low-Frequency Calibration Services, Electronic Calibration Center, NBS, Boulder, Colorado.

Connections

The changes in capacitances produced by the connections to the capacitor can also be a source of error. These connection errors were described in some detail in the *Experimenter* a few years ago.[1] In capacitors with unshielded plug-and-jack connectors, a portion of the calibrated capacitance is associated with the terminals of both the capacitor and the bridge on which it is measured. Small changes in the geometry or in the environment of these terminals may produce capacitance changes as large as 0.1 pf. To eliminate uncertainties of this order, which are important in accurate calibrations of 1000 pf or less, the terminal geometry can, with care, be defined and controlled to the required precision. Or, more easily in most cases, the terminal capacitances and their uncertainties can be eliminated by the use of three-terminal capacitors and three-terminal measurements.

A NEW REFERENCE STANDARD

A new capacitor has been designed to obtain a standard in which capacitance changes remain small compared to 20 ppm without the use of unusual care in handling, in environmental control, or in measurement. This is the new TYPE 1404 Reference Standard Capacitor, a three-terminal, sealed, dry-nitrogen-dielectric capacitor with direct capacitance of 1000 pf or 100 pf. Stability in this capacitor has been obtained not by unusual design but by the use of a simple, solid, homogeneous structure of a single, low-temperature-coefficient material sealed in an invariant atmosphere.

Construction

The capacitor, as shown in Figure 1, is made up of a stack of round Invar plates, mounted on six Invar posts and spaced from one another by Invar spacers. The posts are mounted on a ¼-inch-thick Invar baseplate, and insulated from it by ceramic spacers. This almost complete use of Invar results in a capacitor whose temperature coefficient of capacitance closely approximates that of the Invar, about +2 ppm/°C.

The use of a single, low-temperature-coefficient metal makes the coefficient of the capacitor more reproducible and eliminates the differential drift that can occur when the capacitor uses two metals of higher but mutually compensating coefficients.

The capacitor is mounted inside a hermetically sealed heavy brass enclosure. All electrical connections are made through glass-to-metal seals. Before the exhaust tube is sealed, the enclosure is evacuated to remove water vapor and is filled with dry nitrogen at atmospheric pressure. This permanent, positive seal-

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

Figure 3. Panel view of the Reference Standard Capacitor.

Figure 4. View of capacitor with cabinet removed, showing the sealed container and the three-terminal trimmer.

ing in an invariant atmosphere makes both capacitance and dissipation factor virtually independent of environmental changes in pressure, altitude, or humidity.

The sealed capacitor is mounted on a solid aluminum casting, which is fastened to the front panel of the cabinet, as shown in Figure 4. Webs in the casting provide shielding between the two leads from the capacitor, which are connected to two recessed locking TYPE 874 Coaxial Connectors on the panel. The left or H connector is completely insulated from the panel to eliminate ground-loop troubles when long leads are used and to facilitate the use of the capacitor as a dissipation-factor standard. The panel connectors can be converted to most other common types of coaxial connectors by the use of the appropriate TYPE 874 Adaptor, and the locking version of the adaptor can be used to make the connection semipermanent.

Also mounted in the web is a three-terminal trimmer capacitor used to adjust capacitance over very small ranges. The capacitance of this trimmer is such a small part of the total, about 0.01%, that its effect on over-all stability is negligible.

Stabilization and Test

After assembly and sealing, each capacitor is subjected to a number of hot and cold cycles of temperature to stabilize the structure and to determine the temperature coefficient and the magnitude of the hysteresis. The capacitor is heated to approximately 65 C or 150 F (T_H in Figure 2), then cooled to a room temperature, T_R, of 23 C or 73 F and measured to determine the capacitance C_{RH} after a hot cycle. Similarly, it is cooled to a temperature, T_C, of -18 C or 0 F, then measured at room temperature to determine the capacitance, C_{RC}, after a cold cycle. The hot cycle is then repeated to return the capacitor to the capacitance C_{RH} and to determine the retraceability of the cycle. The limits for acceptability are that the cycle retraces within ± 5 ppm and that the capacitance change at room temperature, ΔC_R, does not exceed 20 ppm for these hot and cold cycles. The capacitance change from hysteresis is typically less than 10 ppm. The change in capacitance at room temperature, $\Delta C_R = C_{RH} - C_{RC}$, is the measure of hysteresis.

The temperature coefficient is determined from measurements of capacitance made during this cycling while the capacitor is at a known temperature above or below room temperature. The coefficient is, typically, constant within ± 1 ppm/°C over the temperature range of these cycles. The acceptable range of temperature coefficient is from $+0$ to $+4$ ppm/°C. The typical coefficient is $+2 \pm 0.5$ ppm/°C.

The temperature cycling is also a test for leaks in the hermetic seals. When leaks are present, the cycles do not retrace and the capacitance changes with time.

Adjustment and Calibration

After a capacitor has passed the tests for stability, temperature coefficient, and hysteresis, the capacitance is adjusted by means of the trimmer to make the measured capacitance very close to the nominal value of 1000 or 100 pf. The TYPE 1404 capacitor, unlike most previous standard capacitors, can be adjusted easily with an accuracy almost equal to the precision of measurement, which is better than ±1 ppm. The measurement is made by comparison on a TYPE 1615-A Capacitance Bridge with one of a group of TYPE 1404 working standards that have been calibrated from a group of similar reference standards periodically measured by the National Bureau of Standards. The accuracy of the NBS calibration of these reference standards is ±20 ppm.

Each capacitor is adjusted at a room temperature of 23 ± 1 C and a frequency of 1000 ± 10 cps to a capacitance 5 ppm above the nominal value with respect to the General Radio reference standards. The adjustment to a value above nominal (e.g. 1000.005 pf) is made because the standard is a little more convenient for use in bridge calibration when it is slightly greater instead of less than nominal (e.g. 999.995 pf). Although the precision of adjustment exceeds 1 ppm, the uncertainties of room temperature and capacitor temperature coefficient add to the adjustment error, so that the adjustment accuracy at the stated temperature is approximately ±5 ppm.

The final adjustment of capacitance at room temperature is always made after the capacitor has last been through a hot cycle to 65 C, so that the capacitor is at the position similar to C_{RH} in the cycle of Figure 2.

Stability

After adjustment and calibration, the value of the capacitor as a standard depends primarily upon its stability.

The TYPE 1404 capacitors show very small changes with orientation. In typical units the change is less than 5 ppm when the capacitor is turned in all directions, and any change is reversible. The acceptable limit of change with orientation is 10 ppm.

The capacitors are relatively free from microphonics; therefore, the short-term stability is determined mainly by changes in temperature produced by environmental temperature changes. With the temperature coefficient of +2 ppm/°C, a high degree of stability can be obtained with only moderate temperature control. When higher stability is required, the capacitor can be operated in an air or oil bath with close temperature control, since the effects of connecting cables can be made negligible with three-terminal connections and measurements. When an oil bath is used, the panel with connectors and trimmer can be kept above the oil by the addition of longer spacers and shielded leads between panel and capacitor; only the sealed container of the capacitor is immersed. The modification can be made without change in the calibrated capacitance.

Any reference standard capacitor wears along with that title an implicit "Handle with Care" sign. Careful handling of the TYPE 1404 capacitors is always a wise precaution, but it is not always a necessity because the structure is not delicate. Sample capacitors have been put through impact shock tests of from 30 to 50 g with 11-millisecond durations, and the resulting capacitance changes have not exceeded 50 ppm and have, in some cases, been only a few ppm. The capacitors have also withstood equally well those immeasurable, and apparently unavoidable, shock tests which occur in normal shipment.

Protection from both mechanical and thermal shock is provided by the shipping container of expandable polystyrene. The capacitor can be kept in this attractive plastic case, not only for storage and reshipment but also for reduction of thermal transients during laboratory measurements. The thermal time constant for changes in ambient temperature is increased from about 1 hour to 2.5 hours when the metal cabinet is covered by the plastic case and cables are connected through holes in the case.

The long-term stability (the capacitance change with time) of a well-coddled capacitor is as important as it is particularly difficult to measure when the changes may be no more than a few ppm. Many months or years and many capacitors of the highest stability are required for stability measurement, and neither has been available in adequate quantity for this new capacitor. Present estimates of long-term drift must be based upon the intercomparison of a few capacitors for the period of a year or less and upon a few calibrations by NBS, but the available data indicate a drift rate well within 20 ppm per year. Data of more significance are now being accumulated by NBS and by the many standards laboratories which are already using the TYPE 1404 capacitors and sending them periodically to NBS for calibration.

High-Frequency Performance

Although intended primarily for low-frequency applications, the TYPE 1404 capacitors can be used at higher frequencies if certain considerations are kept in mind.

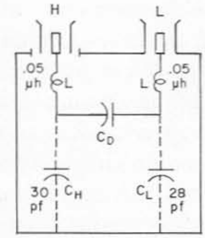


Figure 5. Equivalent circuit of Type 1404 Capacitors. C_D = 1000 pf for Type 1404-A C_D = 100 pf for Type 1404-B

The direct or three-terminal capacitance at the terminals of the capacitor increases with frequency, primarily as the result of the resonance (in the equivalent circuit of Figure 5) between the series internal lead inductances, L, and the capacitance, C_D, shunted by the ground capacitances, C_H and C_L, in series. The effective capacitance is $C \cong C_o(1 + f^2/f_o^2)$, where C_o is the low-frequency capacitance and f_o is the resonance frequency. The resonance frequencies are approximately 16 Mc for the 1000-pf TYPE 1404-A and 47 Mc for the 100-pf TYPE 1404-B, and the corresponding measuring frequencies, f, for a capacitance increase of 50 ppm are 113 kc and 332 kc.

When leads are connected to the capacitor, however, the series inductance and shunt capacitance of the leads will cause a capacitance increase similar to and probably larger than that produced by the internal residuals. Correction can be made for the effects of internal and external residual impedances, but high accuracy is difficult to obtain with increasing frequency. Capacitors that can be connected to the bridge terminals without leads are recommended as standards for frequencies above, say, 10 kc.

Dissipation Factor and D Standard

The losses in the TYPE 1404 capacitors are extremely low because the only effective dielectric in the calibrated direct capacitance is dry nitrogen. All the ceramic insulation affects only the capacitances to ground, which are excluded in a three-terminal measurement. The loss is low enough to be comparable to the uncertainties in the calibration of most available standards of dissipation factor. The best estimate at present is that the dissipation factor at 1000 cps can be maintained below 10 ppm and is typically less than that.

Because the dissipation factor is very low and constant in this sealed capacitor, the capacitor can also be used as a standard of dissipation factor, for example, in bridge calibration. The desired magnitude of D can be obtained by the addition of loss in the form of a calibrated fixed or decade resistor in series or in parallel with the capacitor.*

Uses

The primary use of Type 1404 capacitors is as reference or working capacitance standards of the highest order for the calibration of other capacitors and bridges. The high stability should permit the accuracy of NBS calibrations to be transferred to other laboratories with uncertainties less than ±20 ppm.

For many calibrations, such as that of the Type 1615-A Capacitance Bridge, either the 1000-pf Type 1404-A or the 100-pf Type 1404-B capacitor can be used with equal accuracy. There is no significant difference in quality between the two models, but the difference in capacitance is useful for some special purposes, such as the extension of the precision of the Type 1615-A bridge.

— John F. Hersh

* Detailed procedure for this use of the Type 1404 capacitors may be found in the Operating Instructions for the Type 1615-A Capacitance Bridge.

CREDITS

The design and development of the Type 1404 Reference Standard Capacitor was carried out by Dr. Hersh, with mechanical design support from G. A. Clemow, Design Engineer.

— Editor

SPECIFICATIONS

Calibration: A certificate of calibration is supplied with each capacitor giving the measured direct parallel capacitance at 1 kc and at 23 ± 1 C. The measured value is obtained by a comparison to a precision better than ±1 ppm with working standards whose absolute values are known to an accuracy of ±20 ppm, determined and maintained in terms of reference standards periodically measured by the National Bureau of Standards.

Adjustment Accuracy: The capacitance is adjusted before calibration with an accuracy of ±5 ppm to a capacitance about 5 ppm above the nominal value relative to the capacitance unit maintained by the General Radio reference standards.

Stability: Long-term drift is less than 20 parts per million per year. Maximum change with orientation is 10 ppm, and is completely reversible.

Temperature Coefficient of Capacitance: 2 ± 2 ppm/° C from −20 C to +65 C. A measured value with an accuracy of ±1 ppm/°C is given on the certificate.

Temperature Cycling: For temperature cycling over range from −20 C to +65 C, hysteresis (retraceable) is less than 20 ppm at 23 C.

Dissipation Factor: Less than 10^{-5} at 1 kc.

Residual Impedances: See equivalent circuit (Figure 5) for typical values of internal series inductances and terminal capacitances.

Maximum Voltage: 750 volts.

Terminals: Two coaxial, locking Type 874; easily convertible to other types of connectors by attachment of locking adaptors. Outer shell of one connector is ungrounded to permit capacitor to be used with external resistor as a dissipation-factor standard.

Accessories Supplied: Two Type 874-C58A Cable Connectors.

Cabinet: Sealed inner container mounted in outer lab-bench aluminum case. Easily adaptable to oil immersion of inner sealed container.

Dimensions: Width 6¾, height 6⅝, depth 8 inches (175 by 170 by 205 mm), over-all, including handle.

Net Weight: 8½ pounds (3.9 kg).

Shipping Weight: 12 pounds (5.5 kg).

Type		*Code Number*	*Price*
1404-A	**Reference Standard Capacitor**	1404-9701	**$225.00**
1404-B	**Reference Standard Capacitor**	1404-9702	**225.00**

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

THE NEW LOOK IN HIGH-FREQUENCY OSCILLATORS

The General Radio high-frequency oscillators have found widespread use as simple signal sources. They cover a very wide frequency range, and, with accessory equipment, which includes modulators, mechanical sweeps, attenuators, coaxial fittings, and a variety of power supplies, they can be assembled into more sophisticated systems to meet specific needs. Some of these possibilities are indicated in Figure 2.

To enhance further the adaptability and convenience of these oscillators, a redesign of panel arrangements has been carried out. The "new look" provides a simple uniform package which is readily attached to any one of an expanded line of companion power supplies or mounted in a standard relay rack. While the economical L-bracket construction that has become a virtual trademark of these oscillators has been retained, the panels are now 7″ high and 8″ wide, the same size as the previously announced TYPE 1361-A UHF Oscillator (450 to 1050 Mc)[1] and the TYPE 1211-C Unit Oscillator (0.5 to 50 Mc)[2]. Figure 1 shows the TYPE 1209-CL Unit Oscillator. The new models with their frequency ranges are tabulated on page 12.

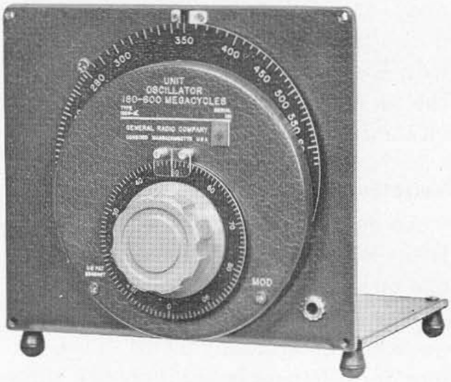


Figure 1. Panel view of the Type 1209-CL Unit Oscillator.

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

[2] E. Karplus, "The TYPE 1211-C, An Improved Unit Oscillator," *General Radio Experimenter* 36, 10, October, 1962.

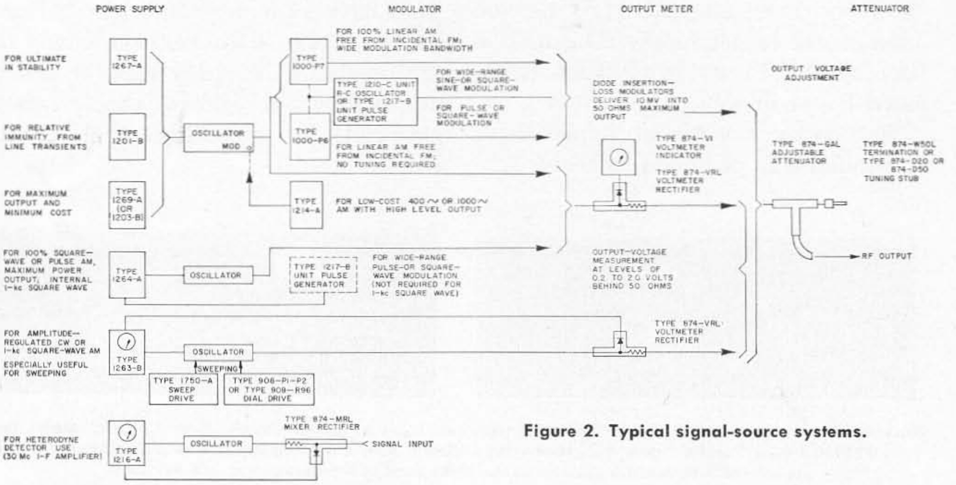


Figure 2. Typical signal-source systems.

Tapped holes near the four corners of the front panel permit rigid attachment to an associated power supply or, by means of low-cost adaptor plates, to a relay rack. The oscillators all have 6-inch precision dials and are equipped with Type 874 Locking Connectors for the RF output. The modulation jack is on the front panel.

Versatile Power Supplies

An outstanding feature of these oscillators is the provision for use with any one of several different power supplies.

Power-supply characteristics are frequently a determining factor in the performance of an oscillator. For such applications as parametric-amplifier pumps, oscillators must be stable against all power-line variations and free of modulation from power-supply ripple. For these extreme requirements, both plate and heater supplies should be regulated, well filtered dc, as in the Type 1267-A Regulated Power Supply.

Where relative freedom from line transients is required without ultimate reduction in long-term drifts and hum modulation, regulated plate supply is desirable, but unregulated ac may be used for the heater supply. This need is met by the Type 1201-B Unit Regulated Power Supply.

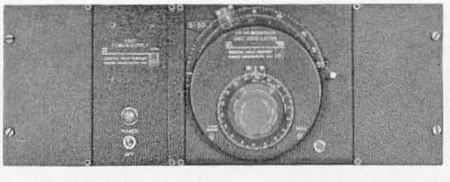
For many noncritical applications, unregulated dc plate and ac heater supplies are entirely adequate and represent considerable economy. The Type 1269-A Power Supply is of this type.

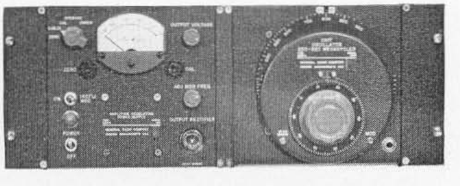
Typical power-output curves for the several oscillators, when operated from these power supplies, are shown in the specifications.

Other applications require power supplies in which the plate-supply voltage is controllable to modulate or to regulate the oscillator output. The Type 1264-A Modulating Power Supply provides 100% amplitude modulation at high level by square waves or pulses as well as cw operation. The Type 1263-B Amplitude-Regulating Power Supply includes a feedback loop to maintain constant oscillator output as the oscillator frequency is varied. Constant output not only speeds and simplifies measurements where the oscillator is tuned manually, but is essential when making sweep measurements. The Type 1263-B Amplitude-Regulating Power Supply has an internal 1-kc oscillator for square-wave modulation.

The Types 1267-A and 1269-A power supplies† are new items, designed specifically for use with these oscillators. They have a 7-inch panel height, matching the oscillators and attach readily to the oscillator for either rack or bench use, as shown in Figure 3. The necessary hardware for attaching oscillator to

† See page 13.





Rack-mount arrangements of a Unit Oscillator with two types of power supply. Figure 3 (*left*) shows the Type 1269-A Power Supply; Figure 4 (*right*) the Type 1263-B Amplitude-Regulating Power Supply. For bench mount, the rack-adaptor plates, shown at the ends of the assemblies, are not used.

power supply is furnished with the power supply. Rack adaptor panels are listed on page 13.

Figure 4 shows how the TYPES 1263-B and 1264-A power supplies attach to the oscillator for rack mount. The older Unit power supplies, TYPES 1203-B and 1201-B, are still available and connect to the oscillator through a plug-in cable, as shown in Figure 5.

— G. P. McCouch

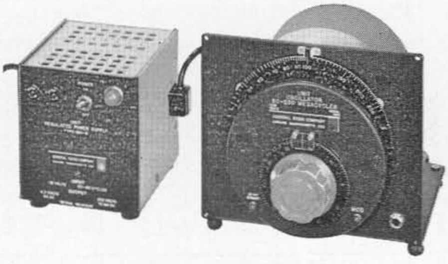


Figure 5. Oscillator with older type of Unit Power Supply, Type 1201-B.

SPECIFICATIONS

Frequency Control: TYPE 908 Gear-Drive Precision Dials are used on all models. Vernier drive ratio is 15:1.

Output Power: Output power is shown in tabulated specifications. With the TYPE 1263-B Amplitude-Regulating Power Supply, the maximum useful power output is 20 milliwatts. The available power is adequate for practically all laboratory measurements with bridges, slotted lines, admittance and transfer-function meters, tuned circuits, etc.

Output System: A short coaxial line brings the output from an adjustable coupling loop to a locking TYPE 874 Coaxial Connector. The output connector is located at the rear of the oscillator. Maximum power can be delivered to load impedances normally encountered in coaxial systems. Adaptors are available to convert the TYPE 874 Connector to any other common type. These adaptors lock securely in place, yet are easily removed.

Power Supply: The external power supply should be chosen from the group listed in the *Summary of Oscillator Power-Supply Characteristics* on page 13. Operation from 400-cycle lines is permissible with many of these power supplies.

Modulation: Amplitude modulation over the audio range can be obtained by superimposing a modulating voltage on the plate supply. A jack is provided on all GR oscillators for this purpose. The audio source must be capable of carrying the dc plate current of the oscillator. The inexpensive TYPE 1214 fixed-frequency oscillators are recommended as modulators, and are usually used in conjunction with the TYPE 1269-A, 1201-B, or 1267-A power supplies. For 30% a-m, incidental fm in this system is of the order of 0.01% at the lower part of the tuning range, and increases to about 0.05% at the high-frequency end. Approximately 40 volts across 8000 ohms is adequate to produce 30% modulation.

Square-wave or pulse modulation can be obtained on all oscillators, except the TYPE 1208-C, by use of the TYPE 1264-A Modulating Power Supply.* All oscillators, except the TYPE 1208-C, can be square-wave modulated at 1 kc by the TYPE 1263-B Amplitude-Regulating Power Supply.*

For video modulation up to 30% with 5-Mc bandwidth, the TYPE 1000-P6 Crystal-Diode Modulator* can be used at carrier frequencies from 20 to 1000 Mc. No tuning adjustments are required. This low-level absorption modulator introduces negligible incidental fm, but the output capability is limited to approximately 10 millivolts, peak, into 50 ohms.

Sweep Application: Mechanical sweep at speeds suitable for oscilloscopic display can be obtained by use of the TYPE 1750-A Sweep Drive.* The TYPE 1208-C is not recommended for this service because of the sliding contacts in its tuned circuit.

Slower mechanical sweep for use with XY recorders is possible with the TYPE 908-R96 Dial Drive.*

The TYPE 1263-B Amplitude-Regulating Power Supply is recommended to hold the oscillator output constant as the frequency is varied, particularly when mechanical sweep is employed. It can be used with all these oscillators except the TYPE 1208-C.

Mounting:

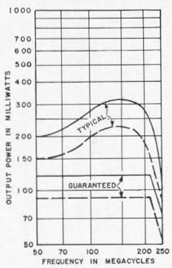
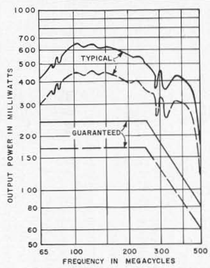
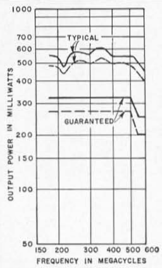
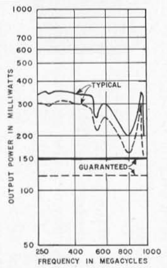
Bench Use — Any of the oscillators can be used on the bench with any of the recommended power supplies; interconnecting cables are supplied. All oscillators and all power supplies, except the TYPES 1201-B and 1203-B, are 7″ high and can be attached to each other with the hardware supplied to form a rigid assembly.

Relay-Rack Use — Any oscillator can be relay-rack mounted together with a TYPE 1263-B, 1264-A, 1267-A, or 1269-A power supply in a space 7″ high. When the TYPE 1201-B Power Supply is used, separate rack-adaptor panels are necessary.

* Consult the latest General Radio catalog for details.

(Continued on page 12)

SPECIFICATIONS (Continued)

Type Number	1215-C	1208-C	1209-CL	1209-C
Frequency	50 to 250 Mc	65 to 500 Mc	180 to 600 Mc	250 to 960 Mc
Tuned Circuit	Semi-Butterfly	Variable *L* and C	Butterfly	Butterfly
Calibration Accuracy	±1%	±2%	±1%	±1%
Warmup Frequency Drift (typical)	0.4%	0.5%	0.2%	0.2%
Output into 50 ohms with Type 1269-A or 1203-B supply	120 mw from 50 - 215 Mc 70 mw from 215 - 250 Mc	240 mw from 65 - 250 Mc 80 mw from 250 - 500 Mc	320 mw from 180 - 500 Mc 240 mw from 500 - 600 Mc	150 mw
Output into 50 ohms with Type 1267-A, 1201-B, or 1264-A supply	90 mw from 50 - 215 Mc 50 mw from 215 - 250 Mc	170 mw from 65 - 250 Mc 60 mw from 250 - 500 Mc	270 mw from 180 - 500 Mc 200 mw from 500 - 600 Mc	120 mw
Typical and Guaranteed Output Power into 50 ohms Upper curves are typical Lower curves are guaranteed —— with Type 1269-A (or 1203-B) Supply – – – with Type 1267-A, 1201-B, or 1264-A* Supply *Not for use with Type 1208-C.				
Panel Dimensions	8 × 7 in. (180 × 205 mm)	8 × 7 in. (180 × 205 mm)	8 × 7 in. (180 × 205 mm)	8 × 7 in. (180 × 205 mm)
Depth Behind Panel	7½ in. (190 mm)	7⅜ in. (190 mm)	7⅜ in. (190 mm)	7⅜ in. (190 mm)
Net Weight	7¼ pounds (3.3 kg)	6 pounds (2.8 kg)	6 pounds (2.8 kg)	6 pounds (2.8 kg)
Shipping Weight	15 pounds (7 kg)	12 pounds (5.5 kg)	13 pounds (6 kg)	13 pounds (6 kg)
Code Number	1215-9703	1208-9703	1209-9933	1209-9703
Price	$210.00	$250.00	$285.00	$285.00

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

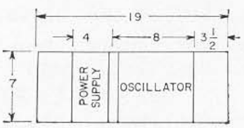
SUMMARY OF OSCILLATOR POWER-SUPPLY CHARACTERISTICS

Type	*Applications*	*DC Plate Supply*	*Heater Supply*	*Panel Width*
1267-A[1]	Ultimate stability for cw	300 v @ 70 ma, regulated	6.3 v dc @ 1 amp, reg	4″
1201-B[1]	Relative freedom from line transients	300 v @ 70 ma, regulated	6.3 v ac @ 4 amp	*
1269-A[1] **1203-B**[1]	Maximum output and minimum cost	380 v open circuit; 300 v @ 50 ma	6.3 v ac @ 3 amp	4″ *
1264-A[1,2,3]	100% square wave and pulse a-m	200–300 v @ 50 ma, reg.	6.3 v ac @ 2.1 amp	8″
1263-B[2]	Amplitude-regulated cw or 1-kc square-wave output	0-300 v @ 30 ma	6.3 v dc @ 0.5 amp	8″
1216-A[1]	Hetrodyne detector	300 v @ 30 ma	6.3 v ac @ 1 amp	*

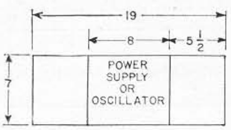
*Unit Instrument Cabinet.
[1]May be operated from 400-cycle supply. [2]Not for use with TYPE 1208-C Unit Oscillator.
[3]Requires adaptor cable when used with TYPES 1215-C, 1209-CL, and 1209-C Unit Oscillators (see latest General Radio catalog).

Accessories for Relay-Rack Mount

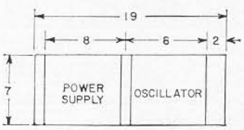
The panel extensions listed below can be readily attached to any of the 7″-high oscillators, power supplies, or oscillator-power supply assemblies to permit mounting in a standard 19″ relay rack.



Adaptor Plate Set Type 480-P412 used to rack-mount an assembly of a 4″-wide power supply (Type 1267-A or 1269-A) and oscillator.



Adaptor Plate Set Type 480-P408 used to rack-mount a single 8″-wide power supply (Type 1263-B or 1264-A) or oscillator.



Adaptor Plate Set Type 480-P416 used to rack-mount an assembly of an 8″-wide power supply (Type 1263-B or 1264-A) and oscillator.

Type		*Code Number*	*Price*
480-P408	**Adaptor Plate Set,** for one 8″-wide instrument (7″ high)	0480-9648	**$ 8.00**
480-P412	**Adaptor Plate Set,** for assembly of one 8″- and one 4″-wide instrument (7″ high)	0480-9642	**7.00**
480-P416	**Adaptor Plate Set,** for assembly of two 8″-wide instruments (7″ high)	0480-9646	**6.00**
480-P4U1	**Relay-Rack Adaptor Panel,** for Type 1201-B or Type 1203-B Power Supply only (7″ high)	0480-9984	**11.00**

THE NEW POWER SUPPLIES

To obtain the ultimate performance from our line of Unit Oscillators, the TYPE 1267-A Regulated Power Supply provides both regulated plate and heater voltages. Regulation is such that effects of line voltage on the oscillator performance are essentially eliminated. As a result, the residual fm of the oscillators is approximately the same as that obtained with battery operation.

A vacuum-tube series regulator is used for the 300-volt, 70-ma, dc output and a transistor regulator for the 6.3-volt, 1-a, dc output. The vacuum-tube regulator shown in Figure 2 uses a differential-input amplifier to compare the output voltage against a voltage-reference tube, a cascode amplifier for gain, a cathode follower for maximum bandwidth, and a series power tube for control. This combination results in an 80-db reduction of ripple voltage and a low output impedance over a wide frequency range.

The regulator circuit for the 6.3-volt dc output utilizes three high-gain transistor stages to provide a similar 80-db reduction of ripple voltage and input transients. Current limiting at one ampere and reduction of the small temperature effects of the transistor and Zener reference diode are added bonuses for those who would like to use these versatile supplies for other purposes than operating Unit Oscillators.

Figure 1. View of (*left*) Type 1267-A Regulated Power Supply and (*right*) Type 1269-A Power Supply.

The TYPE 1269-A Power Supply is a simple unregulated supply adequate for many uses of the Unit Oscillators. It is similar in electrical characteristics to the TYPE 1203-B Unit Power Supply.

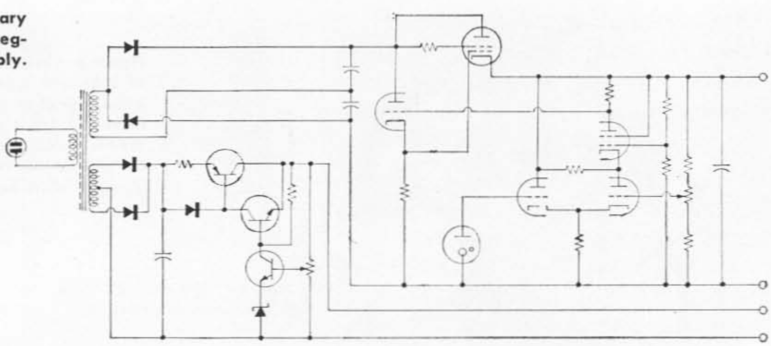
— M. C. HOLTJE

SPECIFICATIONS

Type	**1203-B**	**1269-A**	**1201-B**	**1267-A**
Input				
Volts	105 to 125*	105 to 125 or 210 to 250	105 to 125*	105 to 125*
Watts Full Load	50	50	90	90
Line Frequency (cps)	50 to 60; can also be operated from 400-cycle supply of 110 to 125 volts**			
Output (At 115- or 230-volt input) DC volts	300 @ 50 ma		300	
ma (max)	50		70	
regulation	No load voltage about 400		±0.25% (combined line & load)	
ripple, rms, at full load (120 cps)	80 mv		1 mv	
DC volts	—		—	6.3
amp (max)	—		—	1
regulation				±0.25% (combined line & load)
ripple, rms, at full load (120 cps)				1 mv
AC volts	6.3		6.3	—
amp (max)	3		4	—
Accessories Supplied	Mating plug for output connector, 3-wire line cord.			
Dimensions inches	5x5$\frac{3}{4}$x6$\frac{1}{4}$	4$\frac{1}{4}$x7$\frac{5}{8}$x9$\frac{1}{4}$	5x5$\frac{3}{4}$x6$\frac{1}{4}$	4$\frac{1}{4}$x7$\frac{5}{8}$x9$\frac{1}{4}$
Dimensions mm	130x150x160	110x195x235	130x150x160	110x195x235
Net Weight pounds	5	5$\frac{3}{4}$	6	7$\frac{3}{4}$
Net Weight kg	2.3	2.7	2.8	3.6
Shipping Weight pounds	6	7	7	9
Shipping Weight kg	2.8	3.2	3.2	4.1

* Add Q18 to type number for 210 to 250 volts (see price table).
** Will operate any vhf or uhf unit oscillator from 400-cycle supply of 105–125 volts.

Figure 2. Elementary schematic of the Regulated Power Supply.



Type		*Code Number*	*Price*
1203-B	Unit Power Supply, 105 to 125 volts	1203-9702	$ 55.00
1203-BQ18	Unit Power Supply, 210 to 250 volts	1203-9818	60.00
1201-B	Unit Regulated Power Supply, 105 to 125 volts	1201-9702	95.00
1201-BQ18	Unit Regulated Power Supply, 210 to 250 volts	1201-9818	105.00
1269-A	Power Supply	1269-9701	70.00
1267-A	Regulated Power Supply, 105 to 125 volts	1267-9701	170.00
1267-AQ18	Regulated Power Supply, 210 to 250 volts	1267-9911	180.00

FLASH-DELAY UNIT SIMPLIFIES MOTION ANALYSIS IN HIGH-SPEED MACHINES

For many years the STROBOTAC® electronic stroboscope has been a valuable tool in the development and maintenance of all kinds of rotating and reciprocating equipment. Two accessories greatly expand the usefulness of this stroboscope in the study of high-speed motion, the new TYPE 1531-P2 Flash Delay and the TYPE 1536-A Photoelectric Pickoff.[1]

[1] "Using a Photocell Where it Counts," *General Radio Experimenter*, 36, 10, October, 1962.

Figure 1. The Flash Delay and Photoelectric Pickoff in combination with the Strobotac® electronic stroboscope. The Flash Delay attaches conveniently to the Strobotac.

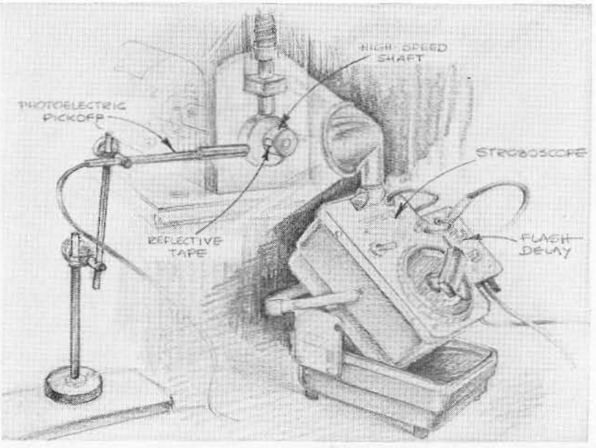


Figure 2. Sketch showing the use of reflective tape to produce a pulse signal in the Photoelectric Pickoff. Pulse is then delayed by the Flash Delay to fire the Strobotac at any desired point in the rotational cycle.

The combination of pickoff and flash delay provides a convenient means of synchronizing the STROBOTAC flash to rotating equipment, even when the speed of the equipment is irregular. The flash can be delayed with respect to the pickoff signal so that the moving object can be made to appear completely stationary at any point in its rotation cycle.

When a moving object is observed under stroboscopic light with the flashing rate determined by the stroboscope's internal oscillator, slight variations in the speed of rotation will cause the moving object to appear to rotate slowly. Continual adjustment of the flashing rate is then required to obtain a stationary image at a particular point in the cycle.

If a small piece of reflective tape is placed on the rotating object, as shown in Figure 2, it is possible to obtain from the photoelectric pickoff a signal which is synchronous with the rotation, regardless of speed. By means of the flash delay, an adjustable time delay can be introduced between the pickoff and the stroboscope, so that the stroboscope can be made to flash at any desired position of the rotating object. By continually varying the time delay, the user can observe the object at all positions during a cycle of rotation. Small speed variations will not affect the image. If the speed varies widely, the reflective tape can be placed just ahead of the desired viewing point so that only a small time delay will be required.

The photoelectric pickoff does not mechanically load the rotating equipment and can therefore be used on very-

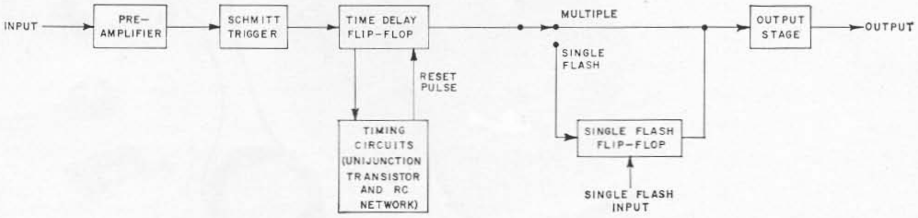


Figure 3. Functional block diagram of the Flash Delay.

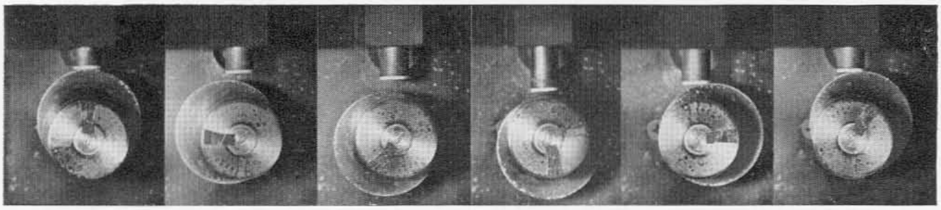


Figure 4. The action of cam followers can be easily examined with the Strobotac-Flash Delay combination. These photographs show the bounce of a cam follower at high speeds. The cam is rotating counterclockwise.

low-power devices such as relays, mechanical choppers, etc. The pickoff, with a time constant of approximately 200 μsec, can be used with equipment rotating at speeds in the hundreds of thousands of rpm.

The TYPE 1531-P2 Flash Delay makes possible single-flash photographs of rotating equipment at any desired position in its cycle. The single flash of the STROBOTAC is synchronized both with the time the camera shutter is open and with the desired position of the rotating object.

Description

The TYPE 1531-P2 Flash Delay was designed primarily for use with the TYPE 1536-A Photoelectric Pickoff.[1] It can be triggered, however, by any transducer that will generate a positive electrical pulse of at least 0.3 volt. The block diagram of Figure 3 shows that the flash delay consists of a preamplifier, a Schmitt-circuit pulse shaper, a time-delay generator (consisting of a flip-flop, a unijunction transistor and RC network), and an output stage. Each trigger pulse from the Schmitt circuit starts a delay cycle. When the voltage across a capacitor in the RC circuit reaches approximately 9 volts (one-half the 18-volt charging voltage), the unijunction transistor fires, discharging the capacitor, resetting the delay flip-flop, and sending a pulse to the output amplifier.

There are three delay ranges available. Range 1 allows an adjustment over 360 degrees for rotational speeds of 6000

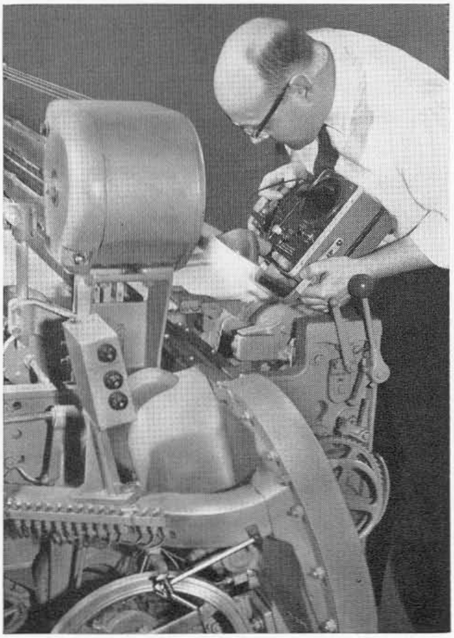


Figure 5. A typical application in the textile field: observing tape and filling-carrier behavior of a Draper DSL shuttleless loom. Speed of the filling carrier is 274 picks per minute. The Flash Delay makes it possible to observe the filling-carrier at any particular point on its path. Synchronism with loom is accomplished with the Type 1536-A Photoelectric Pickoff located near a rim connected to the main power shaft and shown at the bottom of the photograph.

[1] *Loc. cit.*

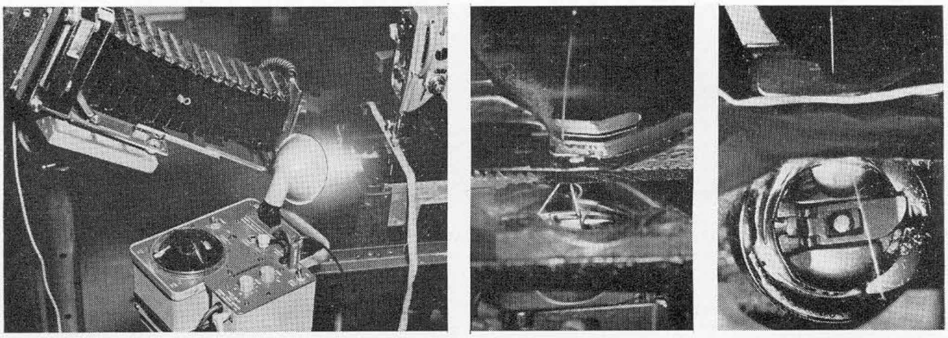


Figure 6. Study of thread behavior in high-speed sewing machine. Machine speed was 5000 stitches per minute; hook speed was 10,000 rpm. Photograph at left shows setup using Linhoff 4 x 5 with Polaroid film, Strobotac with attached Flash Delay, and sewing machine (the base of which is cut away to expose the parts underneath). Center and right photographs show the bobbin and hook action on thread at a specific phase selected by means of the Flash Delay. Photographs courtesy of The Singer Company.

rpm or higher; range 2 provides the 360-degree adjustment for speeds between 600 rpm and 6000 rpm; range 3 is used for speeds below 600 rpm and for special applications in which a delay as long as 0.8 second is required.

For single-flash photography, the output pulse from the delay circuit goes to a flip-flop gate circuit instead of directly to the output stage. If the x contacts of a camera shutter are connected to a jack on the flash delay, their closure will make the gate circuit conduct, and the next synchronized, delayed pulse will pass to the output stage. After this one pulse passes, the flip-flop gate will reset and again become nonconducting. The flash delay, therefore, allows the first synchronized pulse occurring after the camera shutter opens (x-contact closure) to trigger the stroboscope. Synchronism is thus obtained with both the shutter opening and the desired position of the rotating object. It is necessary to set the shutter speed so that the shutter will be open for one complete rotation cycle.

The flash delay is housed in an aluminum case with bracket which clips directly to the STROBOTAC electronic stroboscope to make a convenient, compact assembly, as shown in Figure 1.

Applications

The TYPE 1531-A STROBOTAC® electronic stroboscope with the TYPE 1531-P2 Flash Delay and the TYPE 1536-A Photoelectric Pickoff has wide applications in the development, test, and maintenance of all kinds of moving machinery. The textile, automotive, machine-tool, and business-machine industries are only a few of the many that will find this combination an invaluable tool. The ability to obtain single-flash photographs at any desired position of a mechanism further enhances the value of these instruments. Figures 4 through 6 show a few of the applications of this versatile stroboscope assembly.

— M. J. FITZMORRIS

SPECIFICATIONS

Time-Delay Range: Approximately 100 microseconds to 0.8 second in three ranges.

Output Pulse: Better than 13 volts available for triggering the TYPE 1531-A Strobotac® electronic stroboscope.

Sensitivity: As little as 0.3-volt input will produce sufficient output to trigger the stroboscope.

Inputs: Phone jack for triggering; jack for camera synchronization.

Power Requirements: 105 to 125 (or 210 to 250)

SPECIFICATIONS (Cont)

volts, 50 to 60 cps. 5 watts with TYPE 1536-A connected.

Accessories Supplied: Trigger cable, phone-plug adaptor, and leather carrying case.

Accessories Available: TYPE 1536-A Photoelectric Pickoff.

Mounting: Aluminum case with bracket which clips directly onto the STROBOTAC electronic stroboscope.

Dimensions: 5⅛ by 3⅛ by 3¾ inches (135 by 86 by 96 mm).

Net Weight: 2 pounds (1 kg).

Shipping Weight: 5 pounds (2.3 kg).

Type		*Code Number*	*Price*
1531-P2	**Flash Delay**	1531-9602	**$160.00**

MEASURING SURFACE SPEEDS

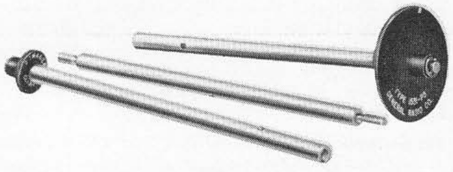


Figure 1. View of the Surface-Speed Wheel, showing the two speed discs and the sectional shaft.

The STROBOTAC® electronic stroboscope, widely used for the measurement and analysis of rotary, reciprocating, and other repetitive motions, can now be used for speed measurement of straight-line motion. The new TYPE 1531-P3 Surface-Speed Wheel accessory makes the STROBOTAC dial *direct reading in feet per minute* for measurements such as the following:

Lineal speeds of metal strip, textiles, paper, wire, plastic films, conveyed material, etc.

Surface speeds of processing rolls, machine-tool cutting or grinding operations, drums, belts, webs, pulleys, etc.

Belt slippage on drums and, especially, between belts on multiple-belt pulleys to avoid unequal load distribution and excessive wear.

Description

The new accessory consists of two wheels of different sizes mounted on opposite ends of a three-section, stainless-steel rod. The smaller wheel, with a diameter of 0.764 inch, is better for slow surface speeds, while the larger wheel, with a diameter of 1.910 inch, is best suited for higher surface speeds. However, their useful ranges have a large amount of overlap, where the choice of which one to use can be based on accessibility. The range of surface speeds with the smaller wheel is 10–2500 feet per minute, and the range of the larger wheel is 50–12,500 feet per minute.

Operation

Operation is extremely simple. One of the wheels is simply allowed to ride on the surface whose speed is to be measured, and the wheel's image is "stopped" by means of the stroboscopic light beam, after which the surface speed in feet per minute is read directly from the dial of

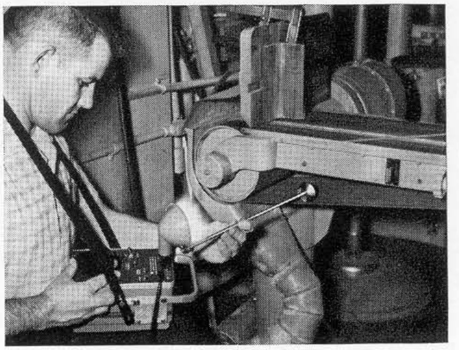


Figure 2. Measuring belt speed with the Surface-Speed Wheel.

the STROBOTAC. The fact that only the wheel has to be close to the surface whose speed is to be measured means that measurements can be made in "close quarters." The light from the STROBOTAC can penetrate well into the interior of machinery, and it is possible to build the wheel into such machinery if regular measurements must be made. For a built-in wheel, a "push-to-engage" lever is recommended in order to save wear on the wheel when a measurement is not actually being made.

The combination of the STROBOTAC electronic stroboscope with the surface-speed wheel provides an extremely sensitive indicator of small variations in linear speed and of differences in speed between two or more surfaces having the same nominal speed. A fraction of an rpm is prominently indicated when the speed of the wheel changes.

— W. R. THURSTON

CREDITS

The TYPE 1531-P3 Surface-Speed Wheel was designed by R. A. Mortenson of Mechanical Design Group. — EDITOR

SPECIFICATIONS

Accuracy: The basic accuracy of the STROBOTAC electronic stroboscope is 1% of reading; an additional 0.5% must be added to account for errors in the diameter of the wheel, giving an over-all accuracy of measurement of 1.5% of reading for surface speed over the entire range of measurement.

Speed Range: 10 to 2500 feet per minute with small wheel and 50 to 12,500 feet per minute with large wheel.

Dimensions: Wheels are 0.764 and 1.910 inches in diameter, respectively. Shaft totals 20 inches in length.

Net Weight: 8 ounces (0.3 kg).

Shipping Weight: 2 pounds (1 kg).

Type		*Code Number*	*Price*
1531-P3	**Surface-Speed Wheel**	1531-9603	**$15.00**

MONTREAL SALES-ENGINEERING OFFICE

R. J. Provan

General Radio's new Montreal Sales-Engineering Office opened August 1, 1963, just six years after the opening of our first Canadian office in Toronto.

The new office is operating as a branch of our Toronto office to provide better coverage and service for customers in Quebec and the Maritime Provinces. The Montreal office also covers Ottawa, although Government tenders should still be directed to the Toronto office.

R. J. Provan is in charge of the Montreal office, with Miss Beverley Gliddon as his secretary. Dick Provan, who has been at our Toronto office since its opening, is well known to Canadian engineers and scientists, having had ten years' experience selling General Radio products.

The Montreal office is located at Office 395, 1255 Laird Boulevard, Town of Mount Royal, Quebec, telephone 737-3673.

General Radio Company
WEST CONCORD, MASSACHUSETTS, U. S. A.
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THE GENERAL RADIO
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VOLUME 37 Nos. 9 & 10 SEPTEMBER-OCTOBER, 1963

NEW PERFORMANCE, *NEW* CONVENIENCE WITH THE *NEW* SOUND AND VIBRATION ANALYZER

The TYPE 1564-A Sound and Vibration Analyzer is designed primarily for the frequency analysis of acoustic spectra having components in the frequency range between 2.5 cps and 25 kc. It incorporates many important improvements over its predecessor, the TYPE 1554-A,[1] which make it more useful and easier to operate.

Two bandwidths are provided, each a fixed percentage of the frequency to which the analyzer is tuned. The one-third-octave bandwidth is useful with moderately varying continuous spectra

[1] J. J. Faran, Jr., "A New Analyzer for Sound and Vibration," *General Radio Experimenter*, 33, 12, December, 1959.

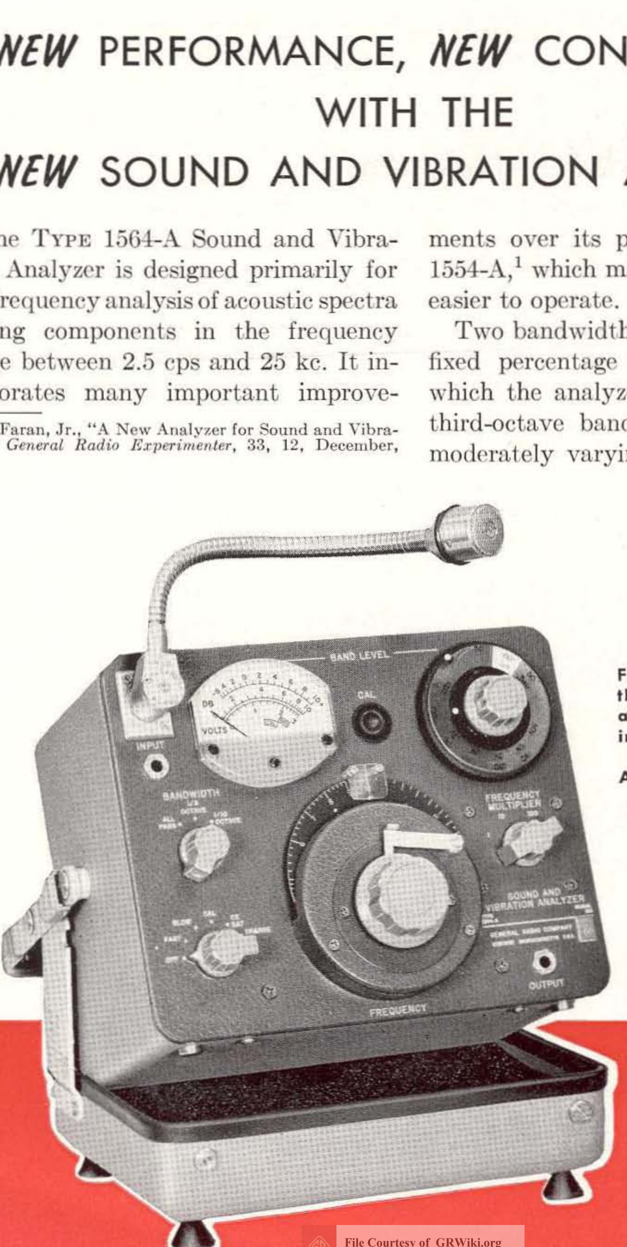


Figure 1. Panel view of the Type 1564-A Sound and Vibration Analyzer in Flip-Tilt case, with cover removed. Also shown is the Type 1560-P4 PZT Microphone Assembly.

CONTENTS OF THIS ISSUE *Page*

(noise). The one-tenth-octave bandwidth can resolve sharply varying continuous spectra or discrete frequency components. The center frequency in each case is continuously tunable. In addition, a flat (ALL PASS) amplifier response permits measurement of the over-all level of the input signal. The analyzer can operate directly from a transducer (microphone or vibration pickup) or, for greater sensitivity, from the output of sound-level and vibration meters. With the TYPE 1521-A Graphic Level Recorder,[2] it forms a recording analyzer for automatic amplitude-frequency plotting.

Equally at home in the laboratory or in the field, the analyzer is available in the convenient Flip-Tilt case, weighing less than 15 pounds, or in a rack-mount adaptation. It can be powered by either a 115/230-volt line or by the internal, rechargeable nickel-cadmium battery.

It can also analyze electrical signals, and an accessory audio-frequency probe is available to facilitate connection to circuit elements.

[2] M. C. Holtje and M. J. Fitzmorris, "A Graphic Level Recorder with High Sensitivity and Wide Ranges," *General Radio Experimenter*, 33, 6, June, 1959.

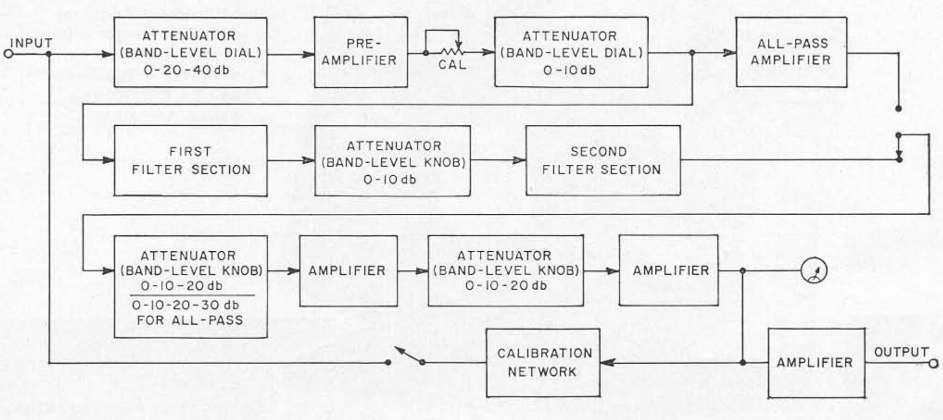
CIRCUIT

Figure 2 is a functional block diagram of the TYPE 1564-A Sound and Vibration Analyzer showing the three basic sections: preamplifier, filter, and output amplifier.

Preamplifier Section

The preamplifier section serves to adjust the amplitude of the input signal. The step attenuators are controlled by the knurled outer dial of the coaxial

Figure 2. Functional block diagram of the analyzer.



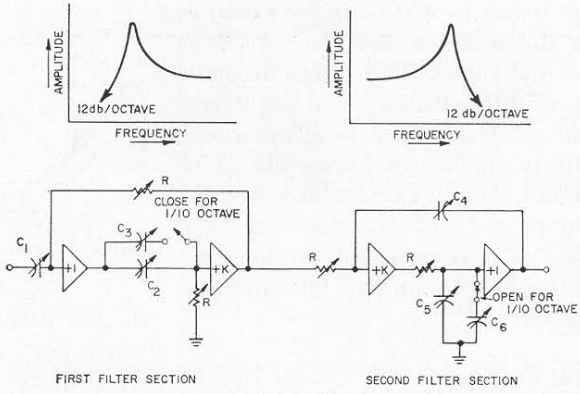


Figure 3. Elementary schematic of the filter sections.

BAND LEVEL control (see Figure 1). The panel CAL control adjusts the gain over a range of 12 db and is used to calibrate the instrument to read directly in volts, sound-pressure level, or other appropriate units. The amplifier at the input uses a field-effect transistor to provide the high input impedance and low noise needed for operation with piezoelectric transducers.

Filter Section

The filter is synthesized as an isolated cascade of two resonant (second order) sections. The resonant frequencies of the sections are staggered about the selected center frequency to produce a filter with a noise bandwidth of one-third octave. To obtain a one-tenth octave response, the sections are synchronously tuned. Figure 3 is a functional diagram.

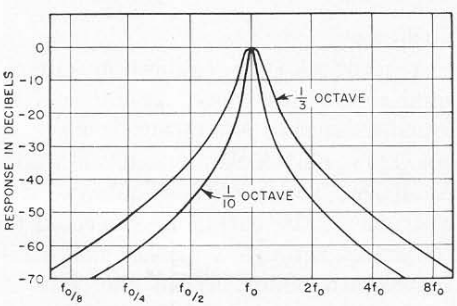


Figure 4. Filter response characteristics.

Capacitors C_1 through C_6, switched by the FREQUENCY MULTIPLIER control, determine the tuning range. The four resistors (R) are adjusted simultaneously by the FREQUENCY control to span the ten-to-one range selected. Frequency responses that are mirror images of each other result from interchanged placement of resistors and capacitors for the two sections. A symmetrical over-all filter response is thus obtained.

Filters similar to these have, in the past, required very close-tolerance, stable components to maintain a stable transmission. In a tunable filter, this necessitates close tracking between the tuning components, a requirement that is difficult and costly to achieve. For the circuit configurations given in Figure 3, there are an infinite number of solutions for component values that will yield the desired transmission. It can be shown, however, that when the instabilities (tracking errors, tolerances, and aging effects) of all circuit parameters are considered, there is only one solution that will yield both the desired transmission and minimum drift. The peak transmission of a filter section in the TYPE 1564-A Sound and Vibration Analyzer is about 3.5 times less sensitive to tracking errors than it would be if, for example, both the resistors and the capacitors had equal values. This design accounts in part for the small size and low weight of the analyzer, since it allows small, relatively simple potentiometers to be used for tuning. It has also made possible an improved tolerance on the uniformity of peak response (see Specifications). Figure 4 shows the filter response characteristics.

Output-Amplifier Section

The output amplifier consists of a cascade of amplifiers and attenuators, which ultimately drive the detector-meter circuit and provide a one-volt output signal, corresponding to a full-scale meter indication. The output signal is supplied from an isolating amplifier so that the load has no effect on analyzer operation. The detector-meter circuit is driven by a push-pull amplifier to ensure high linearity and low temperature drift. The detector characteristic[3] is essentially rms for all waveforms except low-duty-ratio pulses.

Three detector averaging times are available. They ensure that the user will not be burdened with either a slow-acting meter when analyzing at high frequencies or with a widely fluctuating meter when tuning noise signals at low frequencies. The two faster speeds satisfy the ASA specification for "General Purpose Sound Level Meters." The slowest speed gives the meter rise and fall characteristics analogous to those of simple resistance-capacitance networks. Rise and fall time constants for this speed are two and six seconds respectively. Detector speed is dependent

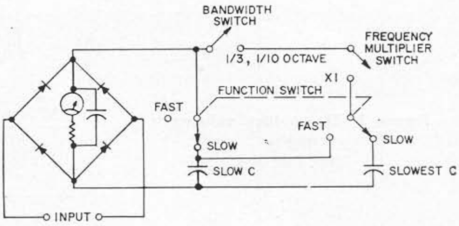


Figure 5. Switching arrangement for the meter circuit.

on the settings of the BANDWIDTH and FREQUENCY MULTIPLIER controls, as well as on the setting of the panel FAST-SLOW switch. Figure 5 shows the interconnection of these panel controls.

The step attenuators in the output-amplifier section, and also the one between the filter sections, are operated by the BAND LEVEL knob (inner control) and are used to set the level of the frequency component to which the filter is tuned.

Power Supply

The power supply permits either battery or line operation. The battery is a rechargeable nickel-cadmium unit, which also serves as a ripple filter for line operation. When the line voltage is interrupted, the battery automatically takes over. A fully charged battery permits the analyzer to be operated for about 25 hours; fourteen hours are required for charging.

Calibration

A feedback-type calibration circuit similar to those used in other GR sound-measuring equipment is used in the TYPE 1564-A Sound and Vibration Analyzer. To amplitude-calibrate the instrument, the output is connected to the input through a limiter and calibrated attenuator. When the gain is adjusted to equal the *known* loss in the

[3] E. E. Gross, "Improved Performance Plus a New Look for the Sound-Level Meter," *General Radio Experimenter*, 32, 17, October, 1958.

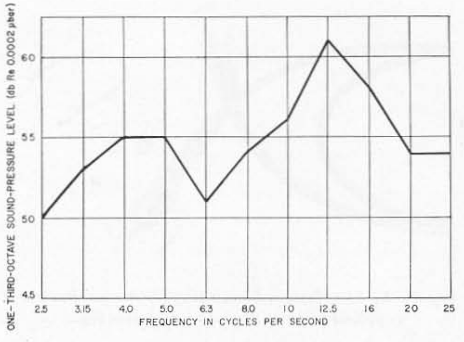


Figure 6. Subaudio sound spectrum measured in a quiet office.

feedback path, the system oscillates. The frequency of oscillation is determined by the filter. The analyzer can be calibrated when the BANDWIDTH is set to 1/10 OCTAVE, 1/3 OCTAVE, or ALL PASS. For ALL PASS calibration, a 1-kc filter is included in the calibration network and determines the frequency of oscillation. The loss in the feedback network is adjustable by means of an internal control calibrated in terms of microphone sensitivity. An additional reference point provides for a calibration direct reading in volts.

APPLICATIONS

The TYPE 1564-A Sound and Vibration Analyzer fills the gap between the simple octave-band noise analyzer and narrow-band analyzers that supply more detailed information but whose operation is more time consuming. Although the octave-band analyzer yields ample data for many purposes, a closer look at the spectrum is often necessary. This is especially true when the analysis may lead to expensive modifications of the object under test. Here, the sound and vibration analyzer helps to identify the various sources of the noise so that effective corrective measures can be taken.

Use with Microphone

The 25-megohm input impedance of the new analyzer, coupled with its high sensitivity, allows piezoelectric transducers to be connected directly to the INPUT.

For analysis of sound spectra where band-pressure levels exceed 44 db, a TYPE 1560-P3 or -P4 PZT Microphone[4] is recommended. These microphones have identical response characteristics. The TYPE 1560-P4 includes a short, flexible conduit for mounting the microphone on the instrument. The -P3 model can be plugged directly into the analyzer or used with the TYPE 1560-P34 Tripod and Extension Cable. When connected to the analyzer, the microphone has a response that is essentially flat from 20 cps to 8 kc; the low-frequency end is limited only by the input time constant (product of microphone capacitance and analyzer input resistance) for frequencies above 2.5 cps. For the measurement of subaudio sound spectra, sometimes of interest in connection with jet aircraft and missile tests, a capacitor can be connected across the microphone terminals to extend the low-frequency range as desired. When levels are not sufficiently high, the microphone-capacitor combination can be used to drive the TYPE 1553-A Vibration Meter,[5] which in turn drives the analyzer.* Figure 6 shows a subaudio spectrum measured in a quiet office.

Vibration

For analysis of acceleration spectra in the frequency range from 2.5 cps to 1

[4] W. R. Kundert, "New, Compact, Octave-Band Analyzer," *General Radio Experimenter*, 36, 10, October, 1962.

[5] E. E. Gross, Jr., "The TYPE 1553-A Vibration Meter," *General Radio Experimenter*, 35, 11, November, 1961.

* The vibration meter, rather than the sound-level meter, is used because of its better low-frequency response.

kc, the TYPE 1560-P52 Vibration Pickup[6] is recommended for use with the analyzer. This combination measures band levels from 0.0007 to 100 g, rms. For lower-level measurements, the vibration meter is recommended as a preamplifier. High-frequency vibration pickups can be used to extend the upper frequency limit to 25 kc.

Electrical Noise

The TYPE 1564-A is useful for analyzing the noise voltage produced by amplifiers, tape recorders, semiconductors, and other electronic devices.

Bands of noise can be generated for transfer and reverberation studies when the analyzer is driven by a TYPE 1390-B Random-Noise Generator.[7]

Wave Analysis

The TYPE 1564-A Sound and Vibration Analyzer can also be used as an analyzer for periodic electrical signals. A TYPE 1560-P41 Audio-Frequency Voltage Probe (Figure 7) is available for convenient connection to high-impedance sources. The probe, at the end of a 40-inch length of cable, presents to the source under test an impedance of 25 megohms in parallel with 20 pf. It inserts a 20-db loss ahead of the analyzer so that the range of full-scale sensitivity becomes 3 millivolts to 300 volts.

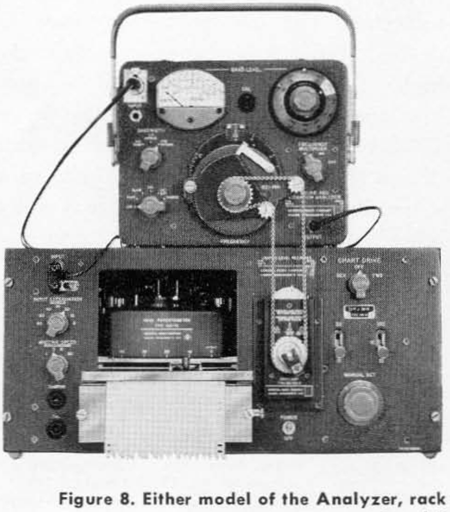
Figure 7. The Audio-Frequency Voltage Probe is supplied with a variety of probe tips.

Automatic Recording

Continuous, unattended, amplitude-*vs*-frequency recording in conjunction

[6] E. E. Gross, Jr., "New PZT Ceramic Vibration Pickup and Control Box for Vibration Measurements," *General Radio Experimenter*, 36, 11, November, 1962.

[7] A. P. G. Peterson, "A New Generator of Random Noise," *General Radio Experimenter*, 34, 1, January, 1960.



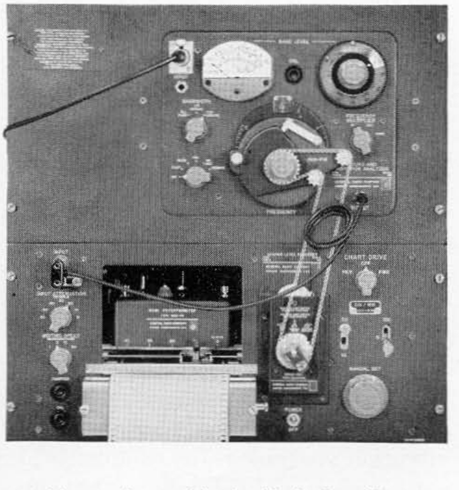


Figure 8. Either model of the Analyzer, rack or portable, can be combined with the Graphic Level Recorder.

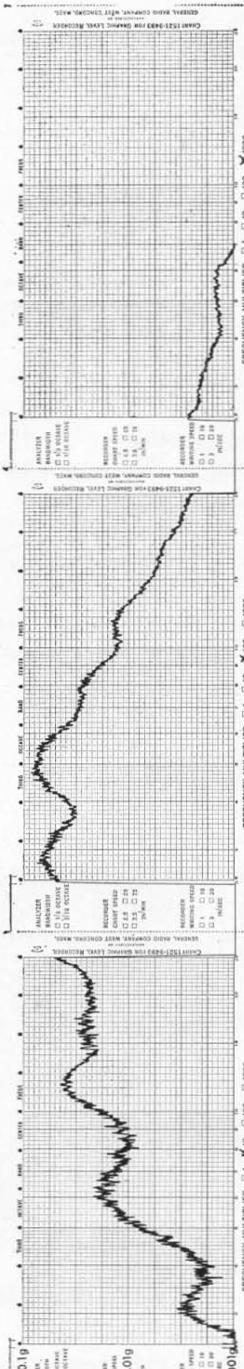


Figure 9a. Chart record of a vibration acceleration spectrum measured on the chassis of a calculating machine. For this measurement a high-frequency vibration pickup is used.

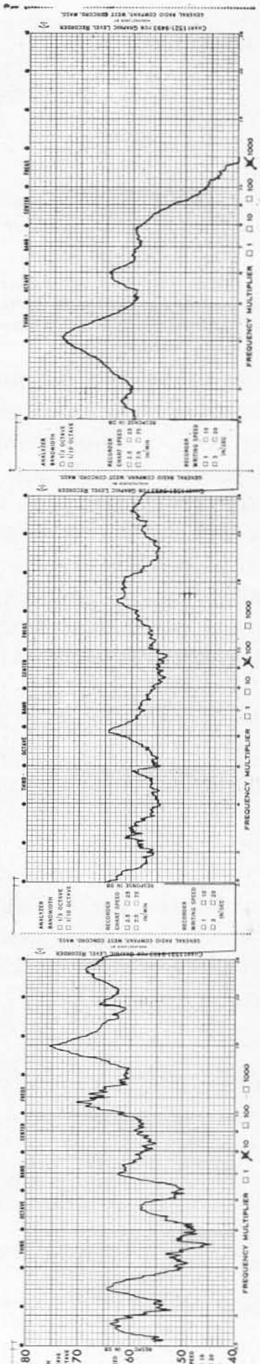


Figure 9b. Sound-pressure spectrum in the vicinity of an air compressor, measured with the recording analyzer and the Type 1560-P4 PZT Microphone Assembly.

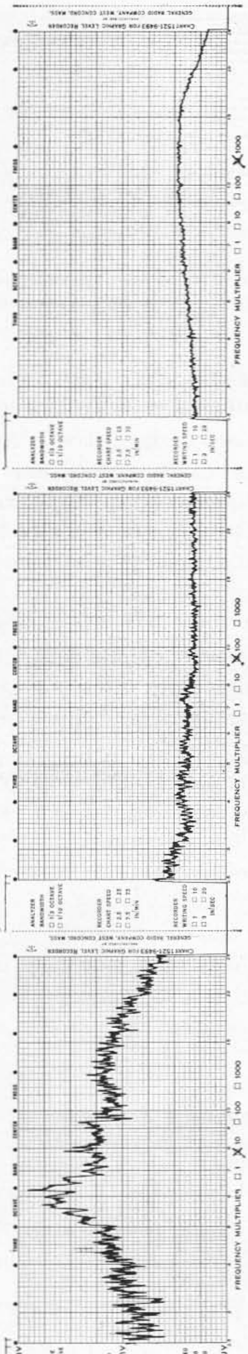


Figure 9c. Electrical noise spectrum of a tape recorder.

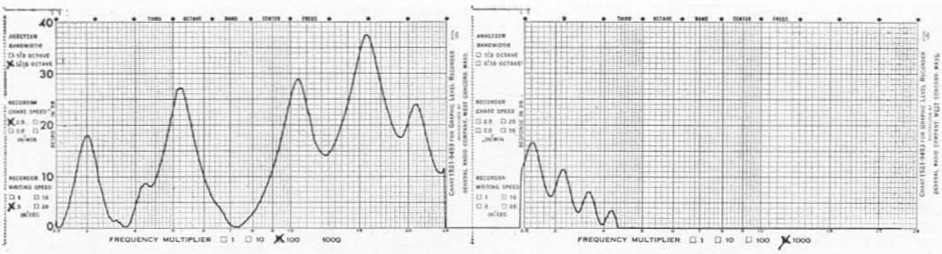


Figure 9d. Voltage spectrum generated by the oboe stop of an electric organ at C_5 (523 cps). Note the presence of the fifth, sixth, and seventh harmonics of the 60-cycle power-line frequency and the pronounced 1500-cycle formant frequency.

with the TYPE 1521-A Graphic Level Recorder is made possible by an automatic range-changing device. After each revolution of the main FREQUENCY dial (a frequency span of ten to one) the FREQUENCY MULTIPLIER control (see Figure 1) advances one position. When the tuning control is driven continuously by the recorder, the analyzer sweeps repeatedly through its entire frequency range. Both the FREQUENCY dial and the chart produced by the recorder have logarithmic frequency scales. Manual operation is simplified by a detent device which can be engaged by a panel control to locate the dial at the ASA-preferred one-third-octave frequencies or, optionally, at any series of frequencies related by one-third octave.

Automatic plotting of one-third-octave and narrow-band data has become almost standard practice. The reasons for this are obvious. Data can be accumulated in a small fraction of the time required for manual analysis and with much less chance of error. Figure 8 shows analyzer-recorder combinations. Chart paper, TYPE 1521-9493, permits a continuous amplitude-frequency plot from 25 cps to 25 kc. The automatic range-changing device in the analyzer operates when the tuning potentiometer is in its "dead" region. During this period the signal path is shorted, so that generated transients will not reach the output terminals and the recorder pen returns to low scale. The chart produced has an active length of 7.5 inches per decade and a total length of 9 inches per decade. Figure 9 shows several charts made with a recorder-analyzer combination.

—W. R. KUNDERT

SPECIFICATIONS

FREQUENCY

Range: From 2.5 cps to 25 kc in four decade ranges.

Dial Calibration: Logarithmic.

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

Filter Characteristics: Noise bandwidth is either 1/3 octave or 1/10 octave.

One-third-octave characteristic has at least 30-db attenuation at one-half and twice the selected frequency (see plot). One-tenth-octave characteristic has at least 40-db attenuation at one-half and twice the selected frequency. Ultimate attenuation is greater than 70 db for both characteristics.

For both bandwidths peak response is uniform ± 1 db from 5 cps to 10 kc and ±1.5 db from 2.5 cps to 25 kc.

INPUT

Impedance: 25 megohms in parallel with 80 pf (independent of attenuator setting).

Voltage Range: 0.3 millivolt to 30 volts full scale in 10-db steps.

OUTPUT

Voltage: At least 1 volt open circuit when meter reads full scale.

SPECIFICATIONS (Cont.)

Impedance: 6000 ohms. Any load can be connected.

Meter: Three scales, 0 – 3 volts; 0 – 10 volts; −6 to +10 db.

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

GENERAL

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

Detector: Quasi-rms with three averaging times. Faster two speeds conform with ASA standard for sound-level meters.

Power Requirements: Operates from 115 (or 230) volts, 50-60 cps, or from nickel-cadmium battery supplied. Battery provides 25 hours of operation when fully charged and requires 14 hours for charging.

Accessories Supplied: TYPE CAP-22 Power Cord, shielded cable, and TYPE 1564-2020 Detented Knob and Dial Assembly.

Accessories Available: TYPE 1560-P4 PZT Microphone Assembly or TYPE 1560-P3 PZT Microphone for direct acoustic pickup; TYPE 1560-P52 Vibration Pickup for solid-borne vibrations; TYPE 1560-P41 Audio-Frequency Voltage Probe for voltage measurements.

Cabinet: Flip-Tilt; relay-rack model also is available.

Dimensions: Portable model, case closed — width 10¼, height 8⅛, depth 8 inches (260 by 210 by 205 mm), over-all; rack model — panel 19 by 10½ inches (485 by 270 mm), depth behind panel 6 inches (155 mm).

Net Weight: Portable model, 14½ pounds (7 kg); rack model, 15½ pounds (7.5 kg). TYPE 1560-P41, ¼ pound (115 grams).

Shipping Weight: Portable model, 23 pounds (10.5 kg); rack model, 30 pounds (14 kg).

Type		*Code Number*	*Price*
1564-A	**Sound and Vibration Analyzer,** Portable Model	1564-9701	**$1150.00**
1564-9820	**Sound and Vibration Analyzer,** Rack Model	1564-9820	**1150.00**
1560-P41	**Audio-Frequency Voltage Probe**	1560-9641	**45.00**

U. S. Patent Nos. 3,012,197; D187,740; and 2,966,257.

IMPROVED COAXIAL TERMINATION

New 50-ohm terminations, the TYPES 874-W50 and -W50L, replace the TYPE 874-WM. These new terminations, identical except for the type of connector used, are more accurate than their predecessors, and they have a lower standing-wave ratio and a higher power rating. Figure 2 is a plot of standing-wave ratio.

Figure 1.

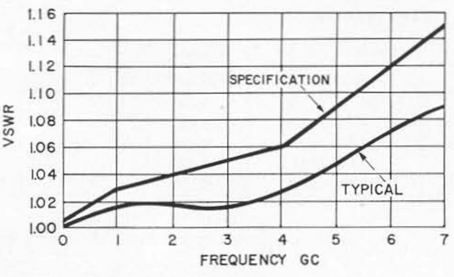


Figure 2.
VSWR of Type 874-W50.

Both are equipped with TYPE 874 Coaxial Connectors, TYPE 874-W50 with the non-locking version, TYPE 874-W50L with the locking type.

DC Resistance: 50 ohms ± 0.5%.

Maximum Power: 2 watts continuous.

VSWR: Less than 1.06 at 4 Gc; see curve.

Net Weight: TYPE 874-W50, 2½ ounces; TYPE 874-W50L, 3 ounces.

Type		*Code Number*	*Price*
874-W50	**50-ohm Termination**	0874-9952	**$18.50**
874-W50L	**50-ohm Termination (Locking Connector)**	0874-9953	**19.50**

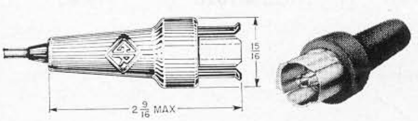
U. S. Patent No. 2,548,457

NEW CONNECTORS, NEW ADAPTORS FOR THE 874 LINE

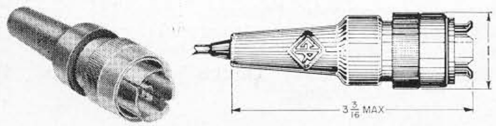
CONNECTORS

A set of connectors to fit RG-174/U 1/10-inch cable, a panel feedthrough connector, and a set of adaptors to Microdot connectors are the latest additions to the Type 874 line of coaxial equipment.

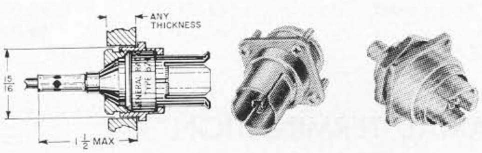
The 174-connector series consists of cable and panel connectors in both locking and non-locking versions. These will fit RG-174/U, -188/U, and -316/U 50-ohm cables; also RG-161/U and -179/U cables. The panel feedthrough connector mates any pair of Type 874 Connectors directly through a panel or bulkhead.



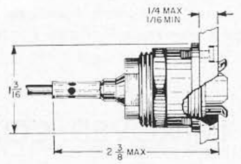
TYPE 874-C174A



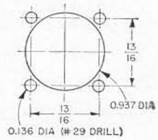
TYPE 874-CL174A



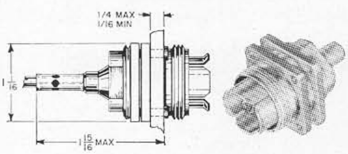
TYPE 874-PB174A



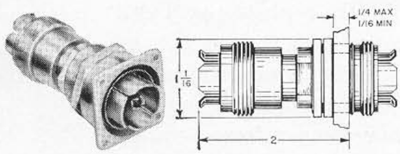
TYPE 874-PRL174A



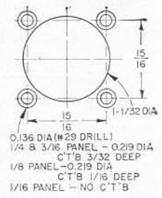
Mounting dimensions for flanges; (above) non-recessed type, (below) recessed type.



TYPE 874-PL174A



TYPE 874-PFL



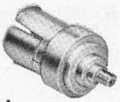
Type		*Code Number*	*Price*
874-C174A	Cable Connector	0874-9418	$4.50
874-CL174A	Cable Connector, locking	0874-9419	5.50
874-PB174A	Panel Connector, flanged	0874-9448	5.00
874-PL174A	Panel Connector, locking	0874-9449	5.00
874-PRL174A	Panel Connector, locking, recessed	0874-9469	5.00
874-PFL	Panel Connector, locking, feedthrough	0874-9451	9.50

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

ADAPTORS

Adaptors to Microdot connectors include both locking and non-locking types. In addition to their use in connecting between Microdot and 874 structures, they can be combined with other GR adaptors to join Microdot connectors to other UG types. This is easily accomplished by the plugging together of the Type 874 ends of two adaptors.

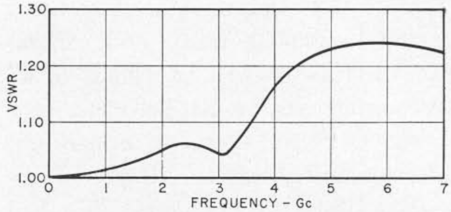
All GR coaxial adaptors are designed for low reflections and have low standing-wave ratios up to several gigacycles.



TYPE
874-QMDJ

TYPE
874-QMDP

Adaptors are now available to types BNC, C, HN, LC, LT, Microdot, N, SC, TNC, and UHF connectors, as well as to 50-ohm rigid line of ⅞-, 1⅝-, and 3⅛-inch sizes.



VSWR of a pair of adaptors (Types 874-QMDP and QMDJL) plugged together.

Type	*Contains 874 and*	*Connects to*	*Code Number*	*Price*
874-QMDJ	**Microdot Jack**	**Microdot Plug**	0874-9720	**$ 9.50**
874-QMDJL*	**Microdot Jack**	**Microdot Plug**	0874-9721	**10.50**
874-QMDP	**Microdot Plug**	**Microdot Jack**	0874-9820	**9.50**

* Locking Type 874.
U. S. Patent No. 2,548,457.

SALES-ENGINEERING OFFICES

NEW CLEVELAND OFFICE

September 1 marks the official opening of our 12th Sales-Engineering Office, in Cleveland. Manager of the new office will be L. C. (Tom) Fricke (BSEE, U. of Illinois, '57), who for the past few years has been at our Chicago Office. He will be assisted by Danny Woodward (BSEE, U. of Illinois, '62), who goes to Cleveland after an intensive training course at Concord. Customers in Ohio, Kentucky, and western Pennsylvania will find this new office a convenient source of technical and commercial information about General Radio products.

The address:

General Radio Company
5579 Pearl Road
Cleveland, Ohio, 44129

Telephone:
(area code 216) 886-0510
TWX:
(area code 216) 888-0716

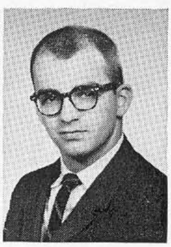
DALLAS

Eric L. Mudama will join the staff of GR's Dallas Office in September. He received his SB in EE degree from MIT in February, 1963, and has been in our sales-engineering training course at Concord since October, 1962.

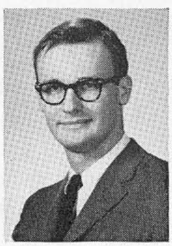
TORONTO

Walter F. Oetlinger was recently appointed Service Supervisor at General Radio's Service Laboratory in Toronto. Located adjacent to the General Radio Canadian Office at 99 Floral Parkway,

Tom Fricke



Danny Woodward



Eric Mudama

Thomas Mujica

Walter Oetlinger

Toronto 15, Ontario, the laboratory provides complete repair and calibration facilities, as well as a stock of replacement parts, for GR products.

Mr. Oetlinger, formerly Supervisor, Electronic Laboratory, Bayly Engineering Ltd., Ajax, Ontario, has had over ten years' experience in this field, and is well known to many of our Canadian customers.

NEW YORK

Thomas H. Mujica, a BEE from Brooklyn Polytechnic Institute in 1960, goes to the New York area office (Ridgefield, N. J.) after three years in sales engineering at Concord.

CANADIAN ELECTRONICS CONFERENCE

Exhibition Park Toronto *September 30-October 2, 1963*

NATIONAL ELECTRONICS CONFERENCE

McCormick Place Chicago *October 28-30, 1963*

We look forward to welcoming our many friends at these two important meetings. At the General Radio booth you will see many of the new instruments recently described in the *Experimenter*, plus others not yet announced.

Engineers from our local offices and from our main plant in Concord will be on hand to demonstrate the equipment and to answer your questions.

GENERAL RADIO COMPANY (OVERSEAS)

announces the appointment,

as exclusive GR representative for Austria, of

Dipl.-Ing. Peter Marchetti

Wien VII
Lindengasse 55

Telephones: 440453
5769053

THE GENERAL RADIO

EXPERIMENTER

VOLUME 37 No. 11 NOVEMBER, 1963

PRECISION COAXIAL EQUIPMENT

the 900 SERIES

A SLOTTED LINE
OF HIGH ACCURACY AND
PRECISION

TERMINATIONS

AIR LINES

ADAPTORS

THE GENERAL RADIO

EXPERIMENTER

Published Monthly by the General Radio Company

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CONTENTS

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GENERAL RADIO COMPANY (OVERSEAS), ZURICH, SWITZERLAND
REPRESENTATIVES IN PRINCIPAL OVERSEAS COUNTRIES

PRECISION COAXIAL EQUIPMENT

the 900 series

• A SLOTTED LINE OF HIGH ACCURACY • TERMINATIONS • AIR LINES • ADAPTORS

The recent introduction of the TYPE 900-BT Precision Coaxial Connector[1, 2] marks the beginning of a new era in coaxial precision measurement. Prior to the development of this connector, precise impedance-measuring instruments and standards were not commercially available for the microwave region.* Using this new connector, General Radio has developed a line of precision coaxial equipment with performance commensurate with that of the connector. Prominent features of the basic connector are low VSWR, and superior stability, life, convenience, and repeatability. Of these,

[1] A. E. Sanderson, "A Radically New Coaxial Connector," *General Radio Experimenter*, 37, 2 & 3, February-March, 1963.

[2] A. P. Lagon, "A New Precision Coaxial Connector (Type 900)," *NBS Report, No. 7277*, June 29, 1962, pp 54–82.

* In fact, even at low frequencies, for instance in the audio range, the accuracy of two-terminal measurements has been limited by the repeatability and reproducibility of coaxial connectors.

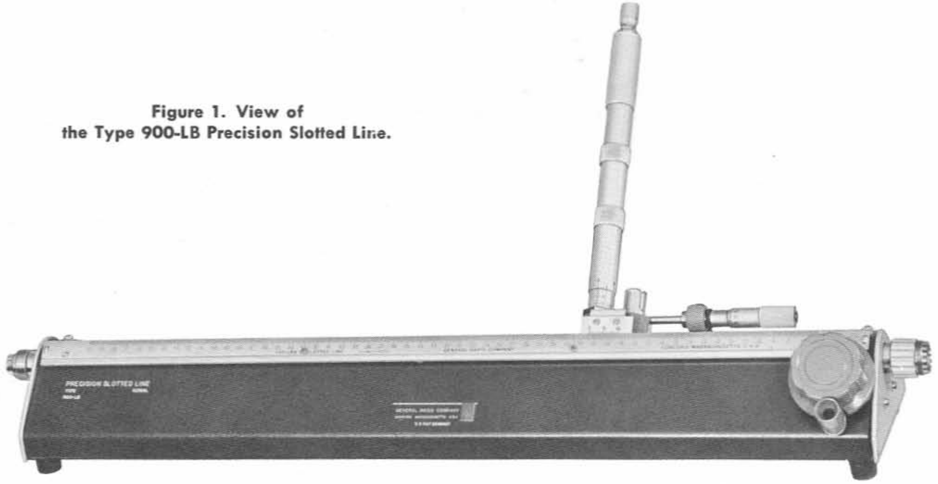


Figure 1. View of the Type 900-LB Precision Slotted Line.

low VSWR and repeatability at uhf and shf were the most difficult to achieve. Once assured, these characteristics led quickly to the development of new uhf-shf instruments and components, including a precision slotted line, air lines, terminations, and adaptors, as well as precisely fabricated tubing and rod stock for coaxial lines.

Use of this system of instruments, however, is not restricted to calibrations or measurement on devices equipped with the TYPE 900 Precision Connector. Precision adaptors permit a tie-in with popular connectors, such as the type N and the TYPE 874. When a TYPE 900 adaptor to another type of connector is used, the accuracy is limited only by the performance of the other connector. For example, the residual VSWR of the TYPE 900-LB Slotted Line, which is 1.002 at 1 Gc, is still only 1.01 when a type-N adaptor is installed.

TYPE 900-LB PRECISION SLOTTED LINE

The slotted line is the basic immittance- and VSWR-measuring instrument for the uhf and shf ranges. It has yet to be surpassed in absolute accuracy, versatility, and bandwidth. Its accuracy is absolute because its built-in impedance standard is the characteristic impedance of its coaxial line, which is directly dependent upon mechanical dimensions.

Imperfections in the slotted coaxial-line system and the discontinuities at slot end, transitions, and connectors are the principal sources of error. Such imperfections and discontinuities in the coaxial-line section have been virtually eliminated in the Type 900-LB Precision Slotted Line. New manufacturing methods and further development in the conventional methods have made this possible. Furthermore, there is no transition problem because there is no transition; the connection between the slotted section and the connector is a continuous, uniform, coaxial transmission line with very close control of diameters, as in the slotted section. And TYPE 900-BT Connector has effectively eliminated connector errors.

The new precision slotted line is similar in general construction to the TYPE 874-LBA, which has in recent years been constantly improved and ruggedized, and whose accuracy is comparable with that of other commercially available types. Many of its design features have been embodied in the 900 model, along with a number of refinements and improvements.*

The precision slotted line uses an air-dielectric coaxial line, with an outer conductor ID of 0.5625 inch, made to extremely close dimensional tolerances. Connectors are a TYPE 900-BT at the unknown terminals, a locking TYPE 874 Connector at the input side, and a non-locking TYPE 874 at the demodulated detector output terminals.

The following new features have been incorporated:

A new probe assembly, comprised of an externally adjustable probe, with calibrated penetration depth, and a probe tuner with micrometer-type drive, calibrated in centimeters, and having excellent tuning stability.

* The Type 900-LB Slotted Line does not supersede the Type 874-LBA, which is still available.

A vernier scale and, in addition, a micrometer drive for fine resolution.

Provision for direct rf connection to the probe; the tuner is replaced with an rf probe assembly.

A protective cover, which can be closed to prevent dust accumulation and damage. The cover reinforces the basic assembly and adds very little extra weight.

Quick conversion into a precision type N or TYPE 874 Slotted Line by means of low-VSWR adaptors (adaptors to TNC, C, and other types are under development).

The slotted line can be calibrated absolutely with the TYPE 900-BT Connectors to a much higher degree of accuracy than with other connector types. The TYPES 900-L10, 900-L15, 900-L30 Air Lines, and the TYPE 900-W50 Termination are excellent calibration devices for this purpose.

The most important feature, however, is performance:

Residual VSWR is extremely small (Figure 2), $1.001 + 0.001 \times f_{Gc}$. With a TYPE 900-QNJ or -QNP Adaptor to type N installed, over-all VSWR is $1.005 + 0.005 f_{Gc}$.

Constancy of probe coupling, a most important characteristic, is ±0.5%.

Frequency range is 300 Mc to 9000 Mc; probe carriage travel is 50 cm.

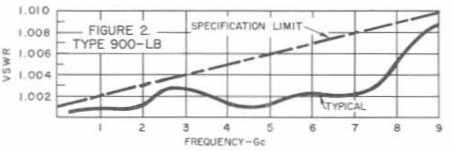
With the precision air lines the length can be extended to permit operation down to 150 Mc.

[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, "An Accurate Substitution Method of Measuring the VSWR of Coaxial Connectors," *The Microwave Journal*, Vol 5, No. 1, January 1962, pp 69–73.

[5] G. A. Deschamps, "A Simple Graphical Analysis of a Two-Port Waveguide Junction," *Proceedings of the IRE*, 42, 859, May 1954.

[6] J. E. Storer, L. S. Sheingold, and S. Stein, "A Simple Graphical Analysis of a Two-Port Waveguide Junction," *Proceedings of the IRE*, 41, No. 8, 1004, August 1953.



Applications

The TYPE 900-LB Slotted Line is well suited to all the well-known slotted line measurements, such as immittance, VSWR, and reflection coefficients of distributed and lumped elements and antennas. More importantly, it is recommended for the absolute calibration of standards.

Additional applications include:

(1) Measurement of connectors and elements by the substitution method.[3,4]

(2) Determination of small-signal characteristics of diodes and transistors. For these measurements, the slotted line is driven through the probe with the special connector provided, and the detector then connects to what is normally the generator end of the line. By this means, adequate sensitivity is maintained at low voltage levels.

(3) Measurement of dielectric constant and loss tangent of dielectric materials.

(4) Precision phase shifter. The slotted line can be terminated with the TYPE 900-W50 Termination and variable phase signal taken from the probe. Phase shift is accurately calibrated in terms of probe travel.

(5) Sliding short-circuit measurements of scattering coefficients of distributed and lumped elements.[5,6]

Those engaged in the development of coaxial devices will find this slotted line an invaluable aid to the design of equipment with truly low standing-wave ratio.

SPECIFICATIONS

Characteristic Impedance: 50.0 ohms ± 0.1%.
Probe Travel: 50 cm. Scale calibrated in centimeters from the reference plane. Attached vernier scale can be read to 0.1 mm.
Scale Accuracy: ± (0.1 mm + 0.05%).
Frequency Range: 300 Mc to 9 Gc. At 300 Mc, covers a half wavelength. Operates below 300 Mc with TYPE 900 Precision Air Line.
Constancy of Probe Pickup: ±0.5%.
Residual VSWR: Less than 1.001 + 0.001 × f_{Gc} (e.g., 1.002 at 1 Gc).
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 diodes); rf probe assembly (with TYPE 874-BL Connector); micrometer carriage drive (accurate to 0.01 mm); spare drive cable; storage box; Smith charts.
Accessories Required: Generator and detector.
Dimensions: Width 27½, height 10, depth 4¾ inches (700 by 255 by 125 mm).
Net Weight: 10¾ pounds (4.9 kg).
Shipping Weight: 27 pounds (12.5 kg).

Type		*Code Number*	*Price*
900-LB	**Precision Slotted Line**	0900-9651	**$575.00**

TERMINATIONS

TYPE 900-W50 PRECISION 50-OHM TERMINATION

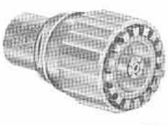
The TYPE 900-W50 Termination is a broadband device with extremely low VSWR, useful from dc to 9 Gc. It comprises an accurately derived, continuous transition and a precision cylindrical resistor. The connector is a TYPE 900-BT. Typical VSWR characteristics are given in Figure 3. The change of resistance and VSWR *vs* heating due to incident power is negligible up to 1-watt incident power.

Applications

As a 50-ohm standard for the calibration of bridges, slotted lines, impedance plotters, reflectometers, etc.

As a termination in measurements of networks with more than one port.

As a precision dummy load.

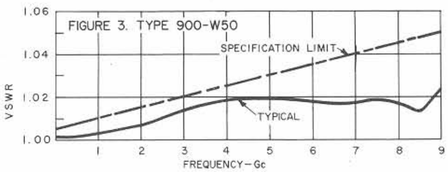


Type 900-W50

Type 900-WN

Type 900-WO

As a precision type N or Type 874 Termination when used with a TYPE 900-QNJ, 900-QNP, or 900-Q874 low-VSWR adaptor.



SPECIFICATIONS

VSWR: Less than 1.005 + 0.005 × f_{Gc}, up to 9 Gc.
DC Resistance: 50 ohms ± 0.3%.
Maximum Power: 1 watt with negligible change; 5 watts without damage.
Temperature Coefficient: < 150 ppm/°C.
Over-all Length: 2 inches (51 mm).
Net Weight: 3½ ounces (100 grams).

TYPES 900-WN AND 900-WO SHORT-CIRCUIT AND OPEN-CIRCUIT TERMINATIONS

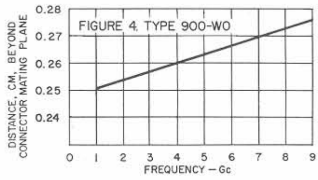
The TYPE 900-WN Short-Circuit Termination and TYPE 900-WO Open-Circuit Termination are low-loss devices, which effectively short circuit or open circuit a coaxial line.

Type 900-WN Short-Circuit Termination

The reference plane of this termination is conveniently located at the mating plane of the Type 900-BT Connector. Ohmic losses are extremely small, as demonstrated by a reflection coefficient of 0.999 or greater at 9 Gc. The termination is a silver-plated brass slug with the necessary Type 900 external hardware, gold-plated for protection against tarnishing. The excellent performance cited is inherent in the Type 900 Connector. The inner conductor shorting contact is achieved by the flat surface of the slug pressing against the Type 900-BT contact.

Type 900-WO Open-Circuit Termination

A Type 900-WO Open-Circuit Termination presents an effective open circuit 0.26 cm from the mating plane of a Type 900-BT Connector. It is a closed-end, standard-size outer conductor with Type 900 external mounting hardware. The open-circuit reference plane cannot be made identical in position to the short-circuit reference plane because of end effect. This end effect can be represented closely by an additional length of line, in this case 0.26 cm, or a capacitance of 0.173 pf shunting the end of the



line. The effective length, however, is frequency dependent. Measured data are shown in Figure 4.

Applications

The Types 900-WN and 900-WO Terminations are useful in the following applications:

Establishing reference planes in direct or substitution coaxial-line measurements.

As low-loss terminations for measurement of networks with more than one port (including loss measurements).

As coaxial-line reactance standards in combination with Type 900-L10, 900-L15, or 900-L30 Air Lines.

SPECIFICATIONS

Reflection Coefficient: > 0.999.
Net Weight: Type 900-WN, 2½ ounces (75 grams); Type 900-WO, 2 ounces (60 grams).
Over-all Length: 1 1/16 inches (27 mm).

AIR LINES

Type 900-L30

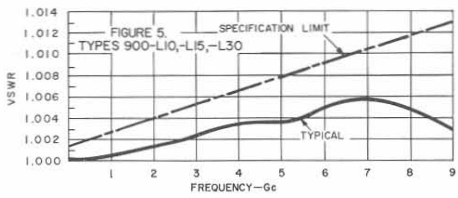
TYPES 900-L10, 900-L15, AND 900-L30 AIR LINES

Type 900-L15

Type 900-L10

The Types 900-L10, 900-L15, and 900-L30 Air Lines are precision coaxial air-line sections fitted with standard Type 900-BT Connectors. The air-line sections are held to extremely close dimensional tolerances. The inner conductor tolerance is ±65 microinches, and variations are restricted to ±25 microinches along a given rod. The outer conductor diameter is held to ±140 microinches.

These tolerances maintain the characteristic impedance at 50 ohms ± 0.65%. The basic materials are brass, with a layer of silver at the conducting surfaces, and a protective gold plating. Typical VSWR characteristics are shown in Figure 5. The low-frequency, skin-effect correction is shown in Figure 9.



Applications

(1) As 50-ohm quarter-wave reference standards. When the lines are used at frequencies where length is an odd multiple of λ/4, any immittance-measuring instrument, Smith-Chart plotter, etc., can be calibrated with respect to 50 ohms and the termination error isolated. The following table lists $(2n - 1)\ \lambda/4$ frequencies for the three air-line sections.

Quarter-Wave Frequencies of Type 900-L Air Lines

900-L10 *Frequency, Gc*	*900-L15* *Frequency, Gc*	*900-L30* *Frequency, Gc*	
0.75	0.5	0.25	4.75
2.25	1.5	0.75	5.25
3.75	2.5	1.25	5.75
5.25	3.5	1.75	6.25
6.75	4.5	2.25	6.75
8.25	5.5	2.75	7.25
	6.5	3.25	7.75
	7.5	3.75	8.25
	8.5	4.25	8.75

(2) As precision time-delay standards. The lines are held to an electrical length of ±0.012 cm, which is equivalent to ±0.4 picosecond.

(3) As reactance standards, with the TYPE 900-WN Short-Circuit Termination or the TYPE 900-WO Open-Circuit Termination.

(4) As extension lines. The lines may be used to extend the lower frequency limit of the TYPE 900-LB Slotted Line below 300 Mc. With a sufficient length of air line, this limit can be reduced to 150 Mc.

SPECIFICATIONS

VSWR: Less than 1.0013 + 0.0013 × f_{Gc}, up to 9 Gc.

Characteristic Impedance: 50 ohms ± 0.1%.

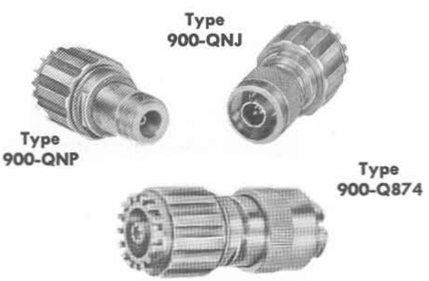
Electrical Length: TYPE 900-L10 — 10.00 ± 0.02 cm; TYPE 900-L15 — 15.00 ± 0.02 cm; TYPE 900-L30 — 30.00 ± 0.02 cm.

Time Delay: TYPE 900-L10, 0.333 nsec; -L15, 0.5 nsec; -L30, 1.0 nsec; all ± 0.4 psec.

Net Weight: TYPE 900-L10, 6½ ounces (185 grams); -L15, 10 ounces (285 grams); -L30, 15 ounces (425 grams).

Over-all Length: TYPE 900-L10, 4 inches (105 mm); -L15, 6 inches (155 mm); -L30, 12 inches (305 mm).

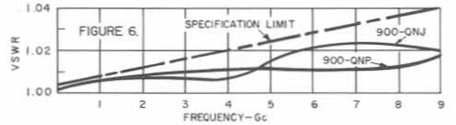
ADAPTORS



TYPES 900-QNJ AND 900-QNP ADAPTORS

Type N Adaptors

There are two type N adaptors: the TYPE 900-QNJ, which consists of a type N jack and a TYPE 900-BT Connector, and the TYPE 900-QNP, which contains a type N plug and a TYPE 900-BT Connector. These adaptors have specially designed, continuous transitions between the two line sizes. The absence of any discrete discontinuities in the transition is a unique feature of these adaptors. The type N jacks and plugs in these adaptors are of a special, low-VSWR design. Although they are compatible with standard military type N connectors, they should be used with special type N connectors for lowest VSWR. The instruction sheets provided with these adaptors show the electrical length and reference-plane as well as other optimum configuration details for the mating plug or jack. VSWR characteristics are shown in Figure 6.



SPECIFICATIONS

VSWR: Less than $1.004 + 0.004 \times f_{Gc}$, up to 9 Gc, either unit.

Electrical Length: TYPE 900-QNP — 5.50 ± 0.03 cm to end of male outer conductor. TYPE 900-QNJ — 5.00 ± 0.03 cm to end of female inner conductor.

Net Weight: TYPE 900-QNP, 3½ ounces (100 grams); -QNJ, 4 ounces (115 grams).

Over-all Length: TYPE 900-QNP, 2-5/16 inches (59 mm); TYPE 900-QNJ, 2¼ inches (58 mm).

TYPE 900-Q874 ADAPTOR

(Connects with either locking or nonlocking Type 874 Connector)

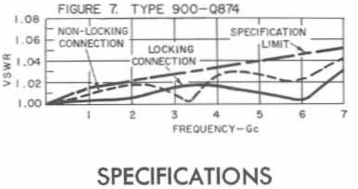
The TYPE 900-Q874 Adaptor comprises a TYPE 874-BL Locking Connector and a TYPE 900-BT Connector, mounted on a short section of precision air line. This adaptor contains a newly designed, fully compensated TYPE 874 support bead. Although the adaptor mates with both locking and nonlocking TYPE 874 Connectors, a mechanically stable, low-leakage connection requires a TYPE 874-BL Connector. For coaxial-line measurements where the reference plane must be determined with the maximum accuracy, however, a TYPE 874-B (nonlocking) connector should be used. The reason for this is that the locking-type connector is intentionally disengaged a slight amount by the locking system, so as to prevent mechanical jamming. This disengagement can vary from 0.006 to 0.042 inch from connector to connector because of tolerance limits. However, it is generally close to a nominal 0.020 inch. The nonlocking connector, on the other hand, mates automatically within much closer limits because the connectors are always fully engaged. The electrical length and reference-plane data are given in the instruction sheet that accompanies the adaptor. VSWR characteristics are shown in Figure 7.

Applications

Extends usefulness of TYPE 900-LB Slotted Line, permitting precision measurements of type N and TYPE 874 components.

As a precision type N or TYPE 874 50-Ohm Termination, when used with TYPE 900-W50.

Converts instruments with type N or TYPE 874 connectors to TYPE 900.



SPECIFICATIONS

VSWR: Less than $1.00 + 0.015 \times f_{Gc}$; $1.01 + 0.005 \times f_{Gc}$ from 1 to 7 Gc.

Electrical Length: 6.50 ± 0.04 cm to front face of mated nonlocking TYPE 874 connector bead.

Over-all Length: 2-9/16 inches (65 mm).

Net Weight: 3½ ounces (100 grams).

TYPE 0900-9782 ADAPTOR FLANGE

This flange is a general-purpose device which converts any Type 900 component connector to a flange connector, making use of the fact that the inner contact of the Type 900-BT works suitably against any flat surface with no special additional contacting device or bullet required. The configuration is shown in Figure 8.

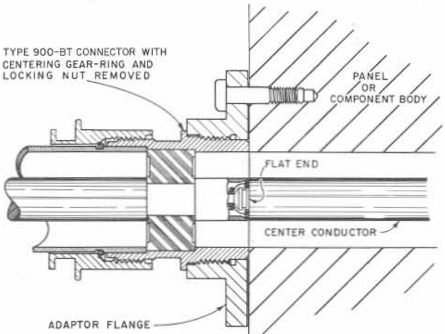


Figure 8.
Flange adaptation on Type 900-BT Connector.

Applications

For connecting to a coaxial system ending in flat, flush surfaces, typically in special bridges.

Specifications

Mounting Holes: 0.157 ± 0.005-inch dia, 120° ± 0.5° apart on a radius of 0.812 ± 0.003 inch.

Net Weight: 3 ounces (85 grams).

PRECISION ROD AND TUBING

For those who wish to assemble coaxial systems using the Type 900 Connector, coaxial air-line rod and tubing having extremely tight diameter tolerances are now offered by General Radio Company. The rod is brass with a layer of silver approximately 0.0005-inch thick and a finished diameter of 0.24425 inch ±65 microinches. The tube has a layer of silver approximately 0.0005-inch thick and a finished inner diameter of 0.5625 inch ±140 microinches. Both tubing and rod are stress-relieved to minimize diameter changes due to machining and

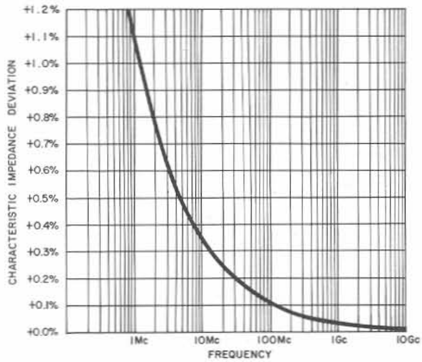
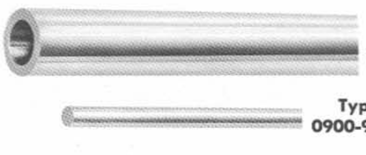


Figure 9. Skin-effect characteristic-impedance error as a function of frequency.

are straightened. The instruction sheet provides directions for machining the material for use with the Type 900-BT Connector, including procedures for minimizing dimensional changes. At frequencies where skin depth is negligible, the characteristic impedance of a transmission line made from this material is 50 ±0.0013 ohms, or ±0.065%. The skin-depth deviation as a function of frequency is shown in Figure 9.

There is a practical limit to the length of the precision air line that can be made from this material because of inner conductor sag. An expression for the sag is given below. This expression is pessi-



Type 0900-9509

Type 0900-9508

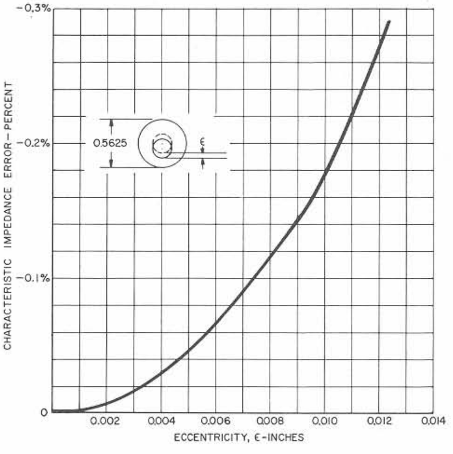


Figure 10. Characteristic-impedance error vs sag in inner conductor.

mistic because the connectors provide some cantilever support. The characteristic impedance of a coaxial transmission line with an eccentric inner conductor is given by

$$Z_o = A \cosh^{-1}\left[\frac{b}{2a}\left(1 - 4\frac{\epsilon^2}{b^2}\right) + \frac{a}{2b}\right]$$

where

A = 59.9368
b = coaxial line outer conductor ID
a = coaxial line inner conductor OD
ϵ = amount by which conductor is off center

The sag, ϵ, at the center is given approximately by,

$$\epsilon \cong \frac{l^4}{15 \times 10^6} \text{ inches}$$

where l is the length of the inner conductor in inches.

For a 16½-inch length, the sag, ϵ, is 0.005 inch at the center.

The characteristic impedance error calculated from the above formula along an incremental length of line at the center is −0.046% for this amount of sag (see Figure 10). Therefore, 16½ inches may be considered the longest permissible air-line section for precision work. With TYPE 900-BT Connectors at each end, the corresponding air line is 45.5 cm long, electrically.

When maximum accuracy is desired for the longer line sections, the line should be mounted vertically.

Applications

Precision sliding loads and shorts, air lines.

Precision 50-ohm air-line impedance and time-delay standards.

General component use.

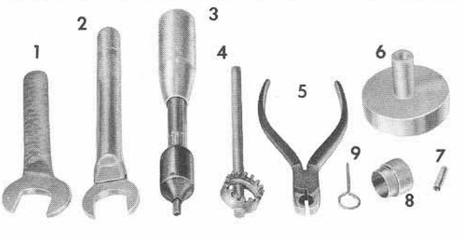
Specifications

Net Weight: Rod, 7 ounces (0.2 kg); tube, 2½ pounds (1.2 kg).

Over-all Length: 27 inches (690 mm).

TYPE 900-TOK KIT

The TYPE 900-BT Precision Coaxial Connector should be assembled on components with the TYPE 900-TOK Tool Kit, both for the best precision and for avoidance of damage to connector. The tool kit, designed for this purpose, includes all the tools required to assemble the TYPE 900-BT Connector on a component and the devices needed to reassemble a connector that has been inadvertently disassembled or to replace damaged parts. The tool kit contains



1. Open-End Wrench
2. Coupling-Nut Torque Wrench
3. Inner-Conductor Torque Wrench
4. Gear Wrench
5. Inner-Conductor Plier
6. Bead Pusher
7. Inner-Conductor Injector
8. Bead Compression Sleeve
9. Spring-Contact Wrench

an open-end wrench, a coupling-nut torque wrench, an inner-conductor gripping plier, and a contact Allen wrench. In addition, for connector reassembly, it contains an inner conductor injector, a bead compressor sleeve, and a bead pusher.

For some users, purchase of the complete tool kit may not be wholly justifiable. It is possible to install the connectors on components with ordinary tools, listed below. It is not possible, however, to reassemble a connector that has been completely disassembled because the parts are press-fitted together with the assembly tools furnished in the TYPE 900-TOK Tool Kit.

The following tools may be employed to install connectors. Extreme care must be used, so as not to apply excessive torque and thus damage connector parts.

1. Two 11/16″ open-end wrenches with 3/32″-wide blade (bicycle type).

2. One, and in some cases two, 5/32″ Allen wrenches.

3. One inner-conductor gripper, a plier device with a padded 0.244″-dia hole to hold the inner conductor upon which the connector is to be installed. Alternately, a gripping device can be made from two strips of plastic, held firmly together in a vise and drilled with a 15/64″ drill. The inner conductor is installed in the hole and gripped in the vise.

4. One 1/16″ Allen wrench.

— JOHN ZORZY

Type		*Code Number*	*Price*
900-L10	**Precision Air Line** (10 cm)	0900-9605	**$ 85.00**
900-L15	**Precision Air Line** (15 cm)	0900-9607	**90.00**
900-L30	**Precision Air Line** (30 cm)	0900-9613	**100.00**
900-Q874	**Adaptor to Type 874**	0900-9883	**45.00**
900-QNJ	**Adaptor** (contains type-N jack)	0900-9711	**50.00**
900-QNP	**Adaptor** (contains type-N plug)	0900-9811	**50.00**
900-TOK	**Tool Kit**	0900-9902	**95.00**
900-WN	**Short-Circuit Termination**	0900-9971	**9.00**
900-WO	**Open-Circuit Termination**	0900-9981	**9.00**
900-W50	**50-Ohm Termination**	0900-9953	**60.00**
0900-9508	**Precision Inner-Conductor Rod**	0900-9508	**25.00**
0900-9509	**Precision Outer-Conductor Tube**	0900-9509	**35.00**
0900-9782	**Adaptor Flange**	0900-9782	**3.50**

OF FUEL GAGES AND THE AERONAUTICAL INSTRUMENTS LABORATORY

To a pilot, it is a matter of some importance that the fuel gage in his aircraft be accurate. The degree of accuracy required and the various types of fuels used by modern aircraft led to the demise of the float-type gage and to the development of a fuel-quantity gage that operates by sensing the electrical capacitance of the fuel-tank probes. This parameter is directly proportional to mass, which in turn is closely related to the energy content of the fuel. To check the accuracy of such a gage, a special capacitance standard ("fuel-gage tester"), connected to the gage in place of the tank, simulates full- and empty-tank conditions.

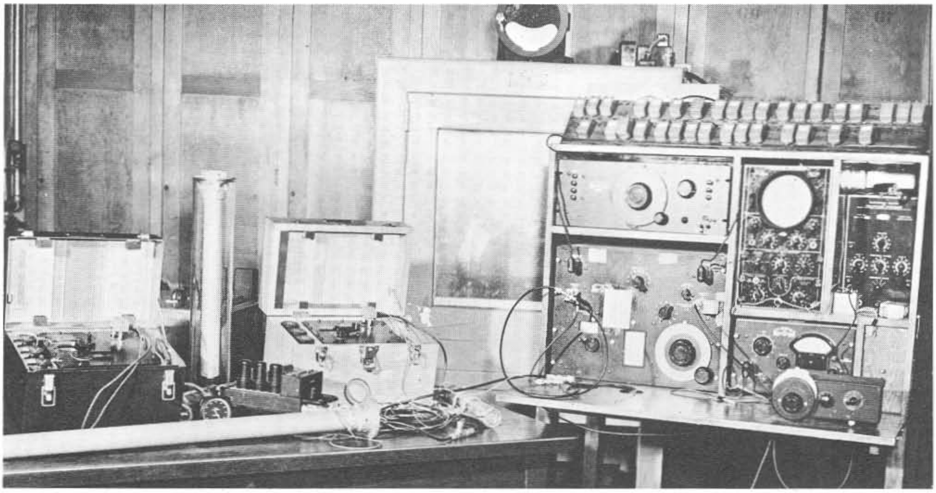
General Radio, an old hand at designing capacitance standards and bridges, contributed importantly from the outset

Technician calibrates fuel gage of modern jet aircraft by means of a GR Type 1429-A Fuel-Gage Tester.

to the development and subsequent refinement of fuel-gage testers. At the Aeronautical Instruments Laboratory of the U. S. Naval Air Development Center at Johnsville, Pennsylvania, GR bridges were used to evaluate differences in dielectric characteristics between aviation gasoline and jet fuel and among fuels refined in different parts of the world. From such measurements came a circuit element to compensate for variations in the density of the fuel.

The General Radio MD-1 Tester was the first to meet military requirements; our current Type 1429-A Fuel-Gage Tester, a slimmed-down version of the MD-1, is widely used to calibrate gages on both reciprocating- and jet-engine aircraft.

In the development of fuel-gage testers, GR has worked in close co-operation with two military agencies: the Aeronautical Instruments Laboratory at Johnsville and the Wright Aeronautical Development Center at Dayton. The Aeronautical Instruments Laboratory is now celebrating its silver anniversary. Inasmuch as our association with this laboratory covers most of those 25 years, we are especially pleased to note the event and to congratulate AIL on its quarter-century of service to the nation.

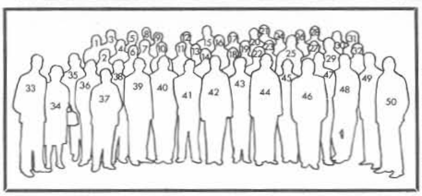


Equipment used in early fuel-gage tester development, shown in this 1951 photo taken at Aeronautical Instruments Laboratory, includes capacitance bridge, generator, and detector. (Official Photograph U. S. Navy)

OVERSEAS SEMINAR IN MILAN

The third biennial sales and engineering seminar for GR overseas representatives was held in Milan during the last week of May, 1963, with nearly forty sales engineers and export sales representatives from fifteen countries attending, plus several from General Radio Company and General Radio Company (Overseas). Technical and sales sessions in the forenoon and laboratory workshops in the afternoon were held to acquaint the participants with latest General Radio equipment.

Much of the credit for the success of the seminar goes to our hosts, the firm of Ing. S and Dr. Guido Belotti, who have represented General Radio Company in Italy for over thirty years. The accompanying photograph shows most of those attending.



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3. Dov Peleg, Israel
4. A. Lara Saenz, Spain
5. R. Danziger, Israel
6. G. F. Molac, France
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13. Miss S. Fiore, Italy
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17. S. Maio, Italy
18. Miss A. Agnisetta, Italy
19. Mrs. O. Curti, Italy
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21. G. Malfassi, Italy
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28. K. Kyriokos, Greece
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43. A. R. Mouriaux, France
44. U. Clementz, Sweden
45. A. R. O. van Lierop, Holland
46. H. A. Molinari, Switzerland
47. H. Klip, Holland
48. J. Beyerholm, Denmark
49. S. W. DeBlois, GR
50. D. B. Sinclair, GR

DETERMINATION OF CAPTURE PROBABILITIES OF PRECIPITATION PARTICLES WITH THE STROBOLUME

by Dr. Roland List*

One of the major problems of modern cloud physics is the description of the growth of precipitation particles (raindrops, graupels and hailstones). Theoretical computations show that the gas-phase contributes negligibly to the growth of the mass, as long as the growing particles show diameters of more than 2 mm. The determining factor for the growth of precipitation particles is, therefore, the accretion, the capture of cloud particles, either water droplets or ice particles with diameters from 10–100 μ.

If we observe, for instance, the growth of ice particles falling in a cloud of undercooled water droplets (temperature less than 0°C), we can determine the collection efficiency based on the growth of the mass of a test particle in form of icing. This can be done by careful determination of weight. The result, however, does not give us dependable information about the number of impinging particles because we do not know exactly how many of the particles are hurled back into the air stream. To determine this, stroboscopic photographs were taken with the General Radio Company Strobolume during icing tests of the climate-controlled wind tunnel on the Weissfluhjoch, Switzerland. The Strobolume switch was in the high intensity position. Figure 1 shows the icing of a 2-cm steel ball in an air stream of a velocity of 20 m/s, at a temperature of -5°C and an absolute humidity of approximately 4 g/m^3. The average size of the water droplets is 50 μ. The photo was taken with an Alpa camera with normal lens and adaptor rings at $f/11$. Agfa, Isopan Record Film, with a sensitivity of 34–40°DIN (2000–8000 ASA) was used. The most important result obtained from this photographic observation is that, under existing icing conditions, no rebounding of impinging water droplets could be observed. Therefore, the number of impinging particles equals the number of captured particles (collision efficiency equals collection efficiency).

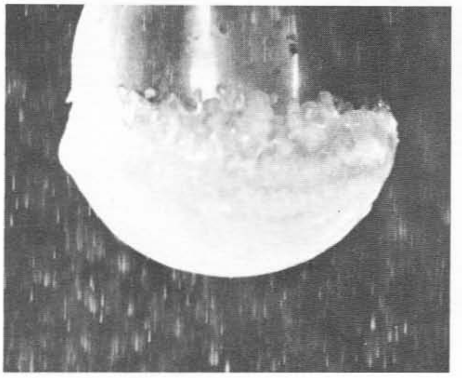

Figure 1. Icing of a 2-cm steel ball in an air stream (temperature -5°C).

The following additional conclusions can be drawn from Figure 1:

a) The direction of movement of droplets can be determined from their appearance in the photograph as streaks of light. Since the electronic flash of the Strobolume shows, directly following trigger, a defined intensity peak followed by a steady decay, the movement vector of a "particle streak" can be seen from

* Federal Institute for Snow and Avalanche Research, Weissfluhjoch-Davos (now with the Department of Physics, University of Toronto).

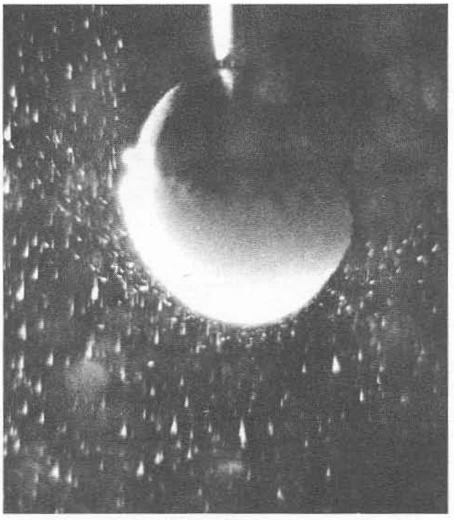

Figure 2. Icing of a 2-cm steel ball in an air stream (temperature −25°C); diameter of the arriving ice particles or subcooled water droplets 50-100 μ. Observe the "boundary layer" of the rebounding particles. For this photograph, a slot illumination (slot opening 2 mm) was used, necessitating a camera opening to $f/1.6$. The visible diffraction pattern (rains) results from reproduction of cloud droplets passing the steel ball at a distance of more than 2 cm in the direction of the camera.

the brightness pattern. For a slot illumination, perpendicular to the camera axis and passing the center of the icing particle, the flow lines of the floating particles can be determined.

b) If the particles arriving at an obstacle are partly iced, the rebounding particles can be observed as such from their "streak direction" (Figure 2).

c) From the direction of the streak image, the velocity of cloud particles can be determined as a function of their location as long as the particles do not differ largely in size.

From these observations, it is apparent that the Strobolume is a useful device for research of the complex capture processes which, in a diversity of manner, play an important role in the formation of precipitation.

The observations described here were made within the framework of the research project No. 2071 of the Swiss National Fonds.

General Radio Company

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GENERAL RADIO COMPANY
extends to all *Experimenter* readers
its best wishes for a
Happy and Prosperous 1964

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CONTENTS

COVER

The Type 916-AL Radio-Frequency Bridge with a null detector employing the new Type 1232-P1 RF Mixer, as arranged for measurements at 4 Mc. The mixer is plugged directly into the detector terminals at the rear right-hand corner of the bridge.

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GENERAL RADIO COMPANY (OVERSEAS), ZURICH, SWITZERLAND
REPRESENTATIVES IN PRINCIPAL OVERSEAS COUNTRIES

Figure 1. Panel view of the Type 1136-A Digital-to-Analog Converter.

HIGH-SPEED DIGITAL-TO-ANALOG CONVERTER WITH STORAGE

The conversion of digital data to analog form provides both a convenient method of presentation and a permanent record. The analog output can be displayed on a graphic recorder, and whenever the input data changes continuously as a function of some other parameter, such as time, temperature, humidity, pressure, etc., the record permits immediate evaluation. A typical application is shown in Figure 2, where the frequency of a 5-Mc crystal is plotted as a function of temperature.

Although the analog output may have no better than 0.1% accuracy, this is quite sufficient for incremental measurements. If the analog output is formed by 3 digits, the minimum increment is 0.1%. By choice of the appropriate 3 digits of the input, the analog system interpolates between the next significant units of the input data. This is illustrated by the example of Figure 2.

When the analog output is formed from the last 3 digits of an 8-digit counter indicating tenths of cycles per second, the total span of the analog output is 100.0 cps even though the counter may be measuring a 5-Mc frequency. The 0.1% accuracy of the analog output, therefore, is equivalent to 0.1 cps out of the total input, and no accuracy is lost. The first 5 digits of the counter remain constant. When these are of any interest they can be read from the counter's visual display and recorded manually. The analog output interpolates between 4,998,400.0 cps as analog 0 and 4,998,499.9 as analog 999. Should the data exceed 4,998,499.9, the analog output will "automatically" shift its 0 to be 4,998,500.0 and the new full scale would be 4,998,599.9. Since the analog is formed from the last three digits, it is not affected by the digits further to the left. This permits high incremental sensitivity without danger of full-scale current being exceeded.

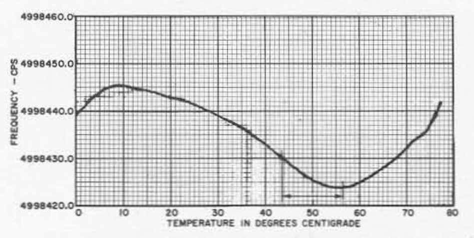


Figure 2. Frequency-vs-temperature characteristic of 5-Mc crystal. Full scale for analog curve was 100 cps, each minor division 1 cps. Only the significant part of the analog record (from 4998420.0 to 4998460.0) is reproduced here. Gate time was 10 seconds.

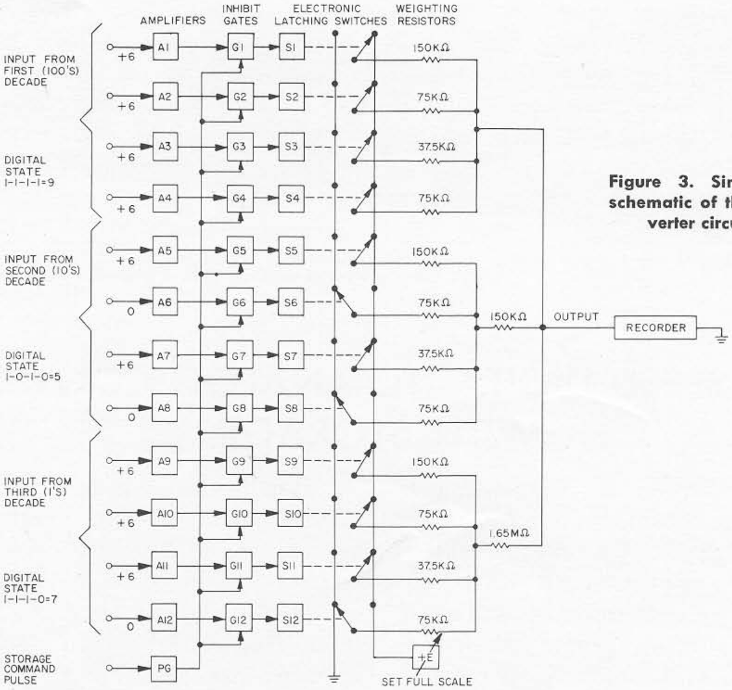


Figure 3. Simplified schematic of the converter circuit.

At GR the advantages of analog recording have long been recognized, and the TYPE 1134-A Digital-to-Analog Converter[1] has been available as a companion instrument to the TYPE 1130-A Digital Time and Frequency Meter.[2] The need for storage of the digital data has been discussed[2] previously. Storage facilities are built into the TYPE 1130 counter. The introduction of new digital instruments without storage has made it desirable to provide a new D-A converter with self-contained storage.

The new TYPE 1136-A Digital-to-Analog Converter has 3-decade BCD input, fast transfer into storage, and 0.1% over-all accuracy. Input data with 1-2-4-2 or 1-2-2-4 weighting is accepted; 1-2-4-8 weighting requires a minor modification; 10-line decimal input is accepted when an accessory, the TYPE 1136-P1 Diode Matrix and Cable, is used. Binary "1" input must be at least 6 v positive with respect to binary "0". The actual voltage may be up to ±150 v from ground. Maximum conversion rate is over 10 kc.

Up to 9 decades of 4-line BCD can be connected to the input, and a selector switch permits selection of any adjacent 3 or the last 2 to form the output. Illuminated indicators show which decades are selected.

Principle of Operation

Figure 3 is a simplified schematic diagram. The input data is applied to the amplifiers $A_1 \ldots A_{12}$. The gates $G_1 \ldots G_{12}$ are normally closed, and the input has no effect on the output

[1] H. P. Stratemeyer, "Analog Output from the Digital Counter," *General Radio Experimenter* (35, 10), October, 1961.

[2] R. W. Frank and H. T. McAleer, "A Frequency Counter with a Memory and with Built-In Reliability," *General Radio Experimenter* (35, 5), May, 1961.

switches (standardizers) $S_1 \ldots S_{12}$. These electronic switches are self-latching and serve as storage elements for the input data. A storage-command pulse (SCP) is applied to the pulse generator (PG) and the gates $G_1 \ldots G_{12}$ are momentarily opened. This transfer system does not require any zero-set (clear) operation before new data is entered into storage. $S_1 \ldots S_{12}$ assume states corresponding to the input. The SCP is generated by the digital source at the beginning of the "display time." Most counters provide a suitable pulse output (print-command pulse). The total transfer time is about 30 μsec. $S_1 \ldots S_{12}$ connect the weighting resistors to ground for binary 0 and to a precise voltage E for binary "1". The analog output is the sum of all the currents through $R_1 \ldots R_{12}$. The 1 ma output is essentially a 15 v swing behind 15 kΩ.

Accuracy — Linearity — Stability

The impedance of the recorder does not affect the accuracy or the linearity of the output. The output matrix is shown in Figure 4.

Examination shows that, while the magnitude of I_o is affected by G_L, the relative contribution of each component is independent of G_L. The magnitude of I_o can be adjusted for the required full-scale value by adjustment of the supply voltage E.

The linearity of the output is determined by the accuracy of the weighting resistors, the precision of the electronic output switches, and the output impedance of the regulated power supply for E (see Figure 4).

The output switches are complementary pairs of inverted transistors. The offset voltage (the saturation voltage) is only 1 to 2 millivolts, and when E is over 15 volts this error does not exceed 0.02% of full scale. The variation of E as a function of the output current from the matrix is negligible.

The stability of the output is determined by the stability of the supply E, the weighting resistors, and the offset voltage. The largest contribution is the temperature coefficient of the zener-reference diode for the supply E ($<$10 ppm/°C) and the temperature influence on the weighting resistors ($<$10 ppm/°C referred to full scale).

In addition to these static errors there is a dynamic error as a function of transfer rate. Consider the change from 3 to 4 in 1-2-2-4 weighted BCD. The "3" output consists of a binary "1" in the first bit and in the second bit, i.e., S_1 and S_2 are

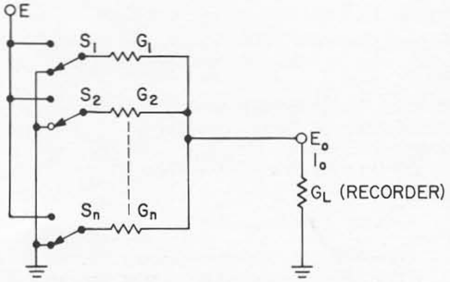
Figure 4. Equivalent circuit of the output matrix.

$G_1 \ldots G_{12}$ are the conductances of the weighting resistors

$S_1 \ldots S_{12}$ the standardizer switches

$E_1 \ldots E_{12}$ the voltages applied to the weighting resistors (0 v for a binary "0", E for a binary "1")

G_L is the conductance of the recorder



$$E_o = \frac{\Sigma(E_n G_n)}{\Sigma G_n + G_L} \qquad I_o = E_o G_L = G_L \frac{\Sigma(E_n G_n)}{\Sigma G_n + G_L}$$

$$I_o = \frac{GL}{G_1 + G_2 + \ldots + G_n + G_L}(E_1 G_1 + E_2 G_2 + \ldots + E_n G_n)$$

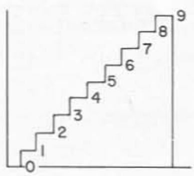


Figure 5a. Perfect output.

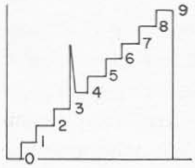


Figure 5b. S_4 turns on before S_1 and S_2 are off.

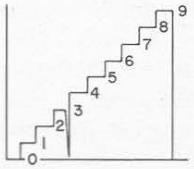


Figure 5c. S_4 turns on after S_1 and S_2 have turned off.

on. To get the "4" output, the first and second bit have to change to binary "0" and the third bit to binary "1". In the switching schematic this means that S_1 and S_2 have to turn off and S_3 must turn on. Suppose that S_3 turns on before S_1 and S_2 are off: then, during this "overlap" the output can be as high as 7, or, if S_3 turns on after S_1 and S_2 have turned off, the output can momentarily drop to zero. Figure 5 illustrates this effect. The use of fast electronic switches keeps this time interval less than 1 μsec. In the worst case this can contribute an output error of .0001% × conversion rate (in cps). The typical error is about three times less. In the worst case, at a conversion rate of 10,000 per second, this amounts to 1%. However, a recorder with response to 10 kc rarely has an accuracy of better than a few percent, so that this error can generally be neglected.

— H. P. Stratemeyer

SPECIFICATIONS

Data Input: BCD weighted 1-2-4-2 or 1-2-2-4. Minor modification adapts for 1-2-4-8 input. Binary 1 at least 6 volts positive with respect to binary 0. Input impedance 50 kilohms. Binary 0 can be offset from ground by ±150 volts. Switch selects any adjacent three or the last two digits of up to nine-decade input.

Conversion Rate: Up to 10,000 conversions per second (controlled by digital-measuring instrument).

Over-all Accuracy: ±0.1% of full scale (includes repeatability, long-term stability, linearity, ±10% line variation, and ±15 C ambient-temperature variations around normal 25 C) ± 0.0001% × conversion rate in cps.

Storage Transfer: 50-μsec transfer time.

Storage Command Pulse: 5 μsec, ±6 volts minimum into 10 kilohms, rise and fall times less than 1 μsec.

Output: 1 milliampere with 15-kilohm source impedance, or 100 millivolts with 100-ohm source impedance. Negative side grounded if binary 0 or input not more than 20 volts from ground. Output floating if offset voltage larger than 20 volts.

Load: 2000 ohms maximum for 1 milliampere output. 1000 ohms minimum for 100 millivolts output.

Linearity: ±0.05% of full scale.

Stability: ±0.02% for ±10% line voltage; ±0.003% of full scale per degree C.

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

Accessory Available: Type 1136-P1 Cable with diode-matrix, required for use with 10-line decimal data from General Radio counters of the 1150 series.

Power Requirements: 105 to 125 (or 210 to 250) volts, 50 to 400 cps, 7 watts.

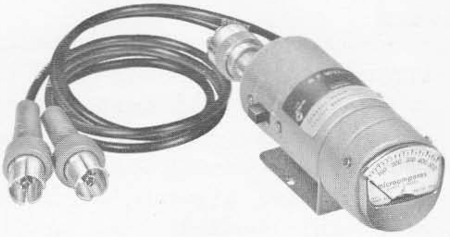
Cabinet: Rack-bench.

Dimensions: Bench model — width 19, height 3½, depth 12 inches (485 by 89 by 305 mm), over-all; rack model — panel 19 by 3½ inches (485 by 89 mm), depth behind panel 11 inches (280 mm).

Net Weight: 13 pounds (6 kg).

Shipping Weight: 17 pounds (8 kg).

Type		*Code Number*	*Price*
1136-AM	**Digital-to-Analog Converter,** Bench Model	1136-9801	**$650.00**
1136-AR	**Digital-to-Analog Converter,** Rack Model..	1136-9811	**650.00**
1136-P1	**Diode Matrix and Cable** (for connection to Type 1150-AP or 1151-AP Counter)......	1136-9601	**160.00**



TWO NEW MIXERS FOR THE DETECTION OF RF SIGNALS

A sensitive, well-shielded detector system is a basic requirement in most audio- and radio-frequency measurements. Detector sensitivity determines the resolution in null-type bridge measurements as well as in the measurement of high values of attenuation. In both these measurements, adequate shielding is a primary factor in determining the ultimate accuracy. Detectors of this description have been available from General Radio for most of the spectrum up to 4000 kc. These are:

(1) The Type 1232-A Tuned Amplifier and Null Detector — 20 cps to 20 kc, with continuous coverage, plus 50 kc and 100 kc, fixed.

(2) The Type 1212-A Unit Null Detector — 50 cps to 5 Mc, untuned; 1 Mc, tuned, with the Type 1212-P1 1-Mc Filter.

(3) The Type DNT Detectors, which are heterodyne types, 40 to 4000 Mc.

Now two new rf mixers fill the gaps below 40 Mc. They operate by the heterodyne method, with low-frequency detector units serving as i-f amplifiers.

The heterodyne detector has a justly deserved preference over other types. It is currently the most convenient means of achieving high sensitivity, wide tuning range, and a high degree of harmonic rejection. It also has a great dynamic range because its amplification is essentially linear over 85-db of input-signal variation. Its disadvantages are few, but the principal one should be mentioned. In its simple form, no selectivity is provided in the signal input circuit, and so it can have some spurious responses from images and harmonics, which make it unsuitable for wave analysis. In general, these are not troublesome, and the addition of circuits to be tuned by the user would complicate the operation.

THE TYPE 1232-P1 RF MIXER

The circuit of the Type 1232-P1 RF Mixer is shown in Figure 1. Included are a microammeter for setting the level of the local oscillator and a high-Q tuned transformer to exclude the local-oscillator signal from the Tuned Amplifier and Null Detector.

Circuit elements are enclosed in an aluminum cylinder to which is appended, in a separate compartment, the meter housing. In addition, double-braid coaxial cable is used on all signal leads. As a result, the mixer is completely

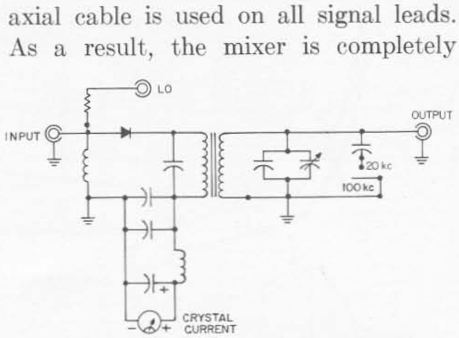


Figure 1. Schematic diagram of the mixer circuit.

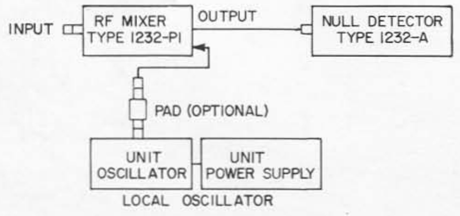


Figure 2. Block diagram of complete detector system using the Type 1232-P1 RF Mixer.

shielded from rf fields, thus preventing spurious null-balance indications.

In order to cover the range from 70 kc to 10 Mc, two i-f amplifier center-frequencies are required. One is 20 kc and is used to cover the range from 70 kc to 500 kc. Actually, the detector can be tuned continuously down to 25 kc, but sensitivity is reduced in this range, and spurious responses are more troublesome. Above 500 kc, the 20-kc frequency increment to which the local oscillator must be set is difficult to resolve, and the tuning is too critical. Therefore, above 500 kc, a switch is made to the 100-kc i-f circuit which is broader in bandwidth. The upper limit of 10 Mc was chosen because above this frequency it becomes difficult to set the 100-kc increment, and, again, the tuning becomes too sharp, so that any frequency drift of the signal source or the local oscillator becomes apparent. Also, above about 20 Mc, the local-oscillator tuning again becomes critical. Otherwise, however, the mixer performs perfectly well, at least as high as 60 Mc, and, with care, satisfactory results can be obtained.

In practice the operation of the system is quite simple. Figure 2 is a block diagram of the complete detector system. The 20kc-100kc switch on the mixer is set to the desired frequency, and the corresponding frequency is switched-in on the Type 1232-A Null Detector. The local-oscillator output is set to produce the required mixer meter indication and the oscillator is then tuned to frequency by adjustment for maximum output indication in the Type 1232-A Tuned Amplifier and Null Detector when an external signal is introduced. For maximum sensitivity in the frequency range below 150 kc, the crystal current must be set to a particular value, as shown in Figure 3.

PERFORMANCE CHARACTERISTICS

The significant performance characteristics of the mixer are given in Figures 4 to 7. The linearity is shown as a function of input signal level in Fig-

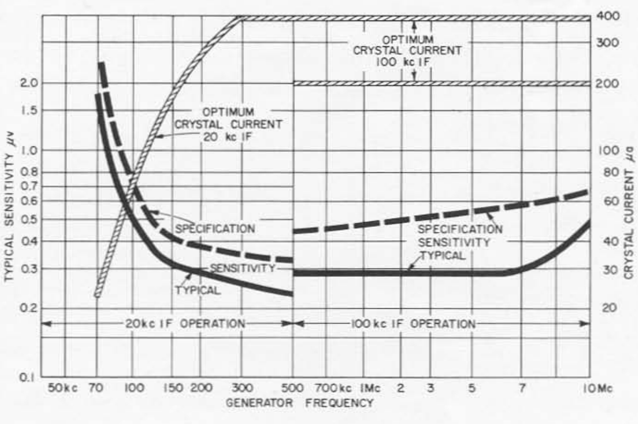


Figure 3. Sensitivity (open-circuit voltage from 50-ohm source, equivalent to noise level) and local-oscillator drive vs signal frequency.

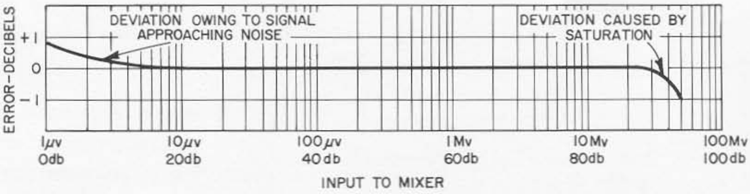


Figure 4. Linearity of the 1232-PL/1232-A detector as a function of input voltage.

ure 4; it can be seen that above about 50-mv input an increase in input voltage produces a smaller-than-proportionate increase in output indication. The sensitivity, defined as the input signal voltage required to increase the output indication 3 db above the noise level, is shown in Figure 3. Other data of interest are given in Figure 5, which shows the sensitivity as a function of local-oscillator drive level, and in Figure 6, which shows the relative conversion loss also as a function of local-oscillator drive level. The degradation of sensitivity below the normal tuning range is shown in Figure 7. The mixer is still usable in this range, but local-oscillator feedthrough produces a larger output indication.

APPLICATIONS

Null Detector

The combination of the TYPE 1232-P1 Mixer, the TYPE 1232-A Null Detector, and a local oscillator is an excellent bridge null detector for the frequency range from 70 kc to 10 Mc. Figure 8 is a block diagram of a complete bridge system using this detector, and a typical setup with the TYPE 916-AL Radio-Frequency Bridge is shown on the front cover.

Attenuation Measurements, etc.

This detector system is particularly well suited for the measurement of attenuation, especially high values of attenuation. For example, with a 100-mw source and reasonable padding (10 to 16 db at the detector) attenuation values as high as 120 db can be measured. A substitution method is employed wherein the attenuation to be measured is compared with a calibrated adjustable attenuator, such as the TYPE 874-GA. The TYPE 1232-A Tuned Amplifier and Null Detector is used as level indicator, since it does not have its own calibrated attenuator. For maximum resolution in these measurements it is essential that the detector circuits be operated within their linear range. Detector linearity for the 1232-P1/1232-A combination is shown in Figure 4, and applies for all diode-current levels above 200 μa. Figure 9 is a block diagram of the measuring setup.

Attenuation of 10 db or less can be measured with an accuracy of $\pm\frac{1}{20}$ of the db increment being measured by use of the db scale on the meter of the null detector. In this measurement, linearity at both the lowest and highest usable input-signal extremes, for the detector, are important. The usable input-signal

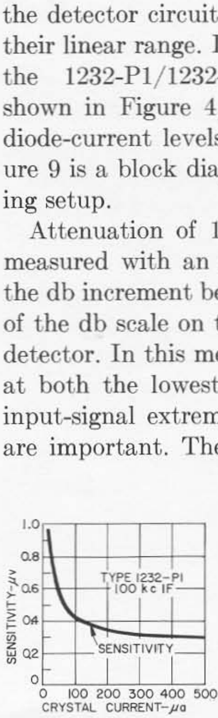


Figure 5. Sensitivity vs local-oscillator drive for 100-kc intermediate frequency.

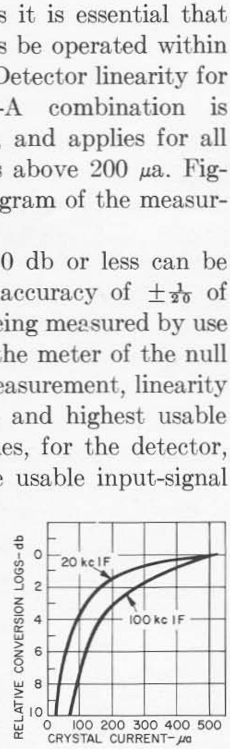


Figure 6. Relative conversion loss vs local-oscillator drive.

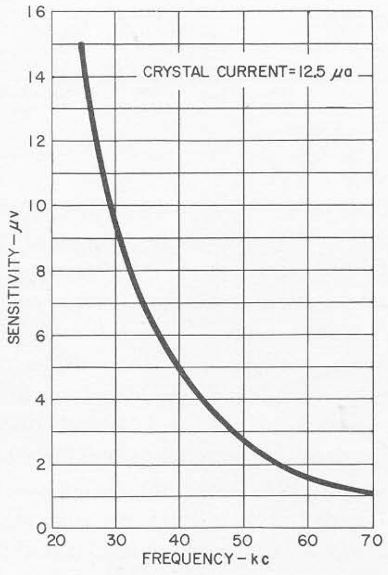


Figure 7. Typical sensitivity at frequencies below normal range.

range can be determined from Figure 4. The deviation from linearity at low levels arises from the relative contribution of the amplifier noise in the output indication, when the signal-to-noise ratio is small.

Specific attenuation measurements to which this procedure is applicable are:

Attenuator or network insertion loss
Filter stop-band response
Coaxial cable loss[1]
Coaxial switch cross-talk
Coaxial cable or connector leakage[2]

Coaxial Switch Crosstalk or Multiport Component Measurements

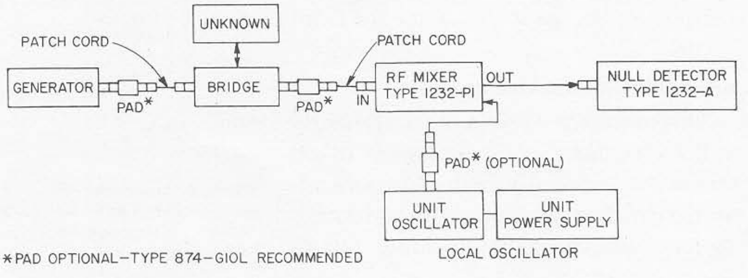
The same basic procedure can be used in the measurement of crosstalk between connections in multiport components, such as coaxial switches, semiconductor switches, and duplexers or multiplexers.

The component to be measured is, for example, driven at its input and the "through" channel (the output connection to which the input is intended to produce an output signal) is terminated in a matched termination, or other desired impedance, depending on the impedance with which the device is normally terminated. The other unused ports are similarly terminated. The detector is connected to the port in which crosstalk is to be measured, and the attenuation with this connection is measured by the substitution method. In the substitution method, a known amount of attenuation is inserted to produce the same output indication that was produced with the component installed.

Most systems operate at a nominal impedance of 50 ohms. The mixer input impedance is about 200 ohms. It can be made very nearly 50 ohms by the addition of an 874-G10 10-db attenuator at its input.

For operation at other than the 50-ohm level, transformers are required.

Figure 8. Block diagram of the detector system used as a bridge null detector.



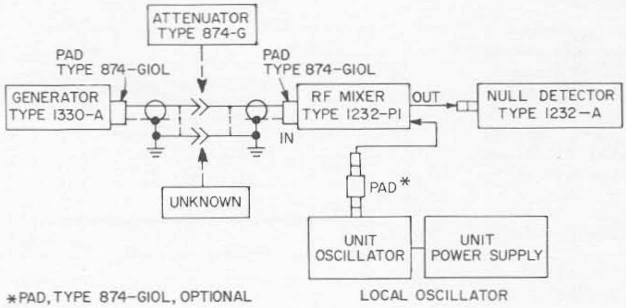


Figure 9. Block diagram of the 1232-P1/1232-A detector system as set up for the measurement of attenuation.

Cable Connector or Leakage Measurements

The leakage or shielding effectiveness of cables or connectors can also be measured by the same procedure as for attenuation measurements. A special test fixture is required in this case. Specific details of this fixture and the procedure are described in the reference cited.[2]

[1] W. R. Thurston, "The Measurement of Cable Characteristics," General Radio Reprint No. E-104.

[2] J. R. Zorzy & R. F. Muehlberger, "R-F Leakage Characteristics of Popular Coaxial Cables and Connectors, 500 Mc to 7.5 Gc," *Microwave Journal*, November, 1961, General Radio Reprint No. A-93.

SPECIFICATIONS

Frequency Range: 70 kc to 10 Mc. (Can be used up to 60 Mc, with care in the selection and identification of local-oscillator frequencies.)

I-F Output Frequencies: Switch-selected to 20 kc or 100 kc.

Bandwidth: 0.8 kc in 20-kc position, 10 kc in 100-kc position with a 20-kilohm output load (Type 1232-P1 RF Mixer alone).

Sensitivity: See Figure 3.

Input Impedance: Approximately 200 ohms.

Output Impedance: Approximately 20,000 ohms.

Dimensions: Diameter 2¼, length 6¾ inches (58 by 175 mm).

Net Weight: 1 pound (0.5 kg).

Shipping Weight: 2 pounds (1 kg).

Type		*Code Number*	*Price*
1232-P1	**RF Mixer**	1232-9601	**$105.00**

TYPE 1212-P3 RF MIXER

The 1212-P3 RF Mixer is essentially of the same construction as the 1232-P1, differing principally in the choice of i-f center frequency, 1 Mc. The circuit is shown in Figure 10. With the 1212-A Unit Null Detector, the lowest frequency of operation is 3 Mc. Below this, the local-oscillator signal feeds through directly into the Unit Null Detector, producing a meter indication in spite of the filter networks provided in the mixer unit. The highest frequency of operation,

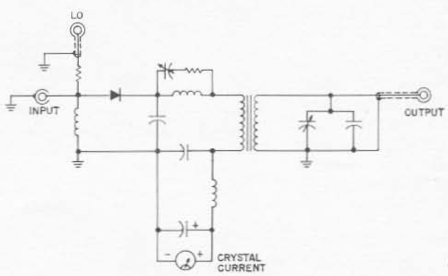


Figure 10. Schematic of the Type 1212-P3 RF Mixer.

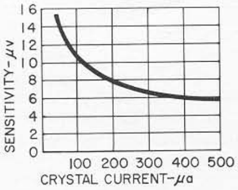


Figure 11. Sensitivity (open-circuit voltage from 50-ohm source, for 1% meter deflection) vs local-oscillator drive for the 1212-P3/1212-A detector system.

again limited by local-oscillator tuning resolution, tuning difficulty, etc., is 60 Mc. Aside from these considerations, the mixer performs perfectly well up to at least 150 Mc.

Null Detector

The response of the Unit Null Detector is approximately logarithmic, rather than linear. For this reason, it does not have a gain control. The system, is, therefore, usable only as a null detector, and, in this application, it is a sensitive, easy-to-use instrument. The principal characteristics of interest are the variation of sensitivity with diode current (Figure 11) and sensitivity over the frequency range (Figure 12).

Figure 13 is a block diagram of the detector shown as part of a complete rf bridge system. The local oscillator is always set higher than the generator frequency when the operating frequency is below 10 Mc, in order to minimize the local-oscillator voltage that gets through to the mixer output.

Use with a Broadcast Receiver

The Type 1212-P3 Mixer can also be used with a standard broadcast receiver in place of the Unit Null Detector. Here, the generator can be modulated in order to obtain an aural null indication. The sensitivity characteristics shown in Figure 13 apply to this application also with one exception: the 9-μv sensitivity value extends to a lower frequency limit, approximately 1.5 Mc. Therefore, with a broadcast receiver set at 1 Mc, a tunable detector from 0.54 Mc to 60 Mc is obtained (if we include the 0.54 to 1.5 Mc range of the receiver itself). There are, however, several precautions to be taken, such as the elimination of broadcast-station interference. These are described in detail in the mixer instruction book and include shielding of the broadcast receiver and care in selection of the gen-

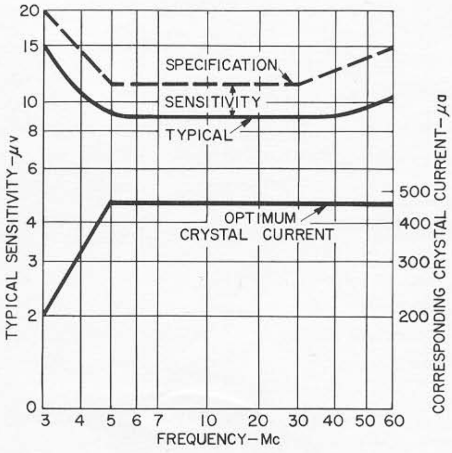
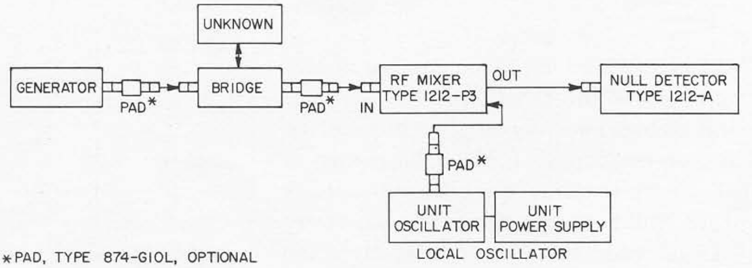


Figure 12. Sensitivity vs frequency.

Figure 13. Block diagram of 1212-P3/1212-A detector system, used as null detector with rf impedance bridge.



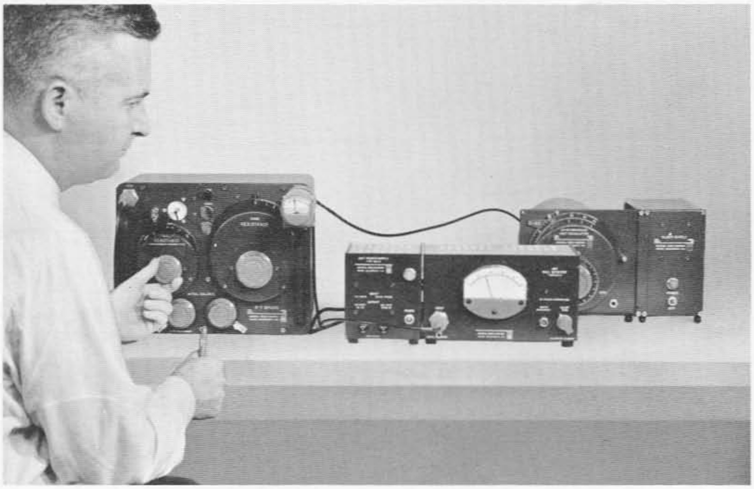


Figure 14. Photograph of system shown in Figure 14. Bridge is the Type 1606-A RF Bridge.

erator frequency to avoid tuning to harmonics of the receiver local oscillator. A transistor portable makes a good receiver for this application, because its small size permits it to be easily surrounded by a complete shield.

The combination of the detector and the TYPE 1606-A Radio-Frequency Bridge is shown in Figure 14.

— J. ZORZY

SPECIFICATIONS

Frequency Range: 3 Mc to 60 Mc. (Can be used up to 150 Mc if care is taken in the selection and identification of local-oscillator frequency.)
I-F Output Frequency: 1 Mc.
Bandwidth: 25 kc with TYPE 1212-A Unit Null Detector.
Sensitivity: See Figure 12.
Input Impedance: Approximately 200 ohms.

Output Impedance: Approximately 50 kilohms.

Terminals: TYPE 874 Coaxial Connector at end of cable.

Dimensions: Diameter 2¼, length 6¾ inches (58 by 175 mm).

Net Weight: 1 pound (0.5 kg).

Shipping Weight: 2 pounds (1 kg).

Type		*Code Number*	*Price*
1212-P3	**RF Mixer**	1212-9603	**$105.00**

ERRATA

TYPE 900 PRECISION COAXIAL ELEMENTS

In the maze of type numbers, tolerances, and tabulations describing this equipment in our November issue, a couple of errors crept in, unnoticed until too late. Since these relate to important specifications, we hasten to correct them.

Page 8, first paragraph:

Tolerance on characteristic impedance is $\pm 0.065\%$.

Page 10 — Precision Rod and Tubing:

Characteristic impedance is 50 ± 0.0325 ohms (0.065%).

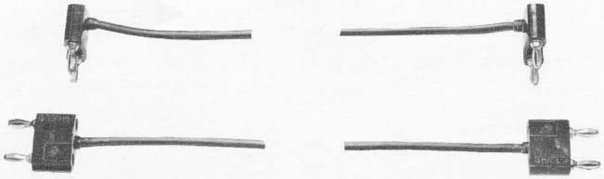


Figure 1. New double-plug patch cords with straight-through and right-angle connections. Each type is available in 1-, 2-, or 3-foot lengths.

Figure 3. New single-plug patch cord, available in red or black and in 9-, 18-, or 36-inch length.

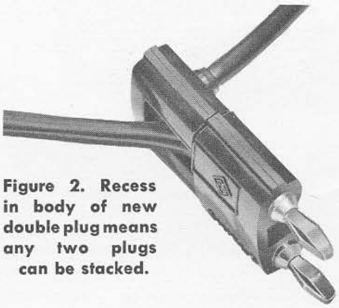


Figure 2. Recess in body of new double plug means any two plugs can be stacked.

Figure 4. Alligator clip slips over single plug to convert plug lead to clip lead.

A NEW PLUG FOR PATCH CORDS

Although known primarily as an instrument manufacturer, General Radio has developed many components and parts that achieved industry-wide popularity. Notable among these was the "banana" plug, introduced in this country by GR in 1924 and manufactured ever since by us as the TYPE 274 Plug. The present crop of banana plugs includes single, double, insulated, and shielded varieties. Two patch cords, each consisting of TYPE 274 double plugs molded on both ends of a shielded cable, have also been available.

A new lineup of 12 TYPE 274 Patch Cords offers (1) a new, improved double plug, (2) a choice of straight-through or right-angle connection to the plug, (3) a wider choice of lead lengths, and (4) new single-plug patch cords.

The new double plug consists of two banana plugs, one gold-plated and one nickel-plated, whose soldered ends are encapsulated first in polystyrene (for its electrical qualities) and then in cellulose-acetate butyrate (for its high-impact properties). At the other end of the connector body are two banana-plug jacks, and the configuration of the connector is such that any double plug can be connected to any other, regardless of whether the plugs have straight-through or right-angle connections (see Figure 2).

The gold and nickel color coding of the banana plugs is in accordance with electrical wiring conventions (the nickel is the shield, or ground connector). In addition, the word SHIELD is clearly marked next to the shield terminal.

Double-plug patch cords are now available in 1-, 2-, and 3-foot lengths, with either straight-through or right-angle connections. Leads are made of low-capacitance, flexible coaxial cable.

The single-banana-plug patch cord is shown in Figure 3. It is available in either red or black and in three lengths: 9, 18, and 36 inches. The connector body is molded cellulose-acetate butyrate and includes a jack for stacking. The banana plug's versatility allows quick conversion of the patch cord to an alligator clip lead by the addition of a TYPE 838-B Alligator Clip, as shown in Figure 4.

All TYPE 274 Plugs and Jacks have a contact resistance in the order of 1 milliohm. Plugs seat firmly in jacks so that the plug springs are not depended on for mechanical stability.

Patch cords with shielded plugs are also available, as listed below.

Type	*Description*	*Part No.*	*Price*
274-LLB	**Single-Plug Patch Cord,** 36-inch, black	0274-9468	**$1.25**
274-LLR	**Single-Plug Patch Cord,** 36-inch, red	0274-9492	**1.25**
274-LMB	**Single-Plug Patch Cord,** 18-inch, black	0274-9847	**1.25**
274-LMR	**Single-Plug Patch Cord,** 18-inch, red	0274-9848	**1.25**
274-LSB	**Single-Plug Patch Cord,** 9-inch, black	0274-9849	**1.25**
274-LSR	**Single-Plug Patch Cord,** 9-inch, red	0274-9850	**1.25**
274-NP	**Double-Plug Patch Cord,** 3-foot, side connection	0274-9880	**3.50**
274-NPM	**Double-Plug Patch Cord,** 2-foot, side connection	0274-9892	**3.50**
274-NPS	**Double-Plug Patch Cord,** 1-foot, side connection	0274-9852	**3.50**
274-NQ	**Double-Plug Patch Cord,** 3-foot, end connection	0274-9860	**3.50**
274-NQM	**Double-Plug Patch Cord,** 2-foot, end connection	0274-9896	**3.50**
274-NQS	**Double-Plug Patch Cord,** 1-foot, end connection	0274-9861	**3.50**
274-NL	**Shielded Double-Plug Patch Cord,** 3-foot	0274-9883	**4.50**
274-NLM	**Shielded Double-Plug Patch Cord,** 2-foot	0274-9882	**4.50**
274-NLS	**Shielded Double-Plug Patch Cord,** 1-foot	0274-9862	**4.50**

HANDBOOKS TO HELP YOU

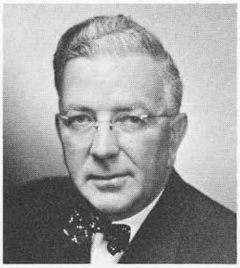
The *Handbook of Noise Measurement* first appeared in 1953 and met with wide acclaim from expert and tyro alike. It brought together in one convenient booklet a wealth of definitions, data, and procedures for the measurement of noise in industry. This handbook has been rewritten and revised with each successive edition, to keep pace with changing standards and new devices. The new fifth edition is a complete and authoritative treatise, full of useful information for those who need to measure acoustical noise — whether product noise, environmental noise, or the transient noise of passing vehicles.

The *Handbook of Noise Measurement* is priced at one dollar ($1.00), postpaid, which is substantially less than it costs us to print and mail it. Size, 6 x 9 inches, 256 pages, an outstanding bargain!

A new handbook has just appeared on the scene, the *Handbook of High-Speed Photography*. This is a compendium of principles and methods of the photographing of objects moving at high speeds. The light sources considered are General Radio stroboscopes, which produce light flashes of one microsecond or less. Objects moving faster than the speed of sound can be recorded on film by these light sources. This 56-page booklet is full of detailed procedures, useful to both professional and amateur. Size, 6 x 9 inches, 56 pages. Free upon request.

The Handbook of Voltage Control, published earlier this year, is designed to help you get the most from your Variac® adjustable autotransformer. Theory, circuits, and applications are covered. Size, 8½ x 11 inches, 40 pages. Free upon request.

CHARLES C. CAREY



Charles C. Carey, late President of this company, came to General Radio in 1927. In 1931 he was made Assistant to the Vice-President for Production; in 1934, Production Superintendent; in 1944, Vice-President for Production; in 1950, a Director of the Company; and in 1956, President.

An alumnus of Boston University and Northeastern University, he was a director of the National Shawmut Bank and a trustee of Northeastern University.

His talents were many, and his interests ranged over many fields. Most important at employee-owned General Radio was Mr. Carey's constant interest in all employees, their successes, and their problems.

Among his many contributions to our Company were his planning and execution of our several expansion programs during and since World War II, including the transfer of all operations from Cambridge to the present site in Concord and our current expansion into a new plant in Bolton, Mass.

On October 17, Charles Carey died at the age of 58. We who were enriched by his 36-year career with GR are saddened by his death.

DONALD B. SINCLAIR

General Radio's new President, elected by the Directors on October 18, is Donald B. Sinclair.

Dr. Sinclair was born in Winnipeg, Manitoba, in 1910, attended the University of Manitoba from 1926 to 1929, then transferred to the Massachusetts Institute of Technology, where he received degrees of SB in 1931, SM in 1932, and ScD in 1935. He joined General Radio in 1936 and subsequently became Chief Engineer. In 1955 he was appointed Vice-President for Engineering and in 1956 was elected a Director. For the past two years he has held the post of Executive Vice-President and Technical Director.

During World War II Dr. Sinclair was in charge of the search receiver work for radar countermeasures at the Radio Research Laboratory at Harvard University, and he was a member of Division Five of the National Defense Research Committee on Guided Missiles. For his work on countermeasures and guided missiles, he received the President's Certificate of Merit in 1948. From 1954 to 1958 he was a member of the Technical Advisory Panel on Electronics of the Department of Defense.

Dr. Sinclair is a Fellow of the IEEE, and was President of the IRE in 1952, following a term as Treasurer in 1949–50. He served on the Executive Committee of the IRE in 1948–1950 and again in 1952–1953, and was on the Board of Directors from 1945 to 1954 and in 1958. He is also a member of Sigma Xi, Eta Kappa Nu, the American Association for the Advancement of Science, the American Physical Society, and the Instrument Society of America.

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