SUGGESTED PRICE 75 CENTS

RCA

operating and
maintenance instructions

WT-501A TRANSISTOR TESTER

RCA | Electronic Components | Harrison, N.J.

Safety Precautions

The WT-501A Transistor Tester is battery operated, therefore has no internal high voltage. In addition, all in-circuit tests using the Tester are made with equipment under test turned off. As an added precaution, it is recommended that the power cord of AC operated equipment be removed from the AC outlet prior to testing.

An important point to remember is that there is always danger inherent in testing electrical equipment which operates at hazardous voltages. Therefore, the operator should thoroughly familiarize himself with the equipment under test before working on it, bearing in mind that high voltages may appear at unexpected points in defective equipment under test. The following safety precautions should always be observed when servicing AC operated equipment.

1. Always use an isolation transformer, such as the RCA WP-25A Isotap, when working with AC/DC equipment having the chassis connected directly to one side of the AC power line. (Use Isotap sockets marked "ISOLATED" for this purpose.)

2. It is good practice to remove power before connecting test leads to high-voltage points. If this is impractical, be especially careful to avoid accidental contact with equipment racks and other objects which can provide a ground. Working with one hand in your pocket and standing on a properly insulated floor lessens the danger of shock.

3. Filter capacitors may store a charge large enough to be hazardous. Therefore, discharge filter capacitors before attaching test leads.

4. Remember that leads with broken insulation provide the additional hazard of high voltages appearing at exposed points along the leads. Check test leads for frayed or broken insulation before working with them.

5. To lessen the danger of accidental shock, disconnect test leads immediately after test is completed.

6. Remember that the risk of severe shock is only one of the possible hazards. Even a minor shock can place the operator in hazard of more serious risks such as a bad fall or contact with a source of higher voltage.

7. The experienced operator continuously guards against injury and does not work on hazardous circuits unless another person is available to assist in case of accident.

Contents

Description

The RCA WT-501A is designed to test transistors accurately both in-circuit and out-of-circuit. Applications ranging from a quick check of dc beta to an extensive analysis of transistor performance make the versatile WT-501A valuable for use in the service shop, factory, or laboratory.

The WT-501A tests transistors out-of-circuit for dc beta, from 1 to 1000, collector-to-base leakage (I_{CBO}) as low as 1.0 microampere, and collector-to-emitter leakage (I_{CEO}) from 20 microamperes to 1 ampere. Reliable in-circuit testing of transistor current gain is made possible by special low resistance circuitry.

The collector current (I_C) is continuously adjustable, from 10 microamperes to 1 ampere, so that both low power and high power transistors can be tested. If desired, a complete DC Forward Current Transfer Ratio Curve (beta vs. collector current) can be plotted. The front-to-back ratio of diodes can also be checked at various current levels.

Two sockets are provided on the panel, one socket for NPN transistors and the other for PNP transistors. This feature permits convenient transistor matching for complementary symmetry applications. Three color-coded test leads are provided for in-circuit testing, or for use with transistors that do not fit the panel socket.

Additional features include color-coded panel for simplified operation, and mirror-scale meter to eliminate inaccurate reading due to parallax. The tester is completely safe; transistors will not be damaged even if leads are improperly connected.

The WT-501A is completely portable, requiring no external power source. Two long-lasting "D" size batteries are used. The instrument weighs only 2¾ pounds, and measures 6⅞ inches by 5¼ inches by 3⅛ inches. Clips are provided on the handle for convenient storage of the test leads.

Items Supplied with WT-501A

Test Leads, yellow, blue, and green
Two 1.5 volt batteries, RCA VSO36
Instruction Manual
RCA Transistor Manual
Warranty Registration Card

WT-501A 3/68
Printed in U.S.A.

Specifications

DC Beta (h_{FE})	
Range	1 to 1000
Accuracy	±5%
Collector Current (I_C)	100μA to 1 Amp, in four ranges; (0 to 1 mA, 10 mA, 100 mA, 1 A)
Collector-to-Base Leakage (I_{CBO})	0 to 100 μA*
Collector-to-Emitter Leakage (I_{CEO})	0 to 1 Amp
Battery Voltage	1.5 volts, two D cells
Meter Scales	
Three	Beta
	Beta Cal (I_C)
	Leakage Current (I_{CBO} & I_{CEO})

Mechanical Specifications

Dimensions (less handle)	
Height	6⅞ inches
Width	5¼ inches
Depth	3⅛ inches
Weight	2¾ pounds

*See section titled "Transistor Leakage" for measuring I_{CBO} above 100μA.

Simplified Test Procedure

A dc beta check of a transistor either in-circuit or out-of-circuit can be made quickly and easily as described below. This is the same procedure provided on the label on back of the WT-501A case. For a more detailed test procedure, refer to the "Operation" section on page 6.

IN-CIRCUIT TEST

1. Turn off equipment under test. Set Function Switch to "OFF." Turn both IN CIRCUIT ZERO ADJ knobs fully ccw, with Coarse knob switched to "OUT-OF-CIRCUIT." Turn both Coarse and Fine CAL knobs fully ccw. Set Range Switch to red "CAL" position of appropriate current range, as follows:

Transistor Type	Use Current Range
signal-type (rf, if)	100 mA
intermediate-power, power, audio	1 A*

2. Connect test leads to in-circuit transistor emitter, base, and collector. Set Function Switch to "PNP" or "NPN" depending on transistor type. If meter deflects up-scale, set pointer to "0" using IN CIRCUIT ZERO ADJ knobs.

3. Turn both CAL knobs cw to bring meter pointer to the "BETA CAL x 1" position at left side of red scale. Set Range Switch to "BETA" position of selected current range. Read current gain (in-circuit beta) directly on upper scale. If on beta reading is obtained, check circuit. If no defects are found, remove transistor and test out-of-circuit.

*Make test quickly to prevent excessive battery drain.

OUT-OF-CIRCUIT TEST

1. Turn Coarse IN CIRCUIT ZERO ADJ knob fully ccw, switched to "OUT-OF-CIRCUIT." Turn both Coarse and Fine CAL knobs fully ccw. Set Range Switch to CAL position of appropriate range, as follows:

Transistor Type	Use Current Range
signal-type (rf, if)	10 mA
intermediate power	100 mA
high-power audio	1 A*

(Use 100 mA range if calibration cannot be made on 1A range)

2. Connect transistor, using test leads or socket. Set function switch to "PNP" or "NPN" depending on transistor type. Note: When testing some power transistors, meter may deflect up-scale. Set pointer to "0" using IN CIRCUIT ZERO ADJ knobs.

3. Adjust CAL knobs to bring meter pointer full-scale to "BETA CAL x 10" mark on red scale. (Inoperative CAL control indicates transistor is defective.) Set range switch to "BETA" position of selected current range. Beta equals BETA scale reading times 10.

In general, dc beta (h_{FE}) should be above 20, although some silicon power transistors have beta as low as 10. Beta may be as high as several hundred.

Leakage

Set Range Switch to "ICBO, 100μA." Read ICBO leakage on lower meter scale.

ICBO reading for most silicon transistors will be less than 1 μA, however the ICBO for some power types may indicate as high as 50 μA. ICBO reading for most low-power germanium transistors will be less than 100 μA. Germanium power transistors often have ICBO exceeding 100 μA, causing meter to peg on ICBO test. See Instruction Manual.

BETA SCALE
For beta, multiply by reading obtained on red CAL scale.

CAL
Outer knob — fine adj.
Inner knob — coarse adj.
Inner knob includes ICEO switch. Use with range switch to adjust Ic. For most applications, adjust for "X1" or "X10" reading on red CAL scale.

RANGE SWITCH
ICBO — Permits measurement of collector-to-base leakage from 0 to 100 μA.
1 ma CAL/BETA range — To measure beta with Ic from 0 to 1 mA.
10 ma CAL/BETA range — To measure beta with Ic from 1 mA to 10 mA.
100 ma CAL/BETA range — To measure beta with Ic from 10 mA to 100 mA.
1A CAL/BETA range — To measure beta with Ic from 100 mA to 1 A.

CAL SCALE
Use CAL scale reading as beta scale multiplier. Also indicates Ic.

ICBO SCALE
Indicates ICBO from 0 to 100μA. Also used to indicate ICEO from 0 to 1 ampere, in four ranges.

IN CIRCUIT ZERO ADJ
Outer knob — fine adj.
Inner knob — coarse adj.
Inner knob includes switch for "OUT OF CIRCUIT" testing.

PNP/OFF/NPN
Set to OFF when not in use.
Set to PNP or NPN depending on transistor type.

SOCKETS
Use PNP or NPN, depending on transistor type.

TEST LEADS
Use for in-circuit testing or with transistors that do not fit sockets.

Function of Controls

Facts You Should Know About Testing Transistors

The WT-501A will provide an accurate indication of transistor gain and leakage. It is important that the test results be evaluated properly to determine whether the device will operate in a particular circuit. A transistor with low beta or excess leakage may work fine in many non-critical circuits, yet would not be acceptable for use in other circuits requiring full gain and low leakage. In some circuits, transistors with beta less than half the normal value and leakage current more than twice the specified level will operate satisfactorily. It is therefore necessary to consider the type of circuit the transistor is to be used in to effectively evaluate the test results.

The following information is helpful in interpreting test results.

- Beta (out-of-circuit) of the various types of transistors ranges from about 10 to several hundred. The beta of a transistor normally will not change as the transistor ages.
- Most low-power silicon transistors have very low leakage, with I_{CBO} usually less than 1 microamp ($1\ \mu A$). High-power silicon transistors can indicate an I_{CBO} up to $50\ \mu A$.
- Germanium transistors normally have more leakage than silicon transistors. I_{CBO} can range from several microamperes to as high as 5 milliamperes, especially in high-power transistors.
- I_{CEO} leakage is always higher than I_{CBO}, since $I_{CEO} = (\beta + 1)\ I_{CBO}$.
- Leakage will vary significantly with temperature. Even body heat from holding a transistor in your hand can increase the leakage current flow.
- If a transistor is tested at an I_C current level higher than its capability, it will saturate, and the Tester cannot be calibrated.
- In-circuit dc beta measurement will often be lower than out-of-circuit measurement. The in-circuit gain for a particular transistor can vary depending on the resistance of the circuit in which it is used.
- The WT-501A test voltage is limited to 1.5 volts to prevent damaging low-power transistors. Gain and leakage characteristics normally do not change appreciably with changes in operating voltage. It is possible however that a power transistor will test normally, yet will not operate in-circuit due to breakdown at higher voltage levels.

Operation

Before using the WT-501A, you should become familiar with the functions of the controls and meter scales, as described on page 5.

The WT-501A has two basic applications; to make a quick and simple check of dc beta and leakage, or to make a more thorough analysis of transistor performance, which can include the plotting of a dc beta curve.

For servicing applications, a dc beta check of a transistor either in-circuit or out-of-circuit can be made quickly and easily with the WT-501A. A step-by-step procedure is provided both on the label on back of the Tester case, and in somewhat more detail below.

To plot a dc beta curve (I_C vs. beta), refer to page 14. For more information regarding transistor leakage refer to page 12.

Most transistors have standard dimensional outlines and terminal locations, and the base, emitter, and collector leads can be identified easily. Several of the more common outlines and terminal locations are shown in Figure 1. Occasionally it may be necessary to test a transistor that does not have standard terminal locations. In this situation, the terminals can be identified either by referring to the manufacturers data or by comparing the transistor in-circuit connections with a schematic diagram. MOS and FET type transistors require a test similar to that used for vacuum tubes and cannot be tested with the WT-501A.

The sockets provided on the Tester will accommodate most low-power transistors with conventional terminal locations. The socket has an extra base pin for use with transistors having "in-line" terminals. The test leads can be used to connect transistors that do not fit the panel socket.

For repeated testing of long-lead or power-type transistors, it is more convenient to use a socket adaptor. Adaptors include the Tektronix* type 013-070 for power types (TO-3), Tektronix 013-609 and Pomona** type 1472 for long-lead types. These adaptors plug directly into the panel jacks of the Tester.

NOTE: Some transistors have a fourth lead connected to an internal shield. Leave this shield lead disconnected in the test procedure.

Refer to the manufacturer's data to determine whether a transistor is a PNP or NPN type. This information can also be obtained from a schematic diagram of a circuit using the transistor. The circuit symbols for PNP and NPN transistors are shown in Figure 2. If no information is available, connect the transistor to the WT-501A using the test leads, and

*Tektronix Corp., P.O. Box 500, Beaverton, Oregon
**Pomona Electronics Co. Inc., 1500 E. Ninth Street, Pomona, California

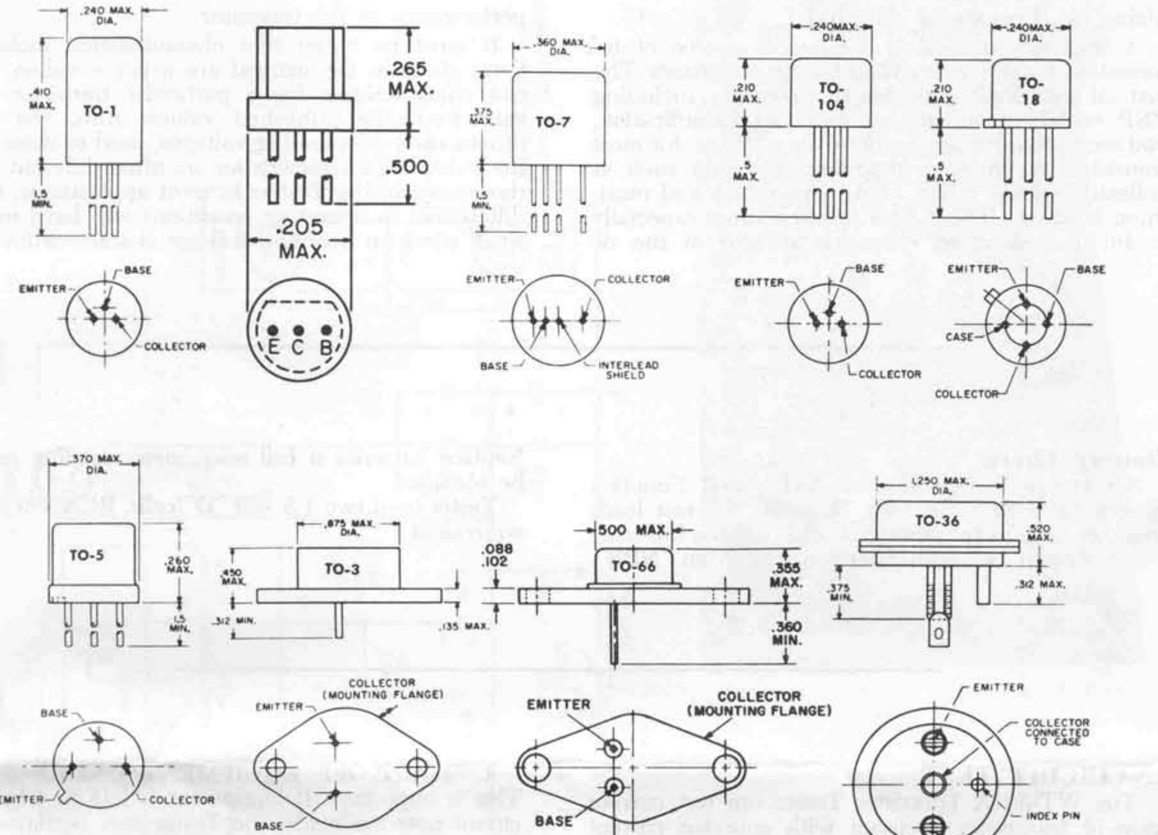


Figure 1.
Common Transistor Outlines and Terminal Locations

try testing it with the function switch set to "PNP". If the transistor is a PNP type, the test should proceed normally. If it is an NPN type, the CAL controls will be inoperative.

An outstanding feature of the WT-501A is the adjustable collector current, permitting low power transistors to be tested at their rated current level. Power transistors can be tested with Ic up to 1 ampere (1 A). While there are exceptions, the approximate current capacity of a transistor can usually be determined by its physical size. Low power signal-type transistors are normally quite small, while power types are substantially larger. If the current capacity for a particular transistor is in doubt, and the manufacturer's data is not available, use the 10 mA range.

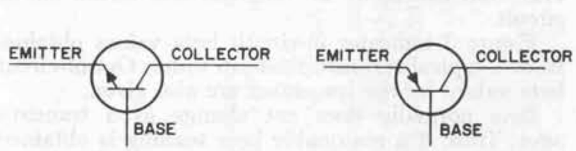


Figure 2. PNP and NPN Transistor Circuit Symbols

Using A Transistor Manual

A transistor manual is a valuable source of information for reference when testing transistors. The manual completely describes the transistor, including PNP or NPN construction, terminal identification, and recommended applications. In addition, for most transistors it provides important test data such as collector current rating (I_C), beta (h_{FE}) and maximum leakage (I_{CBO}). This information is especially useful in making an extensive analysis of the dc performance of the transistor.

It must be noted that characteristics, including beta, given in the manual are average values. The test characteristics for a particular transistor may vary from the published values. Also, test conditions such as operating voltages, used to determine the published characteristics are often different from those used in the Tester. In most applications, these differences in operating conditions will have only a small effect on beta and leakage characteristics.

Battery Check

Set Range Switch to "1A CAL", and Function Switch to "PNP". Connect "E" and "C" test leads together. The meter pointer should pass the full-scale point. Repeat test with Function Switch on "NPN". Replace batteries if full scale meter reading cannot be obtained.

Tester used two 1.5 volt "D" cells, RCA VSO36 or equivalent.

IN-CIRCUIT TEST

The WT-501A Transistor Tester can test current gain of transistors in-circuit with collector current (I_C) adjustable from 0 to 1 ampere. In the in-circuit test given below, low-power transistors are tested with an Ic of 10 mA, using the 0-to-100 mA range. Intermediate power and high power transistors are tested at 100 mA on the 0-to-1 A range. Testing on these ranges provides minimum resistive loading of the WT-501A test circuit.

The in-circuit beta measurement often will be lower than out-of-circuit beta measurement for the same transistor, depending on the resistance of the circuit. In some special applications, such as a TV horizontal deflection stage, the circuit resistance is so low that the transistor cannot be tested in-circuit. These transistors are usually inserted in sockets however, and can easily be removed and tested out-of-circuit.

Figure 3 indicates in-circuit beta values obtained from a typical transistorized am radio. Out-of-circuit beta values for the transistors are also given.

Beta normally does not change as a transistor ages. Thus, if a reasonable beta reading is obtained, the transistor can be considered good. Check batteries before using tester.

Test Procedure

NOTE: The inability to zero or to calibrate the tester in the following steps indicates a defective transistor or other circuit component. If in question, remove transistor and test out-of-circuit.

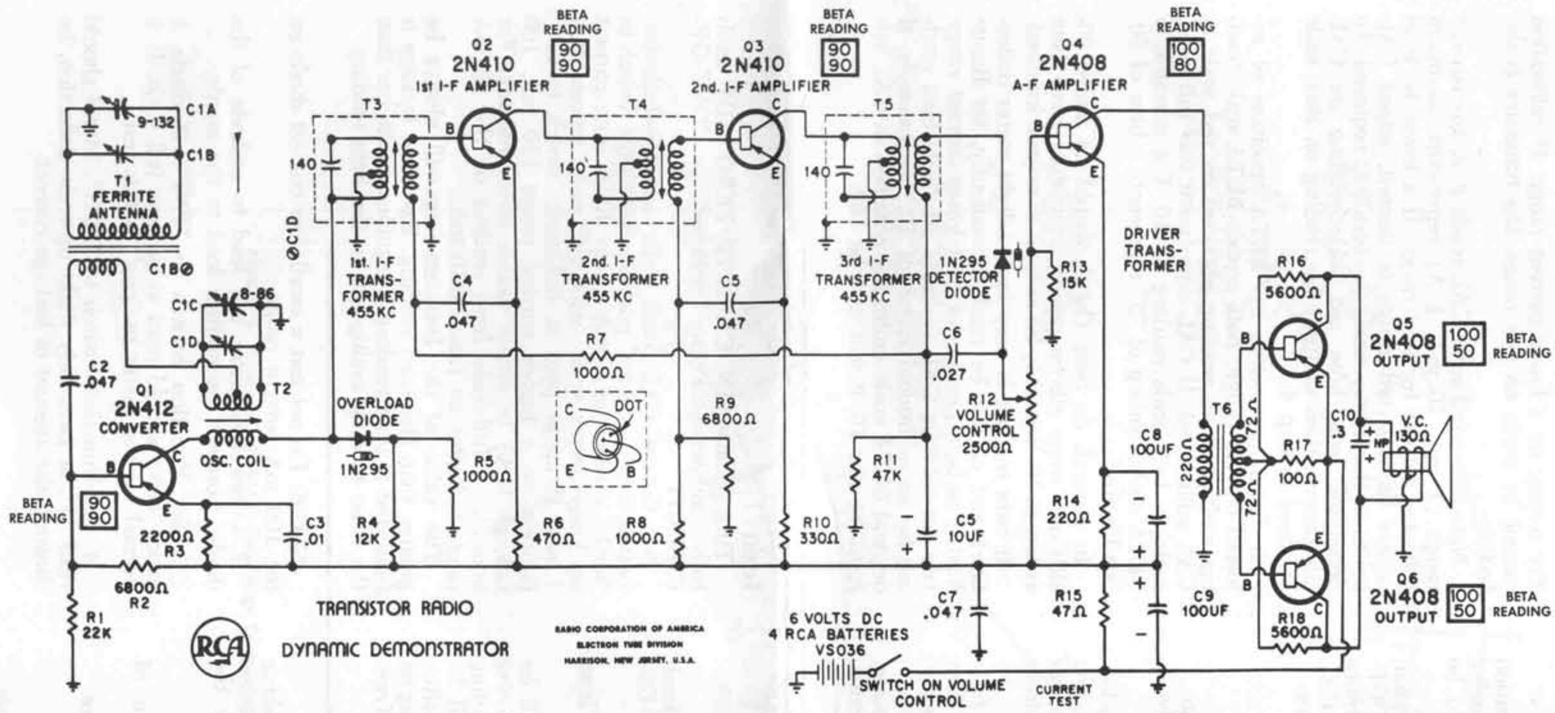
1. TURN OFF EQUIPMENT UNDER TEST. This is important. If equipment is left on when in-circuit tests are made, the Tester may be damaged. Damage of this nature is not covered by the warranty. As a precaution, when testing ac line operated equipment, always remove power cord from ac outlet.

2. Set Function Switch to "OFF". Turn both IN CIRCUIT ZERO ADJ knobs fully counter-clockwise, with coarse knob switched to "OUT-OF-CIRCUIT". Turn both CAL knobs fully counter-clockwise. Set Range Switch to red "CAL" position of appropriate current range, as follows:

Transistor Type	Use Current Range
signal-type (rf, if)	100 mA
intermediate-power, power, audio	1 A

3. Connect test leads to in-circuit transistor emitter, base, and collector. Set Functions Switch to "PNP" or "NPN" depending on transistor type. If meter deflects up-scale, set pointer to "0" using IN CIRCUIT ZERO ADJ knobs.

4. Turn Coarse/Fine CAL knobs clockwise to bring meter pointer to the "BETA CAL X 1" position at left side of red scale. Set Range Switch to "BETA" position of selected current range. Read current gain (in-circuit beta) directly on upper scale. If no beta reading is obtained, check circuit. If no defects are found, remove transistor and test out-of-circuit.



Upper value = out-of-circuit beta
Lower value = in-circuit beta

All out-of-circuit tests made with WT-501A calibrated to 10 mA on 10 mA range.

In-circuit tests made as follows:
Q1 through Q4 tested 10 mA on 100 mA range.
Q5 and Q6 tested at 100 mA on 1 A range.

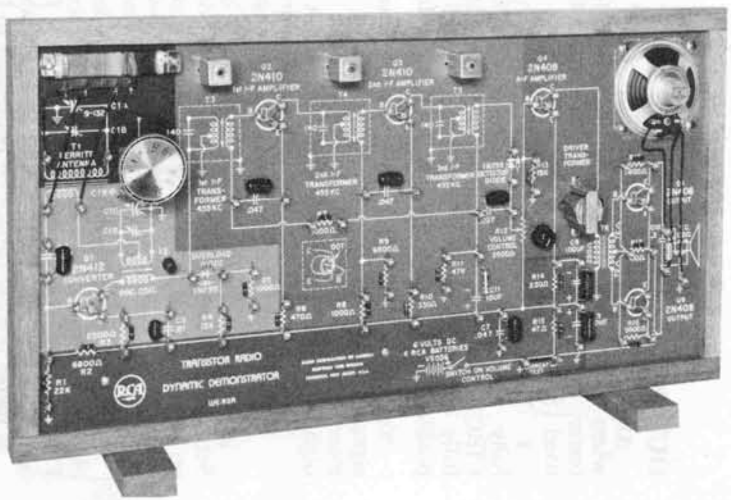


Figure 3. WT-501A Beta Readings Obtained From RCA WE-93A(K) AM Radio Dynamic Demonstrator

OUT-OF-CIRCUIT TEST

Always set Function Switch in "OFF" position when tester is not in use. Test batteries before using tester, especially if high current ranges are to be used (See page 8).

1. Turn Coarse IN CIRCUIT ZERO ADJ knob fully counter-clockwise, switched to "OUT-OF-CIRCUIT". Turn both Coarse and Fine CAL knobs fully counter-clockwise. Set Range Switch to CAL position of appropriate current range, as follows:

Transistor Type	Use Current Range
signal-type (rf,if)	10 mA
intermediate power	100 mA
high-power, audio	1 A* (Use 100 mA range if calibration cannot be made on 1 A range)

2. Connect transistor, using test leads or socket. Set function switch to "PNP" or "NPN" depending on transistor type. NOTE: When testing some power transistors, meter may deflect up-scale. Set pointer to "0" using IN CIRCUIT ZERO ADJ knobs.

3. Adjust Ic by turning Coarse CAL knob fully clockwise or until meter is just below full scale. Turn Fine CAL knob so that reading is exactly full scale, indicating "BETA CAL X 10" on red scale.

If meter pointer cannot be calibrated to full scale, the transistor is either near saturation, or is defective. Try testing on a lower current range. If calibration cannot be made on any range, the transistor is defective.

Note that a full scale CAL reading on any current range (1 mA, 10 mA, 1 A) represents maximum collector current for that range. If a lower Ic level within the selected range is desired, adjust CAL knobs so that meter reads downscale as required. To determine beta, note red scale reading on CAL adjustment, then multiply by reading on beta scale obtained in step 4.

4. Set range switch to "BETA" position of selected current range. Beta equals BETA scale reading multiplied by reading obtained on red scale in CAL adjustment. If CAL adjustment was full scale, multiply beta scale reading by 10. For example, a BETA scale reading of "5" represents a beta of 50. See Figure 4.

In general, dc beta (hFE) should be above 20, although some silicon power transistors have beta as low as 10. Beta may be as high as several hundred.

If beta reading is very high (slight meter deflection) and cannot be read conveniently, set Range Switch to beta position of next lower current range (do not readjust CAL control). Multiply beta reading by an additional factor of 10. For example, if original BETA scale multiplier obtained in CAL adjustment was 10, it will now be 100.

LEAKAGE TEST

ICBO

Turn Coarse IN CIRCUIT ZERO ADJ knob fully counter-clockwise, switched to "OUT-OF-CIRCUIT".

Set Range Switch to "ICBO, 100 μA." Read ICBO on lower meter scale.

ICBO reading for most *silicon* transistors will be less than 1 μA, however the ICBO for some power types may indicate as high as 50 μA. ICBO reading for most low-power *germanium* transistors will be less than 100μA. Germanium power transistors often have ICBO exceeding 100 μA, causing meter to peg on ICBO test. Refer to section on page 24 titled "Transistor Leakage".

ICEO

Turn Coarse IN CIRCUIT ZERO ADJ knob fully counter-clockwise, switched to "OUT-OF-CIRCUIT".

Set Coarse CAL knob fully counter-clockwise, switched to the "ICEO" position. Set Range Switch to "CAL" position of 1 mA range. Read ICEO current on lower meter scale, with full scale representing 1 mA. If meter pegs at full scale, switch to CAL position on a higher current range (10 mA, 100 mA, or 1 A) to obtain usable meter reading. For example, a full-scale ICEO reading on the 10 mA range indicates an ICEO of 10 mA.

The value of the ICEO reading will always be greater than the ICBO reading. Excessive leakage is indicated if ICEO reading is significantly higher than the ICBO reading multiplied by the beta reading.

TESTING DIODES

The WT-501A is a convenient device for making a check of the relative front-to-back ratio of diodes. An important feature is the ability to check the diode at an appropriate current level.

Procedure

1. Set Range Switch to the CAL position of selected current range as follows:

Type of Diode	Use Current Range
small, signal-type	10 mA
intermediate size	100 mA

NOTE: Do not test a small, low current diode on the 100 mA current range.

2. Connect collector test lead to cathode of the diode. Connect the emitter lead to the anode.

3. Set Function Switch to "PNP". If diode is good, meter should read at or near full scale. It is normal for the meter to "peg" in this test.

4. Set Function Switch to "NPN". Meter should read "0", or have only slight up-scale deflection, indicating the amount of leakage current.

*Make test quickly to prevent excessive battery drain.

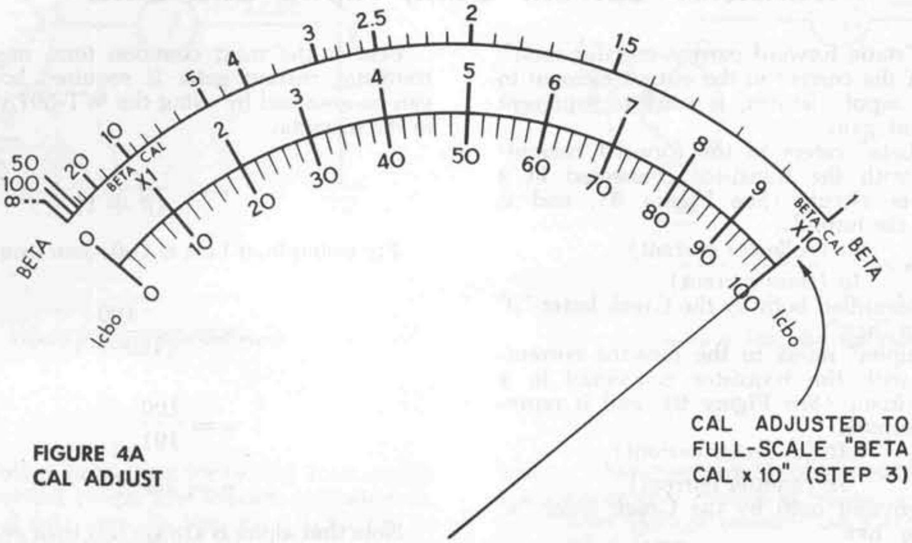


FIGURE 4A
CAL ADJUST

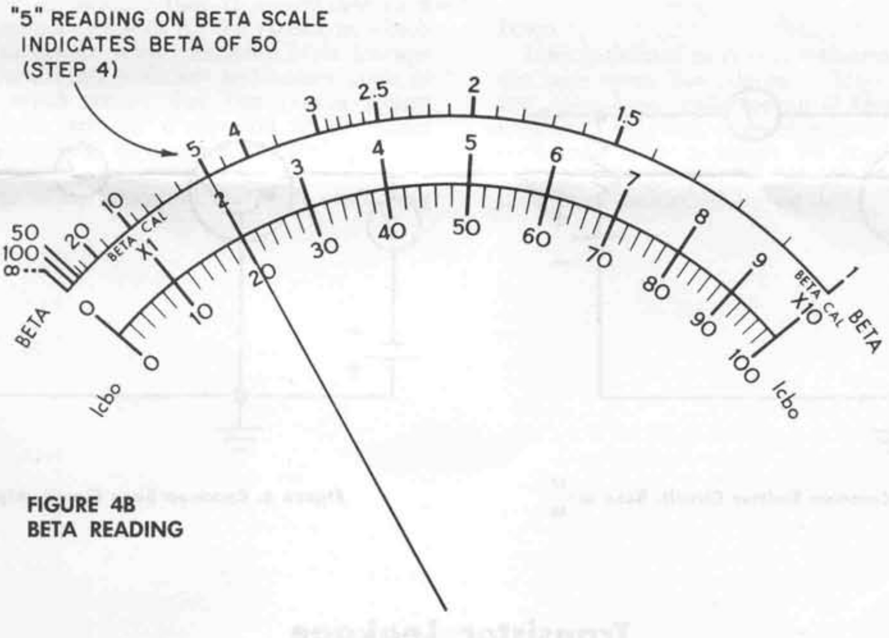


FIGURE 4B
BETA READING

Figure 4. Example of Meter Readings Obtained In CAL and BETA Functions.

Transistor Current Gain, Alpha and Beta

The phrase "static forward current-transfer ratio", i.e., the ratio of the current in the output element to current in the input element, is used to represent transistor current gain.

The term "beta" refers to the forward current-transfer ratio with the transistor connected in a common emitter circuit (See Figure 5), and is represented by the formula:

$$\text{Beta} = \frac{\text{IC (collector current)}}{\text{IB (Base current)}}$$

DC beta is identified both by the Greek letter "β" and by the term "hFE".

The term "alpha" refers to the forward current-transfer ratio with the transistor connected in a common-base circuit (See Figure 6), and is represented by the formula:

$$\text{Alpha} = \frac{\text{IC (collector current)}}{\text{IE (emitter current)}}$$

Alpha is identified both by the Greek letter "α" and by the term "hFB".

Beta is the most common term used to express transistor current gain. If required however, alpha can be obtained by using the WT-501A beta reading in the formula:

$$\alpha = \frac{\beta}{(\beta + 1)}$$

For example, if beta is 100, then using the formula

$$\alpha = \frac{100}{(100 + 1)}$$

$$\alpha = \frac{100}{101}$$

$$\alpha = .99$$

Note that alpha is always less than one.

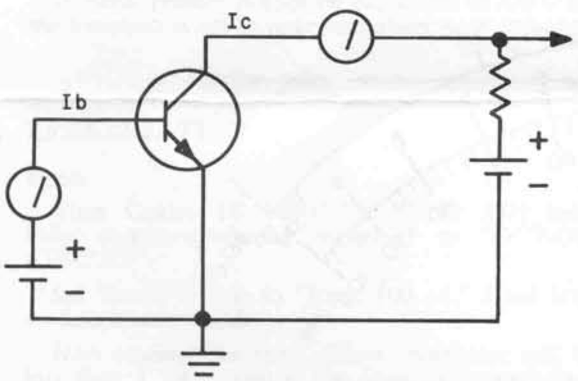


Figure 5. Common Emitter Circuit. Beta $= \frac{I_C}{I_B}$

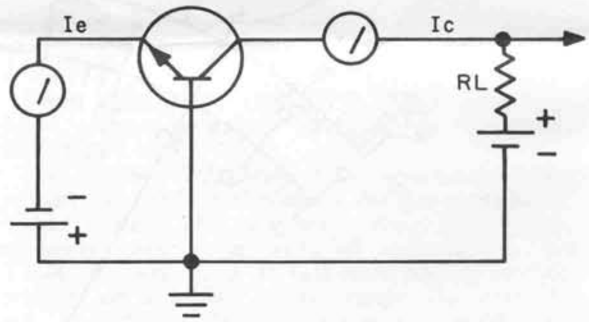


Figure 6. Common Base Circuit. Alpha $= \frac{I_C}{I_E}$

Transistor Leakage

The WT-501A tests for both ICEO and ICBO leakage current. While both terms are useful, ICBO leakage is more commonly used in determining transistor performance. For a complete analysis of the transistor however, ICEO leakage is also important.

ICEO and ICBO are related by the formula:

$$\text{ICEO} = (\beta + 1)\ \text{ICBO}$$

(β measured at ICEO level)

ICBO

ICBO is defined as collector-to-base leakage, with the emitter open. See Figure 7. ICBO is also known as the open-emitter collector-cutoff current since the transistor will not operate if the collector current is below the ICBO level.

The ICBO leakage for most silicon transistors will be less than 1μA, however some silicon power types may indicate ICBO as high as 50 μA. ICBO reading for most germanium transistors will be less than 100 μA. Germanium power transistors often have ICBO exceeding 100 μA, causing the meter pointer to peg on ICBO test. ICBO leakage higher than 100 μA can be determined as follows:

Connect collector test lead to the collector of the transistor. Connect the *emitter* test lead to the tran-

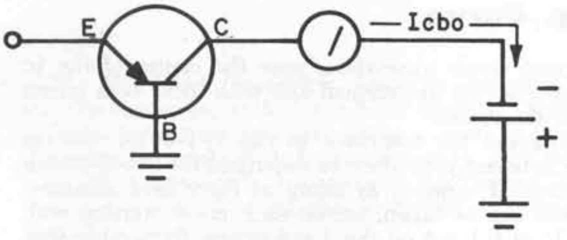


Figure 7. ICBO Current Flow

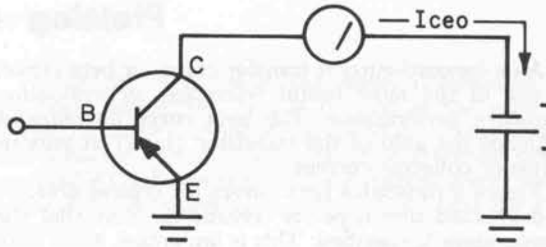


Figure 8. ICEO Current Flow

sistor *base*. Follow procedure for testing ICEO, using appropriate current range. The leakage indicated on the meter will be ICBO. In this way, ICBO up to 1 ampere can be measured.

The amount of leakage that is acceptable in a particular transistor depends on the circuit in which it is used. Transistors with relatively high leakage can be used in circuits with low resistances, such as most audio output stages. For this reason power transistors, where current dissipation is the basic consideration, normally have more leakage than low-power types.

Temperature is an important factor in evaluating leakage characteristics. Leakage normally increases as temperature increases. In transistor manuals, maximum ICBO leakage characteristics are usually given at specified temperatures.

ICEO

ICEO is defined as collector-to-emitter leakage, with the base open. See Figure 8. ICEO is also known as the open-base collector-cutoff current, since the transistor will not operate where in a circuit the collector current is below the ICEO level.

ICEO leakage should not be significantly higher than ICBO multiplied by $(\beta + 1)$.

Plotting A Beta Curve

A dc forward-current transfer curve, or beta curve, is one of the most useful references in evaluating transistor performance. The beta curve indicates at a glance the gain of the transistor (beta) at various levels of collector current.

Figure 9 illustrates beta curves for typical 2N4395 and 2N4396 silicon power transistors. Note that the temperature is specified. This is important, since beta will vary significantly with changes in temperature.

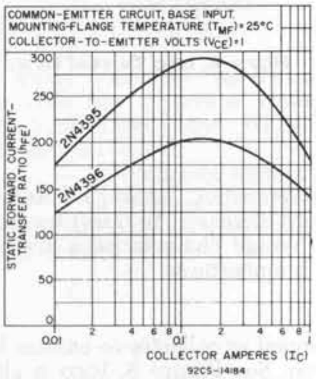


Figure 9. Beta Curve (Ic vs. Beta)
RCA Types 2N4395 and 2N4396

Published beta curves specify the collector-emitter voltage (VCE) that is used. The WT-501A Tester uses 1.5 volts as the operating voltage. In general, beta does not change significantly with operating voltage, as long as the voltage is within the ratings of the transistor.

Graph paper that is logarithmic along the Ic base line, as shown in Figure 9, should be used if possible. A curve obtained in this manner is preferable, since it is easier to determine the spread of current levels that produce the highest beta.

If a typical beta curve for the particular transistor is available, the test graph should be set up in the same manner. If a reference beta curve is not available, set up the base line for Ic from 0.1 to 100 mA for low current transistors, and from 1 mA to 1A for power transistors. If typical beta for the transistor is not known, make one or two sample tests at current levels somewhere near the center of the Ic range. Set up the vertical axis with these beta points near the center.

Connect the transistor to the WT-501A. Set up the beta test procedure as described for out-of-circuit testing. If desired, as many as forty beta measurements can be taken, ten on each range starting with an Ic of 0.1 mA on the 1 mA range. Remember that beta always equals the reading on the beta scale multiplied by the reading on the red scale obtained in the CAL function.

Example: 100 mA range.

Set Range Switch on CAL position of 100 mA range. Adjust the CAL controls so that the meter pointer indicates "BETA CAL X 1" on red scale. Ic is 10 mA. Switch to BETA position of 100 mA range. Beta equals BETA scale reading multiplied by 1.

Set Range Switch back to "CAL" on 100 mA range. Adjust CAL controls so that meter pointer reads "2" on red scale. Ic is 20 mA. Again, switch to BETA position. Beta equals BETA scale reading multiplied by 2.

Repeat procedure for 30 mA, 40 mA on through 100 mA, calibrating to position 3, 4 on through 10 on the red scale. Each time multiply reading on BETA scale by the reading obtained in the CAL procedure.

Read beta for each level of Ic, and make a corresponding point on the graph. Connect the test points with a smooth line.

NOTE: It is also possible to plot a family of curves indicating collector current (Ic) vs. base current (IB). Establish Ic using the CAL procedure described above.

Set switch to BETA position of the selected current range. Refer to the meter indication on the lower scale (ICBO). Consider a full-scale reading to be one-tenth the full-scale value for the particular current range.

EXAMPLE: Set switch to BETA position of 10 mA range. A reading of "50" on lower scale represents an IB of 0.5 mA. (Full scale equals 1/10 of 10 mA, or 1 mA. A half-scale reading therefore would be 0.5 mA.)

Red Scale CAL Reading (Switch set to CAL pos. of selected range)	1 mA Range Ic	10 mA Range Ic	100 mA Range Ic	1 A Range Ic	Multiply BETA Scale Reading by — (Switch set to BETA pos. of selected range)
1	0.1 mA	1 mA	10 mA	100 mA	1
2	0.2 mA	2 mA	20 mA	200 mA	2
3	0.3 mA	3 mA	30 mA	300 mA	3
4	0.4 mA	4 mA	40 mA	400 mA	4
5	0.5 mA	5 mA	50 mA	500 mA	5
6	0.6 mA	6 mA	60 mA	600 mA	6
7	0.7 mA	7 mA	70 mA	700 mA	7
8	0.8 mA	8 mA	80 mA	800 mA	8
9	0.9 mA	9 mA	90 mA	900 mA	9
10	1 mA	10 mA	100 mA	1 A	10

Chart showing CAL scale test points and Beta Scale multipliers for each current range

Circuit Description

The WT-501A Transistor Tester is designed to test transistors for collector-to-base leakage (ICBO), collector-to-emitter leakage (ICEO), and dc beta. Collector current (Ic) is continuously adjustable from 20 microamps to 1 ampere in four ranges. The instrument can also test the in-current dc current gain of a transistor.

A 100 microampere meter movement is used in the measuring circuits for the various test functions. Precision resistors are used to insure accurate test results.

An NPN/PNP switch provides the proper bias polarity to the transistor. Two dual potentiometers provide coarse and fine adjustment of collector current (CAL) and in-circuit zero.

The instrument has two internal 1.5 volt "D"-size batteries. One battery is used in NPN test and the other is used in PNP test. The batteries are also used during in-circuit tests to provide voltage in reverse polarity to cancel the effect of circuit leakage.

Beta Measuring Circuit:

A simplified diagram of the dc beta test circuit is shown in Figure 10. Resistors Rb and Rc serve both to establish the collector current, and to shunt the meter to the required sensitivity. Rb and Rc values are shown below:

Range	Rb	Rc
1 mA	1000 ohms	110 ohms
10 mA	110 ohms	10 ohms
100 mA	10 ohms	1 ohm
1 amp	1 ohm	0.1 ohm

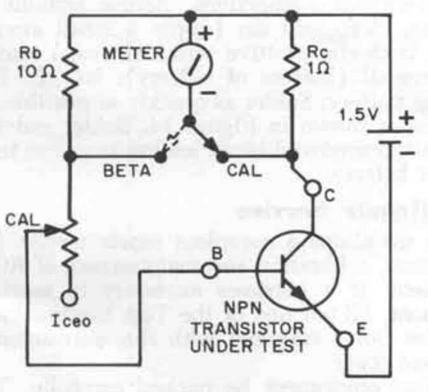


Figure 10. Simplified Beta Measuring Circuit, 0-100 mA Range

When the range switch is set to the CAL function, the meter is in the collector circuit. Collector current is determined by the value of the collector resistor for the particular range, and by the setting of the CAL control.

In the BETA function, the meter is switched to the base circuit. DC beta is defined as the ratio of the dc collector current to the dc base current. Since the collector current is established at a known value by the CAL adjustment, the base current meter reading can be interpreted in terms of dc beta for the transistor.

ICBO Measuring Circuit:

ICBO is the current flow, or leakage, from the collector to the base with the emitter open. As shown in Figure 2, 1.5 volts is applied to the collector and base of the transistor, and the meter is connected in the collector circuit. Collector to base leakage is indicated directly in microamps. A simplified schematic of the ICBO measuring circuit is shown in Figure 11.

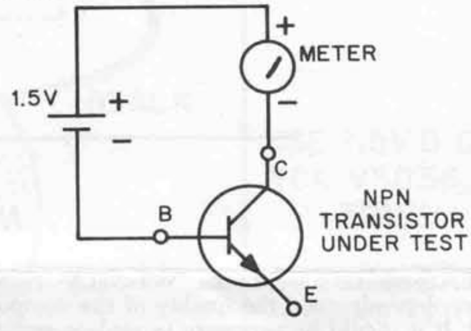


Figure 11. Simplified ICBO Test

ICEO Measuring Circuit:

ICEO represents the leakage from collector to emitter, with the base open. A voltage of 1.5 volts is applied to the transistor, and the meter is connected in the collector circuit. The resistor shunting the meter reduces the meter sensitivity to 10 mA.

Measurement of ICEO is normally made on the CAL position of the 1 mA range. If ICEO exceeds 1 mA however, the range switch can be set to the 10 mA or 100 mA range as necessary. Collector to emitter leakage is indicated in milliamperes, depending on the current range that is used. See Figure 12.

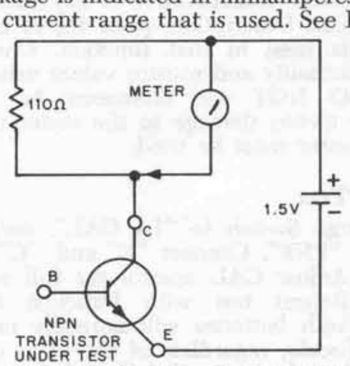


Figure 12. Simplified ICEO Test, 1 mA Range

In-Circuit Beta Test

The test circuit used to measure in-circuit current gain is similar to that used for out-of-circuit beta measurement. The in-circuit zero adjust control applies a voltage of reverse polarity to the collector metering circuit. This voltage compensates for the collector to emitter leakage through the components in the circuit under test, and permits the meter to be set to zero.

The CAL adjustment and the metering circuit are the same as for out-of-circuit measurement.

The resistance of the measuring circuit is low in value so that no significant loading effect occurs from the circuit being tested.

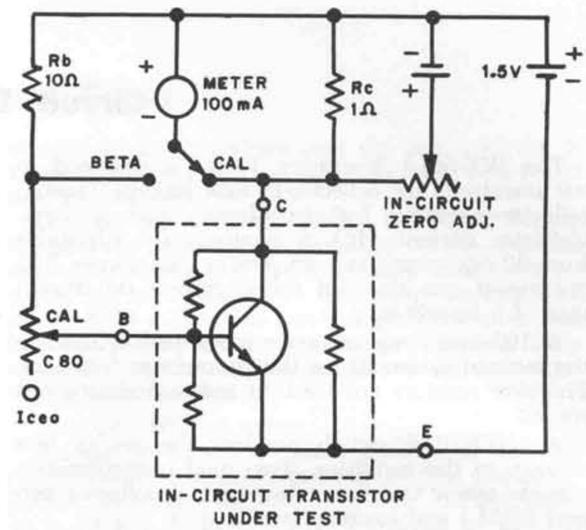


Figure 13. Simplified In-Circuit Beta Test, 0-100 mA Range

Maintenance

The performance of the WT-501A Transistor Tester depends upon the quality of the components used. If it should be necessary to replace any of the component parts, only RCA replacement parts or their equivalent should be used. When ordering replacement parts, refer to the Replacement Parts List on page 18.

The case can be removed from the Tester by removing the four screws on the back.

No calibration or adjustment procedures are required in the WT-501A. The performance and accuracy is determined by the 100 μA meter movement and the precision resistors used in the various functions. Normal maintenance includes only replacing the batteries as necessary.

If the Tester is inoperative in any function, refer to the Circuit Description, page 15, to identify the components used in that function. Check switch contact continuity and resistor values using an ohmmeter. DO NOT use ohmmeter to check the WT-501A meter; damage to the meter may result. A meter tester must be used.

Battery Test

Set Range Switch to "1A CAL", and Function Switch to "PNP". Connect "E" and "C" test leads together. Adjust CAL control for full scale meter reading. Repeat test with Function Switch on "NPN". Fresh batteries will normally cause meter to peg off-scale, regardless of the CAL control setting. Replace batteries if full scale meter reading cannot be obtained.

Battery Replacment

The WT-501A uses two 1.5 volt "D" cells, RCA VS036 or equivalent. Battery connections are soldered to prevent current loss due to resistive terminal connections.

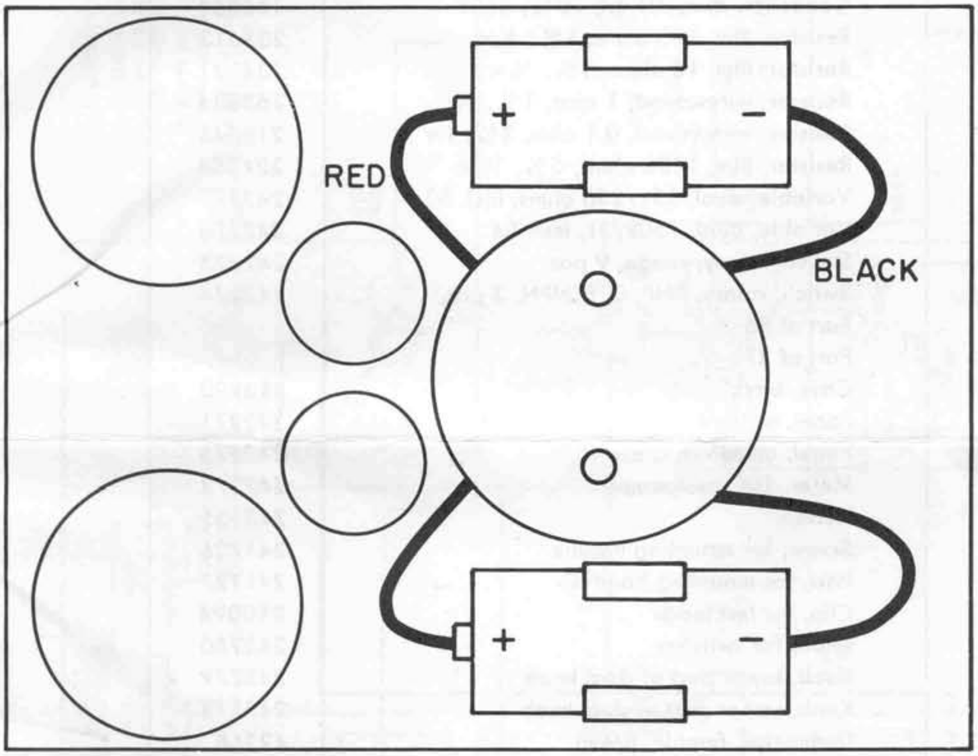
To replace batteries, remove the case, and unsolder terminal connections. Before installing new batteries, clean and tin (apply a small amount of solder) both the positive terminal (cap) and negative terminal (bottom of battery). NOTE: Do not overheat battery. Solder as quickly as possible. Insert batteries as shown in Figure 14. Solder red lead to positive terminal and black lead to negative terminal of each battery.

RCA Repair Service

RCA maintains a complete repair service for the adjustment, calibration and maintenance of RCA test equipment. If it becomes necessary to service this equipment, fill out one of the Test Equipment Service order forms supplied with the instrument. It is important that:

1. Test equipment be packed carefully. The instrument should be double-packed. It is best to pack the unit in its original carton, or similar container, then "float" this carton in at least a 3-inch layer of shredded paper inside the outer carton.
2. A full description of the trouble be included in the report.
3. All probes, cables, and test leads used with the equipment be included in the shipment.

Attention to these details will help prevent damage in transit and delay in repairs.



USE 1.5V D CELL RCA VS036, OR EQUIV.

SOLDER BATTERY CONNECTIONS

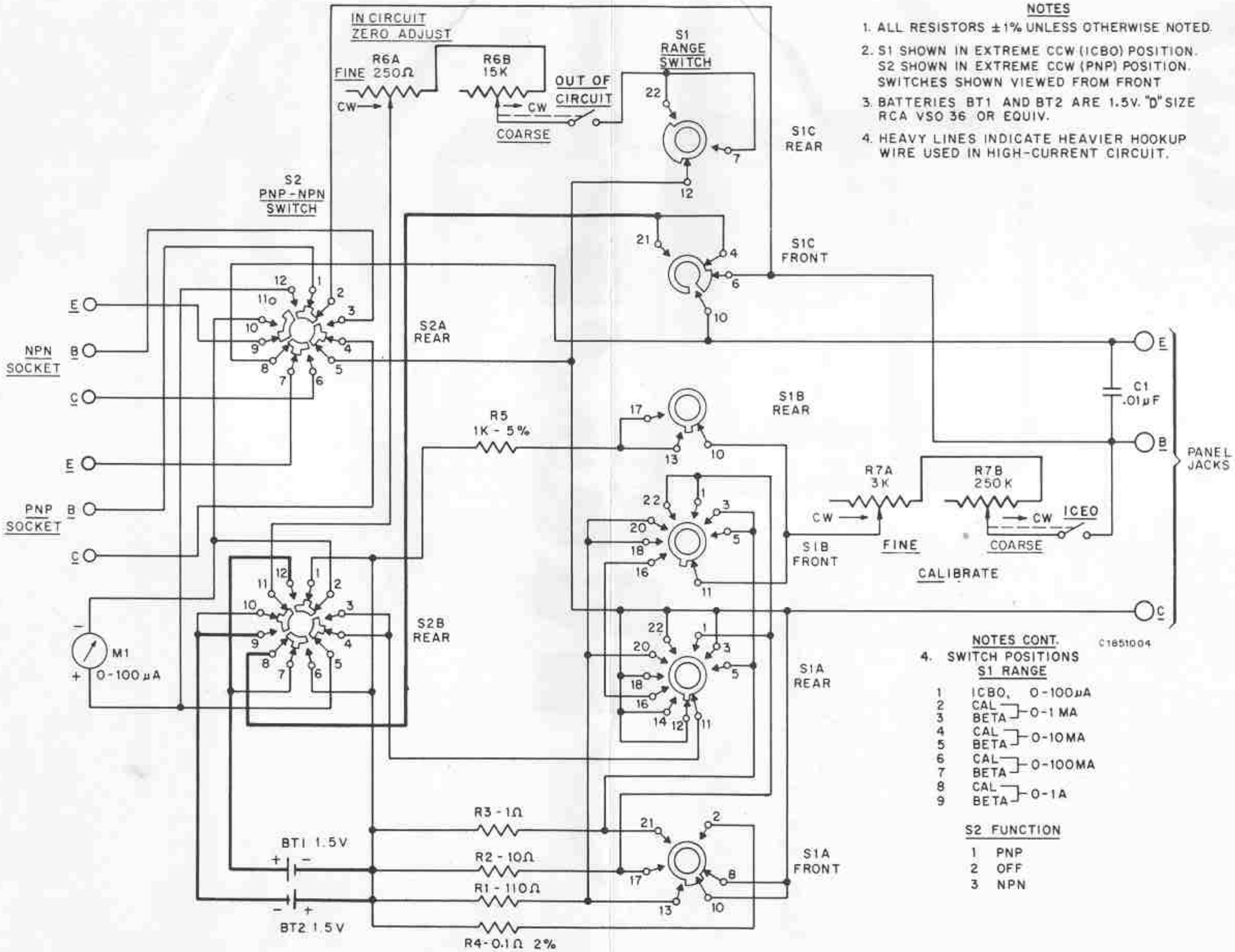
Figure 14. Battery Installation

Replacement Parts List

WT-501A Transistor Tester

When ordering replacement parts, include serial number and code number of instrument. Order parts by stock number, through a local RCA Distributor.

SYMBOL NO.	DESCRIPTION	STOCK NO.
C1	Capacitor, disc, .01 mf, 20%, 500v	106564
R1	Resistor, film, 110 ohms, 1%, ½w	237613
R2	Resistor, film, 10 ohms, 1%, ½w	234921
R3	Resistor, wirewound, 1 ohm, 1%, 1w	263834
R4	Resistor, wirewound, 0.1 ohm, 2%, 1w	219045
R5	Resistor, film, 1000 ohms, 5%, ½w	224254
R6	Variable, dual, 15k/250 ohms, incl. S3	242277
R7	Variable, dual, 250k/3k, incl. S4	242276
S1	Switch, rotary, range, 9 pos.	242275
S2	Switch, rotary, PNP/OFF/NPN, 3 pos.	242274
S3	Part of R6	
S4	Part of R7	
	Case, back	218993
	Panel, molded	242271
	Panel, aluminum dress	242273
MI	Meter, 100 microamps	242272
	Handle	242135
	Screw, for mounting handle	241726
	Post, for mounting handle	241727
	Clip, for test leads	219094
	Knob, for switches	242280
	Knob, lower part of dual knob	242279
	Knob, upper part of dual knob	242278
	Connector, female, green	42268
	Connector, female, blue	242269
	Connector, female, yellow	242270
	Test leads, set of three	244801



NOTES

1. ALL RESISTORS ±1% UNLESS OTHERWISE NOTED.
2. S1 SHOWN IN EXTREME CCW (ICBO) POSITION. S2 SHOWN IN EXTREME CCW (PNP) POSITION. SWITCHES SHOWN VIEWED FROM FRONT
3. BATTERIES BT1 AND BT2 ARE 1.5V. "D" SIZE RCA VSO 36 OR EQUIV.
4. HEAVY LINES INDICATE HEAVIER HOOKUP WIRE USED IN HIGH-CURRENT CIRCUIT.

NOTES CONT.

4. SWITCH POSITIONS

S1 RANGE

1 ICBO, 0-100µA
2 CAL, 3 BETA — 0-1 MA
4 CAL, 5 BETA — 0-10MA
6 CAL, 7 BETA — 0-100MA
8 CAL, 9 BETA — 0-1A

S2 FUNCTION

1 PNP
2 OFF
3 NPN

Figure 15. WT-501A Schematic Diagram

RCA