OPERATING INSTRUCTIONS

TYPE 1661-A

VACUUM-TUBE BRIDGE

1661-A

GENERAL RADIO COMPANY

307-L

OPERATING INSTRUCTIONS

TYPE 1661-A

VACUUM-TUBE BRIDGE

Form 307-L
March, 1959

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

SPECIFICATIONS

Range: Amplification factor (μ), 0.001 to 10,000.

Dynamic internal plate resistance (r_p), 50 ohms to 20 megohms.

Transconductance (g_m), 0.02 to 50,000 micromhos.

Under proper conditions, the above ranges can be exceeded. The various parameters can also be measured with respect to various elements, such as screen grids, etc. Negative as well as positive values can be measured.

Accuracy: Within ±2% for resistances (r_p switch position) from 1000 to 1,000,000 ohms. At lower and higher values the error increases.

The expression $\mu = r_p g_m$ will check to ±2% when the quantities are all measured by the bridge, and when r_p is between 1000 and 1,000,000 ohms.

Tube and Transistor Mounting: Adaptors are provided for 3- and 4-lead transistors (including JETEC 30) and for tubes of 4-pin, 5-pin, 6-pin, small 7-pin, large 7-pin, octal, loctal, miniature button 7-pin, miniature button 9-pin (noval), acorn (5- and 7-pin), flat-press sub-miniature up to 7 wires, and 8-wire sub-minar. In addition, a universal adaptor, with nine soldering lugs, is provided so that unbased transistors, unmounted tubes, or tubes with non-standard bases can be measured conveniently. For short-lead sub-miniature tubes and for transistors, sockets are supplied which can be mounted on the universal adaptor. Thus all standard commercial receiving tubes and transistors can be measured. The panel jack plate and the adaptors are made of low-loss (natural) phenolic, reducing to a minimum the shunting effect of dielectric losses on the dynamic resistance being measured.

Current and Voltage Ratings: Maximum allowable plate current, 400 ma; maximum plate voltage, 1500 volts.

Electrode Voltage Supply: Batteries or other suitable power supplies are necessary for providing the various voltages required by the device under test.

Bridge Source: Type 1214-E Oscillator is recommended.

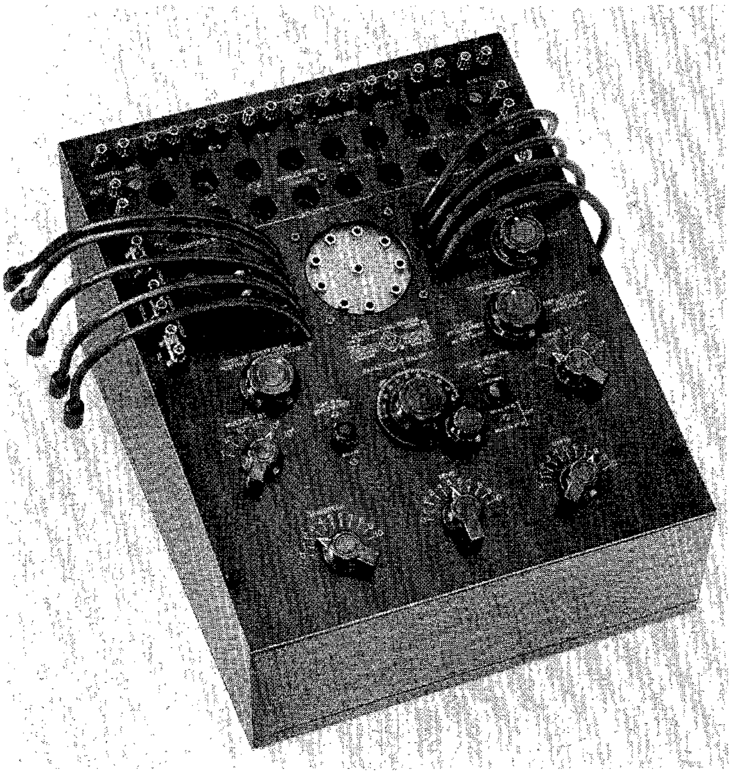
Null Detector: The Type 1212-A Unit Null Detector with the Type 1951-E Filter is recommended.

Accessories Supplied: Adaptors as listed above, all necessary plug-in leads, and shielded patch cords for connecting generator and detector.

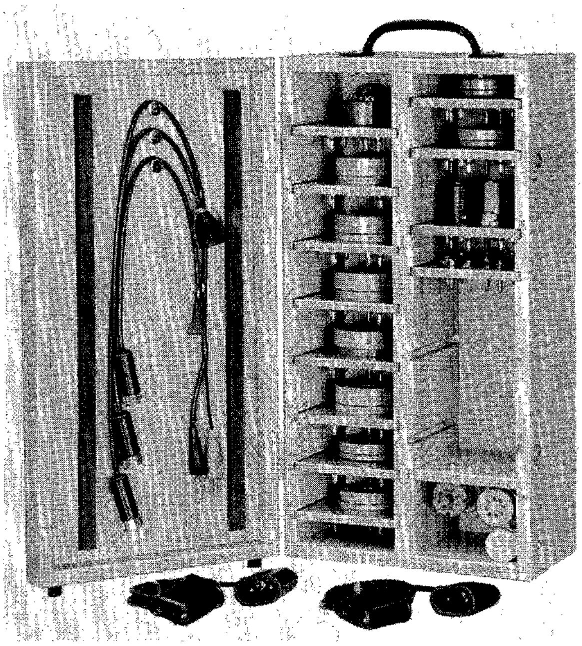
Mounting: The instrument is mounted in a hardwood cabinet. A wooden storage case is provided for the adaptors and leads. Storage space is provided for a spare Universal adaptor, on which any type of socket can be permanently mounted.

Dimensions: (Length) 18½ x (width) 15¾ x (height) 11 inches.

Net Weight: Type 1661-A weighs 40 pounds. The accessories supplied and the accessory box weigh 14 pounds.



Left: Type 1661-A Vacuum-Tube Bridge.
Below: Accessory Storage Case.



TYPE 1661-A
VACUUM-TUBE BRIDGE

1.0 PURPOSE

The Type 1661-A Vacuum-Tube Bridge makes possible the measurement of the low-frequency dynamic coefficients of vacuum tubes and transistors over very wide ranges of values, and under a wide variety of operating conditions. The circuits used are such that independent, direct-reading measurements of forward and reverse voltage-amplification factor, resistance, and transconductance can be made quickly and easily. Interelectrode and other stray capacitances are balanced out in such a manner that awkward correction factors, common to most vacuum-tube bridge circuits, are unnecessary.

The procedure in making measurements is simple and straightforward, and the three coefficients, voltage-amplification factor, "plate" resistance, and transconductance are obtained by following exactly the same procedure. A three position switch is turned to whichever quantity is desired, multiplier switches are set at the appropriate value, and balance is obtained by adjusting a three-decade attenuator and a variable condenser. At balance the decades read directly, to three significant figures, the quantity being measured.

The circuits have large enough current-carrying capacity and sufficient insulation so that low-power transmitting tubes may be tested in addition to receiving tubes and transistors.

The measuring circuits and the control portion of the bridge are completely separated, connection between the two being made by a flexible concentric plug-and-jack arrangement. This makes it possible to measure conveniently grid circuit parameters, or in the case of multi-element tubes and of transistors, parameters referred to any pair of electrodes.

Negative values of the coefficients can be measured directly as readily as positive values, except that in some cases precautions must be taken to prevent dynatron oscillations.

2.0 GENERAL CONSIDERATIONS

A vacuum-tube, a transistor, an attenuator, or an amplifier can each be considered as a 4-terminal transducer as in Figure 1. Two equations can express the input and output currents in terms of applied voltages and four admittance parameters. At the low frequencies used for the bridge (270 to 400 cycles and 1000 cycles), the real (conductance) component only of the admittance is significant. The four conductances are sufficient to define completely the characteristics of the transducer.

$$i_1 = g_{11} v_1 + g_{12} v_2$$

$$i_2 = g_{22} v_2 + g_{21} v_1$$

g_{11} and g_{21} are the input conductance and the forward transconductance obtained with the output terminals shorted. The parameter g_{11} is the reciprocal of the hybrid parameter h_i. g_{22} and g_{12} are the output conductance and the reverse transfer (feedback) conductance with the input terminals shorted. The Type 1661-A Bridge indicates (as resistance) the reciprocal of the input conductance g_{11} and of the output conductance g_{22}; it indicates directly as a transconductance the forward transconductance g_{21} (g_m of a vacuum tube)

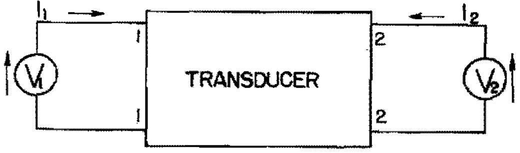


Figure 1. The bridge sees a transducer, regardless of whether it is a tube, transistor, amplifier or attenuator.

and the reverse transconductance g_{12}. In usual vacuum-tube measurements, only the reciprocal of g_{22} (r_p, the plate resistance) and the forward transconductance, g_{21} (g_m), are important. In transistor measurements, the four parameters are important.

The current-amplification factors can be derived from the conductance values, as follows:

Forward current-amplification factor, $\alpha_{21} = -\frac{g_{21}}{g_{11}}$

Reverse current-amplification factor, $\alpha_{12} = -\frac{g_{12}}{g_{22}}$

The Type 1661-A Bridge can measure the voltage-amplification factors (μ) directly. The forward voltage-amplification factor, μ_{21}, is important in vacuum-tube applications. The reverse voltage-amplification factor, μ_{12}, and the forward current-amplification factor are important in transistor applications. The reverse voltage-amplification factor is the hybrid parameter h_r. The forward current amplification is often referred to as β in common emitter applications and as α in common base applications.

The input and output resistance, the transconductances and the amplification factors are the dynamic coefficients of the transducer.

In addition to the short-circuit conductance parameters and the amplification factors described above, transistor applications are also concerned with open-circuit impedance parameters and with hybrid parameters.

At the low frequencies used for the bridge, the impedance parameters can be considered as resistance parameters. They are derived from the following two equations for the unterminated (open-circuit) condition:

$$V_1 = r_{11}i_1 + r_{12}i_2$$

$$V_2 = r_{22}i_2 + r_{21}i_1$$

The resulting parameters are:

r_{11} = input resistance with output a-c open-circuited
r_{22} = output resistance with input a-c open-circuited
r_{12} = reverse transfer resistance with input a-c open-circuited
r_{21} = forward transfer resistance with output a-c open-circuited

These parameters are easily determined from the conductance parameters as described in Section 6.0.

The h or hybrid parameters are quite generally used in transistor applications. They are derived from the two following equations, when the output is a-c short-circuited and the input is a-c open-circuited:

$$V_1 = h_i i_1 + h_r V_2$$

$$i_2 = h_f i_1 + h_o V_2$$

h_i is the input impedance with the output terminals a-c short-circuited. It is the reciprocal of the conductance parameter g_{11}.

h_r is the reverse transfer voltage ratio with input a-c open-circuited. It is the same as the reverse voltage-amplification factor μ_{12} discussed with the conductance parameters.

h_f is the forward transfer current ratio with the output a-c short-circuited. It is the same as the forward current-amplification factor α_{21} discussed with the conductance parameters.

h_o is the output resistance with the input a-c open-circuited.

3.0 PRINCIPLES OF OPERATION

The dynamic coefficients are defined in terms of small incremental voltages or currents in the various electrode circuits. Voltage-amplification factor, for example, is a measure of the change in output voltage required to balance out the effect on the output current of a small change in input voltage.

Although the coefficients are defined in terms of small d-c increments of voltage and current, (or more strictly speaking, as partial derivatives of the operating function), measurements may usually be more conveniently obtained in terms of small alternating voltages superimposed on the steady electrode values. When a-c methods are employed, however, precautions must be taken to insure that the test voltages are accurately in phase, and that stray reactances such as those of the inter-electrode capacities of a tube do not introduce serious error. In the design of the Type 1661-A Vacuum-Tube Bridge particular attention was paid to eliminating these potential sources of error.

With the circuits employed, each of the coefficients is obtained in terms of the ratio of two alternating test voltages. A third voltage is employed in the capacitance-balancing circuit, but its value does not enter into the results.

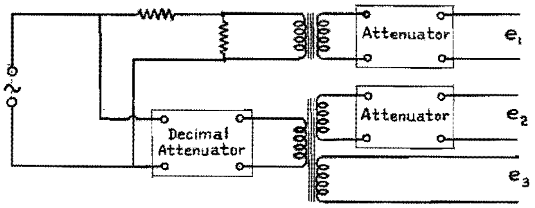


Figure 2. Simplified Diagram of Source of Test Voltages.

Figure 2 shows the circuit for the production of the test voltages. It will be seen first of all that the three voltages are obtained from separate transformer windings so that they are insulated from one another for direct current. This makes it possible to connect the supplies for the electrode voltages to ground potential where they will not increase the stray capacitances.

In order that all three voltages shall be in phase and that the ratio e_2/e_1 shall be accurately determinable, the transformers employed are identical with the exception of the capacitance-balancing winding, which draws negligible current. The respective primary circuits are designed so that both transformers work out of the same resistance. The secondaries work into identical attenuators.

The input attenuator to the second transformer has three dials, the setting of which determines to three significant figures the voltage ratio e_2/e_1 and consequently the factor being measured. The attenuators on the secondary side introduce as multiplying factors various powers of 10, and consequently determine the position of the decimal point in the result.

In Figure 3 are shown simplified circuit diagrams indicating the manner in which the test voltages are introduced into the electrode circuits for the measurement of the coefficients.

In all cases it will be seen that the voltage e_3 in series with a variable condenser is connected directly across the telephones, resulting in quadrature current in opposition to that flowing through the tube or transistor capacitances. If the rest of the measuring circuit is properly designed, this method of obtaining the quadrature balance results in the capacitances having negligible effect on the measured result for extremely wide ranges of the coefficients.

At the center of each diagram is given the equivalent circuit, omitting the capacitance-balancing system.

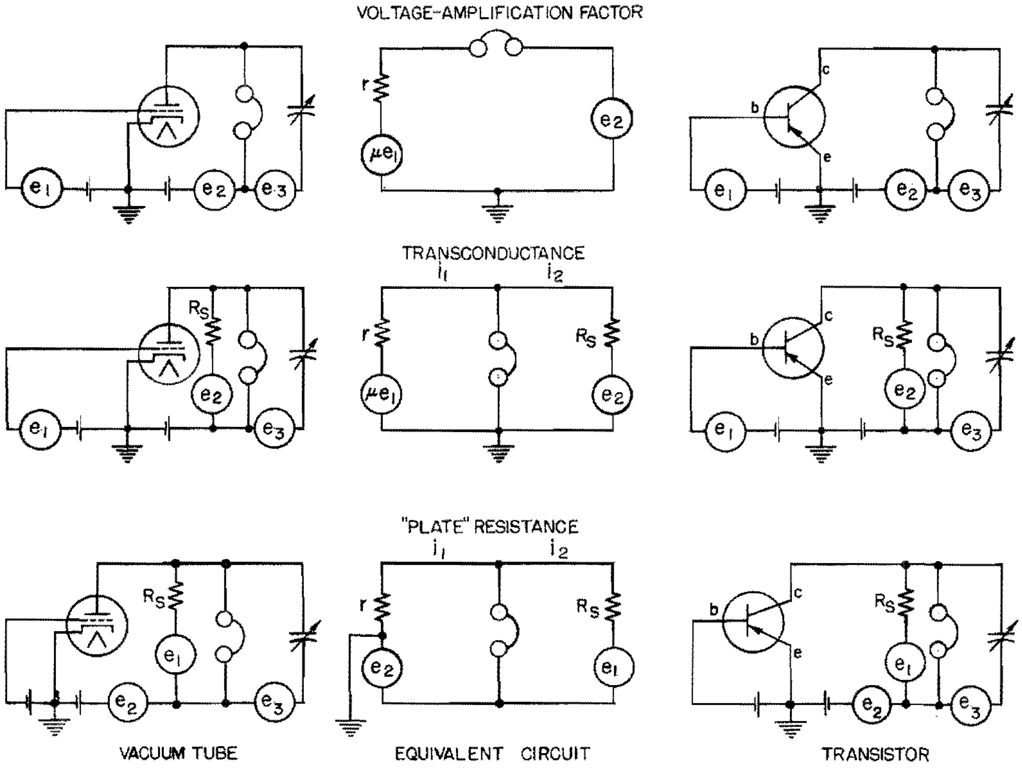
In the circuit for the measurement of voltage-amplification factor the alternating voltage e_1 in the input circuit results in an equivalent voltage μe_1 in series with the output resistance. Balance is obtained when the voltage e_2 is equal and opposite to this equivalent voltage. Then

$$\mu e_1 = e_2$$

or

$$\mu = e_2/e_1$$

Since at balance there is no a-c current flowing in the output circuit, the output is effectively a-c open-circuited.


VOLTAGE-AMPLIFICATION FACTOR

TRANSCONDUCTANCE

"PLATE" RESISTANCE

VACUUM TUBE

EQUIVALENT CIRCUIT

TRANSISTOR

Figure 3. Simplified Diagrams of the Measuring Circuits.

In measuring transconductance we wish to determine the alternating output current flowing as a result of a small voltage introduced into the input circuit, under the condition that there shall be no alternating voltage at the output. The diagram shows that the condition is satisfied, because the telephones are connected directly at the output, and at balance there is no voltage across the telephones.

The equivalent circuit shows that the measurement is made by what is essentially a current balance rather than a voltage balance. The output current is balanced against the current flowing through a standard resistance R_s. When the currents i_1 and i_2 are equal there is no voltage across the telephones. Consequently,

$$i_1 = \mu e_1/r$$

$$i_2 = e_2/R_s$$

and the balance condition becomes

$$\mu e_1/r = e_2/R_s$$

or

$$\frac{\mu}{r} = g = \frac{e_2}{e_1}\frac{1}{R_s}$$

The remaining diagram shows the circuit for the measurement of output resistance. The operation is exactly the same as that of the circuit for obtaining transconductance. The only change is that the test voltage is in the output circuit instead of in the input circuit, and that since a resistance instead of a conductance is being measured, the voltages e_2 and e_1 are interchanged. As before, the balance condition is

$$e_2/r = e_1/R_s$$

or

$$r = R_s e_2/e_1$$

When measuring vacuum-tube coefficients, usually the forward coefficients only are of interest. The "r" and "g" in the above equations are then, r_p, the plate resistance and g_m, the transconductance.

In the circuits for both voltage-amplification factor and transconductance it is evidently necessary that the resistance of the voltage source in the input circuit be low enough so that e_1 is actually applied to the input without change of magnitude or phase. This is the usual condition when measuring vacuum tubes since the input circuit is the grid circuit and its resistance is very high. When measuring transistors, however, the input-circuit resistance can be low and a correction may be necessary. This correction rarely exceeds two percent and usually is negligible. See "CORRECTION DUE TO SOURCE RESISTANCE" on page 11.

Other conditions which must be satisfied in the measuring equipment are that the resistance of both e_1 and e_2 be small in comparison with the standard resistance, and that the resistance of e_2 be small compared with the lowest electrode resistance to be measured.

The conditions are usually satisfied. Even when measuring low-resistance transistors, the error in indicated resistance is less than 1% if 1Ω is subtracted from the measured value. See "CORRECTION DUE TO SOURCE RESISTANCE" on page 11.

It will of course be understood that the discussion given in this section applies not only to the measurement of the usual three coefficients of a triode but also to the measurement of all parameters referred to any pair of electrode circuits in transistors and in the more complex types of electron tubes. In the measurement of the usual grid-circuit coefficients, for example, it is necessary only to interchange grid and plate connections in the diagrams given. Negative amplification factor and transconductance are commonly observed in this case, and are measured by reversing the phase of e_1 by means of the SIGN-OF-COEFFICIENT switch provided.

An effort has been made to refine the design of the measuring circuits to such an extent that no changes of operating technique will be required even over the large ranges of coefficient values encountered in the various electrode circuits of vacuum tubes and of transistors.

A more complete analysis of the circuits employed in the bridge will be found in the paper "Dynamic Measurement of Electron Tube Coefficients" by W. N. Tuttle, Proceedings of the Institute of Radio Engineers 21, pp. 844-857, June, 1933.

4.0 CONSTRUCTIONAL DETAILS

MEASURING CIRCUITS

The switches, multipliers, and dials associated with the measuring circuit are conveniently grouped together on the lower half of the panel. The measuring circuits are brought out to the PLATE, CONTROL GRID and CATHODE panel plugs. When measuring a transistor, or in general when measuring any transducer, the panel plugs labelled PLATE connect to the transducer output and the panel plugs labelled CONTROL GRID connect to the transducer input. Multiple terminals are provided so that multi-element tubes and twin-section tubes may be conveniently measured with various groupings of electrodes.

CONTROL CIRCUITS

All connections from the tube or transistor under test to the measuring circuits and to the necessary electrode voltage supplies are made through the plug and jack arrangement on the upper portion of the panel. At the very top of the panel is a row of eight pairs of supply terminals. These, with the exception of the AC filament terminals, have a common ground connection. Each of the remaining ungrounded terminals is connected to one of the upper row of eight concentric panel plugs. The high side of the PLATE and CONTROL GRID panel plugs are connected directly to the measuring circuit and provide voltage for the pair of electrodes whose coefficients are being measured (normally "plate" and "control grid" for vacuum tubes, in general "output" and "input" for transducers such as transistors).

MOUNTING

On the panel is mounted a nine-point jack base, into which any one of twelve plug plates, each carrying a standard type of socket, may be plugged. A "universal" plug-plate, with soldering lugs, is also provided so that tubes or transistors with non-standard bases or unmounted tubes can be measured. Nine shielded cables terminated in concentric cable jacks protrude from the panel and are connected to the nine terminals of the jack base. Each cable is identified by a number engraved on the panel. The wiring arrangement of the plug plates is such that this number always corresponds to the number of the terminal on the tube socket to which it is connected. Grid lead connectors, for both large and small grid caps, are supplied. These leads are shielded and similar to those connected to the jack base.

The twelve adapter plug plates (in addition to the "universal" adapter) provide for 3- and 4-lead transistors (including JETEC-30) and for tubes of 4-pin, 5-pin, 6-pin, small 7-pin, medium 7-pin, loctal, octal, noval, miniature 7-pin, and acorn (5-pin and 7-pin) design.

In addition to the plug plates, two adapters are supplied for measuring the long-lead sub-minar and flat-press sub-miniature tubes. These adapters plug into the octal plug plate. For sub-miniature tubes with short wire leads and for some transistors, two types of transistor sockets, separate 5-pin, 6-pin and 7-pin flat-press sub-miniature sockets and an 8-pin sub-minar socket are supplied. They can be wired directly to the "universal" plug plate.

These sockets as well as the adapters, plug plates and jack base are moulded of low-loss phenolic. Dielectric losses are thus kept at a minimum and the usefulness of the bridge for the measurement of high-impedance tubes or transistors is enhanced.

ELECTRODE VOLTAGE CONNECTIONS

The various electrode voltages are connected to the several pairs of terminals at the top of the bridge. One side of all voltage sources (except the a-c filament terminals) is at ground potential. This arrangement prevents stray capacitance from supplies to ground from entering into the measurement – an important consideration with high-impedance devices.

VOLTAGE AND CURRENT RATING

The Type 1661-A Bridge has a maximum d-c "plate"-voltage rating of 1500 volts, and a maximum "plate"-current rating of 400 milliamperes.

5.0 OPERATING INSTRUCTIONS

AUXILIARY EQUIPMENT

In addition to supplies for the various electrode voltages, the necessary auxiliary equipment consists of a source of 270-400- or 1000-cycle voltage, and an amplifier with a meter or a pair of head telephones or an oscilloscope.

The input impedance of the bridge is from 550 to 2100 ohms so that either a high- or low-impedance voltage source may be employed without serious mismatch loss. The General Radio Company Type 1214-E Unit Oscillator provides an adequate and convenient source of 270- and 1000-cycle voltage.

Amplifier - It is not necessary that the amplifier employed with the bridge be extremely sensitive, although it will usually be found desirable to have available a voltage gain of at least 40.

The most important characteristic of the amplifier is that it shall be free from outside disturbances, especially pickup, either electrostatic or electromagnetic, from the oscillator supplying the test voltage.

The output circuit of the bridge is of high impedance, so that no input transformer should be used to couple to the first tube of the amplifier. There is a direct-current path between the output terminals. The output transformer of the bridge is tuned to either 1000 cycles or the 270- 400-cycle range depending on the setting of a panel switch.

The General Radio Type 1212-A Unit Null Detector is generally satisfactory for use with the vacuum-tube bridge. It has ample gain, is completely shielded, is self-contained and indicates the balance condition on a large panel meter. When measuring noisy tubes or transistors, greater selectivity may be desirable and can be provided by inserting a Type 1951 Filter between the bridge and the null detector. The Type 1951-A Filter is tuned for 400- and 1000-cycle operation. The Type 1951-E is for 270- and 1000-cycle operation. Since the ear can distinguish a signal in the presence of considerable noise, headphones at the terminals in the rear of the Type 1212-A Detector will permit measurements in spite of an unusually noisy condition.

An alternative detector is the Type 1231-B Amplifier used with the Type 1231-P2 or 1231-P5 Filter and with head telephones.

The Type 1231-B Amplifier is also useful as a preamplifier for the Type 1212-A Unit Null Detector if greater sensitivity than that provided by the Type 1212-A Unit Null Detector alone is desired.

"NOISE"

So-called "noise" is often traceable to one of the power supplies or to the power line. To evaluate the noise source, turn off and disconnect the oscillator; with an oscilloscope connected to the output of the amplifier, set the oscilloscope for triggering from the power line. If the noise source is from a power supply or due to pickup from the power line or from a power-line-operated device, the pattern on the oscilloscope will be stationary. It may consist of pulses, square-waves, or damped high-frequency waves repeated at line-frequency periods. Power-supply rectifiers are essentially off-on switches that not only rectify but also set up surges. Thyratrons can produce damped high-frequency patterns. Semiconductor and vacuum-tube rectifiers also yield their own peculiar high-frequency-surge patterns. If the amplifier input (with isolating capacitor) is connected directly to the plate power-supply output, the noise source may be studied more directly. Usually, careful shielding of the leads from the bridge and the use of a shielded filter will eliminate noise due to B supply or to pickup.

A large spurious signal can be obtained if connections to cathode and heater are not correctly made. When at all possible, connect the heater supply to the A-C FIL terminals, neither of which is grounded. When three heater connections must be used (for example, to connect 6.3 volts to a 6.3/12.6-volt heater), connect the 6.3-volt supply to the D-C Fil terminals, connect the tube heater tap to D-C FIL + and the other two heater leads to the grounded panel plugs either side of the cable arrays. Do not use a CATHODE panel plug for grounding either of the heater leads, because the large heater current and the cathode will then be grounded by a common lead and the a-c voltage drop, though small, will be amplified by the tube and produce a large "noise" signal in the output.

EXTERNAL CONNECTIONS

To prepare the bridge for operation, connect the voltage source and the amplifier to the terminals provided, using the shielded cables and making certain that the low potential sides are connected to the posts marked LOW. Connect a ground wire to the indicated point at the top of the bridge.

For the bias at the control-grid terminals it is desirable to use a fresh battery in order to keep the input-circuit resistance as low as possible. If an a-c rectifier power supply or a potentiometer voltage control is used, or in general if the d-c voltage source has appreciable impedance, a by-pass capacitor of about 40 microfarads should be connected at the control-grid-voltage terminals of the bridge when measuring vacuum tubes, and a by-pass capacitor of at least 750 microfarads when measuring relatively low-input-resistance devices such as transistors. The d-c current through the capacitor may be appreciable and should be considered when measuring the d-c current to the electrode. It is necessary that the control-grid and the plate supplies be entirely separate, especially for large values of coefficient as any appreciable coupling between the two circuits will introduce error into the measurement.

Either batteries or well-filtered, rectified a-c may be used for the "plate" and "screen" supplies. Except where good batteries are used without controlling resistances, all electrode voltages should be separately by-passed. If the output resistance of the device being measured is low, as it can be for transistors, the by-pass capacitor should be at least 750 microfarads. The d-c current through the capacitor may be appreciable and should be considered when measuring the d-c current to the electrode. One method is to connect the ammeter between the capacitor and the bridge terminal taking care to short out the ammeter when obtaining a bridge balance to avoid pickup errors.

When using large capacitors at the CONTROL-GRID and PLATE bridge terminals, the circuit time constant may be annoyingly long if the battery potentiometer or power-supply resistance is too large. As a consequence, an appreciable time will be required to reestablish equilibrium conditions each time the electrode voltage is changed. The obvious solution is the use of low-resistance voltage controls; for example, a 5000-ohm voltage divider is satisfactory when the by-pass capacitor is 750 microfarads.

TUBE CONNECTIONS

With the proper plug plate inserted in the jack base at the center of the panel, plug the tube or transistor in the socket. If the tube or transistor does not fit one of the standard plug plates, solder its leads (or leads from a special socket) to the soldering lugs on the UNIVERSAL plug plate. Using a chart of the tube or transistor base connections as a guide, connect the electrodes to the power supplies and the "plate", "grid", and "cathode" bridge circuits by plugging the numbered concentric-jack patch cords into the appropriate panel plugs. The loose ends of the unused patch cords can be anchored securely out of the way by plugging into the four grounded panel plugs or the two ungrounded panel plugs either side of the jack plate.

There is a choice of "plate", "grid", and "cathode" bridge-circuit panel plugs. For a single-section tube (or for a transistor), use the SINGLE "plate" and the SINGLE "cathode" panel plug, use either of the two "grid" panel plugs, and set the TUBE SECTION SWITCH to SINGLE. For a two-section tube, connect one section to the "plate", "grid", and "cathode" panel plugs labeled I and the other section to the plugs labeled II. When measurements are being made, switch the TUBE SECTION SWITCH sequentially from SECTION I to SECTION II obtaining a bridge balance with the switch first at I, then at II. With the switch at SECTION I, the "plate", "grid", and "cathode" of the section I are connected to the bridge and receive the appropriate plate and grid voltages; the corresponding electrodes of section II are grounded. With the switch at SECTION II, the section II electrodes are active and the section I electrodes are grounded. When the switch is set to SINGLE, the electrodes of both sections are paralleled and are connected to the bridge. See Figure 4. The above circuit description assumes that the shorting links at the

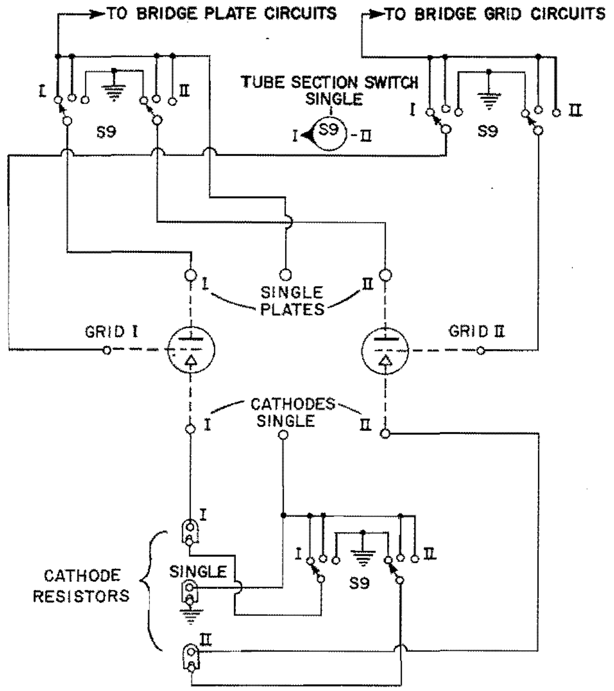


Figure 4. Schematic of connections made by the TUBE SECTION SWITCH. Patch-cord connections can be made for two-section tubes, as shown, for sequentially testing each section without the need of rearranging patch cords. For a single-section tube, the patch cords would be plugged into the PLATE and CATHODE positions labeled SINGLE and into either the I or II grid position.

three pairs of CATHODE-RESISTOR binding posts at left side of the panel are in place. These binding posts are provided to permit connection in circuit cathode-biasing resistors (bypassed or not) or transistor common-electrode resistors. For a single-section tube (or for a transistor) connect the resistor at the binding posts labeled SINGLE. For a two-section tube, connect the separate resistors at I and II with the shorting link in place at the SINGLE terminals. If the same resistor may be used for either section, connect it at the SINGLE terminals and place the shorting links at terminals I and II.

If it is desired to open the cathode circuit of the inactive section while the active section is being tested and to open the cathode circuits of both sections when the switch is at SINGLE, plug the cathode patch cord of tube section I into the CATHODE panel plug II and the patch cord of tube section II into the CATHODE panel plug I; connect the cathode resistor of tube section I to the CATHODE RESISTOR terminals labeled II; connect the section II resistor to the terminals labeled I; remove the shorting link from the SINGLE CATHODE RESISTOR terminals. See Figure 5.

ELECTRODE VOLTAGES

The voltages at the tube or transistor electrodes are essentially the same as the voltages at the bridge terminals. If the output current is quite large, however, the d-c voltage drops across the resistance of the "cathode resistor" and of the primary of the output transformer (34 ohms) and across the "DIVIDE BY" attenuator (5 ohms at 1, 9 ohms at 10 and 1 ohm at 10^2, 10^3, 10^4, and 10^5) may be significant. Similarly, if the electrode voltage is small as it sometimes is when measuring transistors, the d-c voltage drops, though small, may be relatively important. The supply voltage may be corrected for the drops, if necessary, or a voltmeter may be connected between a free "PLATE" panel plug and ground (or the high side of the "cathode resistor" terminal).

With the TUBE SECTION SWITCH at SINGLE, all three PLATE panel plugs are connected together and either of the unused panel plugs is available for "plate"-voltage measurements. With the TUBE SECTION SWITCH at either the SECTION I or the SECTION II position, the PLATE panel plug labeled SINGLE can be used. The voltmeter and its connecting leads must be disconnected before balancing the bridge to avoid errors due to unwanted pickup.

Since the power supplies for transistors can be small batteries, entire multi-stage amplifiers with their supplies can be mounted on the UNIVERSAL adaptor to obtain the amplifier characteristics under normal load conditions.

One precaution should be noted, if the device under measurement is located some distance from the plug plate. The lead connecting through to the PLATE terminal of the measuring circuit must be shielded with the shield connected to the internal PLATE lead shielding of the bridge. The special coaxial lead with the two clip terminals supplied as an accessory can be inserted into the PLATE panel plug to make the connection. It should be noted that the shield terminal is at high d-c potential.

MEASUREMENT ON LOW-POWER TRANSMITTING TUBES

Small transmitting tubes can be measured in an external socket as described above. The plate voltage should be disconnected when the position of the coefficient switch is changed in order to avoid the possibility of arcing between the switch points. It is important that neither the current-carrying capacity nor the voltage rating of the bridge, 400 milliamperes and 1500 volts, respectively, should be exceeded.

MEASUREMENT OF AMPLIFICATION FACTOR, TRANSCONDUCTANCE, AND OUTPUT RESISTANCE

The method of balancing the Type 1661-A Bridge is exactly the same for all three coefficients and for both forward and reverse connections. Set the coefficient switch to the quantity which it is desired to measure, set the LOW Rp - HIGH Gm switch and turn the MULTIPLY BY and DIVIDE BY switches to the proper settings determined by the magnitude of the coefficient. Table I will be found helpful in making these settings. Balance the bridge by varying the three decimal attenuator controls at the bottom of the panel and the CAPACITANCE BALANCE dial. Always have either the MULTIPLY BY or DIVIDE BY switch set at the position "1". This gives maximum sensitivity and accuracy. The SIGN OF COEFFICIENT switch is usually at POSITIVE for vacuum-tube measurements. It sometimes is at NEGATIVE for the measurements of some transistor coefficients.

When a null indication is obtained, the three decimal attenuator dials at the bottom of the panel read directly the value of the coefficient to three significant figures. The factor associated with the particular coefficient, the setting of the LOW Rp - HIGH Gm switch and the setting of the MULTIPLY BY or DIVIDE BY attenuators must be taken into account when determining the location of the decimal point. Table I shows the ranges of the coefficients for various switch settings.

Balance should be obtained, if possible, with the CAP. BAL. MULTIPLIER pushed in, as the adjustment is less critical in this position. It is only when the cur-

TABLE I

COEFFICIENT RANGES OF TYPE 1661-A VACUUM-TUBE BRIDGE

Voltage Amplification Factor	Setting of Attenuators		Low Rp-High Gm Switch
	Multiply By	Divide By	
0.0001 - 0.001	1	10^3	No effect
0.001 - 0.01	1	10^2	"
0.01 - 0.1	1	10	"
0.1 - 1	1	1	"
1 - 10	10	1	"
10 - 100	10^2	1	"
100 - 1000	10^3	1	"
1000 - 10000	10^4	1	"
Mutual-Conductance Micromhos			
0.001 - 0.01	1	10^3	IN
0.01 - 0.1	1	10^2	"
0.1 - 1	1	10	"
1 - 10	1	1	"
10 - 100	10	1	"
100 - 1000	10^2	1	"
1000 - 10000	10^3	1	"
1000 - 10000	10^2	1	OUT
10000 - 100000	10^3	1	"
Plate Resistance Ohms			
10 - 100	1	10^2	OUT
100 - 1000	1	10	"
1000 - 10000	1	1	"
10000 - 100000	1	0.1	"
10000 - 100000	1	1	IN
10^5 - 10^6	10	1	"
10^6 - 10^7	10^2	1	"

rents through the electrode capacitances are relatively large that it will be found necessary to pull out the multiplier switch.

If excessive test voltage is applied, results will not be satisfactory. In this case the harmonics generated will usually be noticeable and will indicate that the voltage applied to the bridge should be reduced. In any case, the voltage applied should be sufficiently small so that further reductions do not appreciably change the measured coefficient values.

A check on the precision of the balances can be obtained by measuring all three parameters independently and substituting the values into the equation $\mu = rg$. The equation should check within 2%, if the device has reached stable operating conditions.

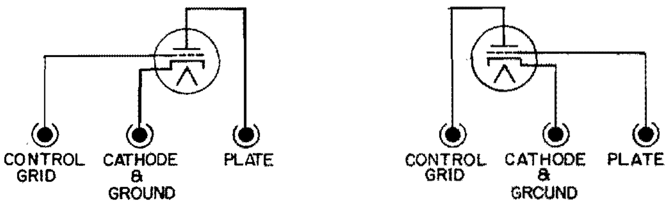
MEASUREMENT OF INPUT-CIRCUIT COEFFICIENTS

The input resistance, inverse voltage-amplification factor, and inverse transfer conductance of a tube or of a transistor are measured by interchanging the connections as indicated in Figure 5. When the measuring circuit connections are interchanged, the supply voltages must also be interchanged. The measurement is made in the conventional manner and the ranges of the coefficients shown in Table I apply equally well to the input-circuit coefficients. Negative values are usually encountered, however, and it is necessary in these cases to throw the SIGN-OF-COEFFICIENT switch accordingly. It is usually necessary to keep the input voltage to the bridge small when measuring the input-circuit coefficients.

To measure grid conductance of a tube directly, instead of its reciprocal, grid resistance, make the cross connections as illustrated in Figure 5 (e). Set the coefficient switch to TRANSCONDUCTANCE and proceed in the usual manner. The same factors are used to locate the decimal point as in the case of mutual conductance, and the ranges are tabulated in Table I.

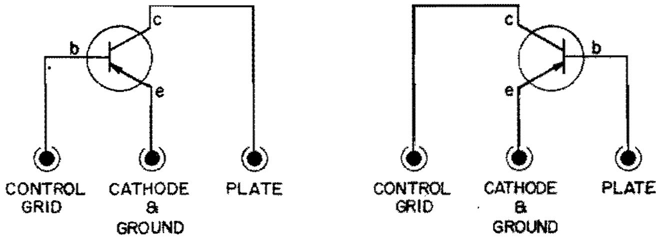
MEASUREMENT OF COEFFICIENTS REFERRED TO ANY PAIR OF ELECTRODES

In the connections described for the measurement of input-circuit coefficients it will be observed that the "grid" and "plate" circuits are merely interchanged in



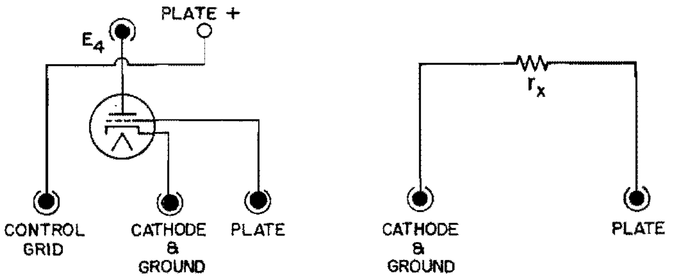
(a) Connections for measurement of μ, g_m and r_p of a tube.

(b) Connections for measurement of reverse μ and g and of r_g of a tube.



(c) Connections for measurement of (forward) μ_{21}, g_{21} and r_{out} of a transistor (common emitter).

(d) Connections for measurement of (reverse) μ_{12}, g_{12} and r_{in} of a transistor (common emitter).



(e) Measurement of grid conductance of a tube. Set COEFFICIENT switch to MUTUAL COND. Connect plate voltage to E-4 terminals and grid bias to CONTROL GRID terminals.

(f) Measurement of Resistance.

Figure 5.
Connections for Typical Measurements.

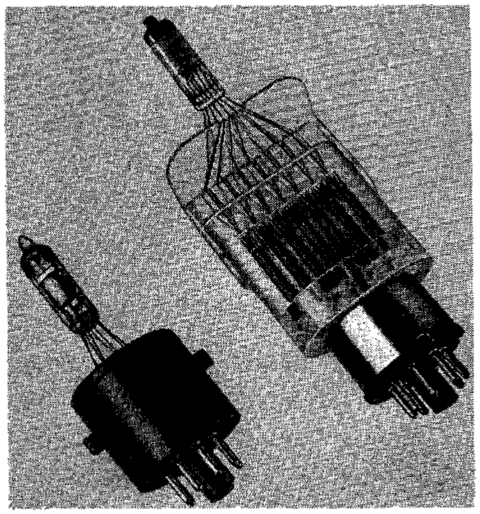


Figure 6. Adaptors for sub-miniature tubes. Flat-press types with up to 7 leads are tested in the Type 561-415-2 Adaptor with a comb-like structure for selecting and guiding the leads into the spring contacts. Eight-wire subminar tubes are tested in the round Type SOA-3 Adaptor, which has provision for locking the leads into the socket. Both types plug into the standard octal plug plate.

their connections to the measuring circuits. In a similar manner any electrode can replace the "plate" and any other electrode the "grid".

MEASUREMENT OF NEGATIVE ELECTRODE RESISTANCE

Dynatron oscillations will occur when the negative plate resistance of a tube is lower than the impedance of the output transformer. Oscillation can always be prevented by connecting a resistance lower than the negative plate resistance across the output transformer. This connection (between the PLATE terminal and plate shield may be made through one of the PLATE panel plugs by means of the special coaxial lead supplied.

No correction need be applied for the shunt resistance employed, as the measurement of none of the three coefficients is affected. A slight reduction in sensitivity will generally be observed, however.

MEASUREMENT OF RESISTANCE

When the coefficient switch is thrown to PLATE RESISTANCE the Type 1661-A Vacuum-Tube Bridge measures the a-c resistance between the PLATE and CATHODE terminals of the measuring circuit. An external resistance can be conveniently measured by connecting it between a pair of terminals of the jack base, with the corresponding connector cables connected to the PLATE and CATHODE panel plugs. No batteries are needed and the PLATE battery terminals should be short-circuited to maintain circuit continuity, when resistance measurements are being made.

The bridge is balanced for external resistance in exactly, the same manner as for "plate" resistance, the multiplying factors fot resistance values being the same as for "plate" resistance, given in Table I.

The bridge is sufficiently sensitive that losses in many insulating materials may readily be measured. It should be noted that the result is the equivalent parallel resistance, the parallel capacitance being balanced out.

TRANSISTOR COMMON ELECTRODE

The vacuum tube is usually operated with grounded cathode but it can be connected with grounded grid or with grounded plate (cathode follower). Similarly the transistor can be connected with grounded emitter, grounded base, or grounded collector. The transistor can be measured for anyone of these connections on the bridge. Moreover, if the coefficients have been determined for one circuit arrangement, the coefficients for the other circuit arrangements can be computed from the simple equations of Table III.

CORRECTION FOR DIELECTRIC LOSSES AND LEAKAGE

When high values of either dynamic electrode resistance or external resistance are being measured it is necessary to consider the errors resulting from losses in the tube base, in the sockets, and in insulating material in certain parts of the bridge. Such a-c losses are usually considerably greater than the d-c leakage. The losses in the transistor base can not be separated out by the method outlined below but all other losses including those in the transistor socket can be corrected for.

All these losses, together with the d-c leakage resistance are equivalent to a single resistance, R_L, connected between the "plate" and ground. The measured output resistance r' is therefore the parallel resistance of R_L and the actual output resistance (r).

The resistance R_L of the losses can readily be measured separately by making the "plate" resistance measurement as usual, with all connections made, but with the filament unlighted or with the transistor out of its socket. In making this test on a tube, it should have been operating for some time previously with normal electrode voltages and with the filament lighted in order that the base may be at the usual operating temperature.

R_L, exclusive of losses in the tube base or transistor socket is normally in excess of 100 MΩ, but the losses in the base and socket may lower this value to a point where it is desirable to correct for it when measuring resistances of one megohm or greater.

TABLE II

A-C RESISTANCE OF VOLTAGE SOURCES		
A-C RESISTANCE AT e_1 ("MULTIPLY BY" SWITCH)	SWITCH SETTING	A-C RESISTANCE AT e_2 ("DIVIDE BY" SWITCH)
1 ohm	10^2 to 10^5	1 ohm
9.3 ohms	10	9.3 ohms
27.2 ohms	1	27.2 ohms

When measuring the effective parallel resistance of external resistors or dielectrics more accurate results will be obtained if correction is made for the bridge losses in all cases where the open circuit reading is less than 100 times the resistance being measured.

The correction is readily made as follows. Let us call r' the measured resistance, R_L the resistance measured with the filament turned off or the transistor or external resistor disconnected and r the true value of resistance. Then

$$r = r' \left[\frac{R_L}{R_L - r'} \right]$$

It can readily be shown that the measured amplification factor is less than the true value by the same factor as the output resistance. Hence

$$\mu = \mu' \left[\frac{R_L}{R_L - r'} \right]$$

where μ' is the directly measured value of voltage amplification factor, and μ is the true value.

The transconductance measurement is not affected by the leakage resistance.

TRANSISTOR MEASUREMENTS

There are two general types of transistors classified according to the nature of the boundary between the N (negative) and P (positive) regions of the semi-conductor: the junction type where the boundaries are relatively large areas and the point-contact type where the boundaries are at or near "cat-whisker" contacts. The point-contact type was first developed; it is noisier and less stable because of inherent positive feedback. Stable operation is obtained by introducing some external positive resistance in series with one of the electrodes to counteract the effects of the internal negative resistance. Manufacturers suggest from 500 to 1000 ohms. It is well to use the same value of resistance that will be used eventually in the circuit application. The junction type is inherently stable.

In both types, the input as well as the output resistance can be relatively low. Because of this, it is important to measure the coefficients for both the forward and reverse directions. Also because of the interdependence of the input and output circuits, it is desirable to reduce the base-to-emitter voltage to zero or to open the base connection before operating the coefficient switch of the bridge; this will avoid a possible transient which may require several seconds to resume equilibrium conditions or may even damage the transistor.

Because the a-c resistance of the test-signal sources (e_1 and e_2 in Figure 2) can be comparable to *the transistor resistance, the next paragraph is important.*

CORRECTIONS DUE TO SOURCE RESISTANCE

The sources of test signal (see Figure 2) are e_1 controlled by the MULTIPLY BY switch and e_2 controlled by the DIVIDE BY switch. The a-c resistance of each test signal source depends on the switch setting (see Table II above).

The a-c resistance of the test signal source (e_2) controlled by the DIVIDE BY switch is significant only when measuring the input or the output resistance of the transducer (coefficient switch at PLATE RESISTANCE). The error due to this source resistance is always less than one percent if one ohm is subtracted from the indicated value ($r = r' - 1\Omega$).

The a-c resistance (r_e) of the test-signal source (e_1) controlled by the MULTIPLY BY switch is significant only when the coefficient switch is at TRANSCONDUCTANCE or at voltage AMPLIFICATION FACTOR. If the input resistance (r) of the device under measurement is sufficiently small, the source resistance (r_e) and the input resistance (r) provide voltage division that effectively reduces e_1. The correct value of transconductance or of voltage amplification factor is then the measured value multiplied by the factor $(1 + \frac{r_e}{r})$. This factor is normally negligible in vacuum-tube measurements and rarely exceeds 1.02 in transistor measurements.

6.0 GENERAL NETWORK CONSIDERATIONS

The transducer of Figure 1 was considered under Section 2.0 and equations which defined conductance parameters were given. These are the nodal equations adopted by the Institute of Radio Engineers in standardizing methods[1] for testing tubes. When a picture of the equivalent network of a transducer is sought, the nodal equations are best expressed by a two-generator network as shown in Figure 7. The Type 1661-A Bridge measures the reciprocal of g_{11} (r_{in}), the direct value of g_{12} (reverse transfer conductance), the direct value of g_{21} (forward transconductance) and the reciprocal of g_{22} (r_{out}).

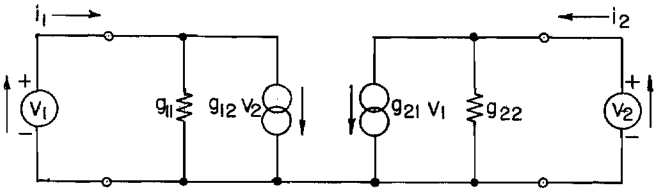


Figure 7. Two-generator nodal-derived equivalent network.

The parameters of the nodal equations can be transformed to new parameters that are depicted by a one-generator π network as shown in Figure 8.

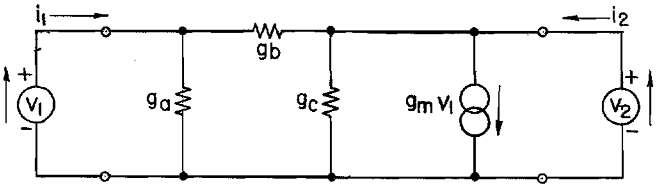


Figure 8. One-generator nodal-derived equivalent network.

The one-generator conductance values are related to the two-generator parameters and hence to the values obtained with a Type 1661-A Bridge, as follows:

$$g_a = g_{11} + g_{12} \qquad g_c = g_{22} + g_{12}$$

$$g_b = -g_{12} \qquad g_m = g_{21} - g_{12}$$

When the transducer of Figure 1 is measured under the assumed condition of open-circuit terminations rather than short-circuit terminations, the preferred equations for expressing the inter-relation between the voltages and currents are of the loop (mesh) form and the resultant parameters are best expressed as impedances for the general case, resistances for our specific consideration of low frequency applications. The two equations that completely characterize the transducer are then:

$$v_1 = r_{11}\, i_1 + r_{12}\, i_2$$

$$v_2 = r_{22}\, i_2 + r_{21}\, i_1$$

The resistance parameters are depicted by a loop-derived 2-generator equivalent network as shown in Figure 9. Here, r_{11} and r_{22} are the input and output resistances measured under open-circuit termination condition. These values differ in the termination condition from the values r_{in} and r_{out} normally obtained on the Type 1661-A Bridge. However, the r_{11} and r_{22} parameters of a transistor, for example, can be obtained directly on the bridge if care is taken to provide the correct d-c bias condition through an impedance that sufficiently simulates an open-circuit at the measuring frequency and if great care is taken to effectively shield this open-circuit or high-impedance circuit in order to prevent it from picking up signal voltage. One method of doing this is to feed the biasing current through the plate circuit of a shielded pentode. Another method involves the use of high resistance or of a shielded choke coil. It is usually simpler to measure the conductance parameters of the nodal-derived equivalent network and transform to the loop-derived parameters as follows:

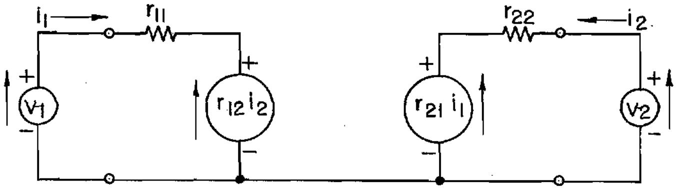


Figure 9. Two-generator loop-derived equivalent network.

Nodal	**Loop**
$g_{11} = r_{22} \div \Delta r$	$r_{11} = g_{22} \div \Delta g$
$g_{12} = -r_{12} \div \Delta r$	$r_{12} = -g_{12} \div \Delta g$
$g_{21} = -r_{21} \div \Delta r$	$r_{21} = -g_{21} \div \Delta g$
$g_{22} = r_{11} \div \Delta r$	$r_{22} = g_{11} \div \Delta g$
$\Delta r = r_{11}\, r_{22} - r_{12}\, r_{21}$	$\Delta g = g_{11}\, g_{22} - g_{12}\, g_{21}$

In performing the transformations, it is important to be careful of signs.

---

[1] "Standards on Electron Tubes: Methods of Testing", Proceedings of the I.R.E., Volume 38, Numbers 8 and 9, August and September, 1950.

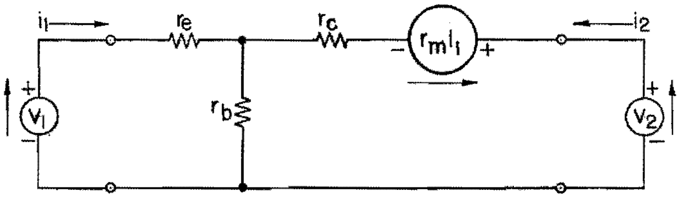


Figure 10. One-generator loop-derived equivalent network.

The loop equations can also be shown as a one-generator equivalent network (Figure 10). The subscripts given in the figure are for a transistor connected for the common-base condition. The one-generator loop derived network parameters are related to the two generator loop-derived network parameters by the following simple equations:

$$r_e = r_{11} - r_{12} \qquad r_c = r_{22} - r_{12}$$

$$r_b = r_{12} \qquad r_m = r_{21} - r_{12}$$

While, in transistor applications, the coefficients that correspond to the two-generator nodal-derived equivalent network will perhaps be the most useful for design applications, it may be desirable to be able to transform quickly from one arrangement to another. The data in Table III simplify conversion[2] from one form of network to another, whether it be one- or two-generator, nodal or loop, common-emitter, -base or -collector connected. When transforming from nodal to loop or vice-versa, the nodal-loop equations above are to be used.

The α_{ce} of the table is the current amplification factor often referred to in transistor literature. It is very close to unity for junction-type transistors and usually between 0.2 and 3 for the point-contact type.

The h or hybrid parameters were discussed in Section 2.0. The two-generator equivalent circuit showing the hybrid parameters is given in Figure 11.

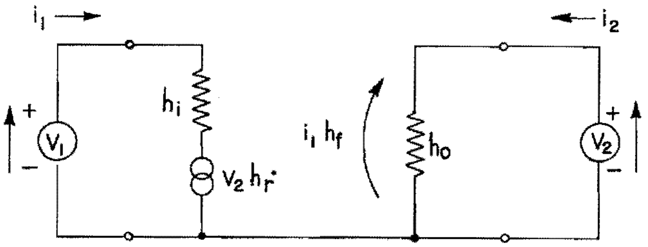


Figure 11. Two-generator loop-derived equivalent network.

COMMENTS ON TABLE III

The parameters are expressed in the table as admittances (y) rather than conductances (g) and as impedances (z) rather than resistances (r) since the table can be useful in considering the more general case of transistor parameters at any frequency.

For the 2-generator networks, the third subscript[2] refers to the common electrode. For the one-generator networks, the pre-subscript refers to the common electrode.

When transforming from one common-electrode circuit to another, not only do the parameters have new values and possibly new signs but the new effective applied terminal voltages may be of different value and sign as indicated in Table III.

HOW TO DETERMINE PARAMETERS

Table IV on page 18 lists the various parameters, indicates the corresponding symbols used in the IRE Standards on Methods of Testing Transistors[3] and describes how to determine each parameter by means of the Type 1661-A Bridge.

The common base α_{21} ($-h_{21}$, $-h_f$) is commonly referred to as α.

The common emitter α_{21} is commonly referred to as β.

$$\alpha = \frac{\beta}{1 + \beta} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

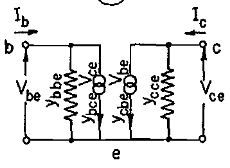
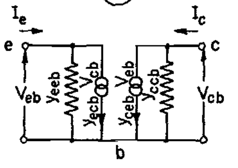
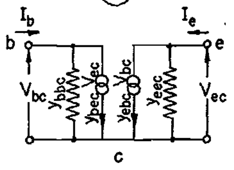
---

[2] L. J. Giocoletto, R.C.A. Review, Volume 14, No. 1, March 1953, pp. 28-46.

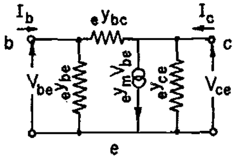
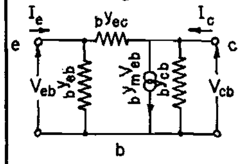
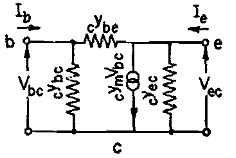
[3] Proceedings of the Institute of Radio Engineers, Vol. 44, No. 11 (November, 1956).

TABLE III

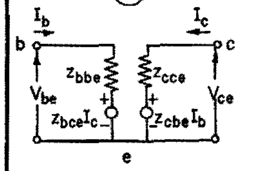
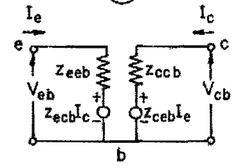
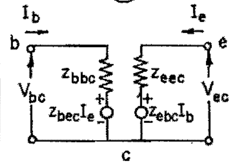
NODAL-DERIVED EQUIVALENT CIRCUITS

EQUATIONS	COMMON EMITTER		COMMON BASE		COMMON COLLECTOR	
	$I_b = y_{bbe} V_{be} + y_{bce} V_{ce}$ $I_c = y_{cbe} V_{be} + y_{cce} V_{ce}$		$I_e = y_{eeb} V_{eb} + y_{ecb} V_{cb}$ $I_c = y_{ceb} V_{eb} + y_{ccb} V_{cb}$		$I_b = y_{bbc} V_{bc} + y_{bec} V_{ec}$ $I_e = y_{ebc} V_{bc} + y_{eec} V_{ec}$	
TWO - GEN.	(1N) 		(2N) 		(3N) 	
AMP. FACTORS	FORWARD	REVERSE	FORWARD	REVERSE	FORWARD	REVERSE
	$\alpha_{cb} = -\frac{y_{cbe}}{y_{bbe}}$ $\mu_{cb} = -\frac{y_{cbe}}{y_{cce}}$ $\phi_{cb} = \frac{\lvert y_{cbe}\rvert^2}{4 g_{bbe} g_{cce}}$	$\alpha_{bc} = -\frac{y_{bce}}{y_{cce}}$ $\mu_{bc} = -\frac{y_{bce}}{y_{bbe}}$ $\phi_{bc} = \frac{\lvert y_{bce}\rvert^2}{4 g_{bbe} g_{cce}}$	$\alpha_{ce} = -\frac{y_{ceb}}{y_{eeb}}$ $\mu_{ce} = -\frac{y_{ceb}}{y_{ccb}}$ $\phi_{ce} = \frac{\lvert y_{ceb}\rvert^2}{4 g_{eeb} g_{ccb}}$	$\alpha_{ec} = -\frac{y_{ecb}}{y_{ccb}}$ $\mu_{ec} = -\frac{y_{ecb}}{y_{eeb}}$ $\phi_{ec} = \frac{\lvert y_{ecb}\rvert^2}{4 g_{eeb} g_{ccb}}$	$\alpha_{eb} = -\frac{y_{ebc}}{y_{bbc}}$ $\mu_{eb} = -\frac{y_{ebc}}{y_{eec}}$ $\phi_{eb} = \frac{\lvert y_{ebc}\rvert^2}{4 g_{bbc} g_{eec}}$	$\alpha_{be} = -\frac{y_{bec}}{y_{eec}}$ $\mu_{be} = -\frac{y_{bec}}{y_{bbc}}$ $\phi_{be} = \frac{\lvert y_{bec}\rvert^2}{4 g_{bbc} g_{eec}}$
TRANSFORMATION EQUATIONS	(4N) → (1N) $y_{bbe} = {}_e y_{be} + {}_e y_{bc}$ $y_{bce} = -{}_e y_{bc}$ $y_{cbe} = {}_e y_m - {}_e y_{bc}$ $y_{cce} = {}_e y_{ce} + {}_e y_{bc}$		(5N) → (2N) $y_{eeb} = {}_b y_{eb} + {}_b y_{ec}$ $y_{ecb} = -{}_b y_{ec}$ $y_{ceb} = {}_b y_m - {}_b y_{ec}$ $y_{ccb} = {}_b y_{cb} + {}_b y_{ec}$		(6N) → (3N) $y_{bbc} = {}_c y_{bc} + {}_c y_{be}$ $y_{bec} = -{}_c y_{be}$ $y_{ebc} = {}_c y_m - {}_c y_{be}$ $y_{eec} = {}_c y_{ec} + {}_c y_{be}$	
	(2N) → (1N) $V_{be} = -V_{eb}$; $V_{ce} = V_{cb} - V_{eb}$ $y_{bbe} = y_{eeb} + y_{ecb} + y_{ceb} + y_{ccb}$ $y_{bce} = -(y_{ccb} + y_{ecb})$ $y_{cbe} = -(y_{ccb} + y_{ceb})$ $y_{cce} = y_{ccb}$		(3N) → (2N) $V_{eb} = V_{ec} - V_{bc}$; $V_{cb} = -V_{bc}$ $y_{eeb} = y_{eec}$ $y_{ecb} = -(y_{eec} + y_{ebc})$ $y_{ceb} = -(y_{eec} + y_{bec})$ $y_{ccb} = y_{bbc} + y_{bec} + y_{ebc} + y_{eec}$		(1N) → (3N) $V_{bc} = V_{be} - V_{ce}$; $V_{ec} = -V_{ce}$ $y_{bbc} = y_{bbe}$ $y_{bec} = -(y_{bbe} + y_{bce})$ $y_{ebc} = -(y_{bbe} + y_{cbe})$ $y_{eec} = y_{bbe} + y_{cbe} + y_{bce} + y_{cce}$	
	(3N) → (1N) $V_{be} = V_{bc} - V_{ec}$; $V_{ce} = -V_{ec}$ $y_{bbe} = y_{bbc}$ $y_{bce} = -(y_{bbc} + y_{bec})$ $y_{cbe} = -(y_{bbc} + y_{ebc})$ $y_{cce} = y_{bbc} + y_{bec} + y_{ebc} + y_{eec}$		(1N) → (2N) $V_{eb} = -V_{be}$; $V_{cb} = V_{ce} - V_{be}$ $y_{eeb} = y_{bbe} + y_{cbe} + y_{bce} + y_{cce}$ $y_{ecb} = -(y_{cce} + y_{bce})$ $y_{ceb} = -(y_{cce} + y_{cbe})$ $y_{ccb} = y_{cce}$		(2N) → (3N) $V_{bc} = -V_{cb}$; $V_{ec} = V_{eb} - V_{cb}$ $y_{bbc} = y_{eeb} + y_{ecb} + y_{ceb} + y_{ccb}$ $y_{bec} = -(y_{eeb} + y_{ceb})$ $y_{ebc} = -(y_{eeb} + y_{ecb})$ $y_{eec} = y_{ceb}$	

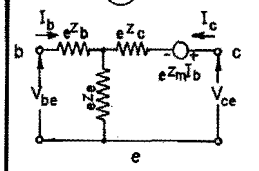
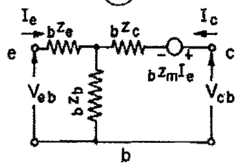
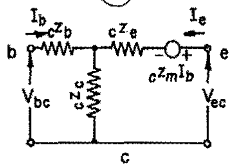
NODAL-DERIVED EQUIVALENT CIRCUITS

EQUATIONS	COMMON EMITTER		COMMON BASE		COMMON COLLECTOR	
	$I_b = ({}_e y_{be} + {}_e y_{bc}) V_{be} - {}_e y_{bc} V_{ce}$ $I_c = ({}_e y_m - {}_e y_{bc}) V_{be} + ({}_e y_{ce} + {}_e y_{bc}) V_{ce}$		$I_e = ({}_b y_{eb} + {}_b y_{ec}) V_{eb} - {}_b y_{ec} V_{cb}$ $I_c = ({}_b y_m - {}_b y_{ec}) V_{eb} + ({}_b y_{cb} + {}_b y_{ec}) V_{cb}$		$I_b = ({}_c y_{bc} + {}_c y_{be}) V_{bc} - {}_c y_{be} V_{ec}$ $I_e = ({}_c y_m - {}_c y_{be}) V_{bc} + ({}_c y_{ec} + {}_c y_{be}) V_{ec}$	
ONE - GEN.	(4N) 		(5N) 		(6N) 	
AMP. FACTORS	FORWARD	REVERSE	FORWARD	REVERSE	FORWARD	REVERSE
	$\alpha_{cb} = -\frac{{}_e y_m - {}_e y_{bc}}{{}_e y_{be} + {}_e y_{bc}}$ $\mu_{cb} = -\frac{{}_e y_m - {}_e y_{bc}}{{}_e y_{ce} + {}_e y_{bc}}$	$\alpha_{bc} = +\frac{{}_e y_{bc}}{{}_e y_{be} + {}_e y_{bc}}$ $\mu_{bc} = +\frac{{}_e y_{bc}}{{}_e y_{be} + {}_e y_{bc}}$	$\alpha_{ce} = -\frac{{}_b y_m - {}_b y_{ec}}{{}_b y_{eb} + {}_b y_{ec}}$ $\mu_{ce} = -\frac{{}_b y_m - {}_b y_{ec}}{{}_b y_{cb} + {}_b y_{ec}}$	$\alpha_{ec} = +\frac{{}_b y_{ec}}{{}_b y_{cb} + {}_b y_{ec}}$ $\mu_{ec} = +\frac{{}_b y_{ec}}{{}_b y_{eb} + {}_b y_{ec}}$	$\alpha_{eb} = -\frac{{}_c y_m - {}_c y_{be}}{{}_c y_{bc} + {}_c y_{be}}$ $\mu_{eb} = -\frac{{}_c y_m - {}_c y_{be}}{{}_c y_{ec} + {}_c y_{be}}$	$\alpha_{be} = +\frac{{}_c y_{be}}{{}_c y_{ec} + {}_c y_{be}}$ $\mu_{be} = +\frac{{}_c y_{be}}{{}_c y_{ec} + {}_c y_{be}}$
	$\phi_{cb} = \frac{\lvert {}_e y_m - {}_e y_{bc}\rvert^2}{4({}_e g_{be} + {}_e g_{bc})({}_e g_{ce} + {}_e g_{bc})}$ $\phi_{bc} = \frac{\lvert {}_e y_{bc}\rvert^2}{4({}_e g_{be} + {}_e g_{bc})({}_e g_{ce} + {}_e g_{bc})}$		$\phi_{ce} = \frac{\lvert {}_b y_m - {}_b y_{ec}\rvert^2}{4({}_b g_{eb} + {}_b g_{ec})({}_b g_{cb} + {}_b g_{ec})}$ $\phi_{ec} = \frac{\lvert {}_b y_{ec}\rvert^2}{4({}_b g_{eb} + {}_b g_{ec})({}_b g_{cb} + {}_b g_{ec})}$		$\phi_{eb} = \frac{\lvert {}_c y_m - {}_c y_{be}\rvert^2}{4({}_c g_{bc} + {}_c g_{be})({}_c g_{ec} + {}_c g_{be})}$ $\phi_{be} = \frac{\lvert {}_c y_{be}\rvert^2}{4({}_c g_{bc} + {}_c g_{be})({}_c g_{ec} + {}_c g_{be})}$	
TRANSFORMATION EQUATIONS	(1N) → (4N) ${}_e y_{be} = y_{bbe} + y_{bce}$ ${}_e y_{bc} = -y_{bce}$ ${}_e y_{ce} = y_{cce} + y_{bce}$ ${}_e y_m = y_{cbe} - y_{bce}$		(2N) → (5N) ${}_b y_{eb} = y_{eeb} + y_{ecb}$ ${}_b y_{ec} = -y_{ecb}$ ${}_b y_{cb} = y_{ccb} + y_{ecb}$ ${}_b y_m = y_{ceb} - y_{ecb}$		(3N) → (6N) ${}_c y_{bc} = y_{bbc} + y_{bec}$ ${}_c y_{be} = -y_{bec}$ ${}_c y_{ec} = y_{eec} + y_{bec}$ ${}_c y_m = y_{ebc} - y_{bec}$	
	(5N) → (4N) $V_{be} = -V_{eb}$; $V_{ce} = V_{cb} - V_{eb}$ ${}_e y_{be} = {}_b y_{eb} + {}_b y_m$ ${}_e y_{bc} = {}_b y_{cb}$ ${}_e y_{ce} = {}_b y_{ec}$ ${}_e y_m = -{}_b y_m$		(6N) → (5N) $V_{eb} = V_{ec} - V_{bc}$; $V_{cb} = -V_{bc}$ ${}_b y_{eb} = {}_c y_{be} - {}_c y_m$ ${}_b y_{ec} = {}_c y_{ec} + {}_c y_m$ ${}_b y_{cb} = {}_c y_{bc}$ ${}_b y_m = {}_c y_m$		(4N) → (6N) $V_{bc} = V_{be} - V_{ce}$; $V_{ec} = -V_{ce}$ ${}_c y_{bc} = {}_e y_{bc}$ ${}_c y_{be} = {}_e y_{be}$ ${}_c y_{ec} = {}_e y_{ce} + {}_e y_m$ ${}_c y_m = -{}_e y_m$	
	(6N) → (4N) $V_{be} = V_{bc} - V_{ec}$; $V_{ce} = -V_{ec}$ ${}_e y_{be} = {}_c y_{be}$ ${}_e y_{bc} = {}_c y_{bc}$ ${}_e y_{ce} = {}_c y_{ec} + {}_c y_m$ ${}_e y_m = -{}_c y_m$		(4N) → (5N) $V_{eb} = -V_{be}$; $V_{cb} = V_{ce} - V_{be}$ ${}_b y_{eb} = {}_e y_{be} + {}_e y_m$ ${}_b y_{ec} = {}_e y_{ce}$ ${}_b y_{cb} = {}_e y_{bc}$ ${}_b y_m = -{}_e y_m$		(5N) → (6N) $V_{bc} = -V_{cb}$; $V_{ec} = V_{eb} - V_{cb}$ ${}_c y_{bc} = {}_b y_{cb}$ ${}_c y_{be} = {}_b y_{eb} + {}_b y_m$ ${}_c y_{ec} = {}_b y_{ec} - {}_b y_m$ ${}_c y_m = {}_b y_m$	

LOOP-DERIVED EQUIVALENT CIRCUITS

	COMMON EMITTER		COMMON BASE		COMMON COLLECTOR	
EQUATIONS	$V_{be}=z_{bbe}I_b+z_{bce}I_c$ $V_{ce}=z_{cbe}I_b+z_{cce}I_c$		$V_{eb}=z_{eeb}I_e+z_{ecb}I_c$ $V_{cb}=z_{ceb}I_e+z_{ccb}I_c$		$V_{bc}=z_{bbc}I_b+z_{bec}I_e$ $V_{ec}=z_{ebc}I_b+z_{eec}I_e$	
TWO-GEN.	(1L) 		(2L) 		(3L) 	
	FORWARD	REVERSE	FORWARD	REVERSE	FORWARD	REVERSE
AMP. FACTORS	$\alpha_{cb}=+\frac{z_{cbe}}{z_{cce}}$ $\mu_{cb}=+\frac{z_{cbe}}{z_{bbe}}$ $\phi_{cb}=\frac{\vert z_{cbe}\vert^2}{4r_{bbe}r_{cce}}$	$\alpha_{bc}=+\frac{z_{bce}}{z_{bbe}}$ $\mu_{bc}=+\frac{z_{bce}}{z_{cce}}$ $\phi_{bc}=\frac{\vert z_{bce}\vert^2}{4r_{bbe}r_{cce}}$	$\alpha_{ce}=+\frac{z_{ceb}}{z_{ccb}}$ $\mu_{ce}=+\frac{z_{ceb}}{z_{eeb}}$ $\phi_{ce}=\frac{\vert z_{ceb}\vert^2}{4r_{eeb}r_{ccb}}$	$\alpha_{ec}=+\frac{z_{ecb}}{z_{eeb}}$ $\mu_{ec}=+\frac{z_{ecb}}{z_{ccb}}$ $\phi_{ec}=\frac{\vert z_{ecb}\vert^2}{4r_{eeb}r_{ccb}}$	$\alpha_{eb}=+\frac{z_{ebc}}{z_{eec}}$ $\mu_{eb}=+\frac{z_{ebc}}{z_{bbc}}$ $\phi_{eb}=\frac{\vert z_{ebc}\vert^2}{4r_{bbc}r_{eec}}$	$\alpha_{be}=+\frac{z_{bec}}{z_{bbc}}$ $\mu_{be}=+\frac{z_{bec}}{z_{eec}}$ $\phi_{be}=\frac{\vert z_{bec}\vert^2}{4r_{bbc}r_{eec}}$
TRANSFORMATION EQUATIONS	(4L)→(1L) $z_{bbe}={}_ez_b+{}_ez_e$ $z_{bce}={}_ez_e$ $z_{cbe}={}_ez_m+{}_ez_e$ $z_{cce}={}_ez_c+{}_ez_e$		(5L)→(2L) $z_{eeb}={}_bz_e+{}_bz_b$ $z_{ecb}={}_bz_b$ $z_{ceb}={}_bz_m+{}_bz_b$ $z_{ccb}={}_bz_c+{}_bz_b$		(6L)→(3L) $z_{bbc}={}_cz_b+{}_cz_c$ $z_{bec}={}_cz_c$ $z_{ebc}={}_cz_m+{}_cz_c$ $z_{eec}={}_cz_e+{}_cz_c$	
	(2L)→(1L) $V_{be}=-V_{eb}$; $V_{ce}=V_{cb}-V_{eb}$ $z_{bbe}=z_{eeb}$ $z_{bce}=z_{eeb}-z_{ecb}$ $z_{cbe}=z_{eeb}-z_{ceb}$ $z_{cce}=z_{eeb}-z_{ecb}-z_{ceb}+z_{ccb}$		(3L)→(2L) $V_{eb}=V_{ec}-V_{bc}$; $V_{cb}=-V_{bc}$ $z_{eeb}=z_{bbc}-z_{bec}-z_{ebc}-z_{eec}$ $z_{ecb}=z_{bbc}-z_{ebc}$ $z_{ceb}=z_{bbc}-z_{bec}$ $z_{ccb}=z_{bbc}$		(1L)→(3L) $V_{bc}=V_{be}-V_{ce}$; $V_{ec}=-V_{ce}$ $z_{bbc}=z_{bbe}-z_{bce}-z_{cbe}+z_{cce}$ $z_{bec}=z_{cce}-z_{bce}$ $z_{ebc}=z_{cce}-z_{cbe}$ $z_{eec}=z_{cce}$	
	(3L)→(1L) $V_{be}=V_{bc}-V_{ec}$; $V_{ce}=-V_{ec}$ $z_{bbe}=z_{bbc}-z_{ebc}-z_{bec}+z_{eec}$ $z_{bce}=z_{eec}-z_{bec}$ $z_{cbe}=z_{eec}-z_{ebc}$ $z_{cce}=z_{eec}$		(1L)→(2L) $V_{eb}=-V_{be}$; $V_{cb}=V_{ce}-V_{be}$ $z_{eeb}=z_{bbe}$ $z_{ecb}=z_{bbe}-z_{bce}$ $z_{ceb}=z_{bbe}-z_{cbe}$ $z_{ccb}=z_{bbe}-z_{bce}-z_{cbe}+z_{cce}$		(2L)→(3L) $V_{bc}=-V_{cb}'$; $V_{ec}=V_{eb}-V_{cb}$ $z_{bbc}=z_{ccb}$ $z_{bec}=z_{ccb}-z_{ceb}$ $z_{ebc}=z_{ccb}-z_{ecb}$ $z_{eec}=z_{eeb}-z_{ecb}-z_{ceb}+z_{ccb}$	

LOOP-DERIVED EQUIVALENT CIRCUITS

	COMMON EMITTER		COMMON BASE		COMMON COLLECTOR	
EQUATIONS	$V_{be}=({}_ez_b+{}_ez_e)I_b+{}_ez_eI_c$ $V_{ce}=({}_ez_m+{}_ez_e)I_b+({}_ez_c+{}_ez_e)I_c$		$V_{eb}=({}_bz_e+{}_bz_b)I_e+{}_bz_bI_c$ $V_{cb}=({}_bz_m+{}_bz_b)I_e+({}_bz_c+{}_bz_b)I_c$		$V_{bc}=({}_cz_b+{}_cz_c)I_b+{}_cz_cI_e$ $V_{ec}=({}_cz_m+{}_cz_c)I_b+({}_cz_e+{}_cz_c)I_e$	
ONE - GEN.	(4L) 		(5L) 		(6L) 	
	FORWARD	REVERSE	FORWARD	REVERSE	FORWARD	REVERSE
AMP. FACTORS	$\alpha_{cb}=\frac{{}_ez_m+{}_ez_e}{{}_ez_c+{}_ez_e}$ $\mu_{cb}=\frac{{}_ez_m+{}_ez_e}{{}_ez_b+{}_ez_e}$ $\phi_{cb}=\frac{\vert{}_ez_m+{}_ez_e\vert^2}{4({}_er_b+{}_er_e)({}_er_c+{}_er_e)}$	$\alpha_{bc}=\frac{{}_ez_e}{{}_ez_b+{}_ez_e}$ $\mu_{bc}=\frac{{}_ez_e}{{}_ez_c+{}_ez_e}$ $\phi_{bc}=\frac{\vert{}_ez_e\vert^2}{4({}_er_b+{}_er_e)({}_er_c+{}_er_e)}$	$\alpha_{ce}=\frac{{}_bz_m+{}_bz_b}{{}_bz_c+{}_bz_b}$ $\mu_{ce}=\frac{{}_bz_m+{}_bz_b}{{}_bz_e+{}_bz_b}$ $\phi_{ce}=\frac{\vert{}_bz_m+{}_bz_b\vert^2}{4({}_br_e+{}_br_b)({}_br_c+{}_br_b)}$	$\alpha_{ec}=\frac{{}_bz_b}{{}_bz_e+{}_bz_b}$ $\mu_{ec}=\frac{{}_bz_b}{{}_bz_c+{}_bz_b}$ $\phi_{ec}=\frac{\vert{}_bz_b\vert^2}{4({}_br_e+{}_br_b)({}_br_c+{}_br_b)}$	$\alpha_{eb}=\frac{{}_cz_m+{}_cz_c}{{}_cz_e+{}_cz_c}$ $\mu_{eb}=\frac{{}_cz_m+{}_cz_c}{{}_cz_b+{}_cz_c}$ $\phi_{eb}=\frac{\vert{}_cz_m+{}_cz_c\vert^2}{4({}_cr_b+{}_cr_c)({}_cr_e+{}_cr_c)}$	$\alpha_{be}=\frac{{}_cz_c}{{}_cz_b+{}_cz_c}$ $\mu_{be}=\frac{{}_cz_c}{{}_cz_e+{}_cz_c}$ $\phi_{be}=\frac{\vert{}_cz_c\vert^2}{4({}_cr_b+{}_cr_c)({}_cr_e+{}_cr_c)}$
TRANSFORMATION EQUATIONS	(1L)→(4L) ${}_ez_b=z_{bbe}-z_{bce}$ ${}_ez_e=z_{bce}$ ${}_ez_c=z_{cce}-z_{bce}$ ${}_ez_m=z_{cbe}-z_{bce}$		(2L)→(5L) ${}_bz_e=z_{eeb}-z_{ecb}$ ${}_bz_b=z_{ecb}$ ${}_bz_c=z_{ccb}-z_{ecb}$ ${}_bz_m=z_{ceb}-z_{ecb}$		(3L)→(6L) ${}_cz_b=z_{bbc}-z_{bec}$ ${}_cz_c=z_{bec}$ ${}_cz_e=z_{eec}-z_{bec}$ ${}_cz_m=z_{ebc}-z_{bec}$	
	(5L)→(4L) $V_{be}=-V_{eb}$; $V_{ce}=V_{cb}-V_{eb}$ ${}_ez_b={}_bz_b$ ${}_ez_e={}_bz_e$ ${}_ez_c={}_bz_c-{}_bz_m$ ${}_ez_m=-{}_bz_m$		(6L)→(5L) $V_{eb}=V_{ec}-V_{bc}$; $V_{cb}=-V_{bc}$ ${}_bz_e={}_cz_e$ ${}_bz_b={}_cz_b-{}_cz_m$ ${}_bz_c={}_cz_c+{}_cz_m$ ${}_bz_m={}_cz_m$		(4L)→(6L) $V_{bc}=V_{be}-V_{ce}$; $V_{ec}=-V_{ce}$ ${}_cz_b={}_ez_b-{}_ez_m$ ${}_cz_c={}_ez_c$ ${}_cz_e={}_ez_e$ ${}_cz_m=-{}_ez_m$	
	(6L)→(4L) $V_{be}=V_{bc}-V_{ec}$; $V_{ce}=-V_{ec}$ ${}_ez_b={}_cz_b-{}_cz_m$ ${}_ez_e={}_cz_e$ ${}_ez_c={}_cz_c$ ${}_ez_m=-{}_cz_m$		(4L)→(5L) $V_{eb}=-V_{be}$; $V_{cb}=V_{ce}-V_{be}$ ${}_bz_e={}_ez_e$ ${}_bz_b={}_ez_b$ ${}_bz_c={}_ez_c-{}_ez_m$ ${}_bz_m=-{}_ez_m$		(5L)→(6L) $V_{bc}=-V_{cb}$; $V_{ec}=V_{eb}-V_{cb}$ ${}_cz_b={}_bz_b+{}_bz_m$ ${}_cz_c={}_bz_c-{}_bz_m$ ${}_cz_e={}_bz_e$ ${}_cz_m={}_bz_m$	

Courtesy of "R.C.A. Review".

7.0 SERVICE AND MAINTENANCE

7.1 GENERAL. This service information, together with the information given in the foregoing sections, should enable the user to locate and correct ordinary difficulties resulting from normal use.

Major service problems should be referred to our Service Department, which will co-operate as much as possible by furnishing information and instructions as well as by supplying any replacement parts needed.

When notifying our Service Department of any difficulties in operation or service of the instrument, always mention the serial number and type number. Also include in correspondence a complete report of trouble encountered, with specific reference to the numbered paragraphs in the Operating and Maintenance Instructions pertaining to the trouble, as well as any information concerning the use of the instrument and steps taken to eliminate the trouble.

Before returning an instrument or parts for repair, please write to our Service Department, requesting a Returned Material Tag, which includes shipping instructions. Use of this tag will insure proper handling and identification when an instrument or parts are returned for repair. A purchase order covering material returned for repair should also be forwarded to avoid any unnecessary delay.

7.2 CONSIDERATIONS. Before a tube is measured, it should be checked for short circuits between electrodes. Failure to do this may cause damage to the bridge or errors in the results.

Connections to the bridge should be carefully checked before measurements are made or if difficulty is suspected.

7.3 CONTINUITY MEASUREMENTS.

7.3.1 All the following points should have continuity to the binding post marked GND:

DET. LOW terminal
GEN. LOW terminal
All three CATHODE panel plugs
D-C FILament minus panel plug
Center jack of adaptor base

Outer conductors of all panel plugs read 33 ohms resistance except the three engraved PLATE.

7.3.2 Continuity should be obtained between the following points:

E4 terminal to plug of E4 panel plug
E5 terminal to plug of E5 panel plug
E6 terminal to plug of E6 panel plug

SCREEN GRID + terminal to plug of SCREEN GRID panel plug

D-C FILament plus terminal to plus plug of D-C FILament panel plug

A-C FILament terminals to plugs of the A-C FILament panel plugs

Between all numbered cables to their respective jacks on the adaptor base (see Figure 12)

7.3.3 Resistance between PLATE + terminal and the center conductor of the SINGLE PLATE panel plug is about 34 ohms for the following conditions:

Panel switch at TRANSCONDUCTANCE
Panel switch at PLATE RESISTANCE
Panel switch at AMPLIFICATION FACTOR
All settings of DIVIDE BY switch
This checks the plate-feed circuit

7.3.4 There should be an open circuit from CONTROL GRID terminal to PLATE + terminal for the conditions of paragraph 7.3.3.

7.4 LEAKAGE TEST. Turn switch to PLATE RESISTANCE, short the PLATE terminals, and plug the No. 3 cable into the SINGLE PLATE panel plug. Push the CAP. BAL. MULTIPLIER in and balance the bridge. Resistance reading should be greater than 100 megohms. This checks cable leakage, or any leakage to ground.

7.5 ATTENUATOR CHECK. With bridge set up as instructed in preceding paragraph, connect resistors of known values (1000 ohms to 1 megohm) between the No. 3 jack on the adaptor base and the center jack (see Figure 12). This resistor can be measured by balancing the bridge in combinations of the MULTIPLY BY and the DIVIDE BY switches, the decades and the LOW Rp - HIGH Gm SWITCH. This checks the over-all operation of the switches.

7.6 MAINTENANCE. Worn switch contacts can be cleaned with very fine sandpaper. Dirt and filings between and around contacts should be removed with a brush. Apply just enough lubricant to allow smooth operation. To remove old lubricant and dirt use a solution of half ether and alcohol, wiping the residue with a clean cloth. Sufficient lubrication should be applied periodically to the notched collars and contact surfaces of the decade switches to prevent excessive wear and oxidation. A lubricant such as "Lubriko" grade MD-T-149 is recommended.

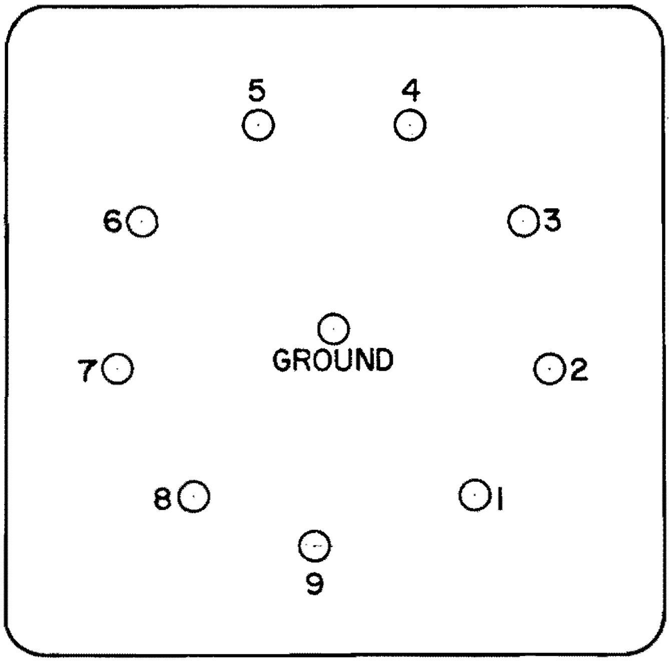


Figure 12. Numbering of jacks on the adapter jack base. The jack number corresponds to the number of the cable connected to it.

TABLE IV

PARAMETER	IRE SYMBOL	HOW TO DETERMINE WITH 1661-A
g_{11}	y_i	Connect input to PLATE; a-c short output; measure as r_p
g_{22}	y_o	Connect output to PLATE; a-c short input; measure as r_p
g_{12}	y_r	Connect input to PLATE; connect output to GRID; measure as g_m
g_{21}	y_f	Connect input to GRID; connect output to PLATE; measure as g_m
g_a		$g_a = g_{11} + g_{12}$
g_b		$g_b = -g_{12}$
g_c		$g_c = g_{22} + g_{12}$
g_m		$g_m = g_{21} - g_{12}$
Δ_g		$\Delta_g = g_{11}g_{22} - g_{12}g_{21}$
r_{11}	Z_i	$r_{11} = g_{22} \div \Delta_g$
r_{22}	Z_o	$r_{22} = g_{11} \div \Delta_g$
r_{12}	Z_r	$r_{12} = -g_{12} \div \Delta_g$
r_{21}	Z_p	$r_{21} = -g_{21} \div \Delta_g$
r_e	r_e	$r_e = (g_{22} + g_{12}) \div \Delta_g$
r_b	r_b	$r_b = -g_{12} \div \Delta_g$
r_c	r_c	$r_c = (g_{11} + g_{12}) \div \Delta_g$
r_m	r_m	$r_m = (g_{12} - g_{21}) \div \Delta_g$
α_{21}	h_f	$\alpha_{21} = -g_{21} \div g_{11}$
α_{12}	α_r	$\alpha_{12} = -g_{12} \div g_{22}$
μ_{21}	μ_f	$\mu_{21} = -g_{21} \div g_{22}$
μ_{12}	h_r	Connect output to GRID; connect input to PLATE; measure as μ
h_{11}	h_i	Connect input to PLATE; a-c short output; measure as r_p
h_{22}	h_o	$h_{22} = \Delta_g \div g_{11}$
h_{12}	h_r	Connect output to GRID; connect input to PLATE; measure as μ
h_{21}	h_f	$h_{21} = -g_{21} \div g_{11}$

TYPE 561-415-2 SUBMINIATURE TUBE TEST ADAPTER

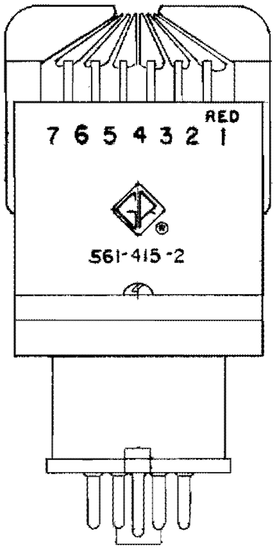
The Type 561-415-2 Tube Adapter is designed to facilitate the testing of flat-press or button-base subminiature tubes with seven or less leads in the same plane having a minimum length of 1-1/2 inches. The adapter is made up of a comb for aligning the tube leads, mounted above a polystyrene spring contact housing, which in turn terminates in a standard octal base. The adapter wiring arrangement between the subminiature tube lead contacts and the octal base pins is shown in the figure.

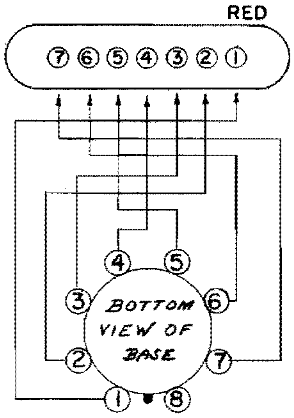
Tube insertion is accomplished simply, as follows:

Step A: Insert the tube leads between the teeth of the adapter comb at a point near the press, or the base of the tube, where the leads are more rigid; the tube should be held about a right angle to the comb with the tip of the tube away from the operator. (See Figure A)

Step B: Draw the tube up and back from the adapter, combing the leads through the teeth of the comb, at the same time bring the tube to a vertical position until the ends of the leads fall into the channels above the lead contact openings. (See Figure B)

Step C: Push down on the tube until the leads are engaged by the lead contact springs. (See Figure C)





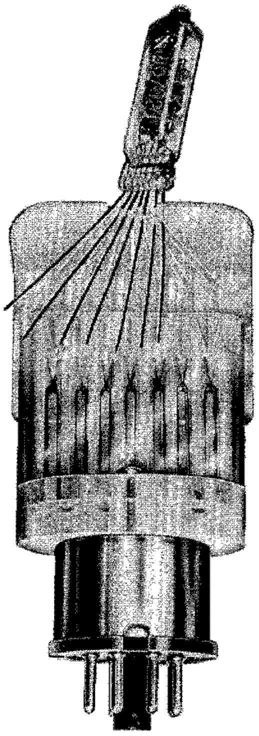


Figure A

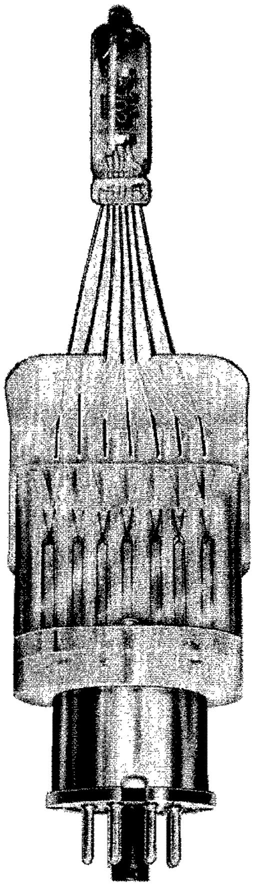


Figure B

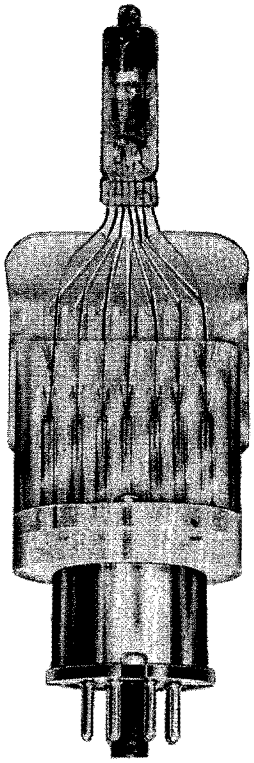
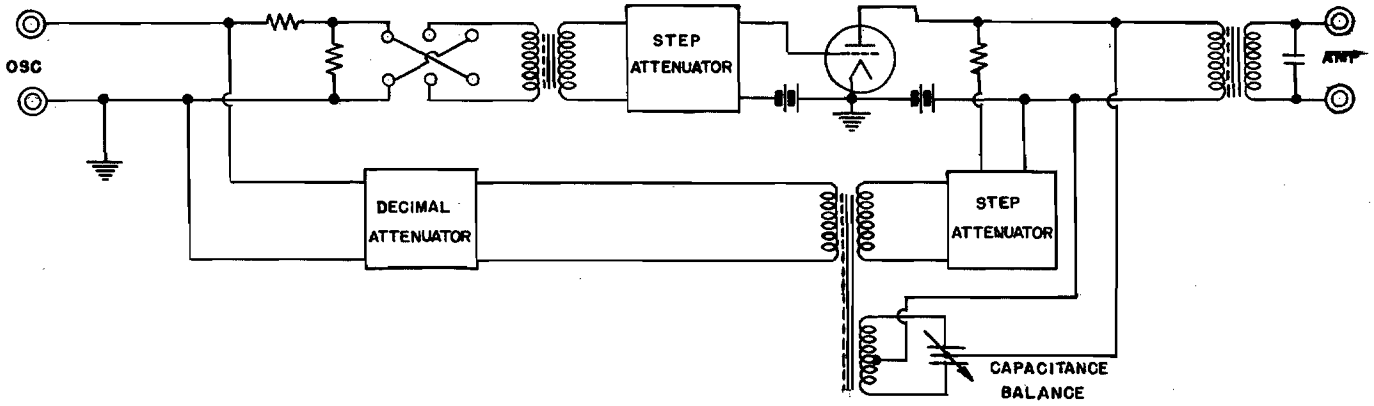


Figure C



ELEMENTARY SCHEMATIC DIAGRAM

PARTS LIST

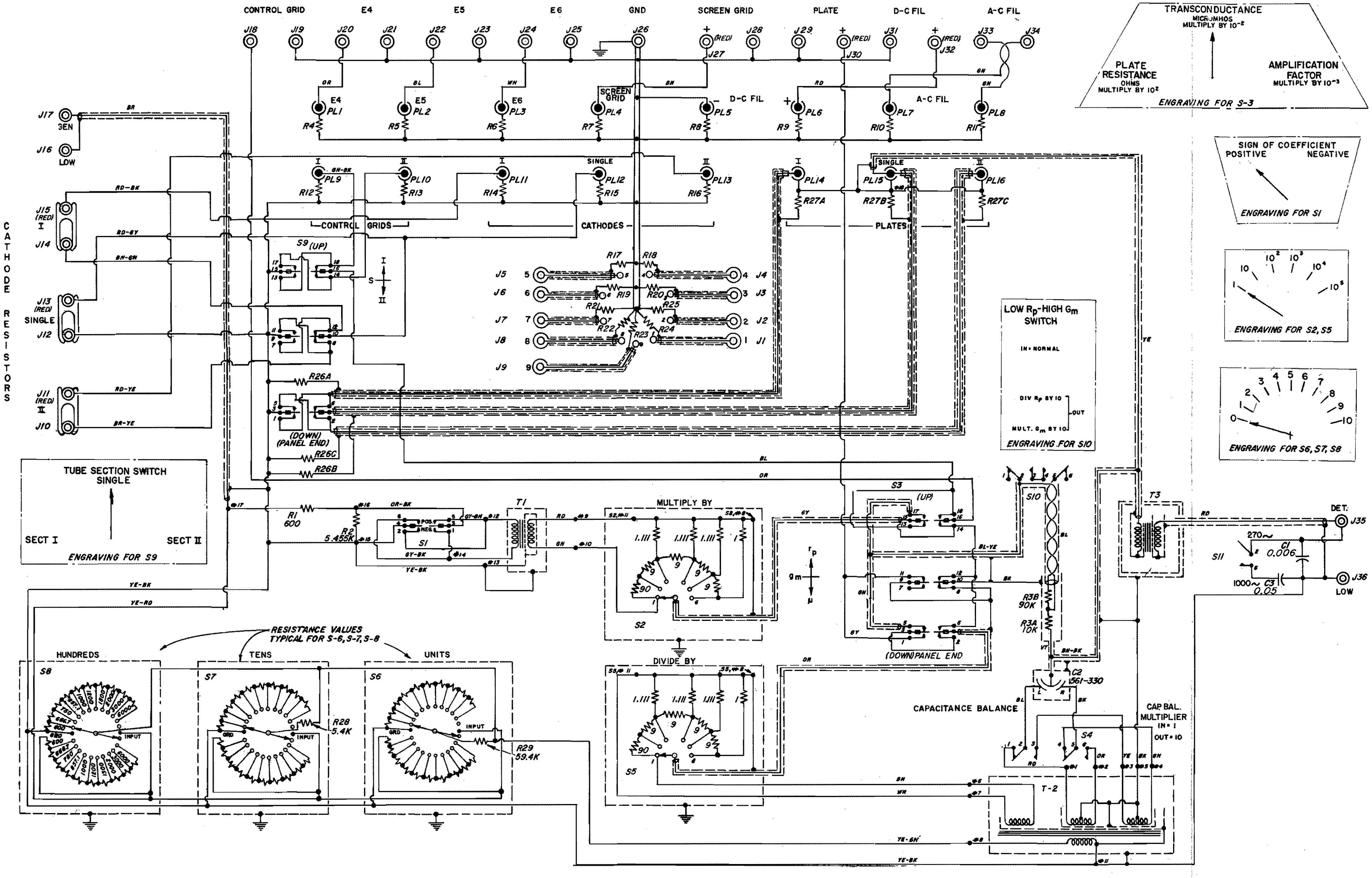
					PART NO. (NOTE A)					PART NO. (NOTE A)
RESISTORS (NOTE B)	R1	600	±1/4%		1661-202	R26C	33	±5%	1/2 w	REC-20BF
	R2	5455	±1/4%		1661-202	R27A	33	±5%	1/2 w	REC-20BF
	R3A	10 k	±1/4%		REPR-16	R27B	33	±5%	1/2 w	REC-20BF
	R3B	90 k	±1/4%		REPR-16	R27C	33	±5%	1/2 w	REC-20BF
	R4	33	±5%	1/2 w	REC-20BF	R28	5.4 k	±1/4%		561-308
	R5	33	±5%	1/2 w	REC-20BF	R29	59.4 k	±0.05%		510-391
	R6	33	±5%	1/2 w	REC-20BF					
	R7	33	±5%	1/2 w	REC-20BF					
	R8	33	±5%	1/2 w	REC-20BF	C1	CAPACITOR, 0.006 μμf			
	R9	33	±5%	1/2 w	REC-20BF		±10%, 600 dcwv			COM-45B
	R10	33	±5%	1/2 w	REC-20BF	C2	CAPACITOR			1661-312
	R11	33	±5%	1/2 w	REC-20BF	C3	CAPACITOR, 0.05 μf			
	R12	33	±5%	1/2 w	REC-20BF		±10%, 600 dcwv			COM-50B
	R13	33	±5%	1/2 w	REC-20BF					
	R14	33	±5%	1/2 w	REC-20BF	S1	SWITCH, dpdt			339-401
	R15	33	±5%	1/2 w	REC-20BF	S2	SWITCH			561-318
	R16	33	±5%	1/2 w	REC-20BF	S3	SWITCH, 6pdt			339-C
	R17	33	±5%	1/2 w	REC-20BF	S4	SWITCH, dpst			SWT-933
	R18	33	±5%	1/2 w	REC-20BF	S5	SWITCH			561-318
	R19	33	±5%	1/2 w	REC-20BF	S6	SWITCH			1661-314
	R20	33	±5%	1/2 w	REC-20BF	S7	SWITCH			1661-305
	R21	33	±5%	1/2 w	REC-20BF	S8	SWITCH			1661-304
	R22	33	±5%	1/2 w	REC-20BF	S9	SWITCH, 6pdt			339-404
	R23	33	±5%	1/2 w	REC-20BF	S10	SWITCH, dpst			SWP-933
	R24	33	±5%	1/2 w	REC-20BF	S11	SWITCH, spst			SWT-323A
	R25	33	±5%	1/2 w	REC-20BF	T1	TRANSFORMER			1661-210
	R26A	33	±5%	1/2 w	REC-20BF	T2	TRANSFORMER			1661-211
	R26B	33	±5%	1/2 w	REC-20BF	T3	TRANSFORMER			1661-212

NOTES

(A) REC-Resistor, composition
REPR- Resistor, precision
COM- Capacitor, mica

(B) All resistances are in ohms, except k = kilohms.

When ordering replacement components, be sure to include complete description as well as Part Number. (Example: R85, 51k ±10%, 1/2w, REC-20BF).



WIRING DIAGRAM FOR TYPE 1661-A VACUUM-TUBE BRIDGE