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COVER

The Transfer-Function Meter described in this issue is a completely new, null-type device, which opens up a new field of measurement. The cover photograph shows the Transfer-Function Meter set up for the measurement of transistors at 400 Mc.

A TRANSFER-FUNCTION METER FOR THE VHF-UHF RANGE

The performance of most electrical devices and circuits can be described by specifying a transfer function, which is the ratio of an output to an input quantity, or vice versa. The "alpha" and "beta" current ratios of transistors, the transconductance of vacuum tubes, the gain of amplifiers, and the loss of attenuators and filters are common examples of widely used transfer functions. The new TYPE 1607-A Transfer-Function Meter[1] can measure these and many other transfer functions over the frequency range from 25 Mc to about 1500 Mc. Since grounded or ungrounded two-terminal impedances can be treated as four-terminal devices,[2] they can be measured as well, with appropriate adaptors. Answers, direct reading except for a multiplying factor, are obtained in terms of complex components by a null method. The phase information provided by measurement of complex components is especially valuable at these high frequencies, where effects of transit time, electrode resonances, and stray capacitances usually dominate the over-all performance of a device.

The Transfer-Function Meter is a basic measuring tool, well suited for laboratory measurements because of its versatility, accuracy, and wide frequency range. It can also be set up for rapid, routine, production tests on transistors, vacuum tubes, amplifiers, or networks, and a high degree of skill or knowledge on the part of the operator is not required. Several specific applications, with results of measurements, are described later in this article.

TYPES OF TRANSFER FUNCTIONS

For purposes of this discussion, four-terminal networks are considered to have separate, but grounded, input and output connections, and three-terminal networks are considered to have one terminal common to both input and output. There are several systems of parameters used to describe the electrical performance of these types of networks:

A. Open-circuit impedance parameters, which are the input and output impedances, Z_{11} and Z_{22}, and the forward and reverse transimpedances, Z_{21} and Z_{12}.

B. Short-circuit admittance parameters, which are the input and output admittances, Y_{11} and Y_{22}, and the forward and reverse transadmittances, Y_{21} and Y_{12}.

C. Hybrid combinations (such as the h parameters often used in transistor work) of impedance, admittance, open-circuit voltage-ratio, and short-circuit current-ratio parameters. For convenience, we define symbols to represent these voltage and current ratios as either E or I with appropriate subscripts, such as E_{21} to mean E_{out}/E_{in} with output open-circuited.

The Transfer-Function Meter can measure all of these functions.

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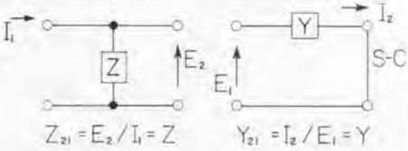
[1] Originally described in a paper presented at the 1956 IRE Annual Convention and subsequently published in the 1956 IRE Convention Record, Part 5, pp. 3-7: "A Transadmittance Meter for VHF-UHF Measurements," by William R. Thurston. The name of the instrument has been changed to Transfer-Function Meter so as to indicate more completely its uses.

[2] Grounded, two-terminal impedance — Ungrounded, two-terminal admittance



THEORY OF OPERATION

To measure a transfer function of a network, it is necessary to supply to it an input driving signal and to measure the resulting output signal in terms of the input signal. It is also necessary to terminate the network output in an open circuit if the desired output signal is a voltage, or in a short circuit if the desired output signal is a current. If the network were terminated otherwise, the answer obtained would depend on the network output impedance or admittance as well as on its transfer functions[3] and would, consequently, be less useful for general calculations.

Nevertheless, there are undoubtedly applications where one wishes only to determine the over-all performance of a network working into a *specific* load impedance. In these cases, it is necessary to include the termination as a part of the network under test. Where output current is of interest, the termination must be in series, and where output voltage is of interest, the termination must be in shunt.

Forward transfer functions are, of course, measured by driving the normal input terminals of a network under test, while reverse, sometimes called "feedback," transfer functions are measured by reversing the network and driving the normal output terminals. Two-terminal impedances or admittances can be connected as four-terminal networks in accordance with the diagrams given in Footnote 2, depending on whether a grounded or an ungrounded element is to be measured.

In the Transfer-Function Meter there are three identical loops, as shown in Figure 1, driven in parallel by an external generator adjusted to the desired frequency of measurement. The currents, I_L, in all three loops are equal in magnitude and phase. Each loop is loosely coupled, through electrostatically shielding slots, to an associated coaxial line. In Figure 1, only the inner conductors of these lines are shown. Each loop can be rotated independently of the others so as to vary its coupling, or mutual inductance, to its associated line. The mutual inductances are designated M_G, M_B, and M_X. The series voltages induced in the three lines by virtue of the couplings to the associated loops are: $E_G = -j\omega M_G I_L$, $E_B = -j\omega M_B I_L$, and $E_X = -j\omega M_X I_L$.

The outer end of the left-hand line, called the G line, is terminated in a

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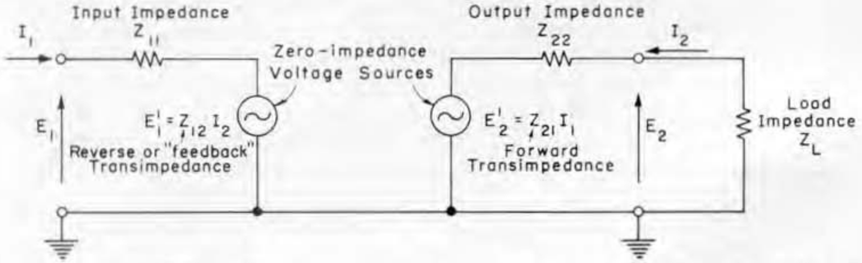
[3] Example: Equivalent circuit using impedance parameters:



Measured forward transimpedance =

$$\frac{E_2}{I_1} = \frac{E'_2/I_1}{1+\frac{Z_{22}}{Z_L}} = \frac{Z_{21}}{1+\frac{Z_{22}}{Z_L}} \cong Z_{21}, \text{ if } Z_L \gg Z_{22}$$

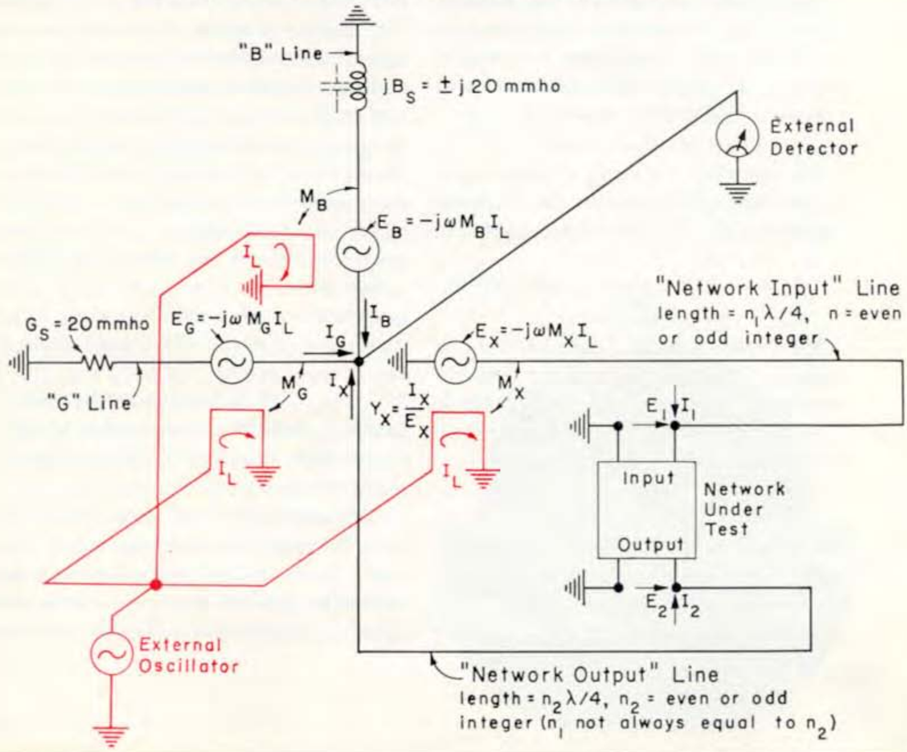
From circuit and equations given, it is seen that the measured transimpedance equals the value of Z_{21} only if the load impedance Z_L is very large compared to the network output impedance, Z_{22}. Otherwise the measured value is in error, and the error can be in phase angle, magnitude, or a combination of both, depending on the phase angles of Z_L and Z_{22}.

known, standard conductance, Y_0 (20 millimhos). The characteristic admittance of the coaxial lines and TYPE 874 Connectors used in the instrument and associated components is also equal to 20 millimhos (characteristic impedance, Z_0, is 50 ohms). The outer end of the upper line, called the *B* line, is terminated in a known, standard susceptance of $+jY_0$ at frequencies below 150 Mc (adjustable capacitor), $-jY_0$ between 150 Mc and 450 Mc (adjustable stub set to $\frac{\lambda}{8}$), and $+jY_0$ above 450 Mc (stub set to $\frac{3\lambda}{8}$). The far end of the right-hand line, which is adjustable in length and is called the *Network Input* line, is connected to the input of the network under test, and its electrical length is always set to equal either an odd or an even multiple, n_1, of a quarter wavelength, depending on which type transfer function is to be measured.

The near end of the *Network Input* line terminates in a short circuit. The inner ends of the *B* and *G* lines come together in a junction with two other lines not previously mentioned, as shown in Figure 1. One of these latter lines is connected to an external detector. The other, which is adjustable in length and is called the *Network Output* line, is connected to the output of the network under test. Its electrical length is always set to equal either an odd or an even multiple, n_2, of a quarter wavelength, depending on which type transfer function is to be measured, but not necessarily the same multiple as that to which the *Network Input* line is set.

The process of measuring complex quantities involves the balancing of the instrument by adjustment of the loop

Figure 1. Schematic diagram of r-f circuits of the Transfer-Function Meter.



couplings until the external detector indicates a null condition. At null, the voltage at the junction of the four coaxial lines is zero, and the three currents, I_G, I_B, and I_X, that enter the detector junction from, respectively, the G, B, and *Network Output* lines, must add up to zero. These line currents are readily calculated, because, for this purpose, the zero-voltage condition at the detector junction can be considered equivalent to a short circuit. For the purpose of simplifying the explanation, the lengths of the *Network Input* and *Network Output* lines will first be assumed to be zero. Under these conditions, $E_1 = E_X$ and $I_2 = I_X$.

The current, I_G, equals the induced voltage, E_G, times the admittance of the G line, which is the known, standard conductance, Y_0. That is,

$$I_G = Y_0 E_G = Y_0(-j\omega M_G I_L)$$
$$= Y_0 M_G(-j\omega I_L)$$

The current, I_B, equals the induced voltage, E_B, times the admittance of the B line, which is the known, standard susceptance, $\pm jY_0$. That is,

$$I_B = \pm jY_0 E_B = \pm jY_0(-j\omega M_B I_L)$$
$$= \pm jY_0 M_B(-j\omega I_L)$$

The current, I_X, equals the product of the induced voltage in the *Network Input* line, E_X, and the transadmittance of the network, Y_X. Therefore,

$$I_X = Y_X E_X = Y_X(-j\omega M_X I_L)$$
$$= Y_X M_X(-j\omega I_L)$$

When the sum of I_G, I_B, and I_X is equated to zero, which is the balance condition, the common $-j\omega I_L$ term is eliminated, and the basic balance equation for the instrument is obtained:

$$\frac{Y_X}{Y_0} = \frac{M_G}{M_X} \pm j\frac{M_B}{M_X}$$

The above equation is normalized with respect to the characteristic admittance of the line and corresponds to the dial calibration, which is normalized because impedances as well as admittances must be measured. As indicated above, the instrument actually measures the real and imaginary parts of the normalized transadmittance, $\frac{G_X}{Y_0}$ and $\frac{B_X}{Y_0}$, of the network connected directly between the input and output terminals of the instrument:

$$\frac{G_X}{Y_0} = \frac{M_G}{M_X}$$
$$\frac{B_X}{Y_0} = \frac{M_B}{M_X}$$

Since the connecting line lengths are assumed to be zero, $Y_{21} = Y_X$, $G_{21} = G_X$, and $B_{21} = B_X$. The mutual inductance, M_X, is the denominator in both the above equations and hence is a common multiplier. The values of the mutual inductances, M_X, M_G, and M_B, depend on the angular positions of the loops and hence can be adjusted from zero to a maximum value by rotation of the loops. The angular position of the G loop can therefore be calibrated directly in normalized transconductance, the B loop in normalized transsusceptance, and the X loop in a common multiplier. Figure 2 shows these calibrations, which are independent of frequency and which, by virtue of the positive and negative ranges for two of the three loops, allow measurements to be made in all four quadrants of the complex plane. The scale associated with the G loop is labeled the A scale and is calibrated from 0 to 1.5. The scale associated with the B loop is labeled the B scale and is calibrated from 0 to ± 1.5. The multiplier is calibrated from ± 1 to infinity.

The assumption of zero length of lines between the instrument and network made in the preceding analysis cannot be realized in practice, since the effective measurement points are located *within* the instrument. However, by the adjustment of the *Network Input* and *Network Output* lines to odd or even multiples of a quarter wavelength, the instrument can be made to indicate directly the transadmittance, transimpedance, complex transfer current ratio, and complex transfer voltage ratio of networks whose terminals are *not* directly the actual measurement terminals of the instrument. Each of the above measurements requires a different setting of the *Network Input* and *Network Output* lines and will be considered in detail in the following paragraphs.

In the following discussion, the term "half-wave setting" means that the line in question is set to an *even* multiple of a quarter wavelength, which is, of course, always a multiple of a half wavelength. A half-wave line has the property of "repeating" at one end all voltages, currents, and impedances appearing at the other end with 180 degrees of phase shift in voltages and currents for each half wavelength. Similarly, the term "quarter-wave setting" means that the line in question is set to an *odd* multiple of a quarter wavelength. A quarter-wave line has the property of "inverting" voltages into currents, impedances into admittances, and vice versa. The reversal of phase which occurs for each added half wavelength will be ignored, since it does not affect the basic theory of operation.

Transadmittance, Y_{21} and Y_{12}

The forward transadmittance of a network with its output terminals short-circuited is Y_{21}. In order to measure this parameter, the *Network Input* and *Network Output* lines are both adjusted to a half wavelength. Under these conditions the output terminals of the network under test are effectively short-circuited, because the half-wave *Network Output* line terminates at the detector junction, which under null conditions has zero voltage and can be considered to be a short circuit. The half-wave line produces a similar short circuit at the network terminals and makes $I_2 = I_X$. The input half-wave line makes $E_1 = E_X$. Therefore,

$$\frac{Y_{21}}{Y_0} = \frac{I_2/E_1}{Y_0} = \frac{I_X/E_X}{Y_0} = \frac{Y_X}{Y_0} = \mathrm{A} + \mathrm{jB}$$

where A and B are the *A* and *B scale* readings.

As previously shown, the instrument directly measures the normalized, real and imaginary components of Y_X, and from the above equation it is evident that it also indicates $\frac{G_{21}}{Y_0}$ and $\frac{B_{21}}{Y_0}$.

The reverse transadmittance, Y_{12}, can be measured by the same procedure as indicated for the forward transadmittance but with the input and output connections of the network interchanged.

Transimpedance, Z_{21} and Z_{12}

The forward transimpedance of a network with its output terminals open-circuited is Z_{21}. In order to measure this parameter, the *Network Input* and *Network Output* lines are both adjusted to a

Figure 2. Dial calibrations of Transfer-Function Meter.

quarter wavelength. Under these conditions the output terminals of the network under test are effectively open-circuited, because the quarter-wave *Network Output* line inverts the equivalent short circuit at the detector junction into an open circuit at the network. Also, the output quarter-wave line "inverts" the voltage E_2 into a constant times the current I_X, and the input quarter-wave line "inverts" the voltage E_X into a constant times the current I_1. It can be shown that

$$\frac{Z_{21}}{Z_0} = \frac{E_2/I_1}{Z_0} = \frac{I_X/E_X}{Y_0} = \mathrm{A} + \mathrm{jB}$$

where Z_0 is the characteristic impedance of the coaxial lines, 50 ohms. Thus the instrument reads directly the normalized transimpedance of the network under test. The readings are in terms of the normalized network transresistance, $\frac{R_{21}}{Z_0}$, read on the *A* scale, and the normalized transreactance, $\frac{X_{21}}{Z_0}$, read on the *B* scale.

Reverse transimpedance, Z_{12}, is measured in a similar manner with the input and output network connections reversed.

Transfer Current Ratio, I_{21} and I_{12}

The forward transfer current ratio of a network with its output terminals short-circuited is I_{21}. For this measurement the *Network Output* line is adjusted to a half wavelength and the *Network Input* line to a quarter wavelength. The output terminals of the network under test are effectively short-circuited, because the half-wave *Network Output* line "repeats" the equivalent short circuit at the detector junction as a short circuit at the network. The half-wave line also makes $I_2 = I_X$. The quarter-wave *Network Input* line makes

$$E_X = \frac{jI_1}{Y_0}. \quad \text{Therefore,}$$

$$I_{21} = \frac{I_2}{I_1} = \frac{jY_X}{Y_0} = \mathrm{B} + \mathrm{jA}$$

Thus the instrument reads directly the real and imaginary components of the complex transfer current ratio of the network. The "j" term in the above equation interchanges the real and imaginary scales.

The reverse transfer current ratio, I_{12}, can be measured by reversing the input and output connections to the network.

Transfer Voltage Ratio, E_{21} and E_{12}

The forward transfer voltage ratio, E_{21}, is measured with the network output terminals open-circuited. In this case the *Network Output* line is adjusted to a quarter wavelength and the *Network Input* line to a half wavelength. The output terminals of the network are effectively open-circuited because the quarter-wave *Network Output* line "inverts" the equivalent short circuit at the detector junction into an open circuit at the network. Also, because of the quarter-wave *Network Output* line, $E_2 = \frac{jI_X}{Y_0}$, and because of the half-wave *Network Input* line, $E_1 = E_X$. Therefore,

$$E_{21} = \frac{E_2}{E_1} = \frac{jY_X}{Y_0} = \mathrm{B} + \mathrm{jA}$$

Here again, the instrument indicates the complex open-circuit transfer voltage ratio of the network under test with the real and imaginary component scales interchanged from those used for transadmittance measurements because of the "j" term in the above equation.

Reverse transfer voltage ratio, E_{12}, can be measured by reversing the input and output connections to the network.

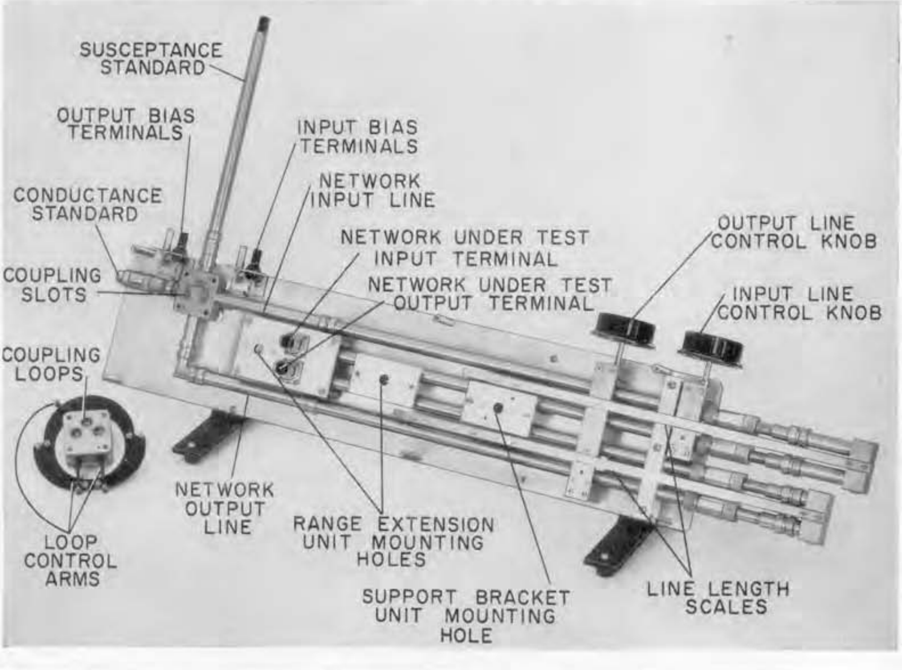
PHYSICAL DESCRIPTION

The physical arrangement of the parts of the Transfer-Function Meter corresponds closely to that shown in the schematic of Figure 1 and is illustrated further in Figure 3, in which the cover of the instrument has been removed and the coupling-loop assembly dismounted. At the left in Figure 3 can be seen the main junction block, in which coupling slots are cut into the coaxial lines within the block. When in place, each of the three loops in the coupling-loop assembly is centered over its respective slots and is coupled magnetically to the corresponding line. The *Network Input* and *Network Output* lines are of the constant-impedance, "trombone" type, driven independently by separate, rack-and-pinion drives having accurately calibrated scales to indicate total effective line lengths directly in cm. The lines are provided with locking sleeves to prevent accidental changes during prolonged work at a single frequency. All these parts are mounted on a heavy aluminum base plate.

In the measurement of active devices, especially transistors, it is important to keep the applied signal level low. In this instrument, the coupling loss of the loop between the external generator and the device under test is about 40 db at 500 Mc and decreases at a rate of 6 db per octave with increasing frequency. For tests on transistors, in which signal levels should be 5 millivolts or less, appropriate attenuators (874-G series) should be used to reduce the level of the signal supplied by the generator when necessary.

Since the external detector is usually of the heterodyne type with a local oscillator, it is important to prevent excessively high local-oscillator signals from appearing at the terminals of the unknown device. This problem is solved by the insertion of a tuned stub, or "trap," in parallel with the detector in-

Figure 3. The Transfer-Function Meter partially disassembled to show details of design and construction.



put and tuned to reject the local-oscillator frequency. This stub is supported horizontally behind the base plate of the instrument.

In measurements on active networks, d-c voltages or currents must be supplied without affecting the r-f circuits. In the Transfer-Function Meter, provisions are included for applying dc to both the input and the output of the network under test. The binding posts for connection to external power supplies are visible in Figure 3, and the internal filters and blocking capacitors are shown schematically in Figure 4. Built-in blocking capacitors isolate the measurement standards, the external detector, and the short circuit on the *Network Input* line. Filter networks, each comprising two chokes and two by-pass capacitors, allow insertion of d-c voltages and currents and prevent r-f leakage. Choke and capacitor ratings limit currents to 100 milliamperes and voltages to 400 volts. The loading effect of the input filter on the *Network Input* line is negligible, because of its proximity to the short-circuited end of the line. The only loading effect of the output filter on the detector line is a small reduction in detector sensitivity.

The range of adjustment of the *Network Input* and *Network Output* lines is such as to allow continuous coverage for all types of measurements above 300 Mc, plus separated bands of coverage below 300 Mc. In order to allow continuous coverage below 300 Mc, a set of extension lines is provided. When needed, these lines and their supports can be snapped into place by means of quarter-turn fasteners, as shown in Figure 5. This photograph also shows the shielded, variable capacitor used as the susceptance standard at low frequencies in place of the stub used at high frequencies.

Generator and Detector

General Radio Unit Oscillators are recommended for use as generators with the Transfer-Function Meter. The recommended detector is the General Radio Type DNT, a heterodyne type that combines high sensitivity with wide frequency range. Both generators and detectors are listed on pages 15 and 16.

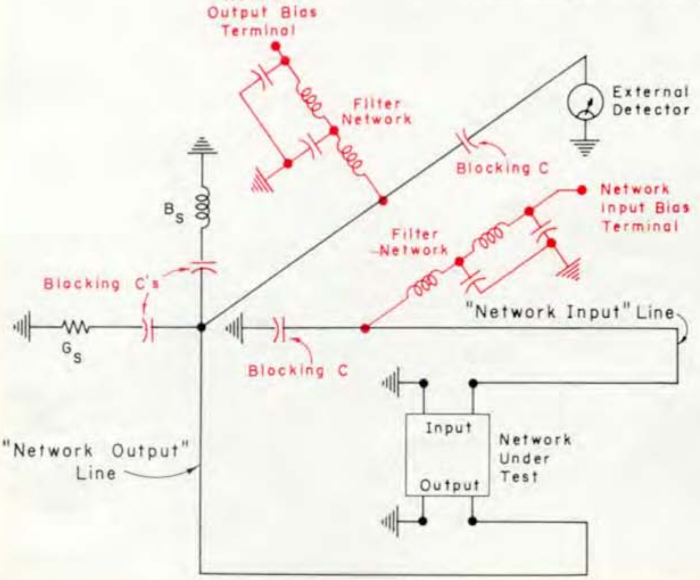


Figure 4. Schematic diagram of d-c circuits of the Transfer-Function Meter.

MEASUREMENT PROCEDURE

The equipment is set up by connecting generator, detector, and d-c supplies, if needed, to the Transfer-Function Meter, and making the necessary adjustments for desired operating frequency and d-c levels. The calibrated susceptance standard is also set to the operating frequency.

If isolation of the local-oscillator signal is desirable, as in measurements on transistors, the "trap" stub is included in the setup and is adjusted for maximum attenuation of the local-oscillator voltage.

Next, the *Network Input* and *Network Output* lines are set to the proper length, in accordance with the type of transfer function to be measured. An appropriate component mount is plugged into the *Network Under Test* connectors, and the unknown device or network is plugged into the mount. The three loop-control arms are then adjusted until the detector indicates a null, and the desired answer is read directly from the scale settings.

If several units of the same type are to be checked at a given frequency, as in the case of production testing of transistors or tubes, each unit successively is plugged into the mount (with due precautions regarding the d-c supplies), the control arms are set for a null, and the answer is read off the scales. This operation can be performed very rapidly by relatively unskilled personnel.

Terminals

The terminals used on the Transfer-Function Meter are Type 874 Coaxial Connectors. General Radio oscillators and detectors are also equipped with these terminals. When generators and detectors having other types of terminals are used, the Type 874-Q series of adaptors provides a convenient means of connection.

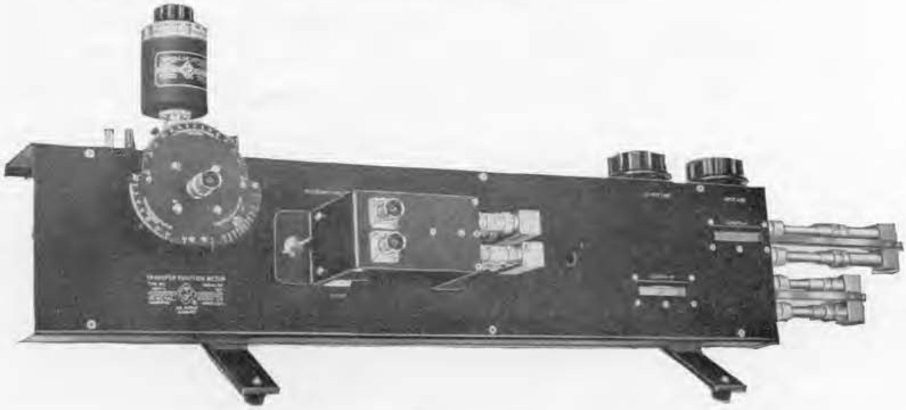
For most types of measurement, suitable mounts must be constructed (see Transistor Measurements, below) to connect the device being measured to the measuring terminals. Type 874 Coaxial Connectors to fit rigid line, panel, and cable are available for building into these mounts.

Both adaptors and connectors are listed on page 16.

Sources of Error

The major sources of error are incidental losses and small reflections in the *Network Input* and *Network Output* lines. The minor sources of error are similar to

Figure 5. View showing Range Extension Unit and low-frequency susceptance standard.



those in the Type 1602-B Admittance Meter[4, 5] and are spurious cross-couplings between the coupling loops and their associated lines, inductances between the junction center and the coupling points, incidental losses in the susceptance standard, and small reflections in the conductance standard.

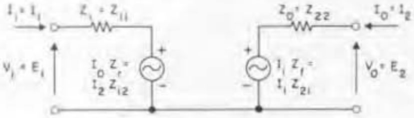
In most measurements, the instrument dial readings can be used directly without any corrections and will be accurate within the limits given in the specifications at the end of this article.

Some of these errors become appreciable under certain conditions, but corrections can be made for them.

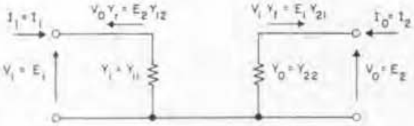
APPLICATIONS

Transistor Measurements

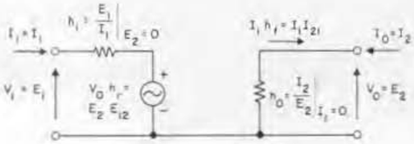
Several different network representations are used for transistors, the most common of which are shown in Figure 6. All of the transfer parameters indicated in these circuits can be directly measured with the Transfer-Function Meter at frequencies between 25 and about 1500 Mc.



A. OPEN-CIRCUIT IMPEDANCE PARAMETERS



B SHORT-CIRCUIT ADMITTANCE PARAMETERS



C. HYBRID PARAMETERS

Figure 6. Equivalent network representations of transistors. Left-hand set of symbols is from "IRE Standards on Electron Devices; Methods of Testing Transistors," *Proc. IRE*, Vol. 44, pp. 1542-1561, November, 1956. Right-hand set of symbols corresponds to those of this article.

Since many transistors operate at very low voltage levels, it is important that all applied signals be kept small during the measurements. As previously mentioned, the r-f signal level can be held below 5 mv, which has been found to be a satisfactory limit.

The high-frequency performance of a transistor or any other component can be greatly affected by the arrangement of the leads used to connect the element in a circuit. Therefore, for reproducible results, the mount used to connect the transistor to the measurement circuit must be standardized and must permit short leads. In a typical experimental transistor mount, the leads are connected to the measuring elements at a point about 1/32″ away from the case. This arrangement probably is reasonably close to that used in most practical high-frequency transistor circuits.

For measurement of the complex current ratios, α (or $-h_f$), the *Network Input* line is set to a quarter wavelength and the *Network Output* line to a half wavelength, as outlined in a previous paragraph. The local-oscillator trap is adjusted, with interchange of the generator and detector connections, by adjustment of the stub line until minimum output is observed on the meter of the detector. The normal connections are restored and the transistor mount plugged into the coaxial connectors on the panel of the instrument. The meter is then balanced by adjustment of the

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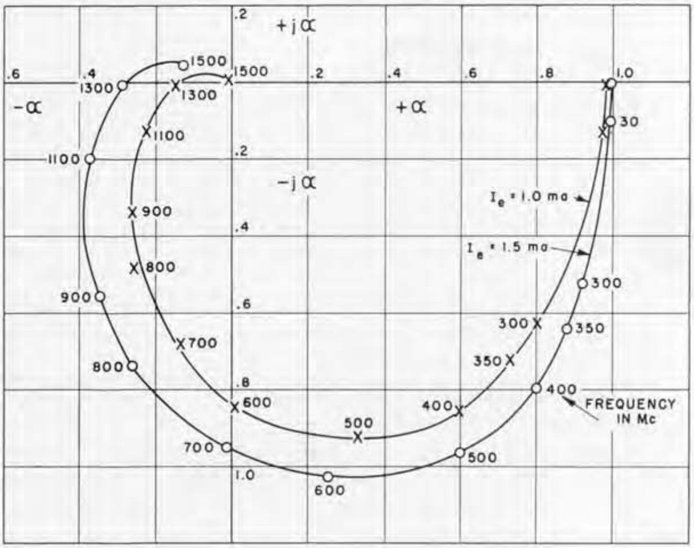
[4] Thurston, W. R., "A Direct-Reading Impedance-Measuring Instrument for the UHF Range," *General Radio Experimenter*, May, 1950.

[5] Soderman, R. A., "Improved Accuracy and Convenience of Measurements with Type 1602-B Admittance Meter in VHF and UHF Bands," *General Radio Experimenter*, August, 1953.

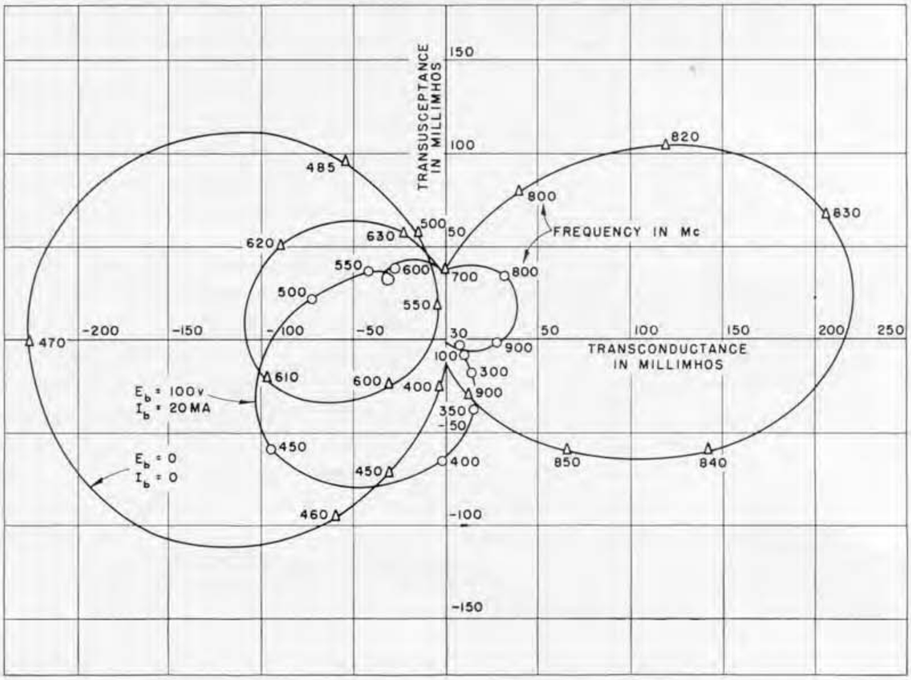
Figure 7. Plot of alpha versus frequency for an experimental high-frequency transistor supplied by Bell Telephone Laboratories.



three arms, and the real and imaginary components of the current ratio are indicated directly on the dial scales. The α-vs.-frequency characteristics of an experimental, Bell Telephone Laboratories, diffused-base, germanium transistor in a grounded-base connection are shown in Figure 7.

The hybrid feedback factor, $h_r (= E_{12})$, can be easily measured by reversal of the coaxial-line connections between the grounded-base mount and the instrument, which is accomplished by 180° rotation of the mount, reversal of the

Figure 8. Transadmittance versus frequency for a grounded-cathode 6AF4 vacuum tube.



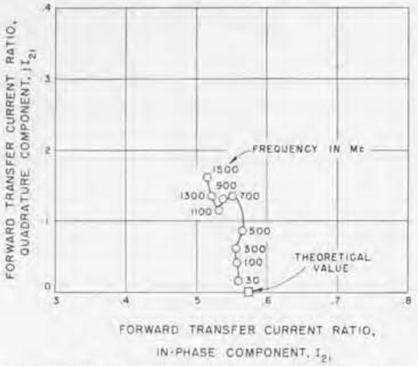


Figure 9. Forward transfer current ratio versus frequency for a Type 874-G10 Attenuator Pad.

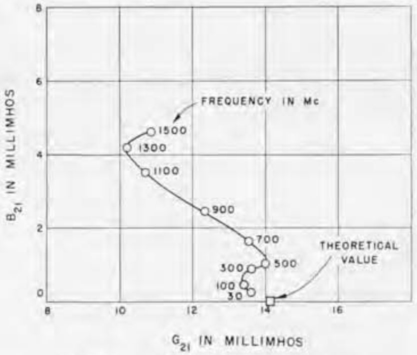


Figure 10. Forward transadmittance versus frequency for a Type 874-G10 Attenuator Pad.

d-c connections, and use of the procedure outlined for voltage-ratio measurements. Under these conditions the input is applied to the collector and the output is obtained from the emitter.

Tube Measurements

The high-frequency, complex, forward and reverse transadmittances of vacuum tubes can also be easily measured under dynamic conditions with the Transfer-Function Meter. D-C plate and bias voltages can be applied to the input and output terminals in the same manner as with transistors. Filters must be provided in the tube mount for heater and screen voltages. However, these filters are not so critical as are the filters associated with the input and output circuits. As with transistors, the mount must be carefully designed in order to give significant and reproducible results. The measured transadmittance of a 6AF4 in the grounded-cathode connection is plotted in Figure 8. The effective transadmittance first increases with frequency, apparently as a result of a resonance between the grid-cathode capacitance and cathode-lead inductance. At higher frequencies, other resonances are apparent, the largest one of which is probably a result of the grid-plate capacitance and plate lead inductance resonance. The large values of transadmittance shown do not result in correspondingly large magnitudes of gain when this tube is used in an amplifier, since the input impedance decreases rapidly as the resonances are approached.

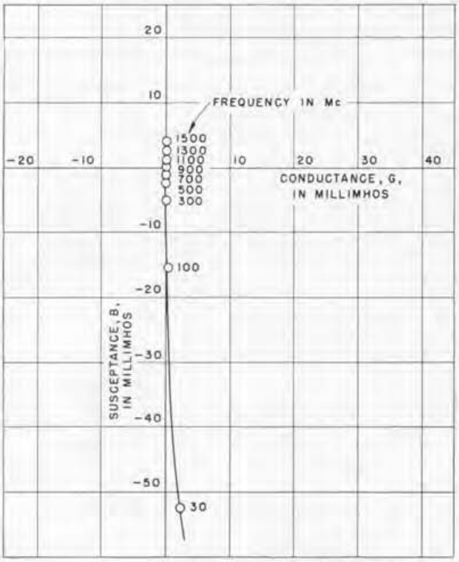


Figure 11. Admittance versus frequency for a 0.1-michrohenry inductor.

Coaxial-Component Measurements

The Transfer-Function Meter can measure the transfer admittance or impedance and attenuation of circuits fitted with coaxial connectors. Figure 9 shows the results of short-circuit, current-ratio measurements made on a Type 874-G10 Attenuator Pad, and Figure 10 shows transadmittance of the same pad. Other possible applications are for filters, coupling networks, amplifiers, and other four-terminal coaxial devices.

Lumped-Component Measurements

The direct admittance between the two ungrounded terminals of a circuit or component can be easily measured with this instrument. As is shown in the diagram in Footnote 2, the direct admittance measurement of a component with neither end connected to ground is not affected by the impedance from either side of the element to ground. This measurement is very useful for determining the characteristics of floating resistors, r-f chokes, capacitance between two ungrounded terminals, and many other three-terminal circuits. Figure 11 shows the direct admittance of one of the chokes used in the d-c supply filter in the Transfer-Function Meter.

—W. R. Thurston
R. A. Soderman

SPECIFICATIONS

Frequency Range: 25 to 1000 Mc, with reduced accuracy up to 1500 Mc.

Measurement Ranges and Accuracy:

Range	*Accuracy*
Voltage and Current Ratios (R) 0-30	$2.5\,(1+\sqrt{R})\%+0.025$
Transimpedance (Z_{21}) 0-1500Ω	$2.5\,(1+\sqrt{\frac{\lvert Z_{21}\rvert}{50}})\%+1.25\Omega$
Transadmittance (Y_{21}) 0-600 mmhos	$2.5\,(1+\sqrt{\frac{\lvert Y_{21}\rvert}{20}})\%+0.5\text{ mmho}$

D-C Bias: Terminals are provided for introducing d-c bias from external sources. Maximum bias current, 100 ma; maximum bias voltage, 400 volts.

Generator and Detector: Unit Oscillators and Type DNT Detectors (see list below) are recommended.

Other Accessories Available:

Type 1607-P101 Transistor Mount for JETEC-30 base arrangement, grounded base. Type 1607-P201 Tube Mount, 7-Pin Miniature grounded-cathode, for 6AF4, 6AF4A, and other tubes with same connections.

Case: The instrument, with accessories, is mounted in a wooden carrying and storage case 11¼ x 14½ x 40 inches.

Net Weight: 63 pounds.

Type		*Code Word*	*Price*
1607-A	**Transfer-Function Meter**	HYDRA	**$1525.00**
1607-P101	**Transistor Mount**		**Price on Request**
1607-P201	**Tube Mount**		**Price on Request**

GENERATORS*

Type	*Frequency Range*	*Code Word*	*Price*
1211-B	**0.5 — 50 Mc**	ATLAS	**$275.00**
1215-B	**50 — 250 Mc**	ADOPT	**190.00**
1209-BL	**180 — 600 Mc**	ADMIT	**245.00**
1209-B	**250 — 920 Mc**	AMISS	**245.00**
1218-A	**900 — 2000 Mc**	CARRY	**465.00**

*Require power supply below.

POWER SUPPLY*

Type		*Code Word*	*Price*
1203-B	**Unregulated**	ALIVE	**$40.00**
1201-A	**Regulated**	ASSET	**85.00**

*Plug-in type; supplies power to any one of the above oscillators.

DETECTORS

Type	*Frequency Range**	*Code Word*	*Price*
DNT-1	40 — 530 Mc...	NALTO	$626.00
DNT-2	40 — 280 Mc...	NERVO	606.00
DNT-3	220 — 950 Mc...	NULLO	659.00
DNT-4	870 — 2030 Mc...	NODDO	879.00

*Fundamental range. To cover a wider range than that listed for any one detector, harmonics of the local oscillator can be used. Thus Type DNT-2 will cover frequencies up to 1120 Mc if harmonics up to the 4th are used. Fundamental sensitivity is about 5 μv; 4th harmonic sensitivity, about 20μv. For this wide range, order also one Type 874-F1000 Low Pass Filter, price $14.00.

Another solution is to use the Type DNT-2 with an additional Type 1209-B Unit Oscillator (see Generators, above) and the Type 874-F1000 Filter. This covers the range with fundamental operation, which is, in general, more satisfactory. Harmonic operation is not recommended for measurement of active networks. Below 40 Mc, use a communications receiver.

COAXIAL ADAPTORS

Types QBJ and QBP

Type	*Fits*	*Code Word*	*Price*
874-QBJ	BNC Plug........	COAXBOGGER	$4.75
874-QBP	BNC Jack........	COAXBUNNER	4.75
874-QCJ	C Plug...........	COAXCOGGER	4.75
874-QCP	C Jack...........	COAXCUFFER	6.25
874-QNJ	N Plug...........	COAXNAGGER	3.75
874-QNP	N Jack...........	COAXNUTTER	4.50
874-QUJ	UHF Plug........	COAXYUNDER	4.00
874-QUP	UHF Jack........	COAXYUPPER	4.25
874-QHJ	HN Plug.........	COAXHAWSER	6.50
874-QHP	HN Jack.........	COAXHANGER	6.50
874-QLJ	LC Plug..........	COAXLITTER	19.50
874-QLP	LC Jack..........	COAXLUGGER	30.00

Adaptors are also available for connection to rigid air-dielectric lines.

COAXIAL CONNECTORS

Type 874-PB Panel Connector

Type 874-B Basic Connector, disassembled

PANEL CONNECTOR

The panel connector mounts with a flange and is available with rear fittings for commonly used RG-type cables. See the General Radio catalog for details. Connector listed below fits GR Type 874-A2 Cable, only.

BASIC CONNECTOR

The basic connector fits rigid, 50-ohm, air-dielectric coaxial line; ⅝″ OD and 9/16″ ID for outer conductor; 0.244″ rod for inner conductor.

Type		*Code Word*	*Price*
874-B	Basic Connector	COAXBRIDGE	$1.25
874-PB	Panel Connector	COAXAPPLER	2.90

CREDITS

The authors wish to express appreciation for the many helpful suggestions and other contributions of many individuals during the development of the Transfer-Function Meter, including Dr. J. M. Early and Mr. D. E. Thomas of the Bell Telephone Laboratories, and Mr. R. Wohl, Mr. S. Friedman, Mr. M. Zimet, and Mr. D. Youla of the Material Laboratory, New York Naval Shipyard.

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