HICKOK

INSTRUCTION MANUAL

for

MODEL 890A

IN-CIRCUIT TRANSISTOR TESTER

Manual No. 2490-590

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TECHNICAL DATA

I. 1. Batteries required:

1 - 22.5 volt
4 - 1.5 volt

2. Meter Scales

I_{CBO}	0 - 50 μa
I_C	0 - 10 ma
Beta	0 - 100, 0 - 50, 0 - 200
Beta Test Accuracy:	± 5% for Circuit Impedances above 150 ohms

3. Meter

Sensitivity - 50 μa - 100 Mv

4. AC Test Signal

1000 cps sine wave, with a variable amplitude
Calibration setting - 5 μa Base Current

5. Transistor Input Resistance:

Range - 50 - 10,000 ohms

6. Circuit Input Impedance:

Range - 100 - 100,000 ohms

7. Collector Voltages

0, 1.5V, 3.0V and 4.5V

8. Transistor Complement:

Symbol No.	Type	Function
Q1	2N1376	1000 cps Oscillator
Q2, Q3, Q4	2N1376	AC Meter Amplifier

PURPOSE AND FEATURES

The Hickok Model 890, Dynamic Beta "In-Circuit Transistor Tester" is designed to test all small and medium power transistors directly in their circuits. The unique features of this instrument are the following:

a. The dynamic Beta is read directly on the meter.

b. The External Input Impedance of the transistor circuit is read from carefully calibrated potentiometers.

c. The Dynamic Input Resistance of the transistor is read from another carefully calibrated potentiometer.

d. The collector cutoff current I_{CBO} can be read directly on the meter. For this test the transistor must be removed from the circuit.

e. The collector current I_C is read directly on the meter.

f. The tester can also be used for "Out of Circuit" transistor tests.

GENERAL INFORMATION

II. 1. Definition

There are a few terms and basic definitions which should be restated in order to help the user of this instrument obtain its maximum usability.

a. Beta is the forward current transfer ratio of a transistor in the common emitter configuration.

$$\frac{\Delta I_C}{\Delta I_B} = B = \text{Beta}$$

b. Alpha is the forward current transfer ratio of a transistor in the common base configuration.

$$\frac{\Delta I_C}{\Delta I_E} = \alpha = \text{Alpha}$$

c. The relationship between Alpha and Beta is established by the following formulas,

$$\text{Beta} = \frac{\text{Alpha}}{1 - \text{alpha}},$$

$$\text{Alpha} = \frac{\text{Beta}}{1 + \text{Beta}}$$

If either of the parameters (alpha or Beta) is known, the other may be found by applying the proper formula.

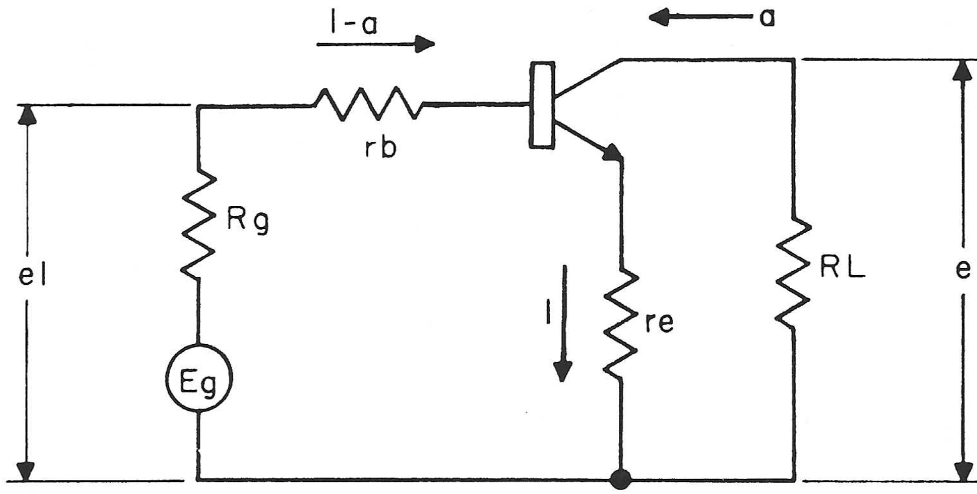

Figure 1

d. Figure 1 shows a simplified common emitter amplifier. From this figure the input resistance is seen to be,

$$R_{IN} = rb + \frac{re}{1 - \alpha}$$

and the approximate voltage gain is,

$$\frac{e2}{e1} = \frac{\alpha\, RL}{rb\,(1 - \alpha) + re} = \frac{\alpha\, RL}{(1 - \alpha)\, R_{IN}} = B\, \frac{RL}{R_{IN}}$$

From the above formula the significance of the measurement of R_{IN} can be appreciated.

e. The definitions of the following terms as used in this manual are:

(1) Out of Circuit - the transistor is completely removed from its external circuitry.

(2) In Circuit - the transistor is connected or partially connected to its external circuitry.

THEORY OF OPERATION

III. A thorough understanding of the theory behind the operation of any instrument will enable the user to obtain greater utility and satisfaction from the instrument. For this reason a brief description of the principal circuits and diagrams of the basic test circuits are given.

The instrument has six basic sections: (1) Battery Supplies, (2) Audio Oscillator, (3) Variable Resistance Bridge, (4) AC Voltmeter, (5) Type Selector Switch and (6) The Test Selector Switch.

1. Battery Supplies

   a. The internal power requirements of the audio oscillator, the A.C. Amplifier and meter circuit are supplied by a 22.5 volt battery.

   b. The collector voltage for the transistor under test is obtained from three 1.5 volt batteries connected in series. Therefore the collector voltage can be varied from 0 to 4.5 volts in 1.5 volt steps by changing the position of the COLLECTOR VOLTS switch.

   c. The collector current can be varied from 0 - 10 ma by varying the current into the base of the transistor under test. This is accomplished by using a potentiometer, IC, across a 1.5 volt battery. This network then gives a variable biasing arrangement for the base to emitter circuit of the transistor under test.

2. Audio Oscillator

   A 1000 cps Colpitts oscillator consisting of a tuned circuit, transistor, and its associated biasing and feedback networks, is used to generate the A.C. test signal. The output of the oscillator is obtained through a step-down transformer and it is connected to the variable resistance bridge through the TEST SELECTOR switch. The amplitude of the oscillator is controlled by the BETA CAL potentiometer which varies the output of the transistor oscillator.

3. Variable Resistance Bridge

   One leg of the bridge circuit is the base to emitter input impedance of the transistor under test. This input impedance can be the parallel combination of the external circuitry impedance of the transistor under test and its dynamic input resistance. The balancing leg consists of one dual potentiometer, "Z Ohm Circuit", and a single potentiometer, "R_{IN} Transistor", which is connected in parallel with the dual potentiometer in the last three positions of the Test Selector Switch.

   The dual potentiometer is used to null out the external circuit impedance of the transistor under test. When an "Out of Circuit" test is performed, this dual potentiometer is removed from the circuit. A SPST switch is provided to accomplish this condition. The single potentiometer, "R_{IN} TRANSISTOR" is used to null out the dynamic input resistance of the transistor.

4. The A.C. Voltmeter Circuit consists of a three-stage amplifier, which is highly degenerative to provide excellent stability, and a crystal diode bridge detector. The input sensitivity of the amplifier is .5 MV P-P or .176 MV RMS for full scale deflection of the meter.

5. Type Selector Switch

The type selector switch is a reversing switch which changes the polarity of the applied voltages to the transistor under test. The position of the switch is determined by the type of transistor being tested, that is, an NPN or a PNP.

6. Test Selector Switch

The Test Selector Switch is a six-position switch which sets up the internal circuitry to perform the various indicated tests. These tests are: (a) ICBO, (b) I_C, (c) Z Ohms Circuit, (d) R_{IN} Transistor, (e) Beta Cal and (f) Beta. The tests are explained below, for a PNP type transistor, by means of a brief description and circuit diagrams.

a. I_{CBO} test

In the I_{CBO} test, a reverse voltage is applied across the collector-base diode of the transistor. The emitter is open circuited. Note: The transistor must be removed from its circuit for this test. The collector cutoff current is read directly on the 0 - 50 μa scale of the meter. The meter is connected in series with a limiting resistor to the applied voltage and the transistor under test. The circuit is shown in Figure 2.

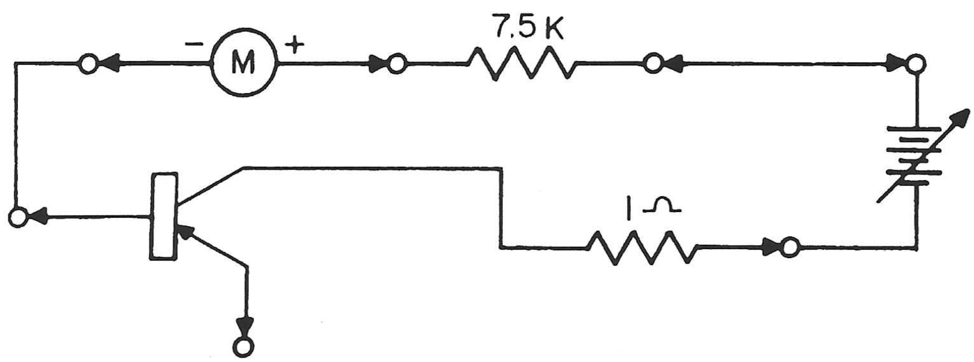

Figure 2. I_{CBO} Test Circuit

b. I_C Test

The adjustment of the I_C control is made in the following manner:

Set the I_C potentiometer to "zero" or its minimum position. Note the shunt leakage current on the 0 - 10 Ma scale of the meter. Under these circumstances the meter is reading the stray leakage current flowing in the external circuitry due to the collector supply voltage. Now adjust the I_C potentiometer for one additional milliampere over the previously noted reading. With this setting one milliampere of collector current will flow through the transistor which is considered standard for a small signal beta test. If a larger collector current is desired, the I_C potentiometer can be adjusted to the desired value. Figure 3 shows the circuitry used to perform this test; it doesn't include the external circuitry of the transistor.

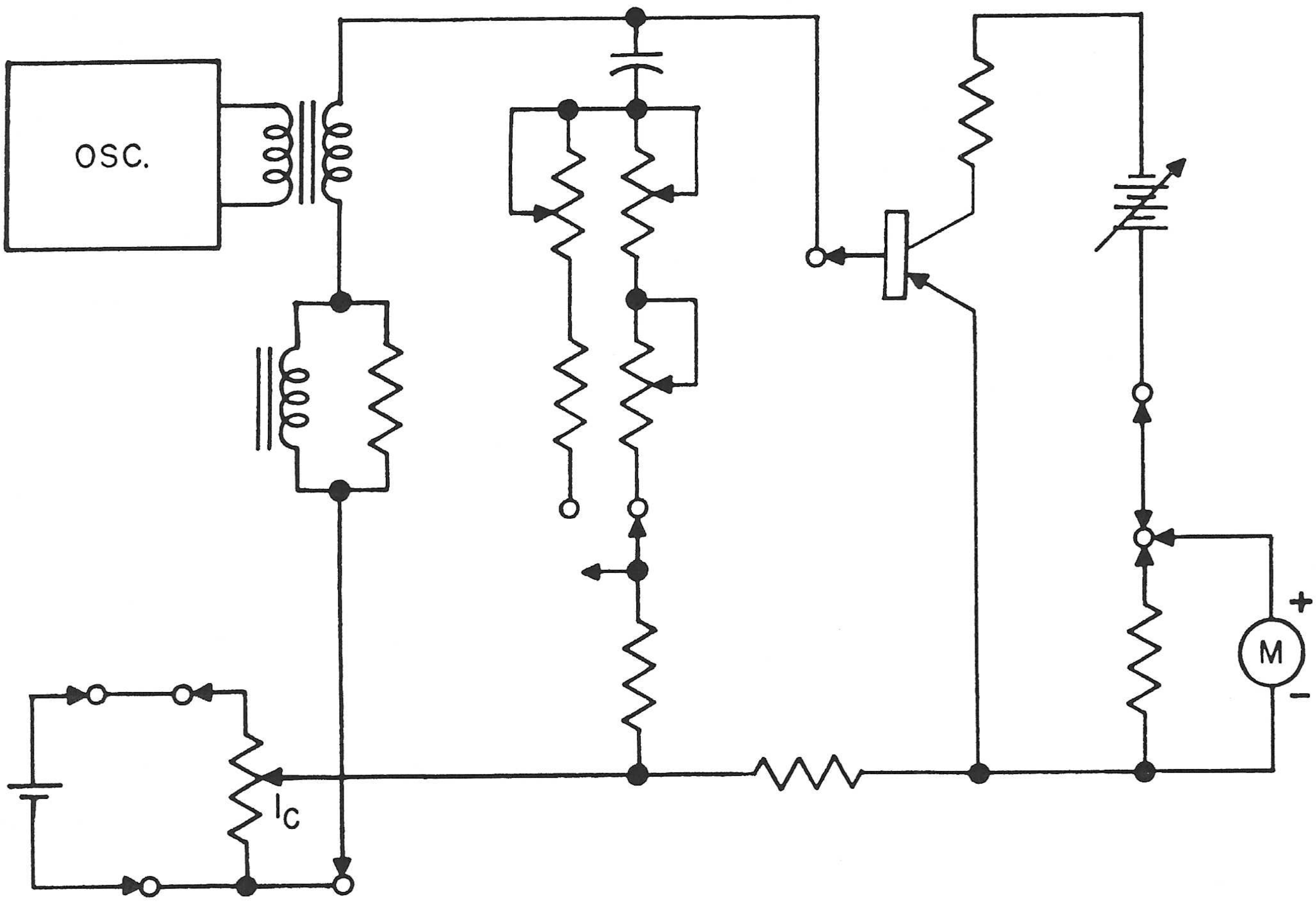

Figure 3. I_C Test Circuit

c. Z Ohms Circuit (external input circuit impedance)

In order to determine the Z input circuit impedance, it is necessary to sèparate the external input circuit impedance from the transistor input rèsistance. This is accomplished by reversing the bias on the transistor so that it is cut off, thus separating the external input circuit impedance from the transistor input resistance.

The external input circuit impedance forms one leg of the bridge circuit and its value is determined by varying the "Z Ohms Circuit" potentiometers until a null is indicated on the sensitive AC voltmeter tied across the bridge. The value of this external input circuit impedance can be read directly from the calibrated dials of the Z Ohms Circuit potentiometers. This null should be made very carefully because it can affect the next test which is the R_{IN} of the transistor.

If the transistor is Out of Circuit the external input impedance is almost infinite. Therefore the Z Ohm potentiometers must be removed from the bridge circuit. This is accomplished with a SPST switch which is ganged to the shaft of the small knob of the Z ohms potentiometer. The switch must be placed to the "Out of Circuit" position in order to remove the Z ohm potentiometers from the bridge circuit. Figure 4 shows the circuit for the above test.

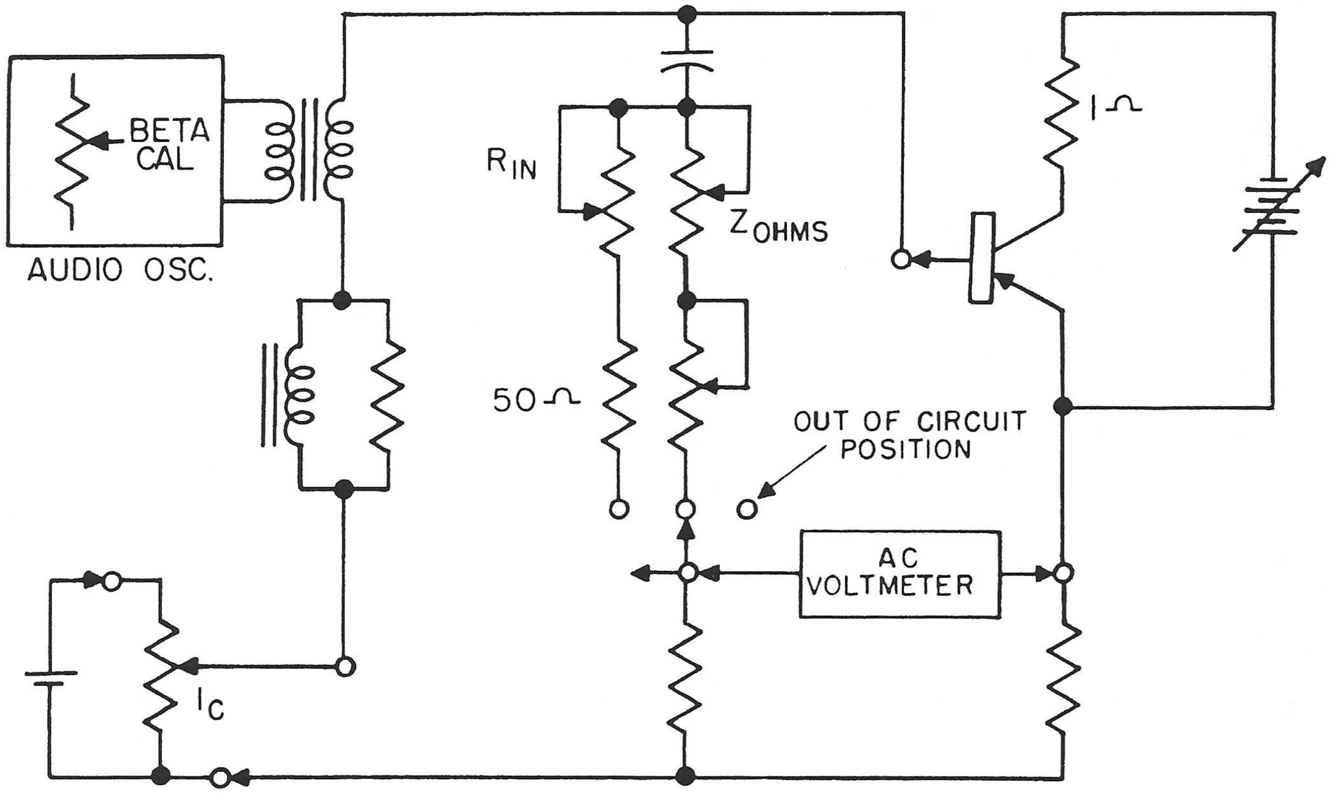

Figure 4. Z Ohms Test Circuit

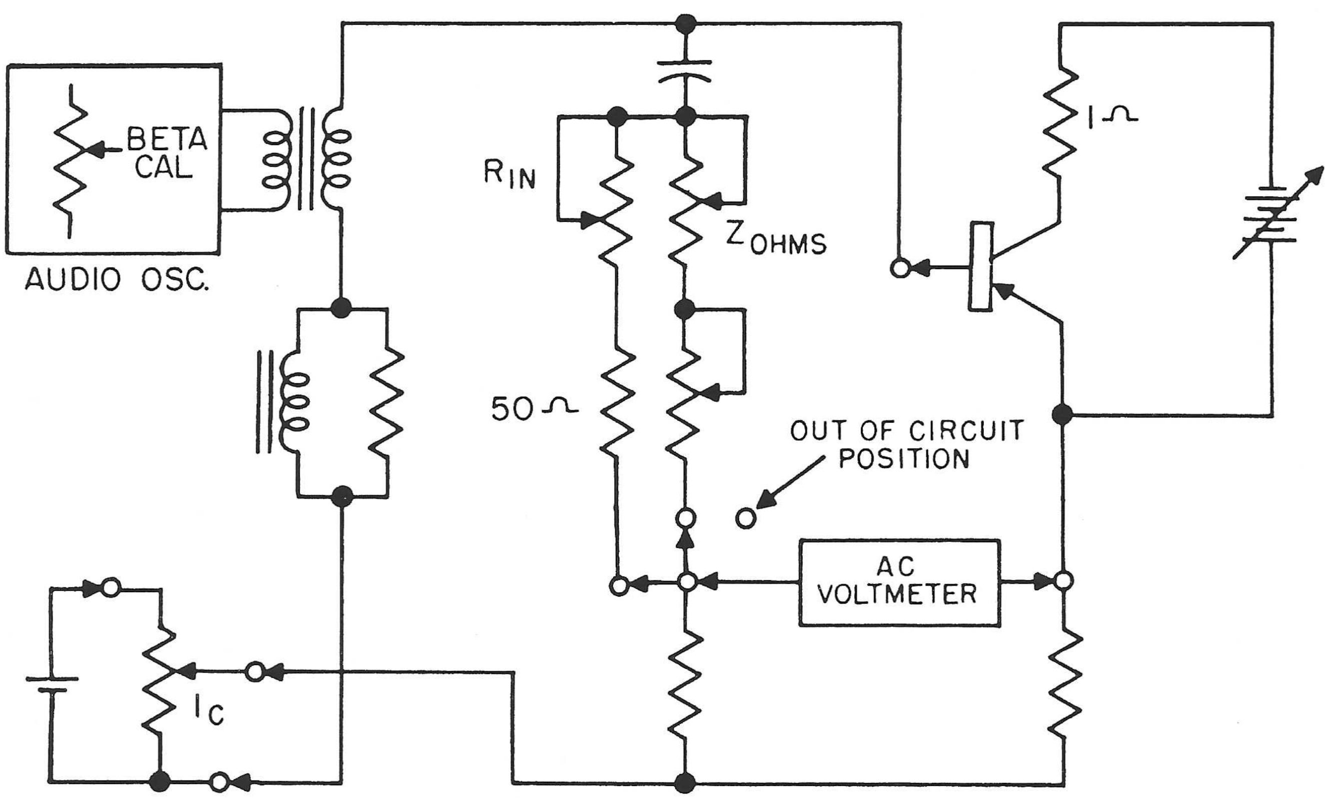

Figure 5. R_{IN} Test Circuit

d. R_{IN} TRANSISTOR (dynamic Input Resistance)

The dynamic input resistance of the transistor can now be determined by using the same technique used in determining the external input circuit impedance. However, in this test the transistor is biased in the forward direction, and the previous settings of the "Z Ohms Circuit" potentiometers are retained. The value of the dynamic input resistance is determined by varying the R_{IN} TRANSISTOR potentiometer until a null is indicated on the meter. The value of the dynamic input resistance can be read directly from the calibrated dial of the R_{IN} TRANSISTOR potentiometer. The circuit diagram for this test is shown in Figure 5.

e. Beta Cal and Beta
&
f. A. C. Beta is the current gain of a transistor in the common emitter configuration and is defined as the ratio of the a. c. collector current to the a. c. base current,

$$\frac{ic}{ib}$$

In order to measure both of these currents, it was necessary to place a monitoring resistor of 50 ohms in the bridge circuit and another monitoring resistor of 1 ohm in the collector circuit. Then, using the sensitive A.C. Voltmeter to monitor the voltage drops across these resistors, the A. C. Beta can be determined. Placing the Test Selector Switch to the Beta Cal position, the A. C. Voltmeter monitors the voltage drop across the 50 ohm resistor, then the Beta Cal potentiometer is adjusted until the meter reads 1/2 scale or Cal Set. Under this condition there is 5 μa of current flowing in the base circuit. The Test Selector Switch is then placed to the Beta position. This switches the AC Voltmeter across the 1 ohm monitoring resistor and the voltmeter reads beta directly. The circuit diagrams for these tests are the same as are shown in Figure 5 with the exception of the location of the AC Voltmeter.

BATTERY INSTALLATION

Normally the Model 890 "In Circuit Transistor Tester" is not supplied with batteries. This is due to the fact that batteries deteriorate with age, and secondly they may cause damage to the tester during shipment.

To put the instrument into operation the following complement of batteries should be installed:

4	Type C flashlight cells
1	22.5 volt, #420 Eveready or K15 Burgess

To install batteries proceed as follows:

1. Remove the eight panel screws.

2. Gently lift the panel assembly out of its case and set to one side.

3. Install batteries in their proper holders.

   a. The holders for the four "C" cells are located in the left portion of the case, the 22.5 volt battery holder is located in the right section of the case. Figure 6 shows the proper location of batteries.

   b. The plus terminal of each battery holder is clearly marked with a plus sign, +. The terminals of the battery holders are marked in this manner in order to show where the plus terminal of each battery is to be located.

   c. CAUTION

      When installing the batteries in their respective holders, the "plus" polarity marking of the batteries and the battery holders must coincide, otherwise, damage to the tester, and the transistor under test will result.

   d. The batteries should be firmly seated in their respective holders to insure good electrical contact.

4. Carefully lower the panel assembly into its case and secure it with the eight screws that were removed.

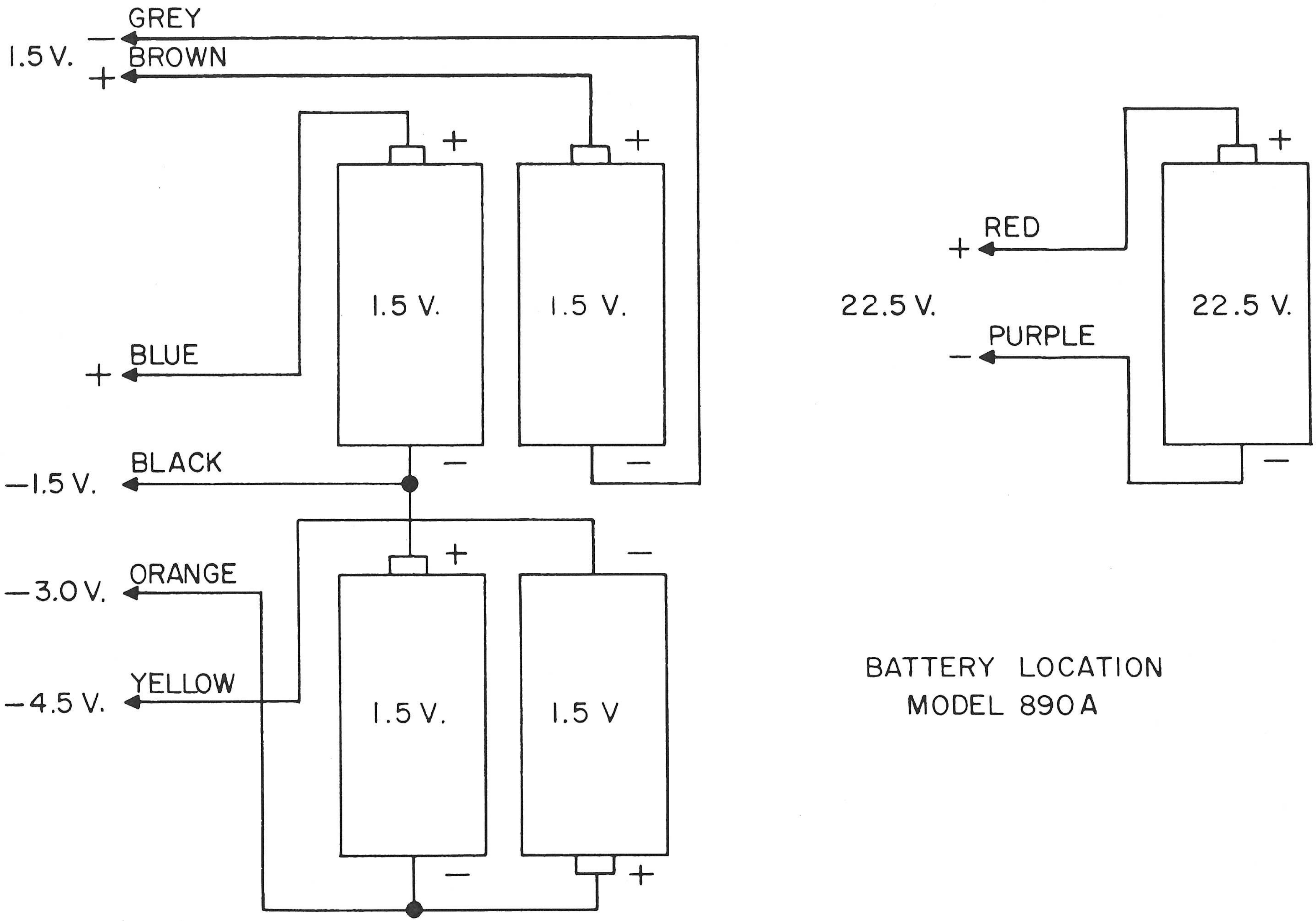

Figure 6. Location of Batteries

For the purpose of quick reference, the bottom views of the most common types of transistors are shown in Figure 7.

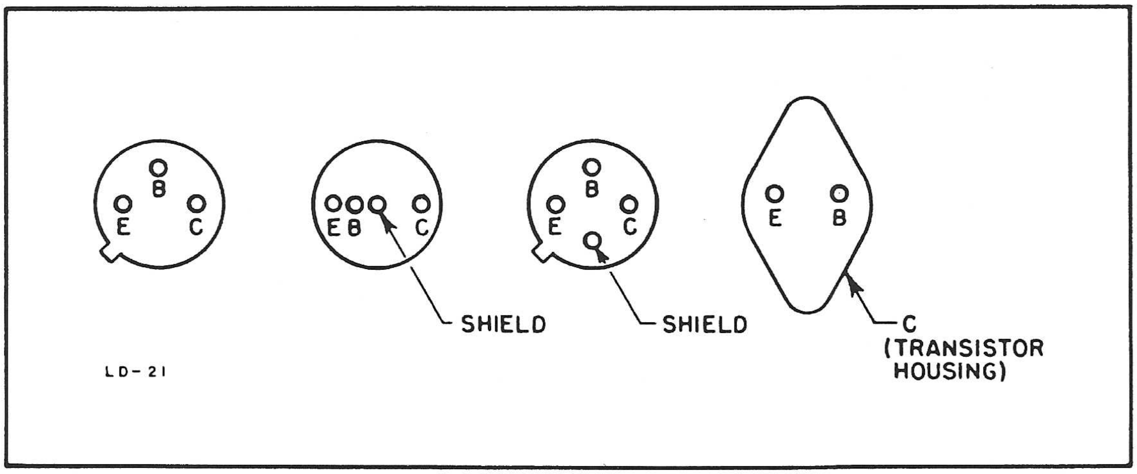

Figure 7. Transistor Lead Identification

Before testing any transistor it is recommended that the manufacturer's specification sheets be consulted. The tests performed by the Model 890 In-Circuit Transistor Tester are I_{CBO}, I_C, "Z Ohms", R_{IN} and Beta. However, when testing a transistor for its collector leakage current, I_{CBO}, the transistor must be removed from its external circuitry. These tests must be performed carefully and in a proper sequence.

Before attempting to test any transistor, make sure that the I_C and Beta Cal potentiometers are turned to 0 or to their minimum positions. This will prevent any possible damage to the transistor to be tested. The test procedure will be separated into two categories -- "In Circuit" tests and "Out of Circuit" tests.

a. The test procedure for the "In Circuit" condition is as follows:

1. Connect the test lead to the 890 in this manner: Place the plug with the yellow lead into the jack marked "E", the plug with the green lead into the jack marked "B" and the plug with the blue lead into the jack marked "C". Then connect the other end of the test lead to the transistor to be tested. The yellow lead is connected to the emitter, the green lead to the base and the blue lead to the collector (refer to basing diagram, Figure 7).

2. Set the Type Selector Switch to either the PNP or the NPN position, depending upon which type of transistor is to be tested.

3. Before attempting to test any transistor, make sure that the I_C and Beta Cal potentiometers are turned to "zero" or their minimum positions.

4. Select the collector voltage desired for testing the transistor: 0 - 4.5 volts in 1.5 volt steps, usually 1.5 volts.

5. Place the Test Selector Switch to the I_C position and depress the "Press to Operate" switch. This energizes the tester. If the meter deflects more than Full Scale, release the Operate Switch immediately. This is a sign of an emitter to collector short.

6. Observe the shunt leakage current on the 0 - 10 ma scale of the meter. Under these circumstances the meter is reading the stray leakage current flowing in the external circuitry due to the collector supply voltage. Now adjust the collector current with I_C potentiometer for one additional milliampere over the previously noted reading. If the stray leakage current is high, 3, 4 or 5 ma, set the collector current to at least twice the noted stray leakage current, by adjusting the I_C potentiometer.

   NOTE: Power types of transistors, which are used in the final audio output stages of transistor radios, should be checked with 5 or 10 ma of collector current.

7. Rotate the vernier of the Z Ohm potentiometer to approximately 250 ohms.

8. Place the Test Selector Switch to the "Z Ohms Circuit" position and depress the Operate Switch.

9. Increase the amplitude of the audio oscillator by turning the Beta Cal potentiometer until the meter reads half scale, and then balance the bridge by varying first the large control of the "Z Ohm Circuit" potentiometer to get an approximate null and then use the vernier to get a precise null. The null will be indicated on the meter. The value of the external input impedance may be read directly from the calibrated dials of the Z Ohm Circuit potentiometers.

10. Place the Test Selector Switch to the "R_{IN}" Transistor position, depress the Operate Switch and increase the amplitude of the audio oscillator, then by varying the R_{IN} potentiometer, balance the bridge circuit. A null will be indicated on the meter when the bridge is balanced. The value of the dynamic input resistance of the transistor may be read directly from the calibrated dial of R_{IN} Potentiometer.

11. Place the TEST SELECTOR switch to the Beta Cal position. Depress the Operate Switch and adjust the Beta Cal potentiometer until the meter reads 1/2 scale or Cal Set. Then place the TEST SELECTOR switch to the Beta position, and read Beta directly on the meter. If the Beta of the transistor is higher than 100, recalibrate the meter to 1/4 scale and then multiply the meter reading by 2. If the Beta of the transistor is below 50 and an accurate value of beta is required, recalibrate the meter to full scale and read Beta directly on the 0 - 50 scale.

b. Out of Circuit Tests

The test procedure for the "Out of Circuit" test condition is almost identical to that of the "In Circuit" test procedure. The only difference in this procedure is that the I_{CBO} test is performed and the "Z Ohms Circuit" test is omitted.

NOTE
When omitting the "Z Ohms Circuit" test, the "Z Ohms Circuit" potentiometers must be switched to the "Out of Circuit" position.

1. I_{CBO} Test (Collector Leakage Current)

The test procedure is the same as that stated for the "In Circuit" test condition, page 11, paragraph 2, 1 through 4. Step 5 for I_{CBO} test is: The TEST SELECTOR switch is placed to the I_{CBO} position, the OPERATE switch is depressed and the leakage current is read on the I_{CBO} scale of the meter. The other tests are exactly the same as for the "In Circuit" test condition, steps 6, 10 and 11, on page 12.

See example below.

c. Conclusions from the Tests Performed

These conclusions will help the user of this instrument to determine the quality of a transistor which was tested. The test results should be within the limits specified in the manufacturer's test specification sheets and the allowable tolerances of the instrument.

In general, small signal types of silicon transistors will have lower values of collector leakage current, I_{CBO}, than small signal types of germanium transistors. A typical value of I_{CBO} for silicon transistors is about 0.2 μa while for germanium transistors it is about 10 μa. The betas of silicon transistors are much lower as compared to germanium transistors. The general beta ranges of silicon transistors are 9 to 90, while for germanium transistors they are 20-300. For power types of transistors the I_{CBO} is much larger than the small signal types and a typical meter reading is about 50 μa for germanium transistors and less than 50 μa for silicon transistors.

Example of an Out of Circuit test for a 2N1376:

a. Place the transistor in socket provided on the unit.

b. Place the Type Selector to the PNP position.

c. Place the Collector Volts switch to 1.5 volts.

d. Place the Z Ohm Circuit potentiometer switch to the Out of Circuit position.

e. Place the Test Selector Switch to the I_{CBO} position and depress the operate switch. Read the 0 - 50 μa scale of the meter. A typical reading is 3.5 μa; then release the operate switch.

f. Place the Test Selector Switch to the I_C position and depress the operate switch. Using the I_C control, set the collector current to 1 ma, then release the operate switch. A typical value for R_{IN} is about 2000 ohms.

h. Place the Test Selector Switch to the Beta Cal position and depress the operate switch. Turn the Beta Cal potentiometer until the meter reads 1/2 scale or "Cal Set". Then turn the Test Selector to the Beta position and read Beta on the 0 - 100 scale of the meter. A typical value is 95.

OPERATING HINTS

When using the Model 890 for checking out an audio driver stage, one should set the volume control to about 1/2 of its resistance. This will eliminate an AC short between base and emitter and make the testing of this stage easier.

When performing a "Z Ohm Circuit" test there are external circuit conditions, under which it is impossible to reverse bias the transistor under test. This is due to extremely low values of self-biasing networks and the collector voltage supply. When these conditions exist, it is necessary to reduce the collector voltage to zero. This will reverse bias the transistor under test, and the external circuitry impedance can be measured as outlined in steps 7, 8 and 9 on page 12. After the "Z Ohms Circuit" test has been made, the Collector Supply voltage switch should be returned to its previous position.

The detection of inter-element shorts, which are emitter to base, base to collector and emitter to collector, of a transistor may be detected by the following reactions of the tester.

1. Base to Collector short will make the meter deflect off scale if an I_{CBO} test is performed.

2. Emitter to Base short will have this effect--low or no I_C reading with the I_C control set to its maximum position. The I_C control has little or no effect on the I_C current.

3. Emitter to Collector short will show up as a high I_C reading on the meter, which cannot be reduced with the I_C control.

GENERAL INFORMATION FOR THE SERVICE TECHNICIAN

To get the most from the instrument be sure to read carefully sections 9 ("Conclusions from tests performed), 10 ("Operating Hints"), 11 ("Circuit Limitations"), and 13 ("Additional Tests"). These sections of the manual will enable you to evaluate individual transistor performance and to anticipate special test conditions that may otherwise lead to confusing results.

The following additional information is offered in an effort to save you time in trouble-shooting portable transistor radios:

IS IT AN NPN OR PNP?

If the Schematic isn't available, note the battery polarity. A positive ground indicates the use of PNP transistors. This is not an infallible rule, however. Any doubts can be resolved with the use of a VOM: Connect the positive lead to chassis ground and touch the negative lead to the collector of the transistor in question. An upscale reading indicates the transistor is a PNP type, and vice versa.

HOW CAN I TELL WHICH IS EMITTER, BASE OR COLLECTOR?

Refer to the standard basing diagrams, Figure 7. Generally, transistor terminals are arranged in a regular sequence of emitter, base and collector from left to right, viewing the transistor from above. Transistors having a triangular pin arrangement usually have the collector pin identified by a red dot or other symbol.

IS THE TRANSISTOR GOOD OR BAD?

Beta is the "figure of merit" for a transistor and is comparable to Mutual Conductance in a vacuum tube. In general, high Beta will give high gain. As a guide, the table in the transistor reference chart lists Beta figures for EIA-registered transistor types. The critical stage in portable radios is usually the mixer-oscillator. This stage will most often use the highest beta transistor in the set. Low beta in this stage will cause oscillator "Dropout" at low battery voltages.

WHAT'S WRONG WHEN I CAN'T GET A "NULL"?

This will show up when adjusting the "Z Ohms" potentiometer; the meter reading will decrease with counter-clockwise rotation of the control but will not pass through a definite null. It may even drop to zero at the zero setting of both the potentiometers. Such a condition indicates that the circuit impedance surrounding the transistor is less than the 150 ohms minimum specified for the 890. If so, check the volume control setting (if you are testing an audio transistor); make sure it is at about $\frac{1}{2}$ maximum resistance. When testing IF transistors, check to see if the AVC bypass capacitor is connected directly to the AVC feed terminal of the IF transformer. If so, or if doubtful, disconnect one end of the capacitor (usually an electrolytic of several microfarads capacitance).

WHAT IS THE SIGNIFICANCE OF THE "Z OHMS" AND "R_{IN}" POT READINGS?

These potentiometers give the actual value of the 1000 cycle impedance surrounding the emitter-base terminals of the transistor under test. They are useful in spotting shorted or leaky components, not only in the RF and IF sections, but particularly in the audio section. In the audio section they are ideal for checking suspected shorts in audio transformers or speaker voice coils.

There are some circuits such as directly coupled PNP or NPN Circuits where a slightly different test procedure is required. This procedure is to preset the Z Ohm Circuit potentiometers to the approximate value of the external input impedance, omit the Z Ohm Circuit Test and continue with the other tests. The reason for this deviation is that the Z Ohm Circuit test reverse biases the transistor under test, however, at the same time it forward biases the previous transistor, which then shunts the input impedance of the transistor under test.

There are some special circuits where the external input circuitry of the transistor exhibits a large capacitance, 0.5 μf or larger, across the base to emitter leads of the transistor being tested. Under this condition it is recommended that one side of the capacitor be disconnected from the circuit while performing the tests.

A Schmitt trigger (Figure 8), is another circuit in which some difficulty may arise when checking the second transistor in the circuit. This is due to the forward biasing network of the transistor under test, which also acts as a collector supply for the first transistor. This difficulty can be eliminated by shorting the collector to the emitter of the first transistor, and then proceeding to test the second transistor as outlined in the Operation Section of this manual.

For some I. F. AVC controlled stages, which have both the base and the low side of the collector tank circuit heavily bypassed; it is possible, even under these adverse conditions, that the Z Ohm Circuit potentiometers can null out the external circuit impedance. However, the value of this impedance will be very low, in some cases almost a short circuit; and it should be remembered that the instrument's accuracy is rated for external circuit impedances above 150 ohms. When these circumstances exist, it is necessary to open one of these bypass condensers. This will remove the low impedance from the emitter base circuit. The stage can then be tested as outlined in the operating section of ths manual.

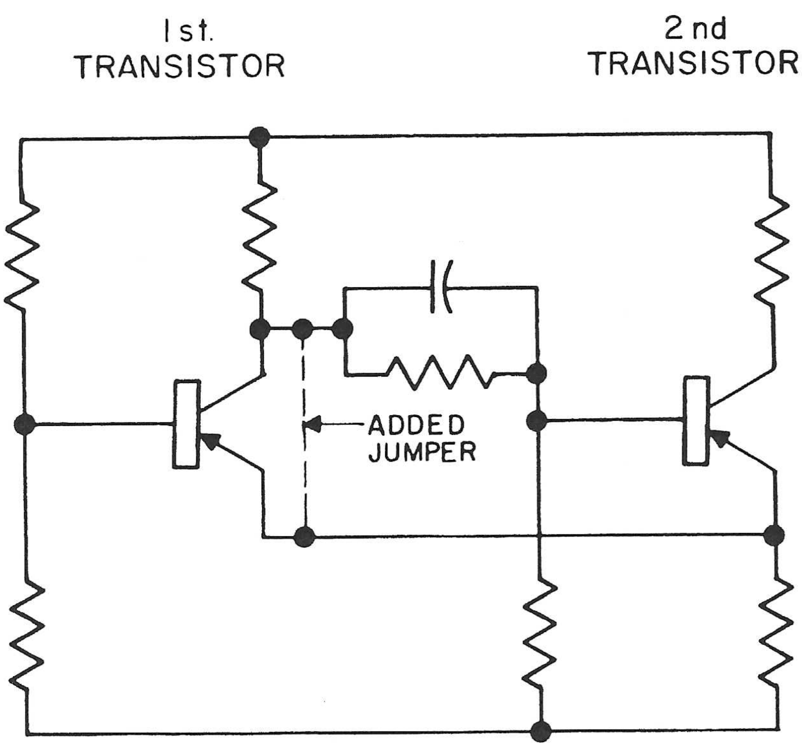

Figure 8.

ADDITIONAL TESTS

The Model 890 can also perform the following tests:

1. I_{CEO} TEST (for small signal types)

   By definition, I_{CEO} is the collector leakage current with the collector reverse biased and the base open-circuited. In general the I_{CEO} leakage current is considerably larger than I_{CBO}. The test is performed in the following manner:

   a. Place the Type Selector to either the NPN or the PNP position depending upon the type of transistor.

   b. Place the Collector Volt Switch to the 1.5V position.

   c. Place the Test Selector Switch to the I_{CBO} position.

   d. Connect the collector to the blue lead and the emitter to the green lead of the cable assembly and leave the base open circuited.

   e. Press the operate switch and read the 0 - 50 μa scale of the meter.

2. I_{EBO} TEST (for small signal types)

   By definition, I_{EBO} is the emitter leakage current with reverse-bias applied to the emitter and the collector open circuited. The test is as follows:

   a. Place the Type Selector to either the NPN or the PNP position.

   b. Place the Collector Volts switch to the 1.5V position.

   c. Place the Test Selector switch to the I_{CBO} position.

   d. Connect the base to the green lead, the emitter to the blue lead of the cable assembly and the collector is left open circuited.

   e. Press the operate switch and read the 0 - 50 μa scale of the meter.

3. Determining the impedance ratio of an Audio Transformer:

   The impedance ratio of an audio transformer can be determined in the following manner:

   a. Connect the primary of the transformer to the yellow and green leads of the cable assembly.

   b. Place the I_C control to its minimum position.

   c. Place the Test Selector switch to the Z Ohms position and make sure that the Z Ohms potentiometers are in the circuit.

   d. Place a resistive load across the secondary.

   e. Press the operate switch and increase the Beta Cal potentiometer until the meter reads full scale. Then vary the Z Ohm potentiometers until a null is indicated on the meter. Release the operate switch. Read the value of reflected impedance from the dial of the Z Ohms potentiometer. Knowing the reflected impedance and the secondary load the impedance ratio can be determined. Also, knowing the impedance ratio the turns ratio can also be determined. The turns ratio is the square root of the impedance ratio. The formula is

$$T_R = \sqrt{\frac{Zp}{Zs}}$$

MAINTENANCE

In general, the Model 890, In-Circuit Transistor Tester will give long uninterrupted service. The Model 890 is a complex and specialized instrument. No repair beyond battery replacement should be attempted. If the instrument does not function properly after battery replacement, it is recommended that the instrument be returned to the factory or any authorized Hickok Service Station.

PARTS LIST

Reference designations have been assigned to identify all parts in this instrument. In ordering parts, refer to the current parts price list for this instrument. Prices are subject to change without notice, and the minimum billing charge is $3. 50.

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
B1 thru B4	BATTERY: 1. 5 volt	2210-1
B5	BATTERY: 22. 5 volt	2210-36
C1	CAPACITOR, FIXED, ELECTROLYTIC: 50 μF, 25 volts	3085-130
C2	CAPACITOR, FIXED, METALLIZED PAPER: 1 μF, 200 volts	3105-278
C3	CAPACITOR, FIXED, METALLIZED PAPER: 2 μF, 200 volts	3105-277
C4	CAPACITOR, FIXED, METALLIZED PAPER: .25 μF, 200 volts	3105-116
C5	CAPACITOR, FIXED, METALLIZED PAPER: .01 μF, 200 volts	3105-276
C6, C7	CAPACITOR, FIXED, ELECTROLYTIC: 6 μF, 25 volts	3085-129
C8	Same as C4	
C9	CAPACITOR, FIXED, METALLIZED PAPER: .1 μF, 200 volts	3105-105
C10, C11	CAPACITOR, FIXED, ELECTROLYTIC: 25 μF, 25 volts	3085-128
C12	CAPACITOR, FIXED, ELECTROLYTIC: 100 μF, 50 volts	3085-127
CR1	CRYSTAL: type SD91	3870-41
CR2 thru CR5	CRYSTAL: 1N34AS	3870-78
L1	COIL ASSEMBLY	3320-199
L2	COIL: oscillator	3320-190
L3	CHOKE: 12 H, 30 mA DC, 400 ohms	3250-81
M1	METER: Model 64, 50 microamps ±1%, 2000 ohms ±1%	640-090
Q1 thru Q4	TRANSISTOR: 2N1376	20861-5
R1, R2	RESISTOR, FIXED, FILM: 270 ohms, 1%, 1/2 watt	18537-93
R3, R4	RESISTOR, VARIABLE: concentric front section 100K ohms, 10%, rear section 500 ohms, 10%, with spst switch	16925-372
R5	RESISTOR, VARIABLE: 10,000 ohms, 10%, 1/2 watt	16925-373
R6	RESISTOR, FIXED, WIRE WOUND: 1 ohm, 1%, 1 watt	18550-206
R7	RESISTOR, FIXED, COMPOSITION: 7500 ohms, 5%, 1/2 watt	18412-751
R8	RESISTOR, FIXED, FILM: 50 ohms, 1%, 1/2 watt	18537-65
R9	RESISTOR, FIXED, FILM: 10 ohms, 1%, 1/2 watt	18537-217
R10	RESISTOR, VARIABLE: 250 ohms, 30%, 1/2 watt	16925-371
R11	RESISTOR, FIXED, COMPOSITION: 470 ohms, 10%, 1/2 watt	18411-472
R12	RESISTOR, FIXED, COMPOSITION: 150K ohms, 10%, 1/2 watt	18414-152
R13	RESISTOR, VARIABLE: 100K ohms, 30%, 1/2 watt	16925-374
R14	RESISTOR, FIXED, COMPOSITION: 22,000 ohms, 10%, 1/2 watt	18413-222
R15	RESISTOR, FIXED, COMPOSITION: 330K ohms, 10%, 1/2 watt (calibration)	18414-332
R16	Same as R14	
R17	RESISTOR, FIXED, COMPOSITION: 100K ohms, 10%, 1/2 watt	18414-102
R18	RESISTOR, FIXED, COMPOSITION: 4700 ohms, 10%, 1/2 watt	18412-472
R19	RESISTOR, FIXED, COMPOSITION: 10,000 ohms, 10%, 1/2 watt (calibration)	18413-102
R20	RESISTOR, FIXED, COMPOSITION: 1000 ohms, 10%, 1/2 watt	18412-102
R21	RESISTOR, FIXED, COMPOSITION: 820 ohms, 10%, 1/2 watt	18411-822
R22	RESISTOR, FIXED, COMPOSITION: 1800 ohms, 10%, 1/2 watt	18412-182
R23	RESISTOR, FIXED, COMPOSITION: 47 ohms, 10%, 1/2 watt	18410-472
R24	Same as R18	
R25	RESISTOR, FIXED, COMPOSITION: 120 ohms, 10%, 1/2 watt	18411-122
R26	RESISTOR, FIXED, COMPOSITION: 15 ohms, 10%, 1/2 watt	18410-152
R27	Same as R11	
R28	RESISTOR, FIXED, COMPOSITION: 12,000 ohms, 10%, 1/2 watt	18413-122
R29	Same as R26	
R30	RESISTOR, FIXED, COMPOSITION: 560 ohms, 10%, 1/2 watt (calibration)	18411-562
R31, R32	RESISTOR, FIXED, COMPOSITION: 220 ohms, 10%, 1/2 watt	18411-222
R33	RESISTOR, FIXED, COMPOSITION: 15 ohms, 10%, 1 watt	18420-152
S1	Part of concentric resistor R3 and R4	
S2	SWITCH: rotary (Type) 2 section, 2 position	19912-437
S3	SWITCH: rotary, 5 section, 6 position (Test Selector)	19912-438
S4	SWITCH: rotary (Collective Voltage) 1 section, 4 position	19912-442
S5	SWITCH: push, 4 pdt	19910-168
	KNOB: black, hole for 17/64" shaft	11505-141
	KNOB: black, with indicator, hole for 1/4" shaft	11505-154
	KNOB: black, with indicator on skirt, hole for 1/4" shaft	11505-155
	KNOB: black, with indicator, hole for 3/16" shaft	11505-158
	LEAD ASSEMBLY	12450-352
	BOOKLET: instructions	2490-590