THE GENERAL RADIO

Experimenter

THE RECIPROMATIC COUNTER

Also In This Issue

New Digital Impedance Comparator

New RF Oscillators and Power Supplies

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CONTENTS

ABOUT THIS ISSUE

The theme of this month's *Experimenter,* if we were given to thematizing, might be "The Resolution Revolution." The lead article describes a counter that can give six significant digits of readout for a frequency as low as 0.6 Hz. At that point the right-hand digit is actually displaying *microhertz,* a unit probably making its debut in print here. Moreover, this counter can make such ultra-low-frequency measurements in a second or less, thanks to a built-in computer that translates a multiple-period measurement into a frequency readout. . . . Then consider the resolution of the new digital impedance comparator (page 10). Here the percent magnitude difference between two impedances is spread over five digits, with five more digits indicating phase difference. Since the full-scale range can be as little as 10 percent, the comparator detects as little as 10 ppm difference between unknown and standard C, R, or L. . . . Tolerances on inner and outer conductors of our GR900® reference air lines (page 26) are 100 and 50 microinches, respectively, electrical lengths are controlled to ±0.002 cm, and both conductors are overlaid with pure silver. The same attention to detail has produced a precision attenuator that represents a fivefold improvement in SWR over previously available units.

The *General Radio Experimenter* is mailed each month without charge to engineers, scientists, technicians, educators, and others interested in the instruments and techniques of electrical and electronics measurements. Address all correspondence to Editor, *General Radio Experimenter,* General Radio Co., West Concord, Mass. 01781.

THE RECIPROMATIC COUNTER

Automatic ranging, fast measurement of low frequencies, full use of six-digit resolution, and no-hands operation make the 1159 a most extraordinary counter.

Added convenience and speed are the key ideas behind much of today's efforts in instrument design. In the area of frequency measurement, the digital frequency counter has eliminated many of the tedious steps associated with older methods. Still, several nagging problems have persisted, especially in the area of low-frequency measurement.

One way of making a precise low-frequency measurement is to count the number of cycles of the unknown frequency until the desired resolution is achieved. But this takes time — too much time in most cases. For example, a six-digit measurement of 60 Hz would take over 2½ hours by this method.

A much faster way of getting high resolution is to measure period rather than frequency — that is, to count not the cycles of the unknown signal but the higher-frequency pulses from the counter's time base, using the unknown signal to start and to stop the count. If the counter time base is a 10-MHz oscillator, there is no problem in producing a six-digit readout in a very short time (for our 60-Hz measurement, about 0.1 second).

A period readout, however, is the reciprocal of the frequency data usually desired and often required by specifications. The operator can, of course, call on a calculator to perform the simple conversion from period to frequency, but this is a time-consuming and potentially error-producing approach.

A better solution is to build a special-purpose computer into the counter, so that a period measurement is displayed in terms of frequency. Our approach to the design problem of adding a computer has led to an exceptional instrument with automatic ranging as well as reciprocal computation.

THE RECIPROMATIC COUNTER

The foregoing is by way of introducing GR's new Recipromatic Counter, which has a frequency range of from 0.6 Hz to 20 MHz, six-digit resolution, and an average measurement time of 100 milliseconds above 6 Hz, 1 second down to 0.6 Hz. All six digits are always used; a measurement at the counter's low-frequency limit is actually presented with *microhertz* resolution.

Automatic ranging is one of the major features of the new counter. As we have seen above, this implies automatic selection of the number of periods to be measured. Many of the earlier, nonautomatic counters with

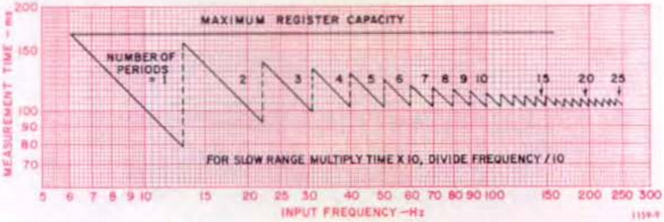

Figure 1. Measurement time as a function of frequency.

which we are familiar have decade period ranges (1, 10, 100 . . . periods). Automatic systems for selecting the decade range are conceivable, but further reflection convinces us that this is the wrong approach. Suppose we program a counter to make a 1-period measurement from 10 to 100 Hz, a 10-period measurement from 100 to 1000 Hz, a 100-period measurement from 1000 Hz to 1 kHz, etc. The measurement time for such a system will vary from 100 ms at the low-frequency end of each range to 10 ms at the high-frequency end. Since the resolution in a multiple-period measurement is proportional to measurement time, a system designed for a specified resolution at the high end of a decade range will require 10 times the measurement time and an extra decade in the counting register for the low end, without gaining any usable increase in resolution. Decade ranges are necessary in standard, general-purpose counters because their only built-in computation facility is that of shifting the decimal point. If, however, we provide an instrument with computational ability sufficient to calculate frequency from period data, then any convenient number of periods can be measured, and it is necessary only to count this number* and to use it as one input to the computation. The quotient of periods/measurement time equals the frequency.

With the foregoing approach our instrument can be programmed for an approximately constant measurement time. The 1159 was designed to give a full six-digit resolution and to use a 10-MHz clock. To obtain this resolution, a measurement time of about 100 ms is required. The lowest frequency that can be measured is that whose period is equal to the maximum capacity of the counting register that counts clock cycles. We must make a single-period measurement from this frequency up to twice this lowest frequency, where we may then change to a two-period measurement. Measurement time will decrease from the maximum value to about half as much at the changeover point. At three times the lowest frequency, where the two-period measurement time has decreased to two-thirds of maximum, we may switch to a three-period measurement and so on, with the lower limit of measurement time increasing with each step. This program makes maximum use of register capacity to give the best possible resolution, but it is rather complicated because of the large number of steps.

The simplest system would be to allow the measurement to be terminated by the first signal pulse occurring after some predetermined measurement time

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*Patent applied for.

hat is slightly less than half of register capacity. This system makes inefficient use of register capacity, however, since it will be only about half full for most frequencies. A compromise system is to make the lower limit for measurement time a function of the number of periods counted for the first few periods and equal to the nominal time for higher numbers of periods. The 1159 was designed with a register capacity of 167 ms, which corresponds to a frequency of 5.99 Hz. The lower limits of measurement time are programmed as follows, with the results illustrated in Figure 1:

Number of Periods	*Minimum Measurement Time*
1	78.6 ms
2	91.8 ms
3	98.3 ms
4 and higher	101.6 ms

It should be borne in mind that the steps referred to in the above program do not represent range changes in the usual sense; that is, there is no interruption of the measurement, but only a decision as to when to terminate. The range (i.e., decimal-point position and measured units) is determined entirely in the subsequent computation.

In order to measure lower frequencies, the measurement time must be increased. This is accomplished by the lowering of the clock frequency. In the 1159, when the frequency drops below 5.99 Hz, the clock frequency is automatically lowered to 1 MHz, permitting measurements down to 0.599 Hz. When the input frequency rises to about 7.88 Hz, the 1159 automatically switches back to the 10-MHz clock. A three-position toggle switch on the control panel permits operator override of this automatic clock-frequency selection in favor of either the 1-MHz or 10-MHz clock.

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Computation in a small instrument initially seemed prohibitively complicated. Although the availability of integrated circuits helped to bring this approach nearer to economic practicality, the key idea was the use of dual-purpose registers, which function in both the measurement and computation parts of the program. Our first efforts along these lines involved schemes to employ standard counting registers in the computation. Several such methods exist, but they are comparatively slow and, in some cases, less accurate than desired. The 1159 employs two registers that can function either as counting registers or as shift registers by application of proper programming signals. These two registers count signal pulses and clock pulses during the measurement; during computation they become, respectively, the dividend and divisor registers in a fairly standard serial computer.

The method of computation is to subtract the divisor from the dividend and to test for a positive remainder. If the remainder is positive, a pulse is applied to the first decade of the quotient register and another subtraction is performed. When the remainder is negative, the divisor is added to restore a positive remainder, completing the calculation of the first digit. The remainder is then multiplied by ten and the process repeated to calculate the second digit. Usually the dividend is initially smaller than the divisor (except where the signal frequency exceeds the clock frequency), so that the first digit is usually zero. The quotient register is designed to ignore such non-significant zeros, however, and will wait until a non-zero digit is recorded in the first decade before transferring its input to the second decade. The steps required to perform this normalization are counted to determine decimal-point position and units. Computation is continued until seven digits have been computed, the last of which is not displayed but is used to generate a round-off in the quotient register. The time required for computation depends upon the frequency, varying from about 150 μs for 10.0000+MHz to about 675 μs for 9.99999 Hz. Because of this short computation time, the result is displayed directly from the quotient register without the need for buffer storage.

While the program of the Type 1159 ensures a constant six-digit resolution, accuracy depends upon the accuracy of the internal crystal oscillator and upon noise. With a resolution of 1×10^{-6} the accuracy requirements of the crystal oscillator are not severe in the light of presently available components. The crystal oscillator for the Type 1159 was nevertheless designed for good lon term aging characteristics in order to make the time between recalibrations as long as possible. In addition, facility is included for phase-locking the internal oscillator to an external 100-kHz or 1-MHz reference standard.

The input circuit is of vital importance to the performance of any period-measuring device. As discussed in a previous article,[1] the accuracy of a period measurement is controlled by the over-all signal-to-noise ratio of the source and the input circuit. The noise of the input circuit is of two kinds: random noise generated by the semiconductors in the circuit, and spurious signals harmonically related to the clock and computational frequencies. In order to obtain the lowest noise level in the 1159, the input circuit has a linear input amplifier followed by a Schmitt trigger of comparatively large hysteresis. The effect of any noise in the Schmitt trigger is thereby reduced by the gain of the amplifier so that performance depends primarily upon the noise level of the amplifier. Random noise is reduced by the circuit design of the amplifier, while the spurious frequencies are reduced by careful shielding and decoupling.

The noise level specified for the Type 1159 is 50 μV. The error in measurement caused by additive noise is given by the formula $E = \dfrac{1}{n\pi\ S/N}$ where S/N is the over-all signal-to-noise ratio and n is the number of periods measured. For single-period measurements, this implies that the root-mean-squared error due to internal noise is reduced to 1×10^{-6} for a signal of 16 volts rms

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[1] R. W. Frank, "Input Noise," *General Radio Experimenter*, February 1966.

sine wave), for two periods for a signal f 8 volts, and so on. At 1600 periods the signal level needed to make internal noise negligible would be 10 mV rms, which is the specified instrument sensitivity. The formula no longer holds at this point because triggering no longer occurs at the axis crossing. For signal levels of 20 mV, however, internal noise will not affect accuracy at frequencies over 8 kHz for the fast range or 800 Hz for the slow range. From the same formula we may infer that noise effects from the signal source will be negligible for $S/N > 110$ dB — 20 log n. At 1600 periods this requires $S/N > 46$ dB.

In the design of the input circuit, consideration must be given to the types of signal that will be measured. Probably the most common type of signal in frequency measurement is a noisy sine wave with a small amount of distortion. In order to minimize the effects of noise with this type of signal, triggering should take place at the steepest part of the waveform, which is the axis crossing. For this reason the 1159 was made ac-coupled. In order to preserve this relationship under large signal conditions, the signal is clipped symmetrically before each stage of the amplifier.

The 1159 input amplifier also has a programmable bandwidth, which may be changed in decade steps from 10 MHz down to 1 kHz by a rotary switch on the control panel. By reducing the bandwidth to the minimum required by the signal, one may often obtain a significant improvement in signal-to-noise ratio.

For non-sine-wave signals, two additional controls help the user to obtain best results from the 1159. First, a slope switch permits selection of either axis-crossing polarity for triggering. This allows the operator to choose the steeper side of a nonsymmetrical waveform or the side with less noise and jitter (for example, the triggered edge of a one-shot). Second, a trigger-level control helps to ensure triggering on low-level pulses with very low duty ratio.

Although the elimination of range selection removes most of the programmability requirements, all the remaining functions mentioned in the preceding paragraphs are programmable. Programming inputs require DTL micrologic input levels except for the display time (variable resistance) and trigger-level (variable voltage) inputs. Programming connections are made through a multiterminal connector on the rear panel of the counter.

BCD data output is available at a multi-terminal connector on the rear panel. The six digits of readout together with range information are supplied in 1-2-4-8 BCD format at DTL logic levels, together with control signals for operating the 1137 Printer, the 1136 Digital-to-Analog Converter and similar devices.

By the use of a prescaler such as the TYPE 1156 Decade Scaler or TYPE 1157 100:1 Scaler, the range of the TYPE 1159 can be extended to 100 MHz or 500 MHz with the same six-digit resolution and automatic ranging features. Because of its period-type measurement, the TYPE 1159 does not lose a factor of ten in resolution as is the case with conventional frequency counters. A three-position switch on the rear panel of the instrument permits multiplying the readout by a factor of 10 or 100 to give direct readout when a prescaler is used. This last function, like all the other controls, is programmable.

APPLICATIONS

The 1159 has applications in all areas where general-purpose counters are used to measure frequency. Automatic range switching and constant six-digit resolution make it superior to conventional counters for many high frequency measurements. Specific areas of application include frequency measurements on crystal oscillators, voltage-to-frequency converters, and communication receivers and transmitters. The TYPE 1159 is outstandingly superior to conventional counters in the area of low-frequency measurements, because of the short measurement time needed to produce high resolution. This characteristic is especially useful in measurements on transducers (such as flow meters and radiosondes) and on rotating devices such as gyros and motors, as well as in acoustics, sonar, and vibration measurements.

Complete programmability and data output make the 1159 a natural component of fully automatic test setups for signal-source monitoring, filter and component inspection, etc.

The 1159 is very useful in the routine calibration and setting of oscillators, signal generators, and other signal sources, since it allows the operator to calibrate each point on a dial without having to select the range on the counter. Calibrations are possible over the entire wide frequency range of the 1159 without resort to period measurement at low frequencies. The standard measurement rate of the 1159 of 10 measurements per second is fast enough to allow the operator to tune the oscillator continuously with the counter continuously following his actions.

Many low-frequency oscillators, such as the GR TYPE 1310-A, are stable enough to be set to ±0.001% wit the aid of an 1159, even though t settability and accuracy of the oscillator dial calibration allow only ±2%. More stable signal generators, like the GR TYPE 1003 Standard-Signal Generator, can be set to ±0.0002% with the help of the 1159 and the fine-tuning adjustment of the generator. Using the generator dial alone, one can achieve only ±0.1%. For signal sources from 20 to 500 MHz, the 100:1 TYPE 1157 Scaler or the 10:1 TYPE 1156 Decade Scaler can be used ahead of the 1159. The resolution remains a full six digits, and the decimal point as well as the units display remains correct.

When used in combination with a stable signal source, the 1159 lends itself to filter testing. For low-frequency filters, the 1159 gives fast six-digit resolution without requiring that test specifications be written and measurements made in terms of period.

The high sensitivity of the 1159 (10 mV rms over most of its frequency range), coupled with symmetrical limiting of the input signal, helps the 1159 to read the signal frequency even in the presence of large amplitude modulation. The 1159 will read correctly as long as the amplitude of the carrier wave at the negative modulation peak exceeds the maximum sensitivity of the counter. For the TYPE 1003 Standard-Signal Generator, the reading of the 1159 remains correct with amplitude modulations up to more than 90% when the counter is connected to the counter output of the generator.

Other useful input-circuit characteristics of the 1159 are high input resistance and low input capacitance, 1 MΩ in parallel with 27 pF (20 pF when the rear-panel input terminal is disconnected). These make it possible to use an 1158-9600 Input Probe, giving a total input impedance of 10 MΩ shunted by 7 pF and a maximum sensitivity of 100 mV (200 mV at 20 MHz) or better. The counter can then be connected to oscillators and circuits without loading them any more than a good oscilloscope would.

The 1159 will be very useful in production-line work. Its automatic range switching capability and excellent low-frequency performance permit an unskilled worker to obtain a six-digit reading of any frequency between 0.6 Hz and 20 MHz without need for manipulation of controls. The few controls connected with the input circuit and display time are covered by a hinged door in order to prevent misadjustment by curious production help. The use of these controls is unnecessary under normal use of the 1159.

— N. L. Westlake
S. Bentzen

SPECIFICATIONS

Frequency-Measurement Range: 0.6 Hz to 20 MHz. In the fast mode, 6 Hz to 20 MHz; in the slow mode, 0.6 Hz to 9.99999 MHz. Extend range to 100 or 500 MHz without loss of accuracy with GR 1156 (10:1) or 1157 (100:1) Scaler.

Frequency-Measurement Accuracy: $\pm 1 \times 10^{-6}$ ± clock accuracy ± noise (see note).

Measurement Rate: Sum of adjustable display time, 0.02 to 10 s and ∞, and measurement time of about 100 ms in fast mode or 1 s in slow mode.

INPUT

Sensitivity: 20 mV rms at 20 MHz; 10 mV rms from 1 Hz to 10 MHz.

Bandwidth: Ac-coupled input, −3 dB at approx 1 Hz. Bandwidth switch sets −3 dB points at approx 10 or 1 MHz, 100, 10, or 1 kHz.

Impedance: 1 MΩ//27 pF for up to 5-V pk-pk input; 0.67 MΩ//30 pF for up to 200 V pk-pk. Input capacitance can be reduced by disconnecting either unused front- or rear-panel input connector. Front only, 20 pF; rear only, 17 pF.

Trigger Threshold: ±20 mV, adjustable.

Slope: Positive- or negative-going, switch-selected.

CLOCK

Internal: 10-MHz, third-overtone quartz-crystal oscillator in proportional-controlled oven.

Temperature Effects: $<1 \times 10^{-6}$ from 0 to 50°C ambient.

Warmup: Within 1×10^{-8} in 10 minutes at 25°C ambient.

Stability: Better than 3×10^{-9} per day after 1 month of operation; better than 1×10^{-6} per year.

External Control: Internal clock oscillator can be phase-locked to external 100-kHz or 1-MHz signal of at least 1 V rms.

GENERAL

Programmability: All control functions can be programmed by contact closures to ground (2- to 4-mA sink current required) except display time, which requires an external resistance of 0 to 100 kΩ, and trigger level, which requires 0 to ±5 V dc.

Note — Noise affects precision of frequency measurement. For additive noise on signal measured, the error in measurement will be $\epsilon = \frac{N}{\pi S n}$ where N is the noise level and S the signal level in the same units; n is the number of periods averaged. Internally produced noise in the counter will determine the limiting error level. For the 1159, this internal noise is approx 50 μV rms.

Data Output: 1-2-4-8 BCD-DTL output for 6 digits of data, decimal point, and measurement units. Data zero is 0.5 V max (12-mA current sinking capability); data one is approx 5 V behind 6 kΩ.

Display: Six neon readout tubes, automatically positioned decimal point, and measurement units. Dimensions can be multiplied by 1, 10, or 100 with rear-panel switch for use with 10:1 or 100:1 prescaler.

Power Required: 100 to 125 or 200 to 250 V, 50 to 400 Hz, 60 W.

Accessories Supplied: Power cord, spare fuses, mounting hardware with rack models.

Accessories Available: GR 1156 (10:1) and 1157 (100:1) Scalers, 1137 Data Printer, 1136 Digital-to-Analog Converter, 1158-9600 input probe (available only with counter).

Mounting: Rack-bench cabinet.

Dimensions (width x height x depth): Bench, 19½ x 4⅞ x 15 in. (495 x 125 x 385 mm); rack, 19 x 3½ x 13⅛ in. (485 x 89 x 335 mm).

Net Weight: Bench, 26 lb (12 kg); rack, 19 lb (9 kg).

Shipping Weight: Bench, 35 lb (16 kg); rack, 28 lb (13 kg).

Catalog Number	*Description*	*Price in USA*
	1159 Reciprocmatic Counter	
1159-9700	Bench Model	$2235.00
1159-9701	Rack Model	2235.00
1158-9600	P6006 Probe, Tektronix Catalog No. 010-0127-00 (not sold separately)	22.00

Figure 1. Type 1681 Automatic Impedance Comparator System.

THE AUTOMATIC IMPEDANCE COMPARATOR

The high-performance specifications of today's electronic equipment require increasing use of precision components and force manufacturers and users of components to check large quantities of resistors, capacitors and inductors to close tolerances. The 1680 Automatic Capacitance Bridge,[1] introduced in 1964, represented a major assault on the problems of high-volume measurements. This bridge can make two capacitance measurements a second and presents data in machine-readable as well as visual form. The success of this system was immediate, and the 1680 and associated equipment can now be found in production, quality-control, and inspection installations throughout the world.

The new 1681 Automatic Impedance Comparator System (Figure 1) is similar in appearance to the 1680, and it boasts most of the 1680's advantages, plus a few important ones of its own. Like the 1680, it can make measurements at high speed (60 to 100 per minute), and it presents data in both in-line digital readout and in binary coded decimal form for use with tape punches, card punches, computers, and other recording and handling equipment. The chief differences are (1) that the capacitance bridge is designed primarily for capacitors, while the comparator is equally at home with resistors, inductors, and capacitors, (2) the comparator measures, not absolute value, but percent difference between the unknown component and a standard, and (3) the comparator, spreading a 10- or 100-percent magnitude difference over five digits, is capable of much greater accuracy than is the 1680.

A convenient, if oversimplified, way of describing the new impedance comparator is to consider it as a digital version of GR's long-popular 1605-A analog impedance comparator.[2] Both the 1681 and the 1605-A express differences in impedance magnitude and in phase angle. The great advantages of

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

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

e 1681 over its older relation are the igh resolution of the digital readout and its compatibility with the automatic component-handling and data-handling equipment so vital in today's technology.

OPERATING FEATURES

The 1681 is a fully automatic comparison bridge providing direct reading in both magnitude and phase-angle difference over a wide range of impedance. The high speed and self-balancing capability of this comparator are obtained without sacrifice of accuracy or impedance range. Basic comparison accuracy is 50 ppm, and impedance range is 2 ohms to 20 megohms. The comparator can detect impedance difference and phase-angle difference to 10 ppm.

The measurement decisions are made by a 1672-A Digital Control Unit, whose circuitry has been described in an earlier article.[3] The operating modes of the digital control unit serve to illustrate the versatility of this instrument.

1. The HOLD RANGE provides speed and maximum resolution of impedance values for components that vary widely in value from the standard. In this mode the bridge balance sequence starts at the most-significant digit.

2. The TRACK CONTINUOUS mode provides continuous tracking of the unknown from the standard. Balance starts from the previous measured value in the least-significant digit. This mode is useful for temperature-coefficient measurements, where small changes in the value of the unknown are being measured.

3. The TRACK SAMPLED mode is used for measurements of components where the difference between the unknown and the standard is small. This is similar to the TRACK CONTINUOUS mode except that balance is achieved here only on command of the operator.

4. The REMOTE position disconnects the front-panel balance control and allows the operating mode to be selected externally by contact closures.

HOW IT WORKS

Figure 2 is a block diagram of the 1681 Automatic Impedance Comparator System. Basically, the 1681 is a transformer ratio-arm comparison bridge with the unknown and standard

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[3] Fulks, op. cit.

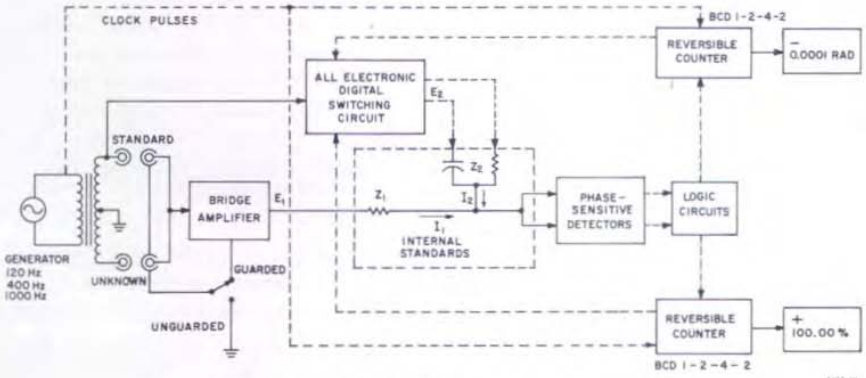

Figure 2. Block diagram of the impedance comparator.

impedances serving as the remaining two bridge arms. The output of the comparison bridge is an unbalance voltage, which is measured by a second bridge, using conventional bridge-balancing techniques as described below.

When the unknown and the standard are unequal, an unbalance voltage results whose phase and magnitude relative to the test voltage are a measure of the impedance difference. The unbalance voltage is fed into a high-input-resistance, low-input-capacitance amplifier so that no loading will occur at the output terminals of the comparison bridge when high-impedance components are measured.

The amplifier's high input impedance is achieved through use of a field-effect transistor in a source-follower configuration. Input capacitance is reduced to a minimum through a guarding technique. Altogether this provides an input impedance of about 1000 megohms and an input capacitance of less than 1 picofarad.

In the case of high-impedance measurement where shielded cable is used to prevent pickup, the cable capacitance to ground will cause phase shift and attenuation of the unbalance signal. The amplifier provides a low-impedance guard voltage, which can be used to drive the amplifier input shield at approximately the same potential as the input signal to eliminate the cable capacitance. The guard can effectively reduce cable capacitance by a factor of about 500.

The unbalance voltage (E_1) at the output of the amplifier is measured by another bridge circuit consisting of E_1, a variable voltage, E_2, and the internal standards, Z_1 and Z_2. If this bridge is unbalanced, the unbalance signal is amplified and fed to phase detectors which separate the error signal into real and imaginary components proportional to the phase-angle difference and the magnitude difference. These error voltages are fed to the digital logic circuitry, which controls electronic switches to change the reference voltage, E_2, until balance is achieved.

At balance, the counter displays the magnitude and phase-angle difference between the unknown and the standard (in the comparison bridge) on an in-line readout with positioned decimal point and appropriate measurement units.

MEASUREMENT MODES

Two measurement modes are provided, to ensure the highest accuracy under a variety of conditions. Figures 3 and 4 are simplified diagrams of the circuitry used in these two modes.

In the ΔR, ΔL, or ΔC mode, the bridge measures the impedance difference as a percent of the standard impedance. This mode provides the most accurate magnitude-difference measurements over a wide deviation range when the phase-angle difference between the standard and the unknown is very small.

In the ΔΘ mode, the bridge measures the impedance difference as a percent of the average of the standard and unknown. This mode is most useful for accurate phase-angle-difference and impedance-matching measurements.

ΔΘ Mode

The ΔΘ mode can be represented by the bridge circuit[4,5] in Figure 3. If the voltages, E, across the inductively cou-

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[4] M. C. Holtje, H. P. Hall, and I. G. Easton, "An Instrument for the Precise Comparison of Impedance and Dissipation Factor," *Proceedings of the National Electronics Conference*, Vol. 10, 1955.

[5] Holtje and Hall, op. cit.

led ratio arms are equal, the complex output voltage, E_o, is:

$$\frac{E_o}{E} = \frac{Z_x - Z_s}{Z_x + Z_s}.$$

The real part of this expression is:

$$R_e\left(\frac{E_o}{E}\right) = \frac{\dfrac{|Z_x| - |Z_s|}{|Z_x| + |Z_s|}}{1 + \dfrac{\cos(\Theta_x - \Theta_s) - 1}{1 + \dfrac{|Z_x|}{2|Z_s|} + \dfrac{|Z_s|}{2|Z_x|}}}.$$

If $(\Theta_x - \Theta_s)$ is small, say less than 0.1 radian, $\cos(\Theta_x - \Theta_s) \approx$ unity and this equation reduces to:

$$R_e\left(\frac{E_o}{E}\right) \approx \frac{|Z_x| - |Z_s|}{|Z_x| + |Z_s|}.$$

Another approximation is necessary to have the bridge measure the impedance difference as a percent of the standard. If $|Z_x| - |Z_s|$ is very small:

$$\frac{|Z_x| - |Z_s|}{|Z_x| + |Z_s|} \approx \frac{|Z_x| - |Z_s|}{2|Z_s|}.$$

In measurements of resistance, capacitance, and inductance, the in-phase component of the bridge output voltage is a measure of the percent difference of the relative components:

$$\left(\frac{R_x - R_s}{R_s} \times 100\%\right), \left(\frac{C_x - C_s}{C_s} \times 100\%\right),$$

$$\left(\frac{L_x - L_s}{L_s} \times 100\%\right).$$

This approximation is quite good for impedance differences less than 5% and is the basis for comparison-bridge operation. For larger impedance differences, the bridge output becomes quite nonlinear and correction is necessary. (The ΔR, ΔL, ΔC mode, designed into the 1681 comparator to overcome the necessity for correction due to this nonlinearity, is discussed below.) The imaginary part of the bridge output voltage in the ΔΘ mode is:

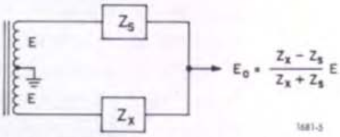

Figure 3. Basic bridge circuit in the ΔΘ mode.

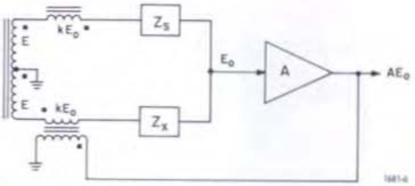

Figure 4. Basic bridge circuit in the ΔR, ΔL, or ΔC mode.

$$I_m\left(\frac{E_o}{E}\right) = \frac{\sin(\Theta_x - \Theta_s)}{\cos(\Theta_x - \Theta_s) + \dfrac{|Z_x|}{2|Z_s|} + \dfrac{|Z_s|}{2|Z_x|}}.$$

If Z_x and Z_s are unequal but the difference is small and $\Theta_x - \Theta_s$ is less than 0.1 radian, this expression reduces to:

$$I_m\left(\frac{E_o}{E}\right) = \frac{1}{2}(\Theta_x - \Theta_s).$$

If relatively pure elements are used (C, with D less than 0.1; R, with Q less than 0.1; L, with Q greater than 10), then $(\Theta_x - \Theta_s) \approx \Delta D$ of C and L, or ΔQ of R.

ΔR, ΔL, or ΔC Mode

The bridge circuit for the ΔR, ΔL, or ΔC mode is shown in Figure 4. The unbalance bridge voltage is:

$$\frac{E_o}{E + kE_o} = \frac{Z_x - Z_s}{Z_x + Z_s}.$$

If feedback from the output to the bridge is such that $k = 1$, then:

$$\frac{E_o}{E} = \frac{Z_x - Z_s}{2Z_s}.$$

This is what is desired.

Robert K. Leong received his BSEE and MSEE degrees from Northeastern University and joined General Radio in 1964. As a development engineer in the Low-Frequency Impedance Group, he specializes in the design of bridges and comparators. He is a member of Tau Beta Pi and Eta Kappa Nu.

The real part of the formula is:

$$R_e\left(\frac{E_o}{E}\right) = \frac{|Z_x|\cos(\Theta_x - \Theta_s) - |Z_s|}{2|Z_s|}.$$

For $(\Theta_x - \Theta_s)$ less than 0.01 radian:

$$R_e\left(\frac{E_o}{E}\right) \approx \frac{|Z_x| - |Z_s|}{2|Z_s|}.$$

This approximation is extremely good; it produces a maximum difference error of 0.005% for $(\Theta_x - \Theta_s) = 0.01$ radian.

The imaginary part of the bridge unbalance is approximately equal to:

$$I_m\left(\frac{E_o}{E}\right) \approx \frac{|Z_x|}{|Z_s|}\,(\Theta_x - \Theta_s),$$

if $(\Theta_x - \Theta_s) \leq 0.01$ radian.

Note that the phase-angle-difference error is directly proportional to the ratio of the unknown impedance over the standard impedance. This error is negligible in comparisons of pure elements (R, L, C) of approximately the same value.

In effect, conventional analog comparison bridges have provided an indication of the percentage difference between the standard impedance and the unknown impedance with respect to the *average* of the two impedances. Ideally, the reading should represent the difference between the unknown and the standard impedances, expressed as a percent of the *standard*. These two approaches produce different readings, but this difference is small when the unknown and standard impedances are close in value. For large differences between the unknown and the standard the readings become widely different, as indicated in Figure 5. For example, an accurate percent difference of 50% would read +40% on one side and −66.7% on the other.

Some analog comparators provide separate meter scales and individual measurement ranges to compensate for this nonlinearity. In the 1681, however, the new ΔR, ΔL, or ΔC mode provides the desired indication over the total measurement range without correction. The other mode is also available and is labeled ΔΘ since it is especially useful in the comparison of phase angles.

APPLICATIONS

Component Measurement

The 1681 can be used to make fast, accurate comparison measurements on almost any type of capacitor. With capacitors of very low value — under 10 pF — the comparator can be made direct-reading in capacitance if a suitable shunting capacitor is connected across the detector. In loss measurements on low-loss capacitors, the user can call on the 10-ppm dissipation-factor resolution of the 1681.

For measurements on voltage-sensitive capacitors, the test voltage can be modified to meet Mil Specifications MIL-C-11015C and MIL-C-39014 for deviation measurements up to ±10%.

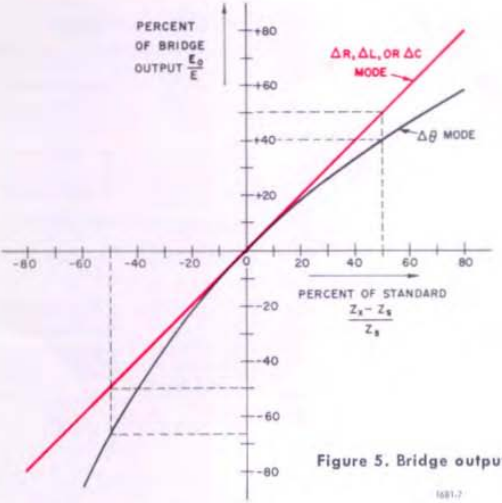

Figure 5. Bridge output characteristics.

The comparator will measure inductors, in terms of inductance difference in percent. Thus the instrument can be helpful in the balancing of transformers and in the adjustment of inductors to precise tolerances.

Resistance measurement — again as a percent difference from a standard — is possible with the 1681. Here also the high resolution of the comparator can be put to good use — in measurements of resistance drift, for example, as small as 10 ppm.

Sorting, Inspection, Quality Control

As the number of components to be measured and sorted increases, speed becomes more and more important. The 1681, like its sister instrument, the 1680 Automatic Capacitance Bridge, was designed for installation and use in automatic systems. General Radio manufactures or can provide a wide array of input and output accessories to handle and to sort components and to record measurement data (see Figure 6).

Dielectric and Temperature-Coefficient Measurements

The enterprising engineer or scientist will quickly find many ways to take advantage of the speed and resolution of the 1681. Samples of dielectric materials can be compared, with precise readout of impedance-magnitude and phase-angle differences. Temperature-coefficient measurements on components in environmental chambers usually involve deviation measurements as a function of temperature, and here the comparator, with its 10-ppm resolution and provision for automatic data collection, is of obvious value.

TEST SYSTEMS

Input Devices

Because so many different types of components can be measured over such a wide impedance range, it is impossible to provide a single, all-purpose terminal arrangement. In many cases, the connection of the unknown component to the comparator can be most convenient-

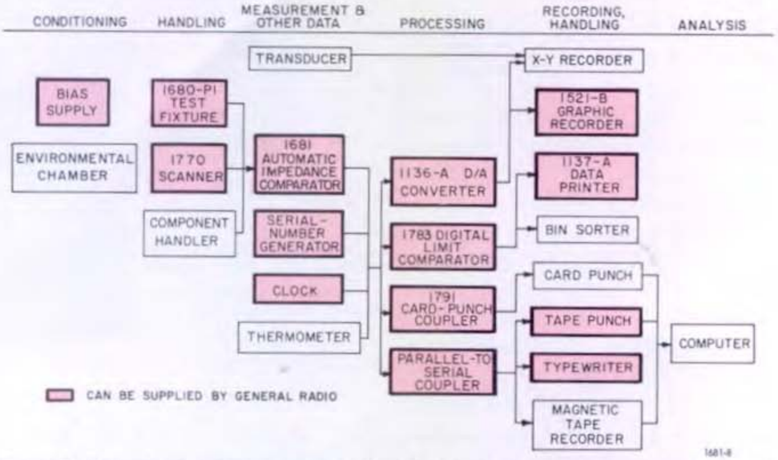

Figure 6. Chart showing instruments and devices that can be used in an automatic component-measuring system. General Radio can supply systems including those components indicated by tinted blocks.

ly made through the use of the 1680-P1 Test Fixture,[6] in which the components are manually inserted.

Automatic input devices, such as the 1770 Scanner System, are available for applications in which components must be connected to the comparator in a prescribed automatic sequence.

Output Devices

Many output devices are available to record the measured data. Among these are printers, analog recorders, card and tape punches, typewriters, and magnetic tape recorders.[7]

The Type 1137-A Data Printer (designed for use with GR digital equipment) is probably the least expensive and simplest way of automatically obtaining a permanent record.

In applications where the output data are desired in the form of an analog plot, such as in temperature-coefficient measurements, a Type 1136-A Digital-to-Analog Converter can be used to translate the data output into a dc voltage or current for analog recording by the Type 1521-B Graphic Level Recorder.

For those who wish to record data in machine-readable form, punched tape is the least expensive solution. A parallel-to-serial converter must be inserted between the bridge and the tape punch because the BCD data from the bridge are punched serially on the tape and the bridge output is presented in parallel form.

A card punch, such as the IBM 526, is the most common output device for obtaining machine-readable records. The chief advantage of the punched card is that, after all the data on a tested component have been punched on a single card, the card can move with the component. The Type 1791 Card-Punch Coupler can be used as the parallel-to-serial converter between the bridge and the card punch.

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[6] Fulks, op. cit.

[7] H. T. McAleer and R. F. Sette, "Automatic Capacitor-Testing Systems," *General Radio Experimenter*, Nov-Dec 1966.

Typewriters and magnetic tape recorders can also be used as output recording devices; they are generally seen only in large measurement systems.

Processing Equipment

A useful member of the processing-equipment family is the new TYPE 1783 Digital Limit Comparator (similar to the 1781 Digital Limit Comparator)[8], which compares the bridge reading against manually set limits to determine whether the measured component is in or out of tolerance. It provides GO/NO-GO visual indication as well as relay contact closures for automatic sorting. Further information on this instrument is available on request.

Standards

An external standard is required for the 1681. This standard may be a component identical to the unknown and selected for a nominal value, or it may be a calibrated, fixed standard or, if more convenient, a variable standard. A wide selection of standards is available: the GR 1422 Precision Capacitors (for small values of C), the 1423, 1424, and 1425 Decade Capacitors (for large values of C), the 1433 and 1434 Decade Resistors, and the 1491 Decade Inductors.

BRIDGE OR COMPARATOR?

The availability of both an automatic capacitance bridge (the GR 1680) and an automatic impedance comparator (the 1681), both at approximately the same price, will lead many to wonder which instrument is better suited to their needs. In most instances, the choice should be easy. The bridge indicates capacitance and loss directly, the comparator indicates percent deviation from an external standard. The comparator offers greater resolution, and it measures resistors and inductors just as easily as it does capacitors.

Bridge or comparator, the result is speed and convenience impossible with manually operated instruments. The higher initial price of the automatic instrument, examined in terms of cost per component tested, is seen as a true saving. Indeed, for the high volume measurer of components, the automatic bridge or comparator is now an economic necessity.

— R. LEONG

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[8] McAleer and Sette, op. cit.

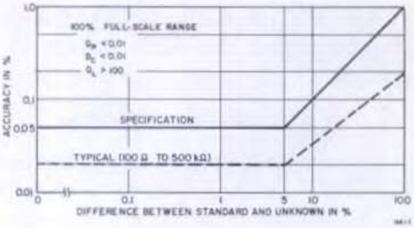
SPECIFICATIONS

	Total Useful Range	*Ranges for Measurement with Stated Accuracy*			
		Full Scale	120 Hz	400 Hz	1000 Hz
Resistance	2 Ω–20 MΩ	100%	10 Ω–2 MΩ	10 Ω–2 MΩ	10 Ω–2 MΩ
		10%	500 Ω–2 MΩ	500 Ω–2 MΩ	500 Ω–2 MΩ
Capacitance	20 pF–800 μF	100%	1 nF–100 μF	400 pF–50 μF	200 pF–20 μF
		10%	1 nF– 5 μF	400 pF– 2 μF	200 pF– 1 μF
Inductance	400 μH–1000 H	100%	5 mH–1000 H	2 mH–200 H	600 μH–100 H
		10%	200 mH–1000 H	50 mH–200 H	30 mH–100 H

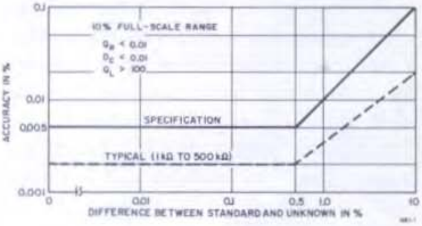
FULL-SCALE RANGES

Magnitude Difference: ±10%, and +100% −40%, full scale.

Phase-Angle Difference: ±0.1 and ±1 radian, full scale. The phase-angle difference is very nearly equal to the D difference (C and L) and the Q difference (R) when the D or Q is less than 0.1.



Accuracy of R, L, or C Difference as Percent of Standard.



ACCURACY

ΔR, ΔL, ΔC Measurement Mode

Magnitude Difference (as % of standard): ±[1% of reading + 0.001 ΔΘ (in counts) + 5 counts].

Phase-Angle Difference: ±[1% of reading + 0.005 ΔZ (in counts) + 5 counts] + additional error when large magnitude differences are measured. Correction chart supplied.

ΔΘ Measurement Mode

Magnitude Difference (as % of average of unknown and standard): ±[1% of reading + 0.001 ΔΘ (in counts) + 5 counts]. Reading in this mode differs from %-of-standard when deviation ≥1%. A correction chart is supplied.

Phase-Angle Difference: ±[1% of reading + 0.005 ΔZ (in counts) + 5 counts].

Max Resolution: 0.001%, 0.00001 radian.

Effects of Leads: For high-impedance measurements with input shield guarded, shielded cables up to 3 feet long can be used without significant error from cable capacitance.

Voltage Across Standard and Unknown: 0.3 V for 100%-full-scale range; 3 V for 10% range. Test voltage can be modified on request to meet MIL Specifications MIL-C-11015C and MIL-C-39014 on ceramic capacitors.

Dc Bias: Can be introduced from external source.

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

Remote Control: Start and balance controls can be activated remotely by contact closures.

OUTPUT

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

Print Command (at completion of balance): Change from "1" level to "0" level.

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

Measurement Rate: Panel control allows adjustment of measurement rate so that display time between measurements is between approx 0.1 and 5 s. The rate can be set manually or remotely at any rate compatible with balance time.

Other Measurement Frequencies: With internal modification, the measurement frequencies can be changed to any value between 100 Hz and 2 kHz.

GENERAL

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

Auxiliary Controls: Sensitivity control on front panel can be used to minimize balance time with a resulting decrease in accuracy. Self start (when component is connected) or ext start (by contact closure) can be selected with a rear-panel switch.

Accessories Supplied: Rack-mounting hardware with rack models; power cord and spare fuses with all models.

Accessories Available: 1680-P1 Test Fixture; R, L, and C standards and decade boxes; various GR digital-data-acquisition instruments and system components.

Mounting: Supplied with hardware for rack mounting or assembled in cabinet for bench use.

Dimensions (width × height × depth): Bench, 19½ × 12 × 19 in. (495 × 305 × 485 mm); rack, 19 × 10½ × 18 in. (485 × 270 × 460 mm).

Net Weight: Bench, 76 lb (35 kg); rack, 71 lb (33 kg).

Shipping Weight: Bench, 160 lb (74 kg); rack, 145 lb (67 kg).

Catalog Number	*Description*	*Price in USA*
	1681 Automatic Impedance Comparator System	
1681-9700	115 V, 60 Hz, Bench	$4975.00
1681-9701	115 V, 60 Hz, Rack	4975.00
1681-9702	115 V, 50 Hz, Bench	on request
1681-9703	115 V, 50 Hz, Rack	on request
1681-9704	220 V, 50 Hz, Bench	on request
1681-9705	220 V, 50 Hz, Rack	on request
1681-9706	230 V, 50 Hz, Bench	on request
1681-9707	230 V, 50 Hz, Rack	on request
1680-9601	**1680-P1 Test Fixture**	95.00

U.S. Patent Applied For.

NEW WIDE-RANGE RF SOURCES

Several recent additions to the General Radio line of wide-range, general-purpose laboratory rf power sources should enhance an already excellent reputation for performance, versatility and dependability at a reasonable price. Two new vhf and uhf oscillators provide increased frequency coverage and improved modulation capability. Three new models of the power supplies offer regulated dc heater voltage for improved oscillator stability. The new oscillators and power supplies are packaged for quick, easy installation and use together, whether on the bench or in a relay rack.

The new oscillators have the low-noise sideband level essential in the local oscillator of a simple superheterodyne receiver using a wide-band single-sideband mixer. In the Type 1241 Heterodyne Detector (see page 24), the 1236 I-F Amplifier and the 874-MRAL Mixer are used with these oscillators to create a precision calibrated receiver. Typical sensitivity is −100 dBm for a 3-dB meter deflection over residual noise with a 0.5-MHz bandwidth. The oscillators achieve both low noise and complete freedom from nonharmonic discrete spurious frequencies in their outputs through the use of high-Q tank circuits operated at high level in a fundamental-frequency mode.

56 to 500 MHz in One Band

The 1363 oscillator delivers power typically in excess of 150 mW from 56 to 500 MHz (see Figure 1a) and replaces the popular Type 1208-C. As a local oscillator in the 1241 Heterodyne Detector, it provides fundamental mixing

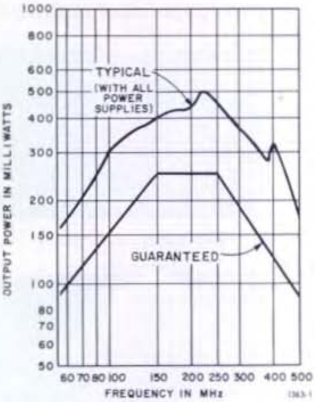


Figure 1a. Output power into a 50-ohm load for Type 1363 Oscillator.

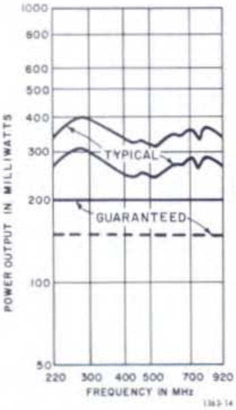
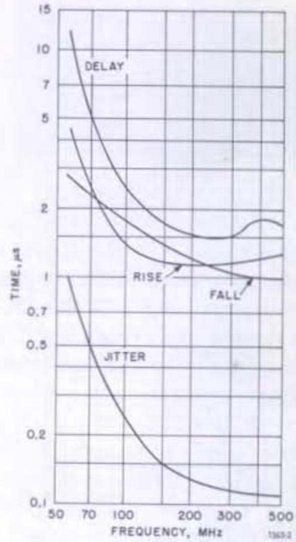
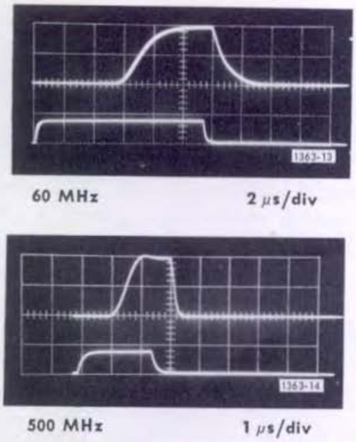


Figure 1b. Output power into a 50-ohm load for Type 1362 Oscillator.





60 MHz **2 μs/div**

500 MHz **1 μs/div**

Figure 2a. Typical rise time, starting delay, and jitter when the 1363 Oscillator is pulsed by the 1264 Modulating Power Supply, driven by a 1217-C Pulse Generator. Oscillograms show modulating and modulated pulse shapes at frequency extremes of the 1363.

for signal frequencies from 40 to 530 MHz. The basic wide-range tuner[1] consists of a variable inductor and a variable tuning capacitor, constructed as an integral unit. This fundamental-frequency LC oscillator circuit is inherently more stable than RC or beat-frequency circuits. In the new oscillator, we have increased the tuning range while reducing the number of wiping contacts from two to one by using a fixed network to suppress the unwanted resonance in the unused portion of the tuning inductor.

Other important circuit changes ensure compatibility with the 1264 power supply, making possible both square-wave and pulse modulation (Figure

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[1] E. Karplus, "VHF and UHF Unit Oscillators," *General Radio Experimenter*, May 1950.

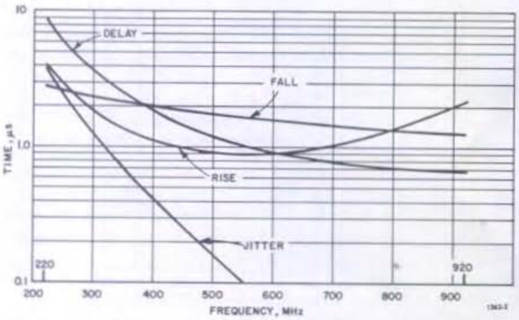
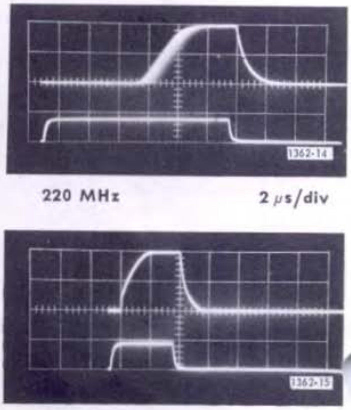


Figure 2b. Pulse characteristics of the 1362 Oscillator. Oscillograms showing modulating and modulated signals are at frequency extremes of the 1362.



220 MHz **2 μs/div**

900 MHz **2 μs/div**

2a). A front-panel output control is provided, and the rf output connector can be installed either on the front or at the rear of the instrument; the user can change the location in a few moments without any special tools. The GR874® output connector can be easily converted by means of GR874 adaptors to any popular coaxial connector series (BNC, C, N, TNC, OSM/BRM, Microdot, etc).

220 to 920 MHz in One Band

The 1362 Oscillator, with an output power typically in excess of 250 mW from 220 to 920 MHz (Figure 1b), supersedes two widely used oscillators, the 1209-CL and the TYPE 1209-C. The frequency range of the new oscillator includes the entire uhf aircraft communications band (220–406 MHz) and the uhf TV band (470–890 MHz), with margin to spare at the top end.* The tuner is a noncontacting butterfly similar to that used in the earlier oscillators.[1,2]

The oscillator tube is the new planar triode Type Y-1266 developed by General Electric Company in close collaboration with General Radio (Figure 3). This tiny ceramic tube has both the low interelectrode capacitances required for wide tuning range and the stable cathode of high emission capability required for high power output. The cathode operates at a moderate temperature, ensuring long, trouble-free life. This tube has demonstrated its excellence in hundreds of recent production 1209 oscillators and in the high-performance TYPE 1026 Standard-Signal Generator.[3]

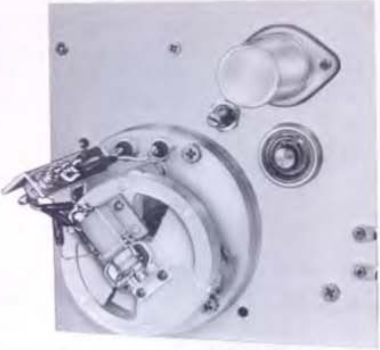


Figure 3. Interior view of the 1362 Oscillator showing new GE Y-1266 planar triode.

The output system is a waveguide-below-cutoff piston, calibrated over a range of 80 dB and adjustable from the front panel. As in the 1361 Oscillator,[4] it is keyed against rotation and can readily be reset to a previously determined position. Relocation of the output coupling loop relative to the butterfly and the use of aperiodic damping to suppress an interdigital rotor resonance result in minimum harmonic content and a very smooth output-versus-frequency characteristic at any setting of the output attenuator.

Leveled operation over the entire oscillator tuning range with a single setting of the output attenuator can be achieved by means of the 1263-C Amplitude Regulating Power Supply. This combination delivers 20 mW into 50 ohms (+13 dBm), either peak, with 1-kHz square-wave modulation, or cw. The level can be reduced as much as 20 dB if desired. Leveled performance is shown in Figure 4. Alternatively, new circuitry permits direct connection to

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[1] *Ibid.*

[2] E. Karplus, "The Butterfly Circuit," *General Radio Experimenter*, October 1944.

[3] G. P. McCouch, "A New 500-MHz Standard-Signal Generator," *General Radio Experimenter*, March 1967.

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

* The region below 220 MHz is covered by both the TYPE 1215 Oscillator (50-250 MHz, noncontacting tuner) and the new 1363. The region above 920 MHz is covered by the 1361 (450-1050 MHz) and the 1218 (900-2000 MHz).

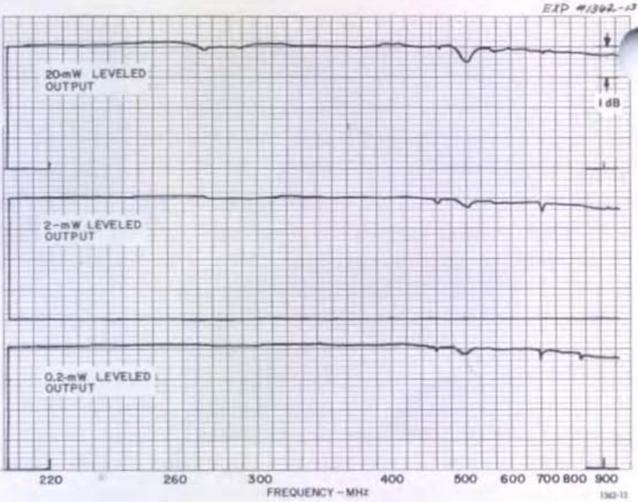

Figure 4. Recordings showing leveled performance of a 1362 Oscillator powered by a 1263-C Amplitude-Regulating Power Supply.

the 1264-B Modulating Power Supply, making possible both square-wave and pulse modulation (Figure 2b). Full power output is delivered during the "on" period and the oscillator is completely cut off during the "off" period.

Improved Stability from New Power Supplies

The new power supplies offer a major improvement in frequency and amplitude stability as well as increased tube life, obtained by close regulation of heater as well as plate supply voltage. The advantages afforded by regulation of both supplies have been clearly established by some years' experience with the 1267-A Power Supply. Well regulated dc heater supplies have now been incorporated in the 1263-C Amplitude Regulating Power Supply and in the 1264-B Modulating Power Supply.

Recent redesign of the 1267 to a "B" model permitted us to maintain the excellent specifications of its predecessor while simplifying the regulators and introducing a dual primary power transformer so that a single model now operates on either 115- or 230-V lines. In all three power supplies, the heater regulators are set to deliver 6.5 volts, thereby allowing 0.2 volt for the drop that occurs in the heater rf filters in the oscillators.

An important feature of the TYPE 1264-B Modulating Power Supply is the internal 1-kHz square-wave generator. A sample of the 1-kHz signal has been brought out to the modulation terminals for use in synchronizing oscilloscope sweeps; conversely, a synchronizing signal from an external oscillator may be injected here.

In the latest model of the 1264, it is much easier to set the 1-kHz frequency to the exact center of the narrow passband of a highly selective detector amplifier, and there is an order-of-magnitude improvement in the stability of the frequency once it is set.

The improved settability of the 1-kHz frequency has been achieved by means of a dual potentiometer with controlled backlash, operated from a single knob. The procedure is to tune with slight overshoot, then, as the con-

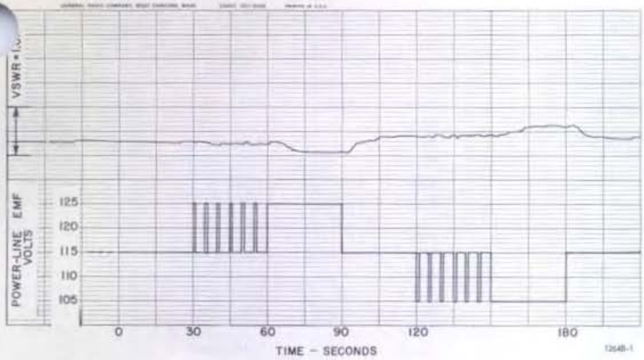

Figure 5. Stability of a 1218-B Oscillator — 1264-B Power Supply Combination used in a slotted-line recording system.

trol is backed up, only the vernier potentiometer comes into play over an arc of 40 degrees. This single control is far easier to use than is the conventional dual concentric knob coarse/fine combination.

The stability against line voltage of a 1264-B used to power a 1218-B Oscillator in an expanded-scale SWR-measuring system[5] is shown in Figure 5. The 1264-B is also ideal for use with other General Radio high-frequency oscillators as a source for conventional slotted-line measurements using the new high-stability 1234 Standing-Wave Meter.[6]

— G. P. McCouch

A brief biography of Mr. McCouch appeared in the March 1967 issue of the Experimenter.

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[5] A. E. Sanderson, "A Slotted Line Recorder System," *General Radio Experimenter*, January 1965.

[6] M. Khazam, "A High-Resolution SWR Meter", *General Radio Experimenter*, February 1968.

Type 1362 UHF Oscillator with Type 1267-B Regulated Power Supply.

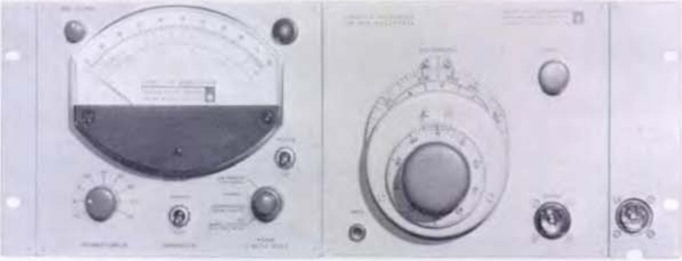
Complete specifications for the instruments described in this article are given in General Radio Catalog T

Catalog Number	*Description*	*Price in USA*
1362-9701	**1362 UHF Oscillator**	**$395.00**
1363-9701	**1363 VHF Oscillator**	**395.00**
1263-9703	**1263-C Amplitude-Regulating Power Supply**	**550.00**
1264-9702	**1264-B Modulating Power Supply** (115 V)	**415.00**
1264-9703	**1264-B Modulating Power Supply** (230 V)	**415.00**
1267-9702	**1267-B Regulated Power Supply**	**195.00**

Oscillator—Power-Supply Combinations

Oscillator	*Power Supply*	*Mounting*	*Catalog Number*	*Price in USA*
1363	**1269-A***	Bench	1363-9419	**$490.00**
		Rack	1363-9509	**515.00**
(56-500 MHz)	**1267-B**	Bench	1363-9417	**590.00**
		Rack	1363-9507	**615.00**
	1264-B	Bench	1363-9414	**810.00**
		Rack	1363-9504	**836.00**
1362	**1269-A***	Bench	1362-9419	**490.00**
		Rack	1362-9509	**515.00**
(220-920 MHz)	**1267-B**	Bench	1362-9417	**590.00**
		Rack	1362-9507	**615.00**
	1264-B	Bench	1362-9414	**810.00**
		Rack	1362-9504	**836.00**
	1263-C	Bench	1362-9413	**945.00**
		Rack	1362-9503	**971.00**

* See August 1963 *Experimenter*.



Type 1363 UHF Oscillator with Type 1236 I-F Amplifier, principal components of a Type 1241 Heterodyne Detector.

NEW HETERODYNE DETECTOR

GR's Type 1236 I-F Amplifier,[1] Type 874-MRAL Mixer,[2] and the oscillators introduced elsewhere in this issue constitute the main elements of a highly sensitive high-frequency heterodyne detector for relative-signal-level measurements and for use as a null detector. We now offer the entire package, including, in addition to the above, a 10-dB pad, a 90° ell, and an appropriate low-pass filter. The assembly is available as the Type 1241 Heterodyne Detector.

Applications for the heterodyne detector are almost limitless. It can be used to measure insertion loss, attenuation, crosstalk, antenna gain, and radiation patterns. It is, of course, a sensitive high-frequency receiver. When calibrated at one signal level and frequency, it can be used at that frequency as a selective voltmeter in a 50-ohm

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[1] M. Khazam, "A New 30-MHz Amplifier with Two Bandwidths," *General Radio Experimenter*, July–August 1967.

[2] *General Radio Experimenter*, July–August 1967, page 19.

stem. It is now the recommended null etector for the 1602-B UHF Admittance Meter, the 1609 Precision UHF Bridge, and the 1607-A Transfer-Function and Immittance Bridge.

As an SWR indicator with a slotted line, it is especially useful for measurements on nonlinear elements, when a high degree of harmonic rejection and a small applied signal level are required.

The price table indicates the fundamental-frequency coverage of the three basic assemblies. These ranges can be extended through the use of oscillator harmonics, but with reduced sensitivity and dynamic range. To cover a very wide frequency range, one might order one complete detector plus the necessary oscillators and filters for the additional ranges desired.

Detailed specifications on the 1241 Heterodyne Detector appear in General Radio Catalog T.

Catalog Number	*Fundamental Frequency Range — MHz*	*Mounting*	*Price in USA*
1241-9700	40-530	Bench	$1270.00
1241-9701	40-530	Rack	1295.00
1241-9702	190-950	Bench	1265.00
1241-9703	190-950	Rack	1295.00
1241-9704	870-2030	Bench	1565.00
1241-9705	870-2030	Rack	1610.00

IMPROVED NBS CALIBRATION ACCURACY FOR COAXIAL IMPEDANCE (1-8 GHz)

Accuracies of impedance measurements in coaxial-line systems have been improved significantly in recent years by the Radio Standards Laboratory (Boulder, Colorado), of the NBS Institute for Basic Standards (U.S. Department of Commerce), and others. This improvement came primarily from the development of precision coaxial-line standards and precision coaxial connectors, such as the GR900® series. According to an NBS release, "these developments have in turn contributed toward improving measurement capabilities of coaxial slotted-line systems to the extent that very accurate measurements are now possible. Errors originally introduced by structural defects of slotted lines have been minimized by the use of precision made, coaxial slotted lines. Refinements in measurement technique have helped, in part, to reduce some systematic errors.

"These improvements, along with other good practices, make the measurement possible of VSWR (Voltage Standing Wave Ratio) up to 8 GHz with an uncertainty in the range of 0.1 to 1 percent. The phase of the reflection-coefficient magnitude can be measured with an uncertainty ranging from 0.1 degree to approximately 1 degree. These uncertainties apply for coaxial impedance standards equipped with the 14-mm precision coaxial connector, where $1 \leq \text{VSWR} \leq 2$, referred to 50 ohms."

Left to right, 900-L3 Air Line, 900-LZ3 Reference Air Line, 900-G6 Precision Attenuator.

NEW GR900® ATTENUATOR, AIR LINES

The usefulness of any connector type depends to a large extent on the number of different things it can connect to, either directly or through adaptors. In this respect, the GR900® precision coaxial connector measures up very well. General Radio alone catalogs over fifty GR900 components, and the basic GR900 connector is used on many devices made and sold by other manufacturers. A full line of GR900 adaptors provides access to all other popular coaxial connectors.

The latest additions to the fast-growing GR900 line are a precision-fixed attenuator and two 3-cm air-line sections.

Attenuator

The accuracy of many microwave measurements (e.g., impedance, attenuation, phase, and power measurements) depends on the impedance match of the generator and detector. Attenuators and pads are commonly used for matching purposes, but the SWR of these devices is usually high enough to limit the accuracy improvement obtainable. In precision applications, the only recourse has been the use of matching tuners and slow, point-by-point measurements. The new GR900 attenuator, with an SWR of less than $1.005 + 0.005\ f_{GHz}$, eliminates the need for tuners in most applications and makes possible accurate swept-frequency measurements.

Attenuation of the 900-G6 is within 0.2 dB of its nominal 6-dB value to 5 GHz and within 0.3 dB of nominal to 8.5 GHz. Since it is equipped with GR900 connectors, it can be accurately calibrated for use as a secondary standard of attenuation.

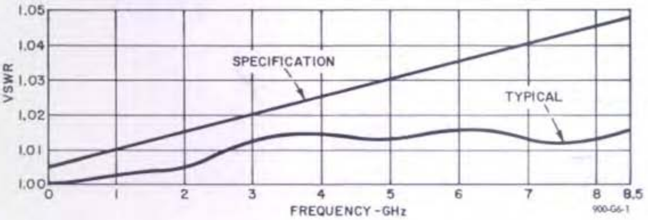
Air Lines

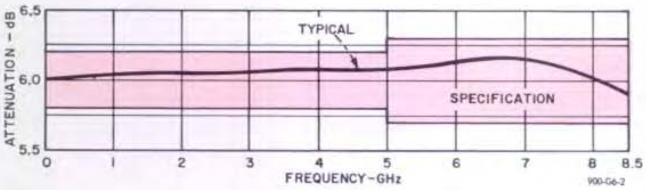
The 900-L3 Air Line and the 900-LZ3 Reference Air Line have been added to the existing series of air lines primarily to extend the usefulness of the series in precise capacitance calibrations. Both units are 2-pF two-port elements.

The chief distinction between the 900-L air lines and the 900-LZ reference air ines is one of precision. The reference lines contain no dielectric material to support the inner conductor, which must therefore be supported from the connectors to which the line is joined. This no-dielectric-support design affords the ultimate in accuracy but obviously requires more time and care in installation. The regular, 900-L air lines include dielectric supports, which make them easier to use but which also introduce uncertainties. (Simple, absolute calibration of capacitance purely on the basis of dimension is not possible, for instance.)

The characteristics of the two types of air lines can be used to complement one another. Where two reference air lines are to be used in series, some means of supporting the inner conductors must be inserted between the two lines. The short 900-L3, with its own dielectric-supported inner conductor, will serve ideally as a minimal-capacitance coupling between two reference air lines.

SPECIFICATIONS FOR TYPE 900-G6





Frequency Range: 0 to 8.5 GHz.
Attenuation: 6.00 ± 0.2 dB, 0 to 5 GHz; ±0.3 dB, 5 to 8.5 GHz.
SWR: $<1.005 + 0.005 f_{GHz}$.
Characteristic Impedance: 50.0 Ω.
Insertion-Loss Repeatability: ±0.001 dB to 30 MHz, ±0.002 dB to 1 GHz, ±0.0025 dB to 8.5 GHz per connector.
Dc Resistance: 50.0 Ω ± 0.3% when terminated in 50.0 Ω.
Max Power: 1.0 W continuous; peak, 500 W with 1-W avg.
Temperature Coefficient: <0.0001 dB/°C/dB.
Dimensions: 3¾ × 1¾ × 1$\frac{1}{16}$ in. (95 × 45 × 27 mm).
Net Weight: 11 oz (310 g).

Detailed Specifications on the 900-L3 and -LZ3 Air Lines appear in General Radio Catalog T

Catalog Number	*Description*	*Price in USA*
0900-9850	**900-G6 Precision Fixed Attenuator (6 dB)**	**$175.00**
0900-9608	**900-L3 Precision Air Line**	**63.00**
0900-9603	**900-LZ3 Reference Air Line**	**76.00**

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