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A HIGH-PRECISION IMPEDANCE COMPARATOR

The increased need for means of rapid sorting of electrical components has led to the extensive use of impedance comparators, which indicate directly the percent difference between two impedances without requiring a bridge balance. Most of these operate either at dc or at a fixed low frequency and are limited in scope to simple applications. The new TYPE 1605-A Impedance Comparator[1] can be used to compare complex impedances of any phase angle and has several important features which allow a much greater degree of precision and considerably more versatility than other instruments available.

This instrument indicates not only the difference in magnitude between the

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[1] Holtje, Hall, and Easton, "An Instrument for the Precise Comparison of Impedance and Dissipation Factor," *Proceedings of the National Electronics Conference*, Vol. 10 1955.

Figure 1. Panel View, Type 1605-A Impedance Comparator.

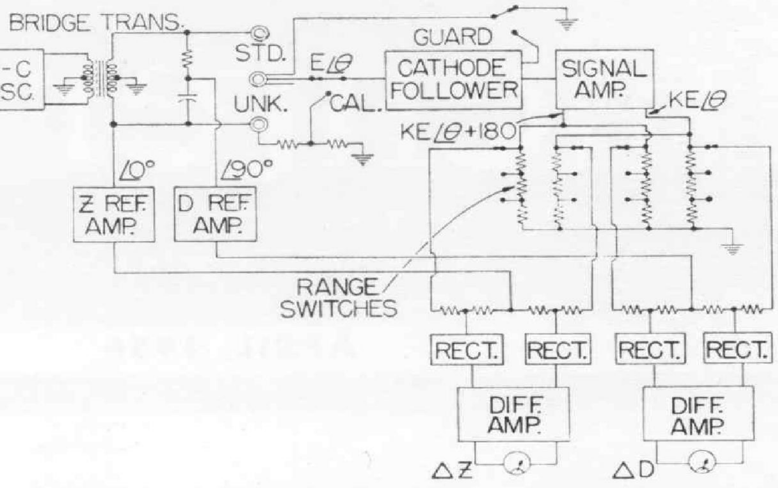


Figure 2. Block Diagram, Type 1605-A Impedance Comparator.

two components that are compared, but also indicates simultaneously the phase-angle difference, which is often of equal importance. The difference in these quantities can be determined to 0.01% and .0001 radian, respectively, on the most sensitive ranges. Both magnitude and phase-angle differences are indicated directly on panel meters.

The Impedance Comparator will indicate differences between components, whether resistive, capacitive, or inductive, with a precision hitherto unobtainable in direct-indicating instruments; measure the phase-angle difference between different types of resistors; indicate the departure from uniformity of units in a gang; measure the degree of unbalance in transformer windings; compare dielectric samples; and facilitate the adjustment of inductors to precise values.

The comparator is completely self-contained, including a calibrating voltage to check the operation of the instrument. The meter voltages are available externally to operate recorders, remote indicators, or automatic selecting devices. If the unknown is remote, the internal guard circuit can be used to minimize the effect of stray impedances.

The internal oscillator provides frequencies from 100 cycles to 100 kc in decade steps, so that components may be checked over a wide frequency range. This feature is particularly important for components that must be checked at a frequency near the desired operating frequency.

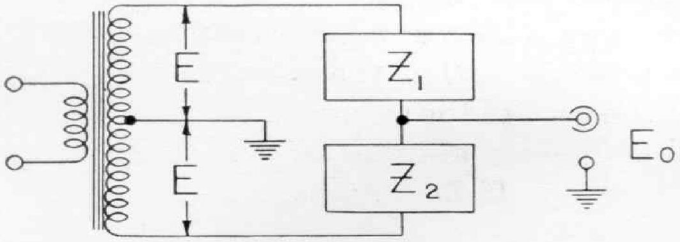
Circuit

The electronic circuitry and the components necessary to provide the impedance-difference and phase-angle-difference information at the desired precision in a single, self-contained unit have produced several interesting development problems.

A block diagram of the instrument is shown in Figure 2. An amplitude-stabilized, R-C oscillator provides the four test frequencies. The oscillator is coupled to the bridge through a special bridge transformer, which also provides the inductively coupled unity-ratio arms. The standard and unknown impedances form the other two arms.

The unbalance voltage from the bridge is amplified, and the push-pull output attenuated with two separate range switches to provide independent magnitude and phase-difference ranges. Separate phase-sensitive detectors are used to measure the in-phase and quadrature voltage components. The two orthogonal components are fed to differential amplifiers, which drive the output meters.

Figure 3. Basic Bridge Circuit.



$$\frac{E_0}{E} = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

The instrument is calibrated by injecting a 1% unbalance voltage and setting the oscillator level to give the correct reading.

The Bridge Equations

The basic bridge circuit is shown in Figure 3. If the voltages across the windings are equal, the complex unbalance voltage is

$$\frac{E_0}{E_{in}} = \frac{Z_1 - Z_2}{Z_1 + Z_2}$$

The real part of this voltage (component in phase with E_{in}) is

$$Re\left(\frac{E_0}{E_{in}}\right) = \frac{\dfrac{|Z_1| - |Z_2|}{|Z_1| + |Z_2|}}{1 + \dfrac{\cos(\Theta_1 - \Theta_2) - 1}{\dfrac{|Z_1|}{2|Z_2|} + \dfrac{|Z_2|}{2|Z_1|} + 1}}$$

If $\Theta_1 - \Theta_2$ is small, the above equation reduces to:

$$Re\left(\frac{E_0}{E_{in}}\right) = \frac{|Z_1| - |Z_2|}{|Z_1| + |Z_2|}$$

Within the range of the instrument ($\Theta_1 - \Theta_2 = .1$ radian), this approximation is extremely good, producing an error of less than 0.25% of the actual impedance-difference range, which is insignificant on all ranges. For example, in a measured difference of 0.3%, this error would amount to 0.25% × 0.3% or 7.5 parts per million.

Since the difference is usually desired as a percentage of the standard impedance rather than as a percentage of the sum of the standard and unknown impedances, another approximation is necessary. If $Z_1 - Z_2$ is small

$$Re\left(\frac{E_0}{E_{in}}\right) = \frac{1}{2}\,\frac{|Z_1| - |Z_2|}{|Z_2|}$$

The error due to this last approximation is negligible except on the 10% range, where the scale becomes non-linear, indicating 9.5% instead of 10% on one side and 10.5% on the other. This is not an error in measurement, but rather a non-linearity of scale. To avoid complicated meter scales, the tolerance can be modified, or the zero shifted, when 10% components are to be sorted to better than ±0.5%.

The imaginary part of the bridge unbalance voltage can be written as

$$Im\left(\frac{E_0}{E_{in}}\right) = \frac{\sin(\Theta_1 - \Theta_2)}{\cos(\Theta_1 - \Theta_2) + \dfrac{1}{2}\left(\left|\dfrac{Z_1}{Z_2}\right| + \left|\dfrac{Z_2}{Z_1}\right|\right)}$$

If the magnitude difference is less than 10%, and the phase-angle difference is less than 0.1 radian (the maximum ranges), the above expression reduces to

$$Im\left(\frac{E_0}{E_{in}}\right) = \frac{1}{2}(\Theta_1 - \Theta_2)$$

with an error of less than 0.25 percent. Note again that this error is a percent of the indicated difference and, therefore, completely negligible.

The Bridge Transformer

In the above calculations on the bridge voltage, it was assumed that the voltages across the two windings of the transformer were equal. A difference in these voltages would cause a corresponding difference on the meter indication. Not only must the two voltages be equal, but the source impedances of the windings must be matched, or an error will result when the low-impedance components are measured. It is also desirable to have the two windings tightly coupled, so that stray impedance shunting one winding will not cause a voltage unbalance.

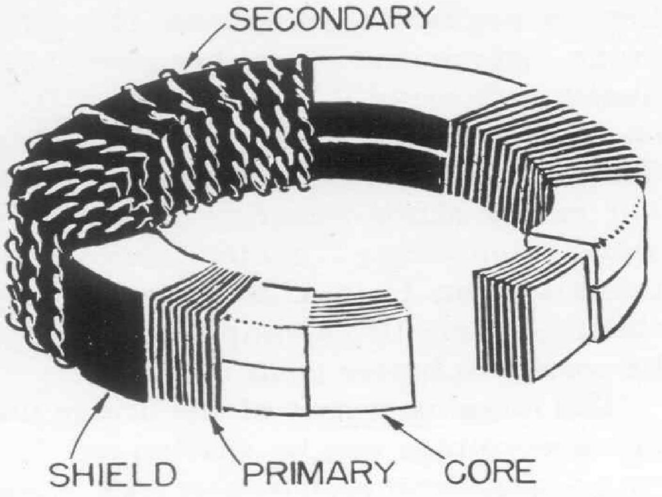


Figure 4. Bridge-Transformer Construction.

Figure 4 is a sketch of this transformer, showing its construction. It is a toroidal structure, with a high-permeability, wound-ribbon core. The inside winding is the primary, which is a modified banked winding, completely and symmetrically covering the core. Over this are two copper cup-shaped shields to prevent unwanted electrostatic coupling to the secondary.

The secondary windings are made by twisting together two identical wires and winding the pair. This is a practical approximation to the ideal situation where the wires of the two windings would occupy the same volume so that the flux linkage would be equal, producing unity coupling and equal output voltages.

This construction works extremely well. The open-circuit voltages are balanced to within 1 part in 10^6, the impedance difference (at 1 kc) is less than 50 microhms, and the coefficient of coupling is greater than 0.9997. These quantities approach the ideal so closely that 0.1 μf placed across one winding at 1 kc will cause an impedance-difference error of .0002% and a phase-angle error of .00005 radian. At 100 kc, with 1000 $\mu\mu$f shunting one winding, corresponding errors are 0.02% and .00005.

With resistive ratio arms, a resistance value as low as 0.1 ohm would be necessary to obtain an equal degree of immunity from shunt capacitance effects.

The Guard Circuit

The output voltage from the bridge is fed to a high-input-impedance cathode-follower-type circuit, which also provides a low-impedance guard voltage isolated from the signal. This guard circuit makes possible measurements of large impedances located at some distance from the instrument itself, as for example, a component in an environmental test chamber.

Since capacitance from one side of the transformer to ground has so little effect, the lead from this terminal to the unknown can be shielded without introducing error. However, capacitance to ground of the other lead, which is connected to the amplifier input, produces attenuation and phase shift of the signal voltage if the measured component is of high impedance. This capacitance is especially large if the lead is shielded to prevent unwanted pickup. In order to reduce this effect, a guard voltage is brought out, which can be used to drive the amplifier input shield. Since the guard voltage is approximately 0.97 of the amplifier input, the capacitance to the shield is effectively reduced by a factor of 30.

The Phase-Sensitive Detector

The circuit of the phase-sensitive detector used to separate the in-phase and quadrature components of the unbalance voltage was chosen for its precision and stability.

The output of the signal amplifier (E_s) is added to and subtracted from the reference voltages (E_r) which are derived from the bridge voltage.

One reference is in phase with the bridge voltage; the other is at ninety degrees.

If the reference voltage is much larger than the signal voltage (Figure 5), the difference in magnitude between the resulting sum and difference is equal to twice that component of the signal which is in phase with the reference.

The condition that the reference be much larger than the signal is easily met when the two meters are set to corresponding ranges, in which case the signal is about one one-hundredth of the reference. However, if one meter is indicating full scale on the 10% (or .1 radian) scale, and the other on the 0.3% (.003 radian) scale, it is possible to increase this voltage ratio to ⅓, causing the readings on the more sensitive scale to be low by 5%. This produces a maximum error of 5% × 0.3% = 0.015%.

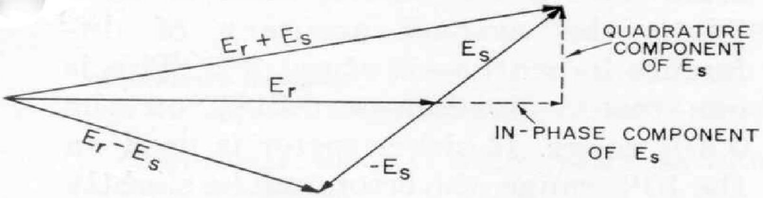


Figure 5. Phase-Sensitive Detector Operation.

Ranges

Four independent ranges are provided for the impedance-difference and phase-angle-difference meters. The impedance-difference ranges are 10%, 3%, 1% and 0.3%, and the phase-angle-difference ranges are 0.1, 0.03, 0.01 and 0.003 radian full scale. On the most sensitive ranges, one scale division represents 0.01% or .0001 radian. The ranges can be increased to 20 or 30 percent by calibrating at half scale, or on a lower scale, which reduces the bridge voltages. If the D or Q of the standard is less than 0.1, the phase-angle difference in radians is very nearly equal numerically to the D or Q difference.

The range of impedances that the instrument will compare is limited by practical considerations at both ends. For reactive components, the wide frequency range makes it possible to extend the range of inductance or capacitance which can be measured.

The low-impedance limit is determined by the difficulty in making low-resistance connections to the comparator and by the power available from the bridge oscillator. The nominal limit is 2 ohms, so that the smallest unbalance that can be determined is 200 μohms. This two-ohm limit can be decreased somewhat by reducing the oscillator voltage, but the sensitivity is also reduced.

The upper impedance limit for this type of instrument depends upon the input impedance of the detector circuit. This dependence can be seen from the equivalent circuit shown in Figure 6.

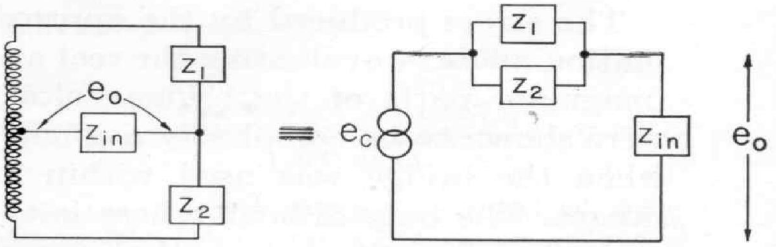


Figure 6. Equivalent Circuit of Loaded Bridge.

The amplifier input impedance attenuates the bridge unbalance voltage so that the actual detector voltage is

$$e_o = \frac{Z_{in}}{Z_{in} + \dfrac{Z_1 Z_2}{Z_1 + Z_2}} \, e_c$$

where e_c is the correct or unattenuated output signal.

To minimize this effect, Z_{in} should be large as possible. The input impedance is approximately 4 $\mu\mu$f in parallel with 200 megohms. Therefore, the indicated difference will be low by 10% when 20-$\mu\mu$f capacitors are compared.

The input resistance will cause a phase-angle error. This error, however, is frequency dependent and can be made small if the measurement is made at high frequencies.

When resistors are measured, the indicated difference will be low by 10% when the value of the standard and unknown components reaches 40 megohms. The phase-angle error due to input capacitance can be minimized by measurement at low frequencies.

Another limitation when high impedances are measured is hum pickup, which can overload the amplifier if the impedances are high at power-line frequencies. This difficulty can usually be overcome by proper grounding and shielding.

Errors

The errors produced by the approximation made in evaluating the real and imaginary parts of the bridge voltage were shown to be completely negligible when the bridge was used within its ranges. The only difficulty here is the scale non-linearity when the impedance difference approaches 10%. This is not really an error, but rather a known calibration change, which can be corrected.

The error in separating the voltage components is negligible, except for the small error produced when the measurement is made on the most sensitive range on one meter with the other meter indicating nearly full scale on its least sensitive range.

The possibility of a 30-to-1 difference in full-scale sensitivity results in several restrictions on the oscillator and phase-shift networks. If the impedance magnitude unbalance is very large, a small departure of the reference-voltage phase angle from 90° will cause some of the large in-phase voltage to produce a small indication on the phase-difference meter when it is set to its most sensitive range. This error is proportional to the impedance difference. If $\triangle|Z|$ is 10%, a 0.1% change in frequency, or in the elements of the phase-shift network, will produce an error of .0001 radian.

Oscillator harmonics will also cause an error since they are not shifted 90° in the phase-shift network.

These errors should be less than a few divisions when $\triangle|Z|$ is 10% and therefore only important when very small phase-angle differences are to be measured with a large impedance difference.

By far the largest error is caused by the one-percent meter. This can produce a measurement error of 2% of full scale since a zero center scale is used. Thus, the over-all accuracy of difference indications is about 3%. This is one meter division or 0.01% on the 0.3% range. If either meter is used on the 10% range, the errors can be slightly larger.

Applications

The versatility of this bridge can be indicated by a brief summary of the uses to which the early models have already been applied. Among these are:

1. Measuring the drift of deposited-carbon resistors. The changes to be measured were very small, and repeated measurements were made on thousands of units. Without the accuracy and the speed of measurement offered by the Impedance Comparator, these studies would have been so time consuming as to be impractical.

2. Inspection of silvered-mica sheets for use in standard capacitors. Sheets

with excessive losses are rapidly identified and rejected.

3. Measuring the phase shift in various types of wire-wound resistors. Here, the problem was to select resistors for audio-frequency voltage dividers in which phase shift could not be tolerated.

4. Measurement of the coefficients of temperature and humidity of components in an environmental test chamber. In this application the guard terminal is used, and, since the meter voltages are brought out to terminals, a graphic recorder is operated to yield a permanent record of the test data.

5. Inspection and adjustment of ganged capacitors and potentiometers for desired tolerance in tracking.

6. Adjusting inductors to precise tolerances by adding or removing turns.

7. Comparing samples of dielectric materials.

8. Inspection of balanced transformer windings.

9. Automatic sorting — two units are already scheduled for use in automatic sorters. The ability to measure both magnitude and phase differences makes possible the automatic inspection of complex networks. An example of this is the testing of etched circuits by measurement at test points.

The precision and speed of this comparator bring laboratory accuracy to production-line testing; conversely, it brings production-test speed to laboratory measurements. Its unusual combination of features make it a truly universal instrument, equally useful in both fields of application.

— Malcolm C. Holtje
— Henry P. Hall

SPECIFICATIONS

Impedance Ranges:
Resistance or impedance magnitude: 2 Ω to 20 MΩ.
Capacitance: 40 µµf to 500 µf; to 0.1 µµf with reduced sensitivity.
Inductance: 10 µh to 10,000 h.

Internal Oscillator Frequencies: 100 c, 1 kc, 10 kc, and 100 kc; all ± 3%.

Meter Ranges:
Impedance Magnitude Difference: ± 0.3%, ± 1%, ± 3%, ± 10% full scale.
Phase Angle Difference: ± 0.003, ± 0.01, ± 0.003, ± 0.1 radian full scale.

Accuracy of Difference Readings: 3% of full scale.

Voltage Across Standard and Unknown: approx. 0.15 volt.

Tube Complement:
1-5651
1-5751
3-12AX7
4-6AL5
5-12AT7
3-6U8
1-6AS7G
1-3A10
1-VE-65A1

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles; 100 watts input at 115 v line.

Mounting: Relay-rack panel with cabinet; Type 1605-AR has fittings to permit either instrument or cabinet to be removed from rack without disturbing the other; Type 1605-AM has end supports for table or bench use.

Dimensions: Panel 10 x 8¾ inches; depth behind panel, 12 inches.

Net Weight: 29½ lbs.

Type		*Code Word*	*Price*
1605-AR	**Impedance Comparator (relay-rack mounting)...**	GUNNY	**$790.00**
1605-AM	**Impedance Comparator (bench mounting)......**	GIPSY	**790.00**

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

NEW COAXIAL ELEMENTS

ATTENUATORS, FILTERS, LINE STRETCHERS, DETECTORS, ADAPTORS

The continuing development program for improving and expanding the line of Type 874 Coaxial Elements has resulted in the addition of several new components. A new series of fixed attenuators having very low VSWR and high stability have been developed, along with two new low-pass filters, two different types of constant-impedance adjustable-length line, adaptors from Type 874 Connectors to Type LC Connectors, and a new crystal detector.

FIXED ATTENUATORS

A fixed attenuator is often used to reduce the VSWR of a generator, detector, or other element; to reduce the signal level by a known amount; or to provide isolation between two parts of a circuit. The requirements for these applications are very satisfactorily met by the new Type 874-G Fixed Attenuators (Figure 1), which are available in 3-, 6-, 10-, and 20-db sizes and have a high power-handling capacity, a low VSWR up to 4000 Mc, and small size.

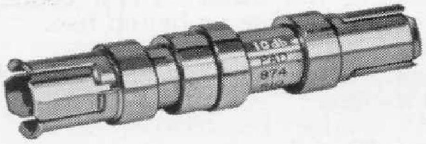


Figure 1. Type 874-G Fixed Attenuator.

The attenuating element is a resistive T-pad made up of deposited-carbon resistance elements on a ceramic base. The resistor assembly is a single integral unit. The use of deposited-carbon resistance elements gives the pads high stability and accuracy. All resistances are held within ±1%.

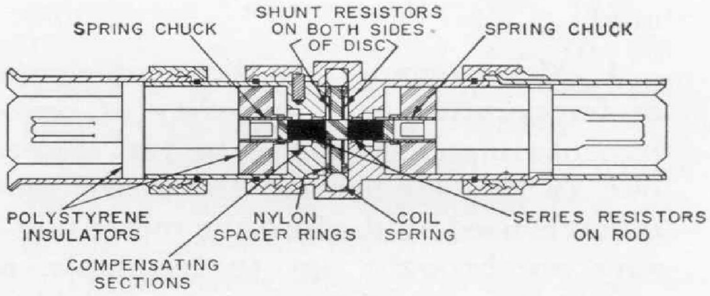


Figure 2. Cross-Section of Fixed Attenuator.

The T elements are mounted as shown in Figure 2, with the series elements connected to the center conductors of the input and output lines by means of spring chucks, and the shunt element connected to the outer shell of the line by means of a coil spring, which is pressed into a groove in the outer conductor. The outer edge of the disk on the T element slides into the ring formed by the spring, compressing the spring radially and causing each coil of the spring to make a good connection between the walls of the groove and the outer rim of the disk. In this manner, an excellent low-inductance connection is produced. The reactances of the elements in the tee are controlled by shaping the outer conductor in the vicinity of the resistive elements.

These pads are equipped with Type 874 Coaxial Connectors at each end. An extensive series of adaptors is available, which makes possible very low-reflection connections to most of the commonly used types of coaxial fittings.[1]

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[1] See *General Radio Experimenter* for March 1956, page 11.

VSWR

These pads have excellent VSWR characteristics. The VSWR of a typical unit from dc to 4000 Mc is shown in Figure 3. For a 20-db pad, the VSWR is below 1.1 up to 1000 Mc and below 1.30 up to 4000 Mc. The VSWR tends to be slightly higher in the lower attenuation units.

Attenuation

The magnitude of the attenuation varies only slightly with frequency and very slightly between units. At dc the 1% tolerance on the resistance elements can cause a maximum error of 0.17 db in the 20-db pad. This maximum error decreases with the attenuation of the pad. The variation in attenuation with frequency of a typical unit is plotted in Figure 3.

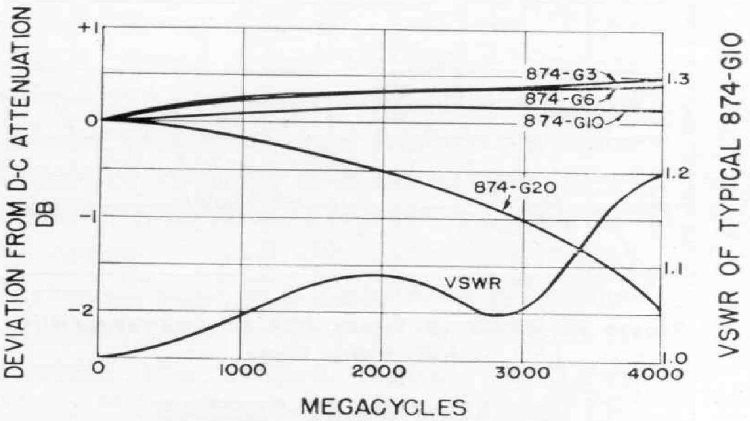

Figure 3. VSWR and Variation in Attenuation with Frequency for Type 874-G Fixed Attenuators.

Power-Handling Capacity

The continuous power rating of 1 watt cw is adequate for most applications. In pulse applications, the deposited-carbon elements will easily stand a pulse having a peak power of 3 kw as long as the average power does not exceed 1 watt.

Constant-Impedance Adjustable-Length Lines

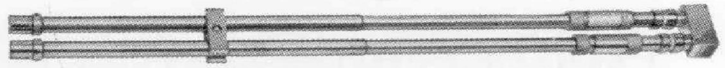

Figure 4. Type 874-LT Trombone Constant-Impedance Adjustable Line.

Two new adjustable-length lines have been developed. One, the Type 874-LT, consists of two Type 874-LK20* Constant-Impedance Adjustable Lines permanently connected to a U-block to form a "trombone" as shown in Figure 4. The advantage of this arrangement is that the length of line can be varied without moving either the input or output connections. In many applications, a considerable amount of bench space can be saved if the trombone is mounted vertically on a Type 874-Z Stand. Two Type 874-EL Ells can be connected to the ends of the line to make the input and output connectors face back-to-back on the same line.

The maximum variation in line length is 44 cm or one-half wavelength at 340 Mc. The VSWR of a typical unit is shown in Figure 5. This line stretcher is primarily designed for use below 2000 Mc, but can be used up to 5000 Mc.

Threaded holes are provided for attaching the unit to a lead-screw or rack-and-pinion drive if desired.

The second new adjustable line is the Type 874-LK10 Constant-Impedance Adjustable Line, which is a shorter version of the Type 874–LK20* Line. The new line is primarily designed for use above 1500 Mc since its length can be varied over a half wavelength at this and higher frequencies. There is, however, no low-frequency limitation on its use. Its small size makes it more convenient to use at the higher frequencies. The VSWR of a typical unit is shown in Figure 5.

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* Formerly, Type 874-LK.

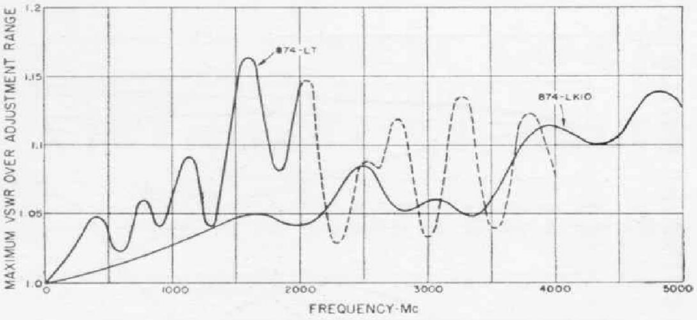


Figure 5. VSWR of Types 874-LT and 874-LK10 Adjustable Lines.

LOW-PASS FILTERS

Two new low-pass filters have been added to the line, for measurement applications in the frequency range above 1000 Mc. These units, the TYPE 874-F2000 and -F4000 Low-Pass Filters, cut off at 2000 Mc and 4000 Mc respectively and are similar to the TYPE 874-F185, -F500 and -F1000 Low-Pass Filters already available. All these filters are designed on a Tsychebyscheff basis, in order to obtain the maximum rate of cutoff and minimum spurious responses in the passband. The design allows a maximum of 4 db of insertion loss in the passband.

In measurements of high standing-wave ratios or of large values of insertion loss, the use of a low-pass filter to eliminate harmonics is usually necessary. The TYPE 874-F series of filters is well suited to these measurements. Figure 6 shows a typical frequency characteristic.

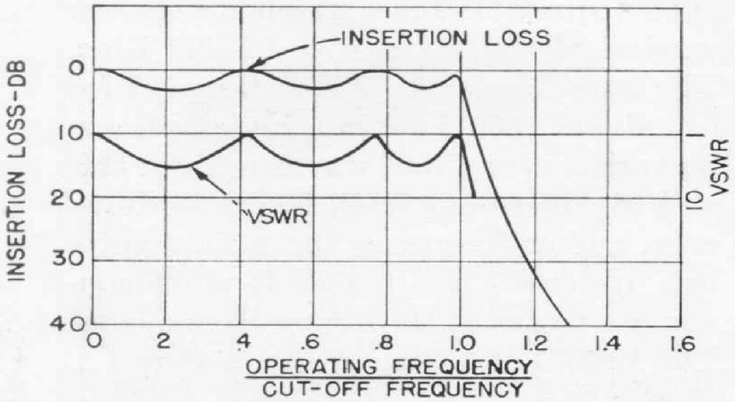


Figure 6 Typical Frequency Characteristic, Type 874-F Low-Pass Filter.

CRYSTAL VOLTMETER DETECTOR

In many measurements, a well-matched detector is needed, or a voltage at some point along a 50-ohm line must be measured or monitored without introducing a large discontinuity in the line. The TYPE 874-VQ Voltmeter Detector will perform either of these functions. As shown in Figures 7 and 8, it is similar to the TYPE 874-VR Voltmeter Rectifier, except that it does not contain a series 50-ohm resistor, and it does contain compensating elements to minimize the discontinuity produced by the shunt reactance of the crystal diode. As shown in Figure 9, this unit produces a very low VSWR in a matched 50-ohm line at frequencies up to 2000

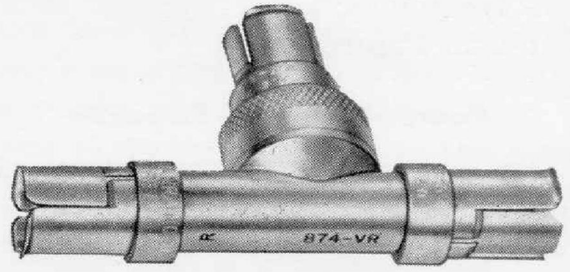


Figure 7. Type 874-VR Voltmeter Rectifier (similar to Type 874-VQ Voltmeter Detector).

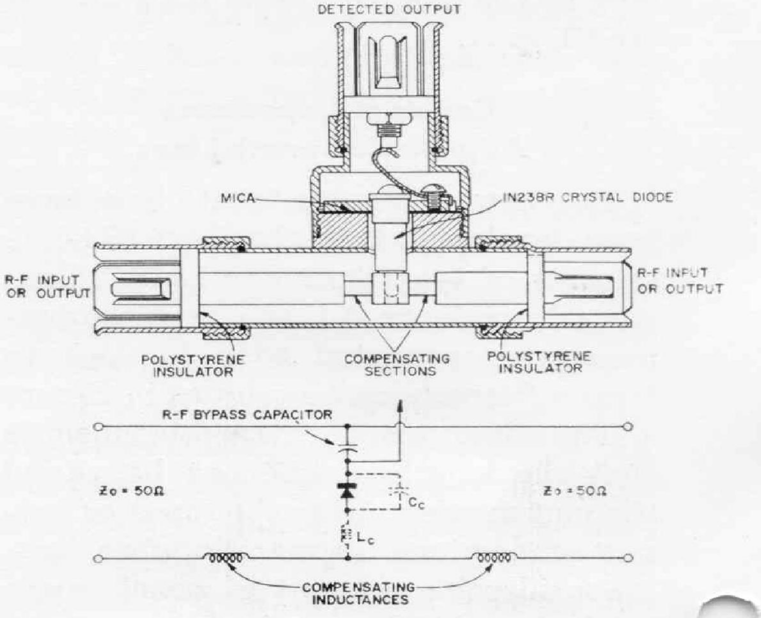


Figure 8. Cross-Section of Type 874-VQ Voltmeter Detector.

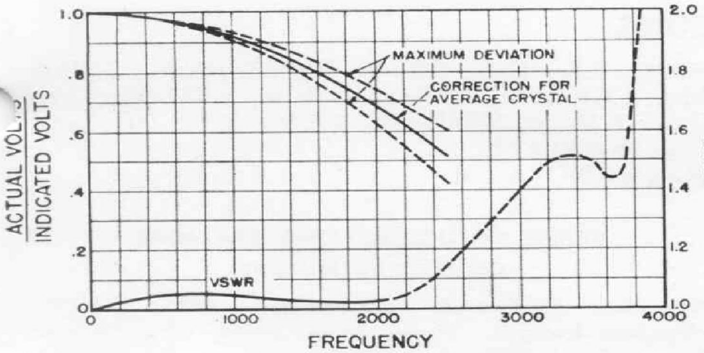


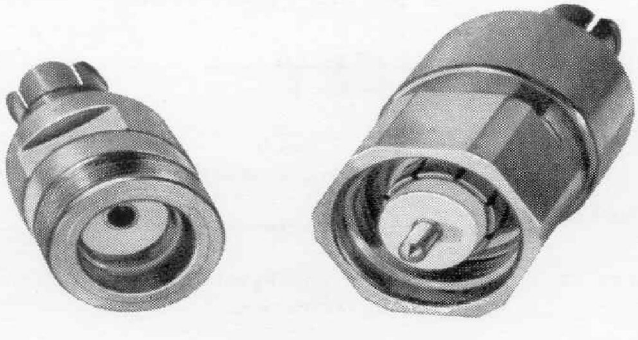
Figure 9. VSWR and Frequency Response of Type 874-VQ Voltmeter Detector.

Mc. The detector can therefore be inserted in a 50-ohm line without destroying the match. Above 2000 Mc, resonances in the crystal cause the VSWR to rise rather rapidly. For voltage measurement, the Type 874-VI Voltmeter Indicator is used. An ordinary d-c voltmeter can be used for monitoring power.

This detector can also be used to recover the modulation from the r-f signal; the modulation appears across the output connector. The output r-f bypass capacitor is 300 $\mu\mu$f; and, therefore, for modulation signals that include high-frequency components, a suitable load resistor must be connected across the output. When one end of the coaxial line is terminated in a Type 874-WM Termination Unit, the assembly can be used as a well-matched detector.

One important application is in conjunction with the Type 874-VR Voltmeter Rectifier, the Type 1263-A Regulating Power Supply, and the Type 1750-A Sweep Drive[2] for measurements of the transmission characteristics of various elements and networks. The voltmeter rectifier is used at the input to the unknown to keep the input voltage constant, and the voltmeter detector, terminated in a Type 874-WM Termination Unit, is used at the output to measure the output signal. A Type 1N23BR Reversed-Polarity Crystal Diode is supplied in order to present a right-side-up response curve on the face of an oscilloscope.

Figure 10. Types 874-QLJ and 874-QLP Adaptors.



ADAPTORS TO TYPE LC CONNECTORS

With the increased activity in the use of large-sized coaxial cable in high-power applications, there has been an increasing demand for adaptors to Type 874 Connectors to facilitate measurements on circuits fitted with Type LC Connectors. The Type 874-QLJ Adaptor mates with low-voltage Type LC plug-type connectors for Type RG17/U cable, similar to Type UG154/U; and the Type 874 QLP Adaptor mates with low-voltage jack-type connectors, similar to Type UG352A/U.

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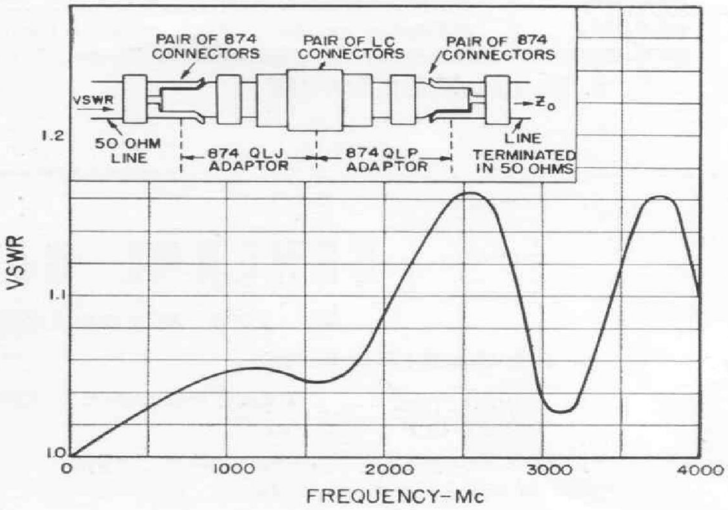
[2] See *General Radio Experimenter* for April, 1955.

Figure 11. VSWR and Diagram of Types 874-QLJ and 874-QLP Adaptors.



SPECIFICATIONS

TYPES 874-G3, G6, G10, G20 FIXED ATTENUATORS

Impedance: 50 ohms ± 1%.
VSWR: Less than 1.1 to 1000 Mc, 1.30 to 4000 Mc for 874-G20, 1.35 to 4000 Mc for all other attenuators.
Maximum Continuous Power Input: 1 watt.
Maximum Peak Power Input: 3000 watts.
Physical Length: 3½ inches over-all.
Weight: 2 ounces.
Accuracy of Attenuation in 50-ohm System: ± 1.5% of nominal attenuation at dc, ± 0.2 db from value indicated in Figure 3 to 1000 Mc, ± 0.4 db to 2000 Mc, ±0.6 db to 4000 Mc.
Temperature Coefficient: Less than 0.0003 db/°C/db.

TYPE 874-LT TROMBONE CONSTANT-IMPEDANCE ADJUSTABLE LINE

Characteristic Impedance: 50 ohms.
Frequency Range: D-c to 2000 Mc.
Adjustment Range: 44 cm (half-wave at 340 Mc).
Physical Length: Adjustable from 61 to 83 cm.
Spacing: 1 3/16 inches between centers.
VSWR: Less than 1.10 to 1000 Mc, and 1.25 to 2000 Mc.

TYPE 874-LK10 10-CM CONSTANT-IMPEDANCE ADJUSTABLE LINE*

Characteristic Impedance: 50 ohms.
Physical Length. Adjustable from 35 to 45 cm (half-wave at 1500 Mc).
VSWR: Less than 1.03 at 500 Mc, 1.06 at 1000 Mc, 1.08 at 1500 Mc, 1.10 at 2000 Mc, less than 1.15 at 3000 Mc, 1.2 at 4000 Mc, and 1.25 at 5000 Mc.
Weight: 10 ounces.

TYPES 874-F2000 AND 874-4000 LOW-PASS FILTERS

Accuracy of Cut-off Frequency: −0%, +10%.
Physical Length: Type 874-F2000, 4⅜ inches; Type 874-F4000, 2⅞ inches.
Weight: Type 874-F2000, 5 ounces; Type 874-F4000, 4 ounces.

TYPE 874-VQ VOLTMETER DETECTOR*

Maximum Voltage: 2 volts.
Resonant Frequency: Approximately 3600 Mc; correction curve supplied.
VSWR Introduced in a Matched 50-ohm Line: Less than 1.1 at 1000 Mc, less than 1.2 at 2000 Mc. Bypass Capacitance: Approximately 300 μμf.
Frequency Range For Use as Matched Detector: 500 kc to 2000 Mc. Can be used at frequencies up to 5000 Mc and down to 60 cycles (with external bypass capacitor).
Crystal: Type 1N23-BR Reversed Crystal to provide proper output polarity for use with d-c oscilloscopes.
Frequency Response: See Figure 9.
Dimensions: 3¾ by 2½ inches.
Weight: 5 ounces.

* Available in July, 1956.

Type	*Description*	*Code Word*	*Price*
874-G3	**Fixed Attenuator, 3 db**	COAXFULLER	**$25.00**
874-G6	**Fixed Attenuator, 6 db**	COAXNODDER	**25.00**
874-G10	**Fixed Attenuator, 10 db**	COAXPELLER	**25.00**
874-G20	**Fixed Attenuator, 20 db**	COAXNEPPER	**25.00**
874-LT	**Trombone Constant-Impedance Adjustable Line**	COAXTROMBO	**85.00**
874-LK10	**10-Cm Constant-Impedance Adjustable Line**	COAXKENTER	**33.00**
874-F2000	**Low-Pass Filter, 2000-Mc Cut-off**	COAXPUSHER	**14.00**
874-F4000	**Low-Pass Filter, 4000-Mc Cut-off**	COAXLENDER	**14.00**
874-VQ	**Voltmeter Detector**	COAXVOQUER	**30.00**
874-QLJ	**Adaptor to UG154/U or A/U Type LC Connector**	COAXLITTER	**17.50**
874-QLP	**Adaptor to UG352A/U Type LC Connector**	COAXLUGGER	**27.00**

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GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE
CAMBRIDGE 39 MASSACHUSETTS
TELEPHONE: TRowbridge 6-4400

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