TF166
AUTOMATIC TRANSISTOR ANALYZER
SERVICE MANUAL

SENCORE

"the all american line"

DESCRIPTION

INTRODUCTION

New types of transistors and FET's are being introduced every day. Some, even though still classed as transistors, resemble an integrated circuit in that they contain protective diodes and/or Faraday shields. Still others are so sensitive that even a few microamps of base current will cause them to saturate. The TF166 incorporates super sensitive IC operational-amplifier circuits and a combination of an AC and DC beta test to give an easy to use, accurate test for these newer types of transistors. The increased sensitivity of the TF166 also provides an accurate test for all types of FET's, including the difficult to test enhancement type MOSFET.

FEATURES

*Fast, automatic testing for all transistors
*Pushbutton set up and test
*Simple GOOD - ? - BAD scale for FET and transistor gain
*In-circuit AC test for both FET's and transistors
*Accurate beta, Gm, I_{GSS}, and I_{CBO} measurements
*DC out of circuit test for diode protected transistors
*Safe, non destructive tests both in and out of circuit

SPECIFICATIONS

REGULAR (BI-POLAR) TRANSISTOR TESTS

AC IN-CIRCUIT TEST:

Test method	Dynamic AC beta
Test frequency	60 Hertz
Signal level	4 volts P-P max.
Formula used	Beta (h_{fe}) = $\frac{I_E - I_B}{I_B}$

DC OUT-OF-CIRCUIT TEST:

Test method	Static DC beta
Test level	4 volts DC max.
Formula used	Beta (hFE) = $\frac{I_E - I_B}{I_B}$

GAIN (Beta) RANGE:

Calibrated scale	0 - 500
Gain Scale code	BAD = 0 - 5
	? = 5 - 10
	GOOD = 10 - 500

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BASE CURRENT LEVELS (GAIN CAL level):

RF - IF	10 microamps
Low power	30 microamps
Medium power	100 microamps
High power	300 microamps

LEAKAGE TEST (I_{CBO}):

Test levels	V_{CB} @ 4 volts DC I_E @ 0
Leakage range	0 - 2500 microamps

FIELD EFFECT TRANSISTOR (FET) TESTS

MUTUAL CONDUCTANCE (transconductance or Gm):

Test method	Dynamic mutual conductance
Test frequency	60 Hertz square wave
Signal level	.5 volts P-P
Voltage levels	V_{DS} @ 6.2 volts DC V_{GS} @ 0
Formula used	$Gm = \frac{I_D}{E_G}$

GAIN (Gm) RANGE

Calibrated scale	0 - 25,000 micromhos
Scale code	BAD = 0 -250 micromhos ? = 250 - 500 micromhos GOOD = 500 - 25,000 micromhos

LEAKAGE TEST (I_{GSS})

Voltage levels	V_{GS} @ 4 volts DC V_{DS} @ 0
Leakage range	0 - 2500 microamps

ZERO BIAS DRAIN CURRENT TEST (I_{DSS}):

Voltage levels	V_{DS} = 6.2 volts DC V_{GS} @ 0
I_{DSS} range	0 - 50 milliamps

GENERAL

Meter	7", 100 microamp, 2%	
Power	105 - 130V AC, 50-60Hz	15 watts
Size	9½ x 7½ x 6	
Weight	8½ lbs.	

CONTROLS

ZERO ADJUST: This control is similar in operation and function to the zero adjust control on a VTVM of FEM. It is adjusted for meter zero indication after the test is selected, and before the transistor is connected.

GAIN CAL: This control establishes the test reference for the device under test. It is adjusted to position meter pointer to GAIN CAL line with transistor connected.

TRANSISTOR TYPE: The first four red pushbuttons in the top row select the test current for regular (bi-polar) transistors. The next two select either gate 1 or gate 2 for the FET test, and the last two select the mode of FET operation.

FUNCTION: The bottom row of eight black pushbuttons select the type of test to be performed on the transistor. The first is the AC power switch that operates with a push on, push off action. The ON condition is indicated by the indicator light above the On pushbutton. Buttons 2 and 3 select the polarity of the test; N for NPN transistor or N channel FET, and P for PNP transistor or P channel FET. (The N and P polarity pushbuttons may be depressed at any time during test without damaging transistor or tester.) Buttons 4 and 5 select either AC or DC test voltages; AC for in circuit tests, DC for out of circuit tests. The remaining three buttons are momentary contact types, used to make the actual test on the transistor or FET. To make any test, just push the appropriate button.

LEAD CONNECTIONS

E-SOURCE: This jack and black clip lead provide test connection to the emitter of the transistor, or the source of the FET.

B-GATE 1: This jack and yellow clip lead provide test connection to the base of regular transistors, gate of single gate FET's, and Gate 1 of dual gate FET's.

C-DRAIN: This jack and red clip lead provide test connection to the collector of regular transistors, and to the drain of FET's.

GATE 2: This jack and blue clip lead provide test connection to Gate 2 on dual gate FET's.

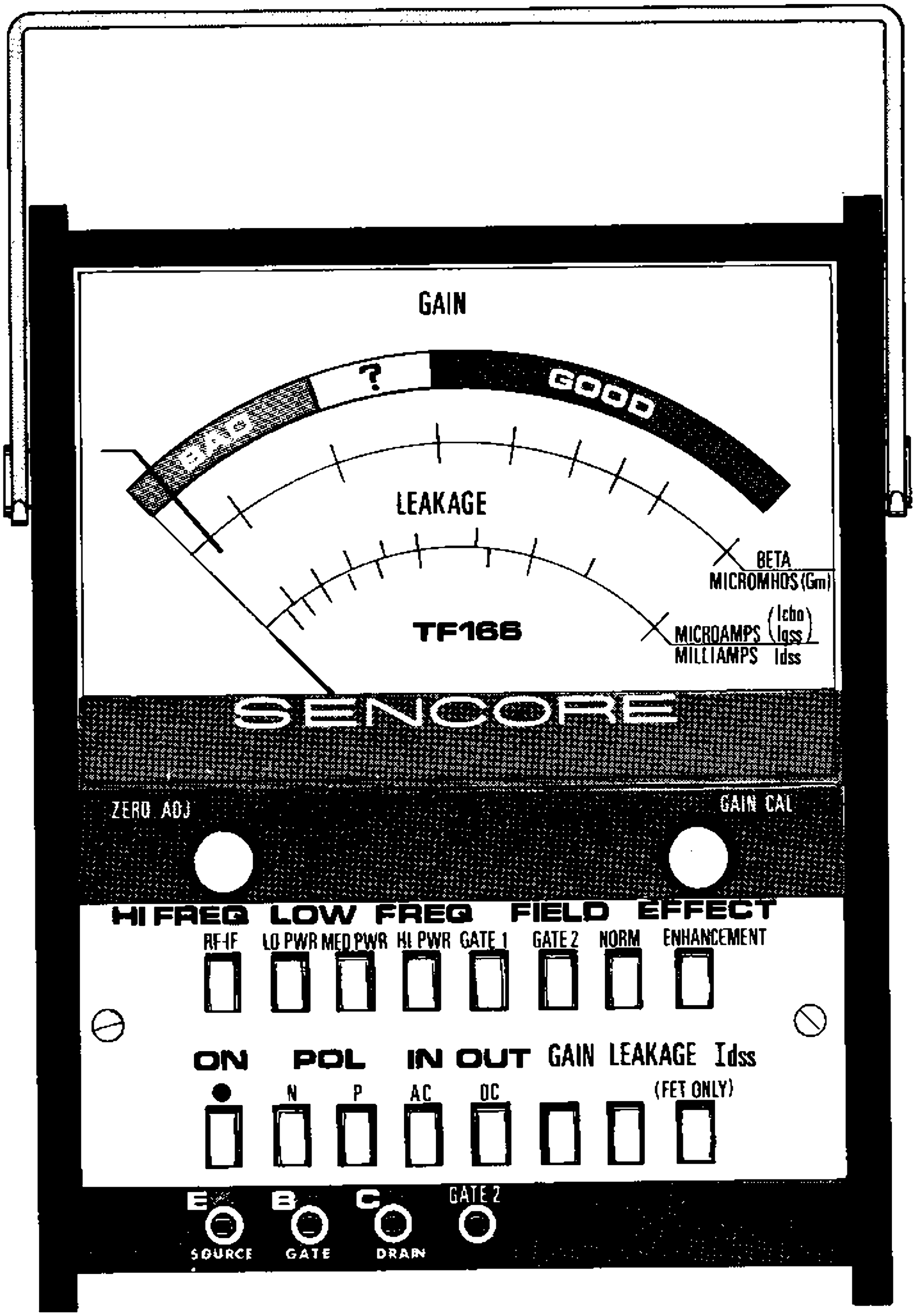


Fig. 1. TF166 Automatic Transistor Analyzer

COMMON TRANSISTOR TERMINOLOGY

The terms used in describing transistors, both bi-polar and FET types, are fairly new to the service industry. By knowing the standard format of the terms, such as I_{CBO} or I_{GSS}, the technician can figure just what each term means. The main letters are I and V and stand for current and voltage. The sub letters are the elements of the device and tell between which elements the voltage is applied or the current flows. The sub letters C, B, and E stand for the collector, base and emitter of a bipolar transistor. The term I_{CBO}, therefore, stands for Current between the collector and base. The O indicates that the third element, the emitter in this case, is left open. I_{CBO} is the term used to designate leakage current in the bi-polar transistor.

In field effect transistors, the term I_{GSS} is the leakage current from the gate to the source. The third sub letter indicates that the third element, the drain, is shorted to the second element, or source. I_{DSS} is referred to as the zero bias drain current. It is, of course, current from drain to the source. The third letter indicates the gate is shorted to the source for a condition of zero or no bias.

When the third letter is missing from the sub letters such as I_{DS}, then the term must have a condition listed with it, to tell what bias is applied to the gate or under what conditions the current is flowing.

Knowing that the subletters indicate the elements in question and that the third letter, when used, indicates the condition of the third element, the technician can readily figure out most of the transistor terms that he will encounter.

Two other terms that the technician should be familiar with are transistor beta and Field Effect Transistor Gm. The transistor beta is defined as the collector (or output) current divided by the base (or input) current $B = \frac{Ic}{Ib}$ ($B = \frac{Ie - Ib}{Ib}$). The Gm of the FET is defined as the change in drain (or output) current divided by the change in gate (or input) voltage. $Gm = \frac{\text{change Id}}{\text{change Eg}}$.

OPERATION

TESTING REGULAR (BI-POLAR) TRANSISTORS

The two most important parameters of bi-polar transistors are beta, and the leakage between the collector and base (I_{CBO}). Beta is the ratio of the collector current divided by the base current. It can be measured

with equal accuracy using an AC or a DC test voltage, however, the AC test will prove more accurate in circuit. It is important to note that the beta of transistors of the same type may vary as much as 5 to 1 and the transistor will still be within the manufacturers specifications. The gain listing in the Sencore Reference Book is the minimum figure specified by the transistor manufacturer. Any transistor that has a beta equal to or greater than this figure should be good.

I_{CBO} leakage is the second most important parameter on a transistor. If this leakage is excessive, it can have an effect on the circuit similar to grid leakage in a vacuum tube. The chart below gives a rough guide to the leakage of various transistors. For a more specific leakage figure, refer to the Sencore Reference Book.

Germanium		Silicon	
RF-IF	0 – 5 uA	RF-IF	0 – .5 uA
LOW	5 – 50 uA	LOW	0 – .1 uA
MED	50 – 500 uA	MED	.1 – 300 uA
HI	500 – 5000 uA	HI	TO 500 uA

Fig. 2. Typical Transistor Leakage Characteristics

Regular or bi-polar transistors can be easily tested either in or out of circuit with the TF166. The test procedure and set up are the same for the AC in circuit test and the DC out of circuit test. Normally the AC test will be used when the transistor is in circuit. However, there are some transistors that contain protective diodes or Faraday shields that will not test accurately with the AC test. The most common application for this type of transistor is in RF or IF circuits. If this type of transistor is encountered, it may be tested in circuit with the DC test with fair reliability, although an out of circuit DC check should be performed before the transistor is rejected.

The TF166 has been designed so that even if the wrong polarity is selected, the transistor is hooked up wrong, or the wrong Transistor Type selected, there will be no damage to the transistor under test. Use the transistor trouble chart to determine the probable cause if a transistor does not test correctly the first time.

IN CIRCUIT TEST

1. Determine the type of transistor to be tested, either RF-IF, Low Pwr, Med Pwr, or Hi Pwr using the Sencore Reference Book, or the chart in Fig. 3, and press the appropriate button on the TF166.

2. Select the correct test polarity by pushing the N button for NPN transistors, and the P button for PNP transistors. (The schematic diagrams in Fig. 4 show the normal symbols and voltages for NPN and PNP transistors). Depress the AC IN CIRCUIT pushbutton and adjust the TF166 ZERO ADJUST control to position the meter pointer to the zero on the left hand edge of the meter.

3. Connect the TF166 to the transistor as shown in Fig. 5 and adjust the GAIN CAL control to position the meter pointer to the GAIN CAL line on the meter.

NOTE: Inability to obtain the GAIN CAL adjustment would indicate a bad transistor or improper lead connections. Recheck lead connections or refer to the transistor trouble chart in this section of the manual.

4. Press the GAIN button and observe the meter scale. The GOOD - ? - BAD scale will provide a quick readout of transistor condition and is all that is normally needed for most service applications. The calibrated Beta scale will provide accurate Beta measurements if this information is needed. Should the test results be questionable, refer to the manufacturers data or the Sencore Reference Book for precise information about the transistor being tested. The accompanying chart shows various transistor defects and the test condition resulting, to help you determine the condition of the transistor.

OUT OF CIRCUIT TEST

Use the same procedure as above for the out of circuit test except depress the DC OUT CIRCUIT test pushbutton.

NOTES ON TESTING TRANSISTORS

1. Occasionally a transistor shunted with another transistor, or a diode directly across one of its junctions, may indicate as a shorted or open transistor. The DC test on the TF166 will, in most cases test this type of transistor in circuit as well as out. If there is any doubt, remove one or two leads of the transistor from the circuit and recheck the transistor.

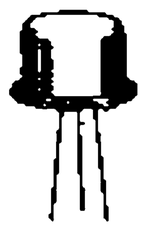
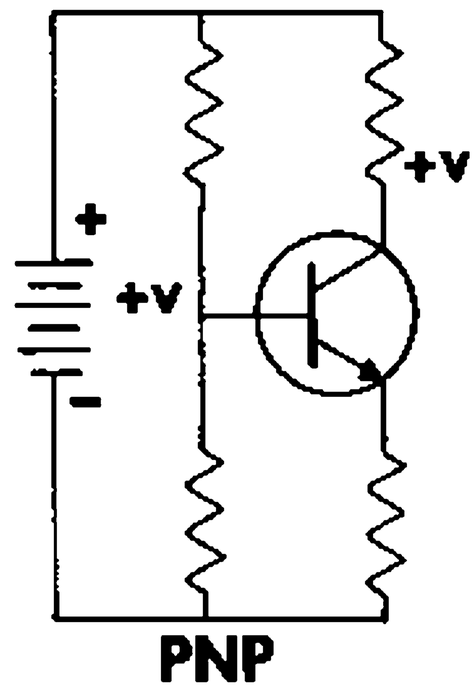
TRANSISTOR:	COMMON USES:
RF-IF	RF AMPS MIXERS OSCILLATORS IF AMPLIFIERS
AUDIO-LOW	PORTABLE RADIOS 1ST VIDEO AND 1ST AUDIO AMPS, SYNC SEPARATORS, SOUND IF, COLOR CIRCUITS, AUDIO IN STEREO
 AUDIO-MED.	AUDIO OUTPUT DRIVER STAGES IN STEREOS, TV RECEIVERS, AUTO RADIOS, AND TAPE PLAYERS, VIDEO AND COLOR DIFFERENCE AMPS, HORIZONTAL DRIVERS, ERROR AMPS
AUDIO-HIGH	HORIZONTAL, VERTICAL, AND AUDIO OUTPUT, POWER SUPPLY REGULATORS, RIPPLE FILTERS

Fig. 3. Transistor Type Identification Chart



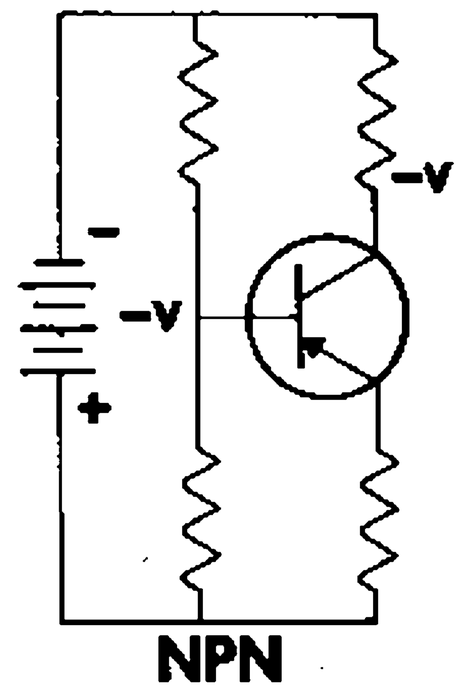


Fig. 4. Typical Transistor Schematic Diagrams

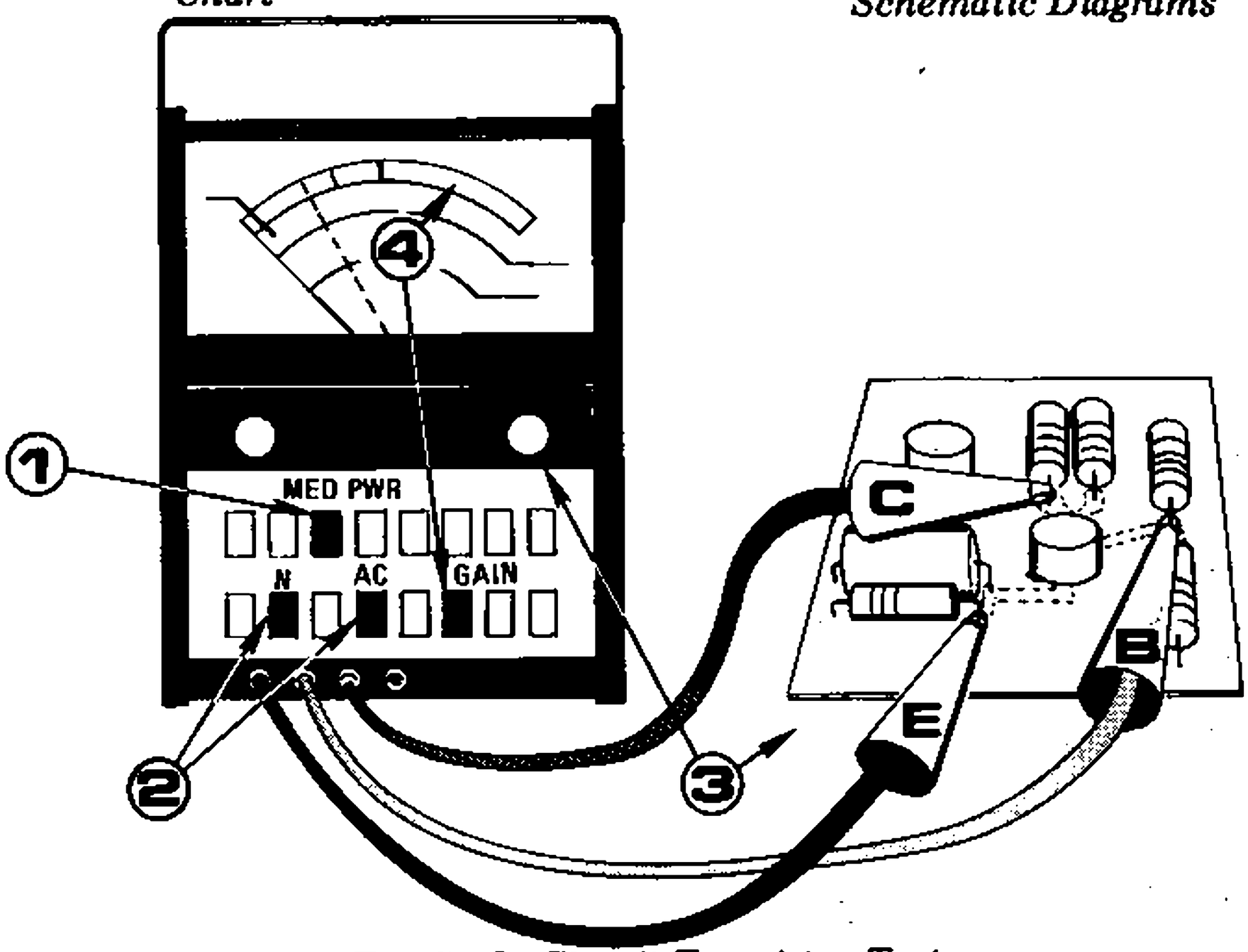


Fig. 5. In Circuit Transistor Test

2. If a transistor checks defective in circuit, but good out of circuit, be sure to check the other components in that circuit for defects, especially capacitors and diodes. It is also a good idea to check the other components in the circuit when a defective transistor is found, as the transistor defect may have been caused by the failure of another component in that circuit.

3. Extensive design has gone into making the TF166 the most reliable in circuit tester on the market. Though the number of circuits that will fool the TF166 is small, they should be mentioned. Circuits that contain resistances between 2.5 ohms and 10 ohms, or capacitors of 250mfd or greater, depending on which transistor elements the impedance is connected between, may fool the TF166 into calling a good transistor bad. It is recommended that the transistor be given a quick DC test after removing it from the circuit. This procedure will serve to eliminate the replacement of a good transistor, when the bad in circuit test results from the circuit configuration or another defect in the circuitry.

TRANSISTOR LEAKAGE MEASUREMENTS

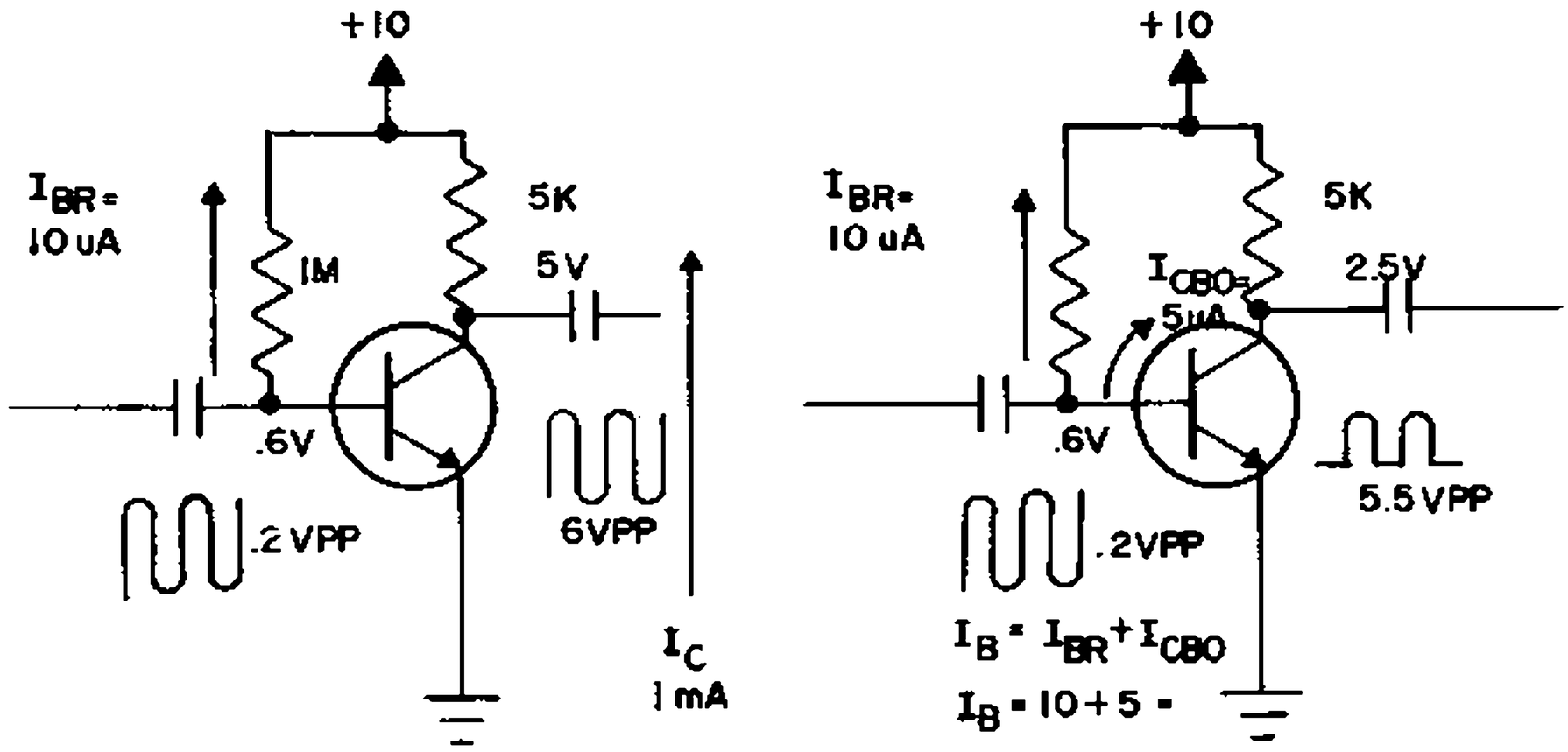
NOTE: Leakage should be measured with the transistor out of circuit, since circuit components can cause false leakage paths. To detect very small leakage currents, press the leakage button, and remove and reinsert the base lead of the TF166 while observing meter. One of the transistor type buttons, (RF-IF, LOW PWR, MED PWR or HI PWR) must be depressed for the leakage test. This is necessary to provide proper test conditions.

TESTING FOR I_{CBO}

I_{CBO} is the leakage current that flows when a voltage is applied between collector and base, with the emitter open, and the collector to base junction reversed biased. (Collector is positive with respect to base for a NPN transistor.) Its effect is similar to grid leakage in a tube in that even a small amount of I_{CBO} will upset the DC bias in the circuit. Fig. 6 shows the effect of I_{CBO} on a typical amplifier circuit. To test a transistor for I_{CBO}, proceed as follows:

1. Select the correct polarity by pushing the N button for NPN transistors, or the P button for PNP transistors.

2. Connect the E lead of the TF166 to the emitter of the transistor, the B lead to the base of the transistor, and the C lead to the collector of the transistor, as shown in Fig. 7.



NORMAL AMPLIFIER TRANSISTOR B= 100 , ICBO = 0

AMPLIFIER SHOWING EFFECT OF ICBO. TRANSISTOR B=100, ICBO= 5uA

Fig. 6. I_{CBO} Effects on Circuit

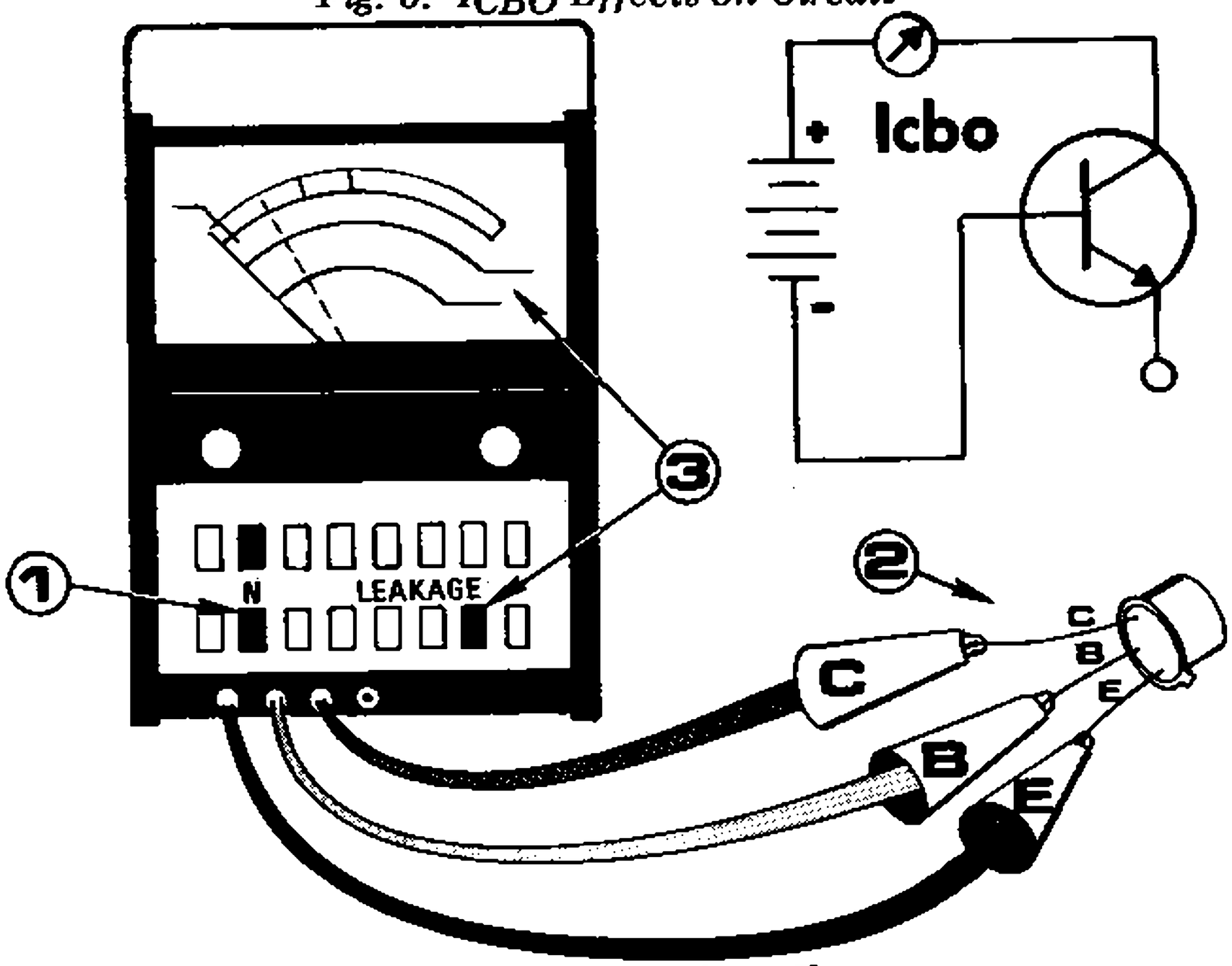


Fig. 7. I_{CBO} Leakage Test

3. Press the LEAKAGE button and observe the red LEAKAGE scale on the meter. Use the Sencore Reference Book, or the chart in Fig. 2 if you have any questions as to the acceptable leakage.

TESTING FOR I_{EBO}

I_{EBO} is the leakage current that flows when a voltage is applied between emitter and base, with the collector open, and the emitter to base junction reverse biased. (Emitter is positive with respect to base for an NPN transistor). I_{EBO} is most important in pulse circuits where the base is driven deep into reverse bias and the leakage current could influence the pulse shaping circuits. To test a transistor for I_{EBO}, proceed as follows:

1. Select the correct polarity by pressing the N button for NPN transistors and the P button for PNP transistors.

2. Connect the B lead of the TF166 to the base of the transistor, the C lead to the emitter of the transistor, and leave the E lead of the TF166 and collector of the transistor disconnected, as shown in Fig. 8.

3. Press the LEAKAGE button and observe the red LEAKAGE scale on the meter. The value of I_{EBO} should be on the same order as I_{CBO}.

TESTING FOR I_{CEO}

I_{CEO} is the leakage current that flows when a voltage is applied between the collector and emitter, with the base open. (Collector is positive with respect to emitter for an NPN transistor.) This leakage is normally equal to the I_{CBO} leakage multiplied by the beta of the transistor, and can be useful for measuring small amounts of I_{CBO}.

1. Select the correct polarity by pressing the N button for NPN transistors and the P button for PNP transistors.

2. Connect the C lead of the TF166 to the collector of the transistor, the B lead to the emitter of the transistor, and leave the E lead and the base of the transistor disconnected, as shown in Fig. 9.

3. Press the LEAKAGE button and observe the red LEAKAGE scale on the meter. If you have any questions as to the acceptable I_{CEO} leakage, refer to the Sencore Reference Book or the chart in Fig. 2, and multiply the I_{CBO} listing by the measured beta of the transistor. To

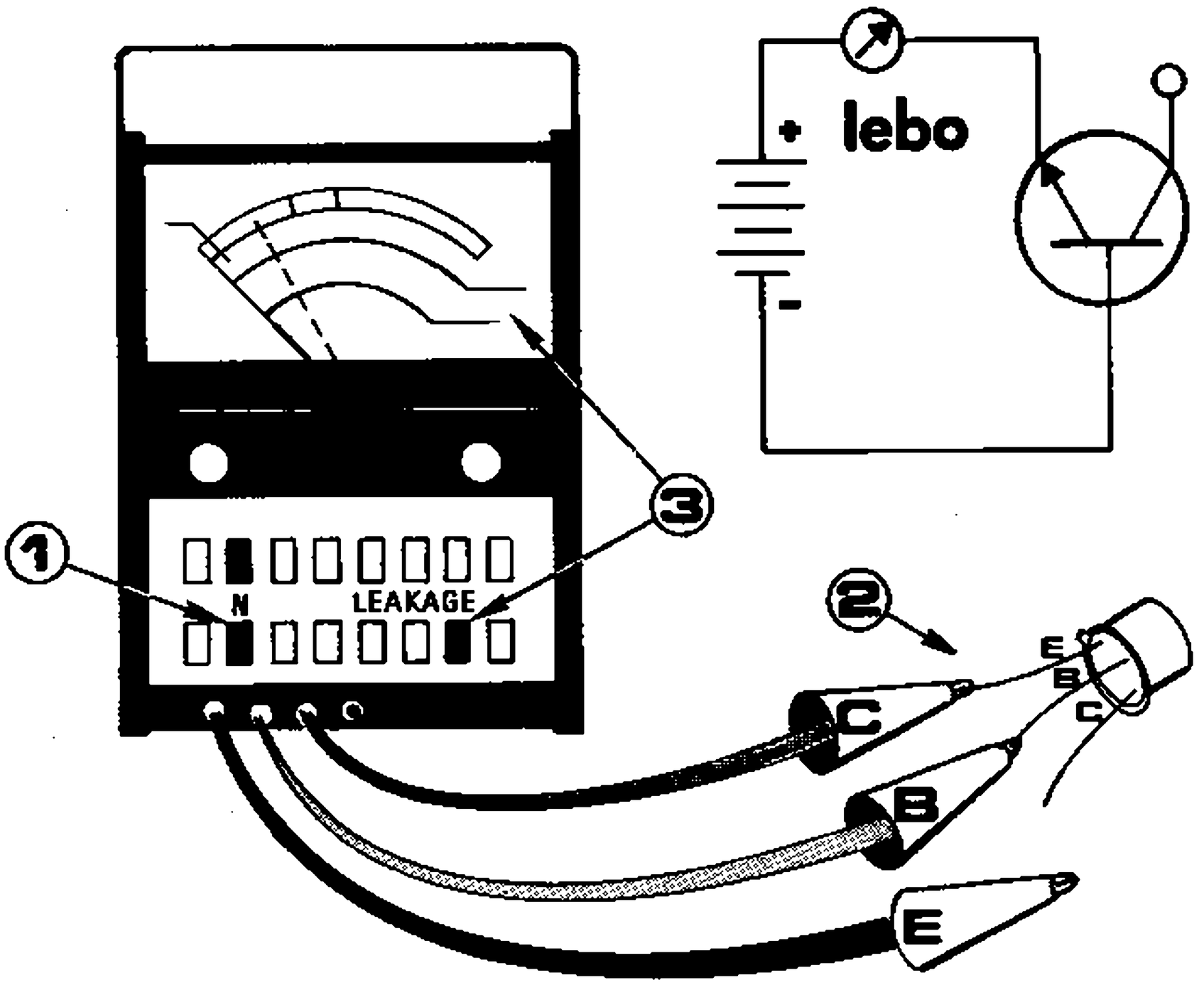


Fig. 8. I_{EBO} Leakage Test

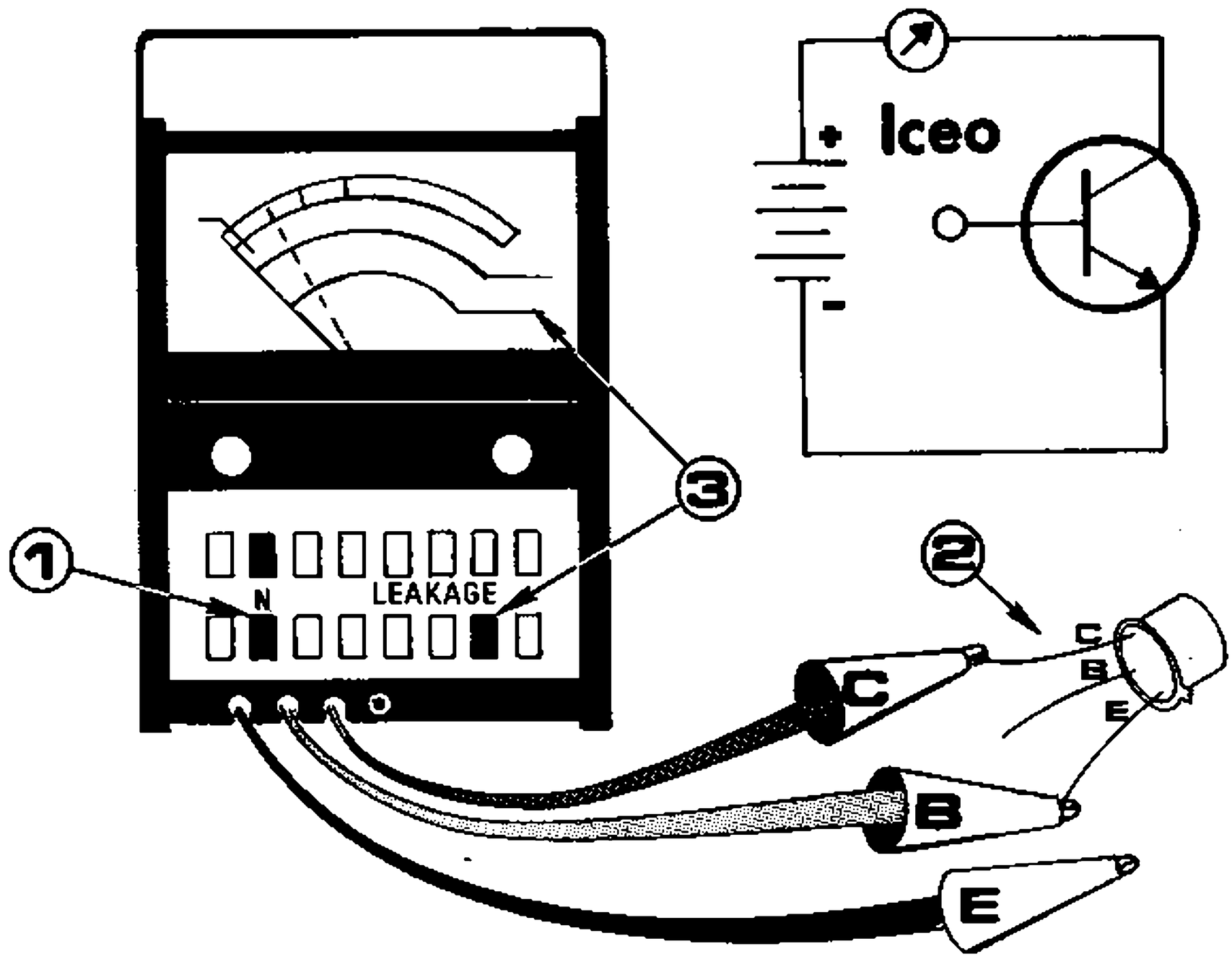


Fig. 9. I_{CEO} Leakage Test

use the I_{CEO} test to determine I_{CBO}, measure the I_{CEO} and beta of the transistor, and divide the I_{CEO} by the measured beta.

TESTING FOR I_{CES}

I_{CES} is the leakage current that flows when a voltage is applied between collector and emitter with the base shorted to the emitter. (Collector positive with respect to emitter.) This leakage is a measurement of the ability of the base to control the collector current, and determines the lowest collector current at which the transistor can operate. I_{CES} leakage is especially important in power output circuits, and can cause large amounts of distortion as the collector current swings toward zero. To test for I_{CES} proceed as follows:

1. Select the correct polarity by pressing the N button for NPN transistors and the P button for PNP transistors.

2. Connect the C lead of the TF166 to the collector of the transistor of the TF166, the B lead to the base and emitter and the transistor, and leave the E lead disconnected, as shown in Fig. 10.

3. Push the LEAKAGE button, and observe the red LEAKAGE scale on the meter. The leakage measured should be the same order of magnitude as the I_{CBO} for that particular transistor.

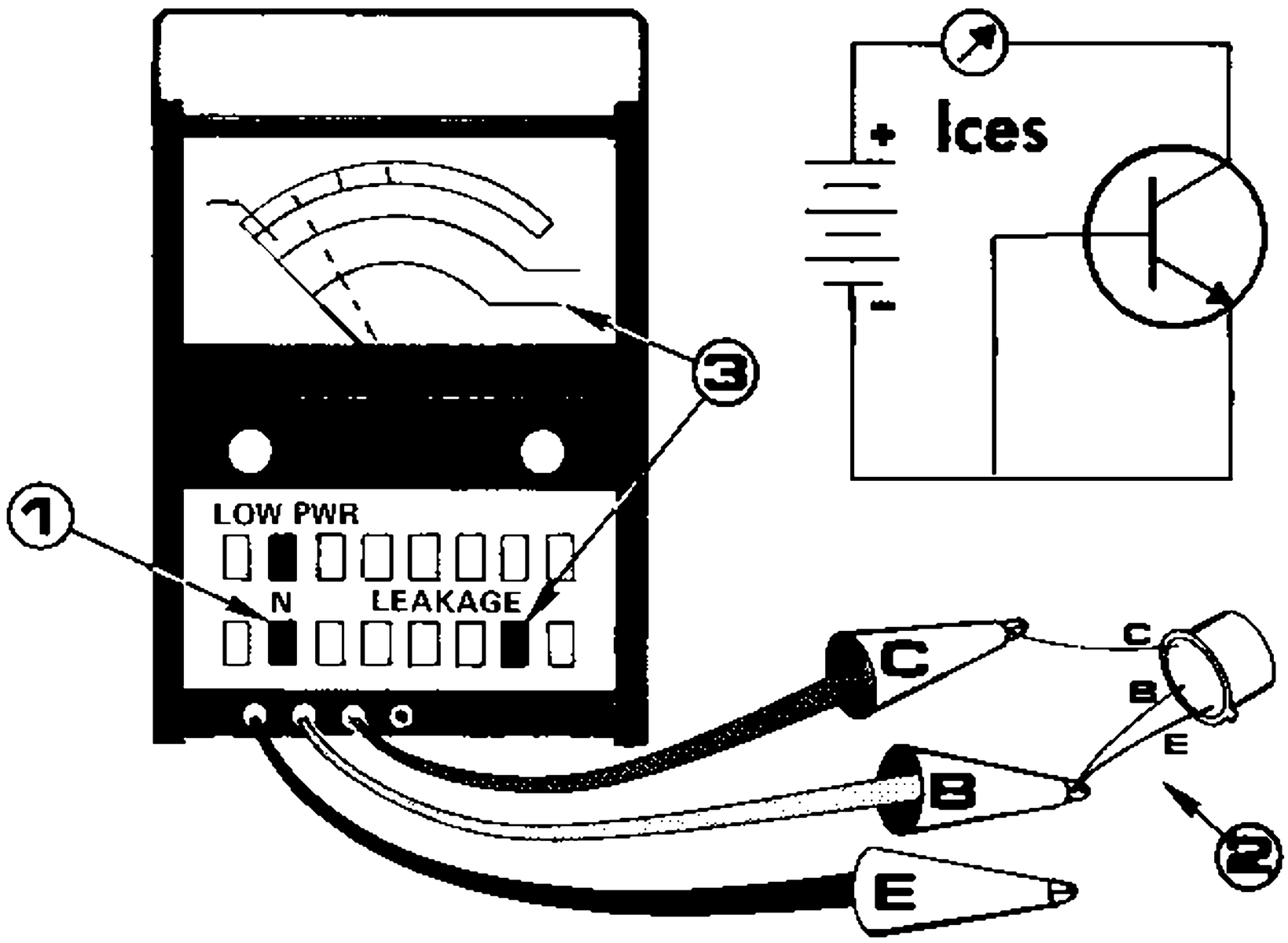


Fig. 10. I_{CES} Leakage Test

TRANSISTOR TROUBLE CHART

TROUBLE	SYMPTOM FOR DC OUT OF CIRCUIT	SYMPTOM FOR AC IN CIRCUIT
TRANSISTOR DEFECTS		
Open base	No gain cal, No gain read	No gain cal, May or may not read gain depending on circuit.
Open emitter	No gain cal. No gain reading	No gain cal. No gain reading
Open Collector	Gain cal OK No gain reading	Gain cal OK No gain reading
Short C-B	No gain cal Gain reading pins meter full scale to right	Gain cal OK Bad gain reading
Short C-E	No gain cal Gain reading pins meter full scale to right	Gain cal goes negative No gain reading
Short E-B	Gain cal Ok No gain reading	No gain cal No gain reading
TESTER SET UP PROBLEMS		
C and E reversed	Gain cal OK Gain reading will depend on transistor. Some transistors with interchangeable E and C will test same either way. Most transistors will check much lower with C and E reversed	Same as DC
C and B reversed	Gain cal OK Bad gain reading	Gain cal OK No gain reading
B and E reversed	No gain cal No gain reading	Negative gain cal Negative gain reading (will gain cal as opposite polarity, but bad gain reading)
Wrong polarity	No gain cal No gain reading	Negative gain cal Negative gain reading

MATCHING TRANSISTORS

Many applications such as audio output stages, balanced amplifiers and bridge circuits require transistors to be matched for beta gain as well as I_{CBO} leakage. The TF166 is an ideal instrument for this purpose because of the sensitive I_{CBO} leakage test and the wide range of base currents available for the beta test. In many instances, only one device in a matched pair need be replaced. Simply use the TF166 to measure the beta and leakage of the good device, and select the replacement that comes as close as possible.

When matching transistors, it is a good idea to check the beta at the next higher PWR setting of the TF166 as well, as some transistors have a different beta at different values of collector current. When matching transistors for leakage it is also a good idea to check for I_{CEO} as described on page 15. This leakage will show up small differences between transistors more effectively than the I_{CBO} test.

TRANSISTOR SUBSTITUTION

Several lines of general replacement transistors are available to the servicing industry. Most lines include an excellent cross reference or replacement guide, however, there will be instances where information for the transistor that needs to be replaced will not be listed. Here the TF166 can be a valuable aid in locating a replacement transistor. The important considerations for a replacement transistor are: Polarity, gain (Beta), leakage, frequency range, collector current (Ic max), emitter to collector break down voltage (BVce), maximum power dissipation, and physical size. In most instances where one of a particular transistor is used in a circuit, there will be others of the same type used. The TF166 can be used to test the good transistor, and the measured gain used as a minimum for the replacement. The leakage measured out of circuit can be used as a maximum for the replacement. The TF166 test will also indicate the correct polarity for the replacement transistor.

The frequency of the transistor is indicated by the circuit that it is used in. Most lines of replacement transistors list the transistors by their applications. (For example, if the transistor to be replaced is the local oscillator in an FM broadcast receiver, the replacement would need a frequency cut off (Ft) of at least 150MHz and would be listed in the replacement guide as an FM oscillator.)

The maximum collector current and collector voltage ratings can be

determined from the schematic or by measurements in the actual unit. The replacement transistor used should have a collector voltage rating of at least the power supply voltage for the circuit that the transistor is used in. The maximum collector current can be found by dividing the power supply voltage by the DC resistance in series with the transistor emitter and collector.

One way to determine the maximum power rating for the replacement transistor is to multiply the maximum possible collector current by the maximum possible collector voltage. This will give the maximum power that the transistor will ever have to dissipate in its circuit.

DARLINGTON AMPLIFIERS

Darlington amplifiers are actually a pair of transistors, contained inside the same case, that are connected internally as a single high gain (Beta of 500 or more) amplifier. Any transistor listed in the Sencore Reference Book with a gain of 500 or more is likely to be a Darlington. Darlington transistors may be tested in or out of circuit using the AC test on the TF166, but may not test out of circuit using the DC test.

DARLINGTON AMPLIFIER

Beta of 500 or more

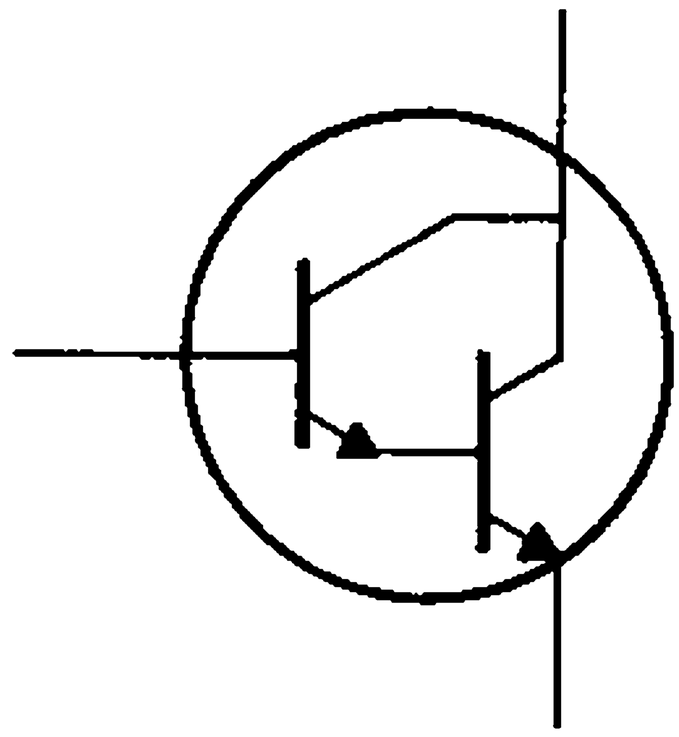


Fig. 11. Typical Darlington Amplifier Configuration

To test a Darlington, follow the same procedure as for a regular transistor but expect the gain reading to be more than full scale, or more than 500.

SOLID STATE SERVICING HINTS

1. Be sure the power to the equipment is turned off or the line cord is removed from the AC receptacle when making in-circuit tests or repairs. Transistors can be damaged from the transients developed when chang-

ing components or inserting new transistors, if the circuit is powered.

2. When servicing solid state TV receivers, use a meter and high voltage probe to measure the 2nd anode potential. If you arc the 2nd anode lead to the chassis for a spark test, as done in tube circuits, you can destroy the high voltage rectifier and possibly the horizontal output transistor. The transient spikes developed may also destroy some of the small signal transistors in the receiver.

3. When working on solid state TV's or radios, do not operate them with any parts disconnected, such as the yoke or speaker. If you do, you are removing the load from the transistor and it can draw excessive current and destroy itself in a short period of time.

4. When replacing power transistors, be sure to use silicon grease to insure maximum heat transfer from the transistor. Both sides of the mica insulation should be covered for best results. Be sure also that no foreign matter such as metal shavings adhere to the mica insulator. This can cause a breakdown at a later time.

5. If an FM stereo receiver still has poor separation after the multiplex section has been realigned, check the switching transistors or demodulator diodes. The transistors should have approximately the same beta figure and the diodes should have the same front to back ratio for best separation and circuit operation. If the devices are not matched, it will cause an unbalance in the circuit and maximum separation will not be obtained.

6. Transistors and FET's are "solid" devices, but there are some cases where an intermittent can occur. If you run across a "tough dog" and suspect that you may have an intermittent, you can check the transistor or FET in-circuit and tap it lightly while watching the gain on the TF166 meter. Any changes will indicate a defective device. A can of freeze spray will also prove to be quite helpful. If the transistor changes its gain drastically or no gain indication is obtained after spraying the suspected transistor, it is an indication of a defective or intermittent transistor.

7. If you work on a particular make or model of set, log the beta or Gm readings from a good working unit on the schematic for future reference. You can take the minimum figures from the Sencore Transistor manual or get them from the manufacturers information as a speed and time saving servicing convenience. Then, you can merely look at the

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schematic to get all the necessary information. In-circuit leakage readings may also be logged in the same manner. Although the readings taken will include the circuit impedances, they can show up a defective stage quite readily if the readings are drastically different than those from a good working set.

8. When servicing transistor radios or amplifiers, be sure that the volume control is set to mid-range. If the control is set to minimum, the first audio transistor can appear to be shorted and cause a misleading reading on the circuit transistor tester.

TESTING FIELD EFFECT TRANSISTORS (FET'S)

The field effect transistor is fairly new to the electronics industry, but its use has become quite widespread. It differs from the regular or bi-polar transistor in many ways.

First is in the mode of operation, or how the applied bias affects the drain current of the device. There are three modes of operation for the FET; the depletion mode, the enhancement mode, and the depletion-enhancement mode. A depletion mode FET is biased much like a tube, with the gate (grid) reverse biased with respect to the source (cathode). At zero bias, the maximum drain (plate) current will be flowing. Increasing the bias in a reverse direction will reduce the level of drain current.

The enhancement mode is opposite the tube, similar in biasing to the regular bi-polar transistor. The gate is forward biased with respect to the source. At zero bias, the enhancement FET is cut off and only a minute amount of drain current will be flowing. Increasing the bias in a forward direction will cause the FET to conduct, increasing the drain current.

The depletion-enhancement mode is a combination of the two types just mentioned and can be operated in either mode.

The TF166 has been designed to enable testing of all FET's, whether the device to be tested is a depletion, enhancement, or depletion enhancement type. The NORM pushbutton near the right of the top row of pushbuttons on the TF166 provides the correct bias for testing depletion type FET's. The last button, ENHANCEMENT, gives correct bias for the enhancement type. The NORM position provides a zero bias, and the ENHANCEMENT position applies a forward bias to the FET. The depletion-enhancement type should test correctly with either bias applied.

The second major difference between a regular transistor and the FET is in their amplifying capabilities. The regular transistor is a current controlled, current amplifying device. It's gain is measured in Beta. The FET is a voltage controlled, voltage amplifying device (very similar to a vacuum tube). It's gain is determined in the same manner as testing the gain of a vacuum tube; mutual conductance or Gm. The chart below gives a comparison between the regular transistor, the FET, and the vacuum tube.

PARAMETER	TRANSISTOR	FET	TUBE
Input Impedance	Low	High	High
Gain	Beta $= \frac{I_{out}}{I_{in}}$	Gm $= \frac{I_{out}}{E_{in}}$	Gm $= \frac{I_{out}}{E_{in}}$
Warm up time	Short	Short	Long
Power Consumption	Small	Small	Large

Fig. 12. Comparison Chart Between Tube, Transistor, and FET

From the chart, you can see that the FET combines the advantages of the bi-polar transistor and those of the vacuum tube. The most accurate method of determining the mutual conductance of an FET is by giving the device a dynamic test. The dynamic mutual conductance test of the TF166, coupled with it's low output impedance drive circuits and sensitive IC OP-AMP meter circuitry, provides an accurate in or out of circuit test for all types of FET's - including the difficult to test enhancement types. The following procedure should be used for testing FET's:

TESTING FET'S FOR MUTUAL CONDUCTANCE (Gm)

NOTE: The IN - OUT CIRCUIT pushbuttons will have no effect on the FET test. The test conditions and signals are the same whether the test is made in or out of circuit.

1. Press the GATE 1 button. Select the correct mode of FET operation by pressing the NORM button for depletion types, or the ENHANCEMENT button for enhancement types. Select the correct polarity by pressing the N button for N channel FET's or the P button for P channel FET's. The diagrams in Fig. 13 show typical circuits and biases for N channel, P channel, enhancement, and depletion FET's.

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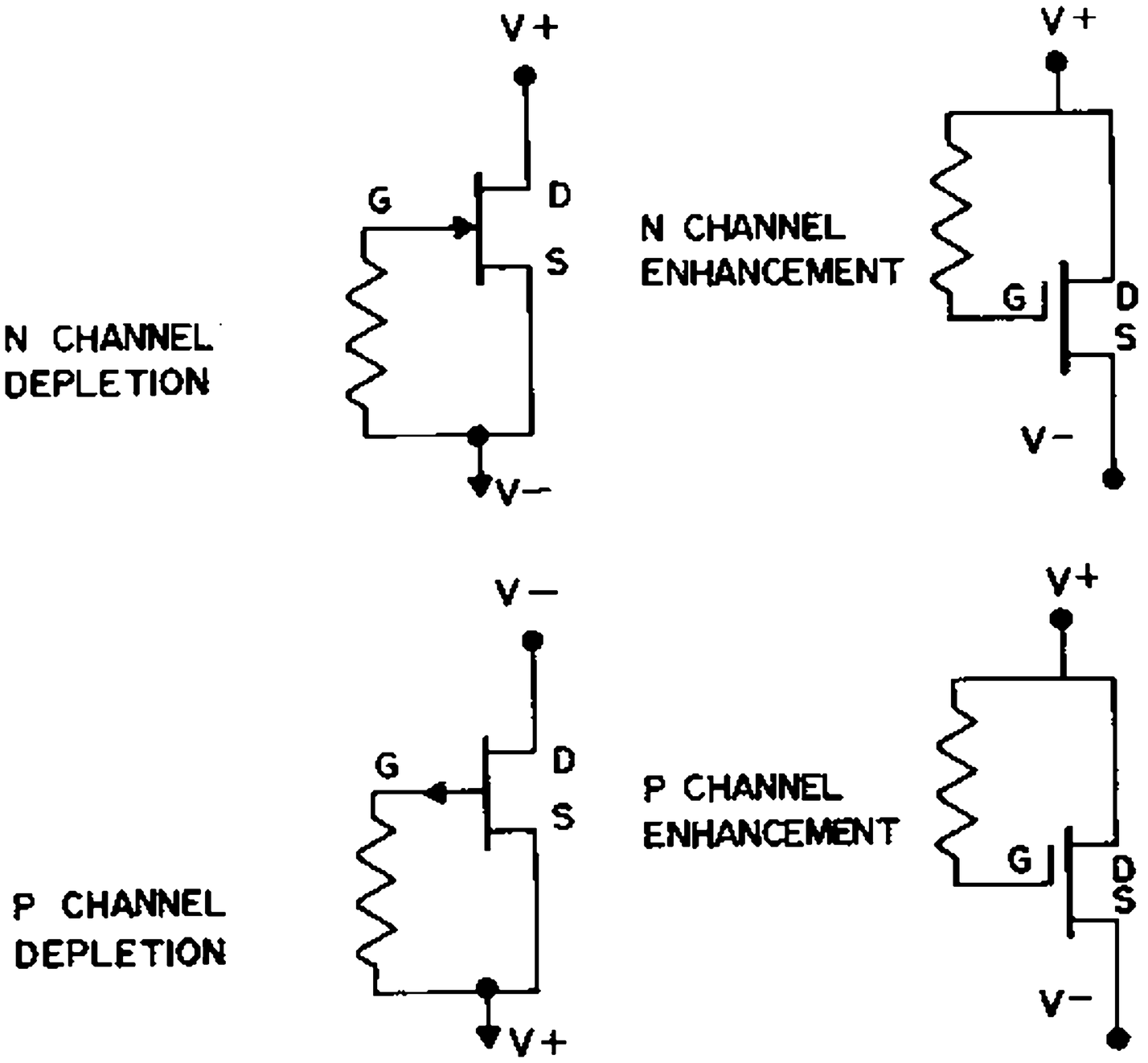


Fig. 13. Typical FET Schematic Diagrams

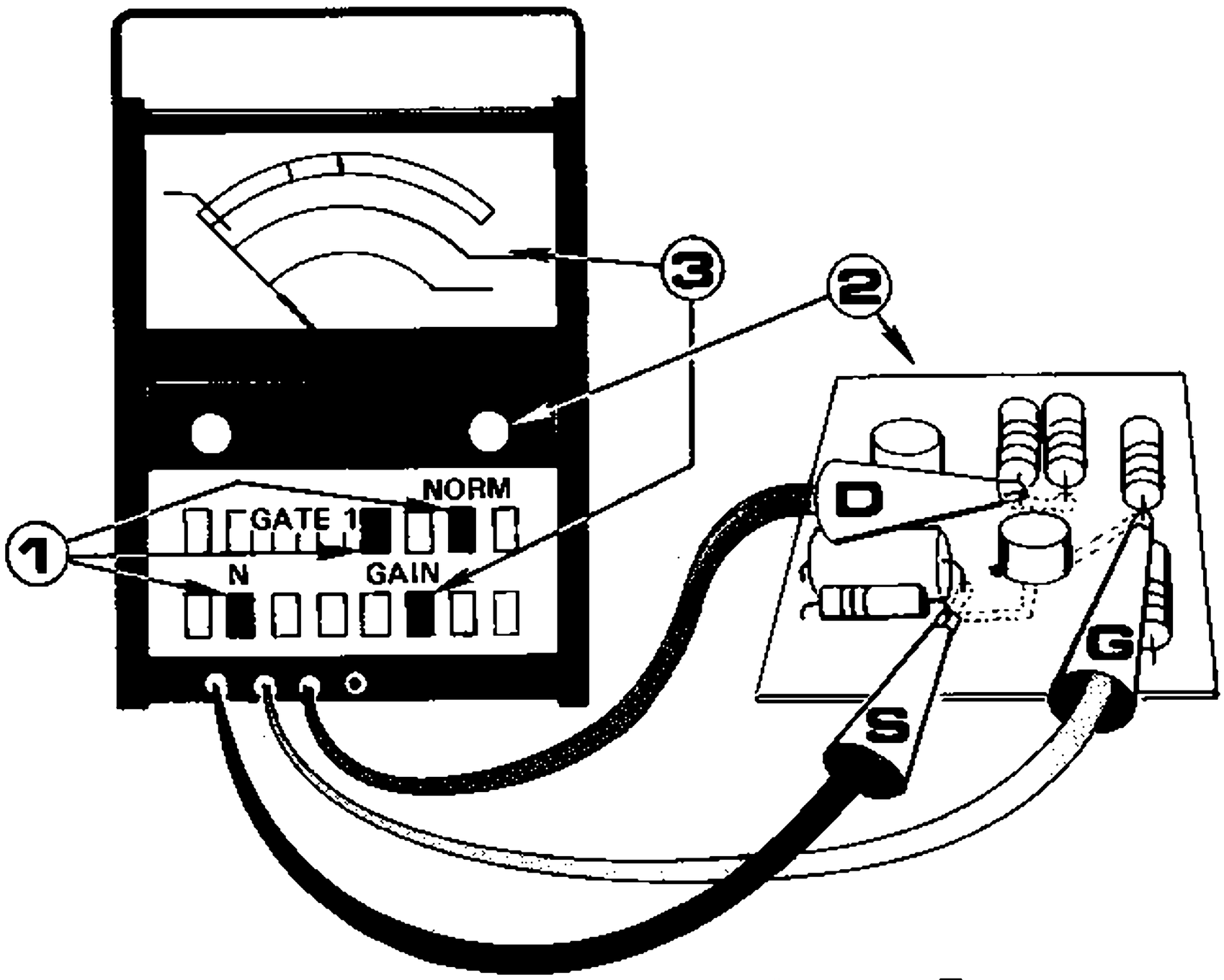


Fig. 14. FET Mutual Conductance Test

2. Connect the FET to the TF166 following the precautions for handling MOS or IGFET outlined in NOTE 1 on testing FET's. (See Fig. 14). On dual gate FET's be sure to connect both gate leads. If the second gate lead is not connected, the FET will test as having an open gate. Adjust the GAIN CAL control to position the meter pointer to the GAIN CAL line on the meter. (NOTE: The GAIN CAL control operation is reversed when testing P-channel FET's).

Inability to obtain GAIN CAL adjustment is an indication of a defective FET, or improper lead connections. Recheck the connections, or refer to the FET TROUBLE CHART in this section.

3. Press the GAIN button and observe the meter scale. The Gm GOOD ? - BAD scale will provide a quick readout of the FET's condition, and is all that is normally needed for most service applications. The calibrated Gm scale will provide accurate Gm measurements if this information is required. (NOTE: When testing dual gate FET's, repeat above procedure with GATE 2 button depressed. The dual gate FET must test GOOD on both gate tests to be acceptable.)

Should the test results be questionable, refer to the manufacturers data sheets or the Sencore Reference Book for precise information about the FET being tested. The accompanying FET trouble chart shows various FET defects and the test results to help you determine the condition of the FET.

NOTES ON TESTING FET'S

1. The MOSFET (metal oxide semiconductor field effect transistor) or IGFET(insulated gate field effect transistor) is a very delicate device that is easily damaged by improper handling. The greatest danger to this type of FET is a static discharge to the gate, causing the gate insulating layer to break down. To prevent this type of discharge, use the following precautions:

   a. Store the FET with all leads shorted together.
   b. Pick up the FET by first touching the surface the FET is connected to, and then the FET.
   c. Set the FET down, by first touching your hand to the surface and then setting the FET in it.
   d. When soldering to the FET always use an iron with a grounded tip.

2. The TF166 has been designed so that even if the wrong polarity is used, the FET hooked up wrong, or the wrong mode of operation selected, there will be no damage to the FET. Use the FET trouble chart to determine the probable cause if the transistor does not test correctly the first time.

3. If an FET checks bad in circuit and good out of circuit, it is a good idea to check the other components in that circuit, especially capacitors and diodes. It is also suggested that other components in the circuit be tested when a defective FET is found, as the FET defect may have been caused by the failure of another component.

4. Extensive design has gone into making the TF166 the most reliable in circuit tester on the market. Though the number of circuits that will fool the TF166 is small, they should be mentioned. Circuits that contain resistances of between 2.5 ohms and 10 ohms, or capacitors of 250uf or above that are connected directly across the FET, depending on which elements they are connected across may fool the TF166 into calling a good FET bad. In this case, the final test is to remove the FET from the circuit and test it out of circuit.

FET TROUBLE CHART

TROUBLE	SYMPTOM FOR OUT OF CIRCUIT TEST	SYMPTOM FOR IN CIRCUIT TEST
FET DEFECTS		
Gate open	Meter pins negative, cannot be adjusted	May gain cal, but bad gain reading
Source open	No gain cal, no gain reading	Gain cal OK, but no gain reading
Drain open	No gain cal, no gain reading	Same as Out of Circuit
Gate drain short	Gain cal OK, gain reading bad, full scale On I_{GSS} and I_{DSS}	Same as Out of Circuit
Source drain short	Gain cal OK, bad gain reading, I_{GSS} OK, I_{DSS} full scale	Gain cal OK, bad gain reading, I_{DSS} full scale
Gate source	Gain call OK, bad gain reading	Same as Out of Circuit

TESTER SET UP PROBLEMS

TROUBLE	SYMPTOM FOR OUT OF CIRCUIT TEST	SYMPTOM FOR IN CIRCUIT TEST
Wrong Polarity	GAIN CAL adjustment operates backward, gain reading goes negative	Same as Out of Circuit
Drain and source rev.	No difference on symmetrical FET's, others will read lower gain	Same as Out of Circuit
Source and gate or drain and gate rev.	Gain cal OK, negative gain reading	Same as Out of Circuit
Depletion tested as enhancement	May test good, but I_{DSS} and gain measurements will be inaccurate	Same as out of Circuit

TESTING FET'S FOR LEAKAGE

The only important FET leakage is I_{GSS}, or leakage measured from the gate to the source and drain shorted together. It is similar to the grid leakage of a vacuum tube and can cause the same type of problems in circuit. In IF circuits, it can upset the gain of the system, and cause AGC problems. The leakage lowers the input impedance of the FET and can cause unbalance of bridge amplifiers using the FET.

The TF166 can check the gate leakage of all types of FET's including junction, MOSFET, and dual gate MOSFET's. Leakage should be checked out of circuit, as the circuit impedances will cause a leakage reading on the meter, even though the FET has no leakage. To test for I_{GSS}, proceed as follows:

1. Connect the FET to the TF166 the same as for the gain test, following the proper precautions.

2. Press the LEAKAGE button and observe the red LEAKAGE scale on the meter. On dual gate FET's, press the GATE 2 button to measure

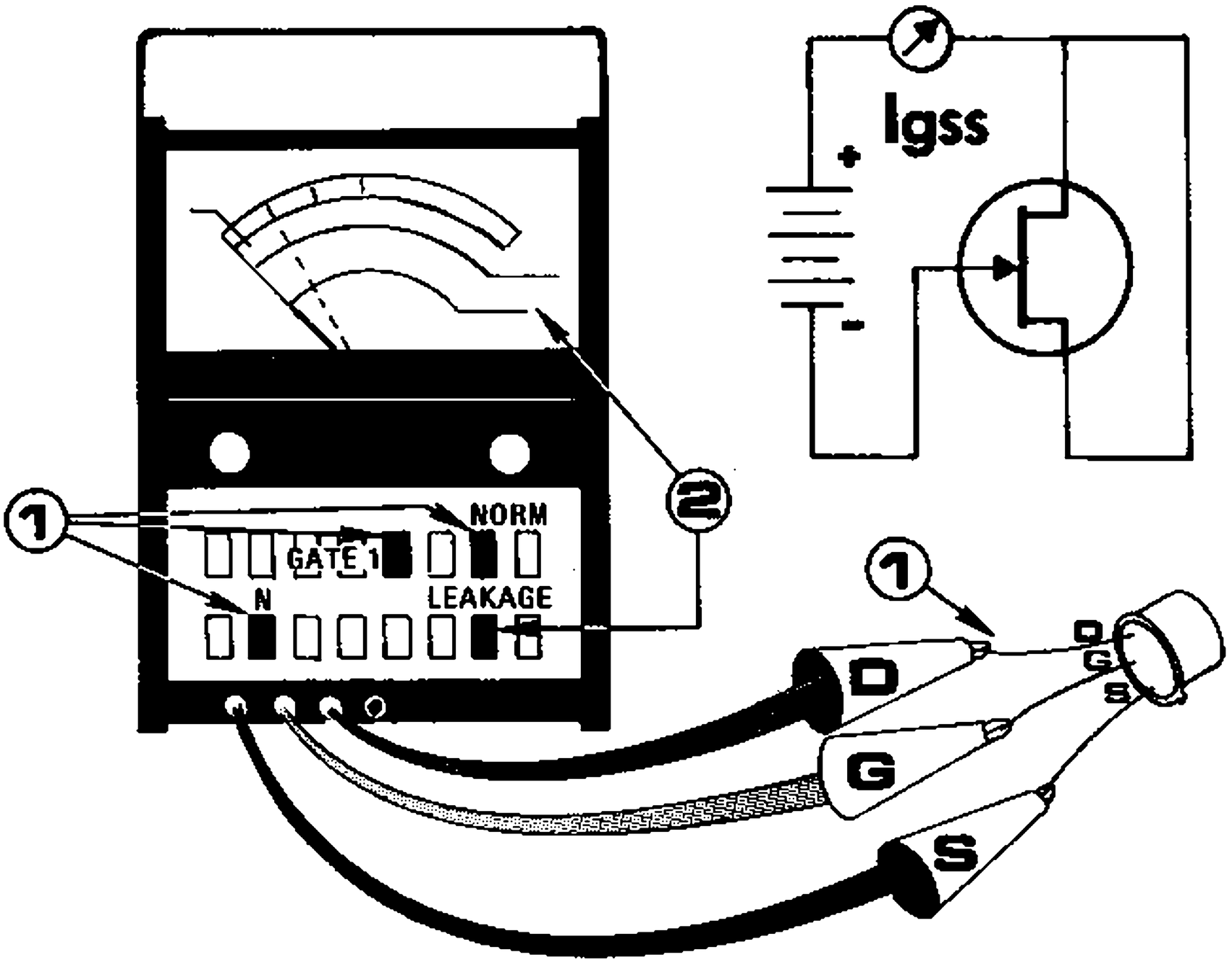


Fig. 15. FET I_{GSS} Test

the gate 2 leakage. Use the Sencore Reference Book if you have any questions as to the acceptable leakage.

ZERO BIAS DRAIN CURRENT (I_{DSS})

This test is used to match or cull FET's for various circuits and for production line testing. An FET may have a very wide range of I_{DSS} and will have to be selected to work in the various circuits designed by the different manufacturers. In a balanced bridge circuit or differential amplifier, the two FET's must be matched for Gm and I_{DSS} for the circuit to be balanced and work properly. In a cascade amplifier circuit, the upper FET should have a zero bias drain current of two to four times that of the lower FET for best gain and stability of the circuit. Thus, manufacturers will select the FET's to match the circuit and will generally color code them. When ordering replacement FET's from the manufacturers, be sure to specify the color code of the FET for best circuit performance.

The following example shows how the zero bias drain current can affect the circuit. If the wrong value is chosen, the possibility of failure in a

very short period of time is great. The example is with the depletion type FET, but the readings obtained with the enhancement mode FET can be used for similar calculations as well as FET matching.

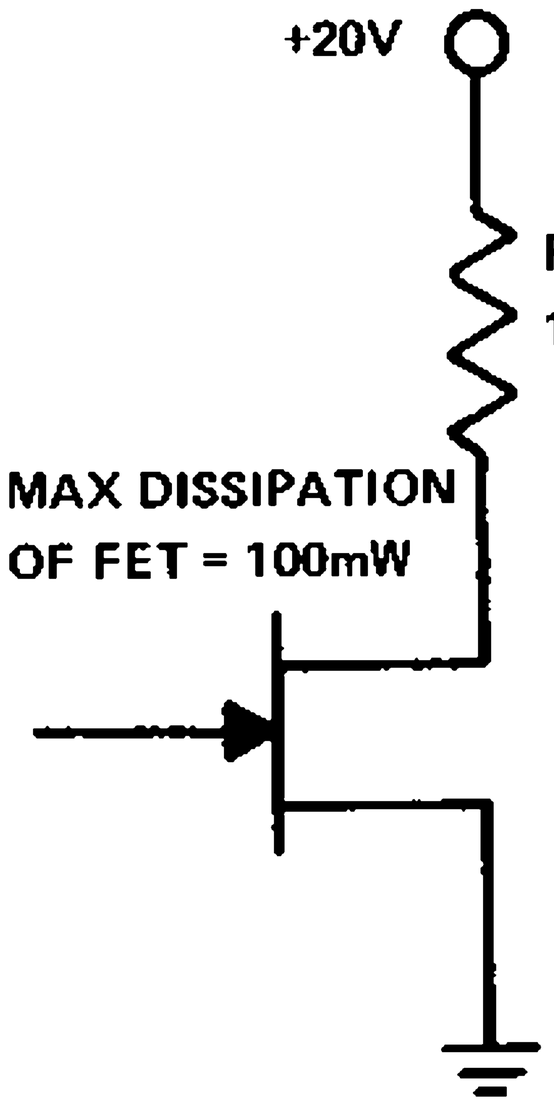
If a replacement type FET is put into a circuit, the zero bias drain current should be checked with the TF166 and the power dissipated across the FET calculated, to be sure that you do not exceed the maximum rating of the device. In the example of Figure 16, three FET's with different I_{DSS} are considered for replacement in the circuit. If the FET has a maximum dissipation of 100 milliwatts, all three could be used. However, FET B would be running at its maximum dissipation and would have a good chance of failure in a short period of time as compared to FET A. To compute the dissipation, follow these simple steps:

1. Measure the I_{DSS} with the TF166.

2. Multiply the current in step one by the value of the drain load resistor.

3. Subtract the voltage across the load resistor from the drain supply voltage.

4. Multiply the voltage across the FET from step three by the I_{DSS} measured in step one. This is the dissipation across the FET in watts.



	FET A	FET B	FET C
I_{DSS}	5mA	10mA	7mA
V_{RL}	5V	10V	7V
V_{DS}	15V	10V	13V
DISSIPATION	75mW	100mW	91mW

Fig. 16. Field Effect Transistor Replacement In A Circuit

With the TF166, the I_{DSS} check will give you the actual zero bias drain current for depletion type FET's. Enhancement type FET's are forward biased and I_{DSS} is not measured. However, the drain test current that is indicated when the I_{DSS} button is pushed is useful for matching, culling, etc. To test for I_{DSS}, proceed as follows:

1. Connect the FET to the TF166 the same as for the gain test, following the proper precautions.

2. Press the I_{DSS} button and observe the red I_{DSS} scale on the meter. Use the Sencore Reference Book if you have any questions as to the acceptable leakage.

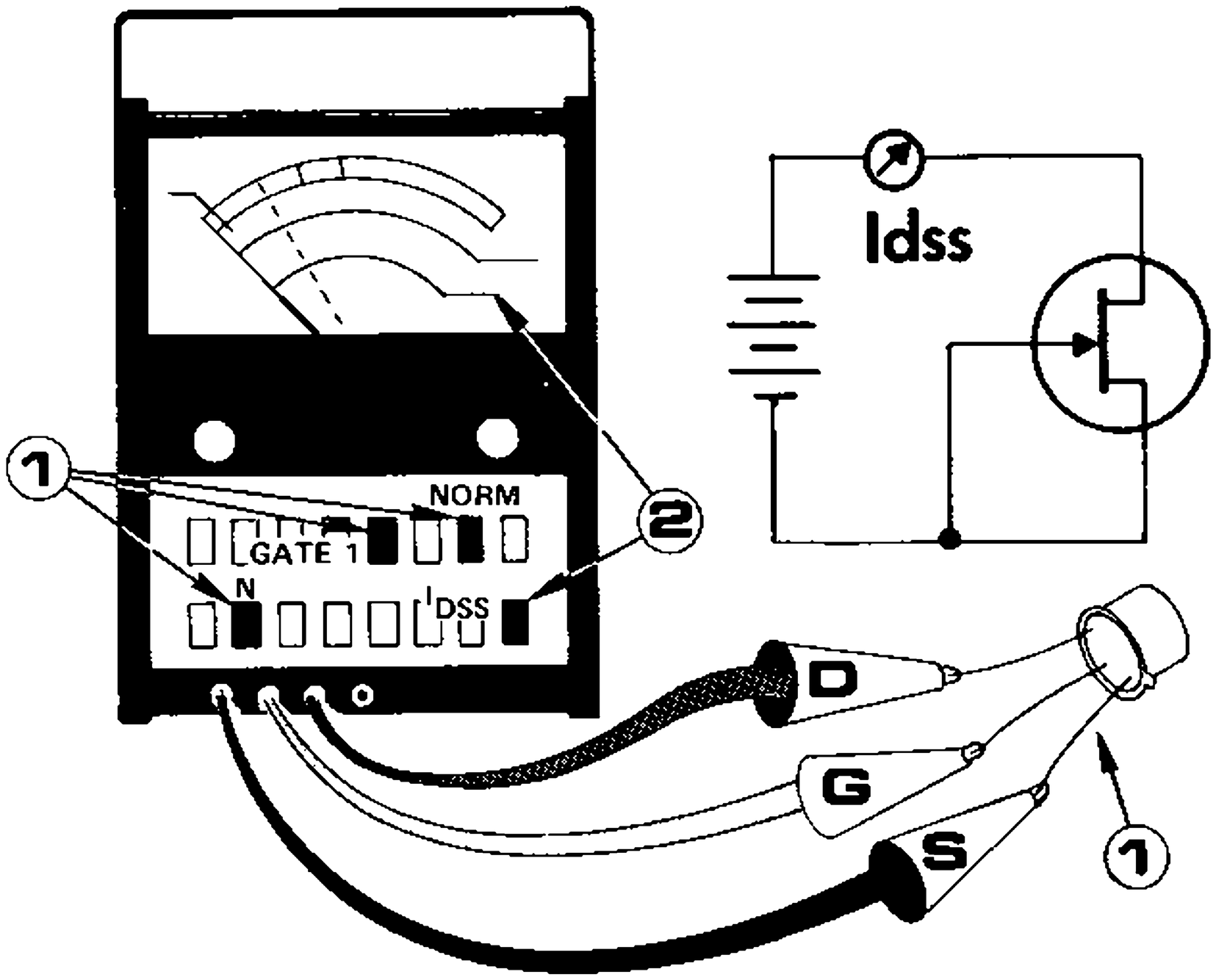


Fig. 17. FET I_{DSS} Test

USING YOUR REFERENCE BOOK

The Sencore Transistor and FET Reference Book has been compiled to be as complete as possible. The format has been simplified to allow quick access to the most important information about any of over 19,000 transistors. In some cases, complete information for the transistor was

not available to Sencore. We have included these transistor types, and the data which was available, to provide as much reference information as possible.

HOW TO USE YOUR REFERENCE BOOK

TRANSISTOR SECTION

TRANS	BASE	POWER	POL	GAIN min.	LEAK Icbo	TRANS	BASE	POWER	POL	GAIN min.	LEAK Icbo
JAN2N1412	41	Hi	P	25	300	2N1483	25	Hi	N	20	15
❶	❷	❸	❹	❺	❻	❶	❷	❸	❹	❺	❻
2N1412A	41	Hi	P	25	300	JAN2N1484	25	Hi	N	20	7

Fig. 18. Transistor Section of Reference Book

1. **TRANS** - Numerical listing of transistor type. This section includes all transistors and FET's for fast identification.

2. **BASE** - The number listed in this column corresponds to the correct basing diagram for the transistor shown at the rear of the book. (Basing information was not available for some transistors. Rather than omit the transistor for this reason, the number 500 was entered to indicate that basing information is not included.)

3. **POWER** - Transistor classification with respect to maximum collector dissipation.

4. **POL** - The letter listed in this column indicates transistor composition. N indicates an NPN transistor, P designates a PNP type.

5. **GAIN MIN** - The gain listings for transistors have been simplified to list only the minimum acceptable gain as specified by the transistor manufacturer. Any transistor testing below this value should be considered defective. Some entries will be marked with an asterisk (*), indicating the minimum gain value was not available and was calculated by Sencore.

The procedure used by Sencore to determine minimum gain is as follows:

Conversion used from Maximum gain to minimum gain. The formula was derived by averaging the ratio existing between maximum and minimum gain for a large sampling of transistors with this dual listing. The average ratio was found to be 4:1. A .25

multiplier represents this ratio and was used to obtain a minimum Beta value for this reference book.

Conversion used from Average gain to minimum gain. The formula used was derived by averaging the ratio existing between average and minimum gain for a large sampling transistors with this dual listing. The average ratio was found to be 1.65:1. A 0.6 multiplier represents this ratio and was used to obtain a minimum beta value for this reference book.

6. **LEAK** - Maximum value of leakage in microamps. This is the I_{CBO} leakage at 4 volts V_{CE} used in Sencore Transistor Testers. This is the maximum value of leakage a transistor should have to be considered good. If the leakage value exceeds this figure, the transistor should be considered defective. The leakage test is to be made out of circuit only.

FET (FIELD EFFECT TRANSISTOR) SECTION

FET	BASE	BIAS	CHAN	Gm GAIN (micromhos) min.	ave.	max.	LEAK Igss	IDSS
P102	32	Norm	P	1000		1600	.01	4.5
❶	❷	❸	❹	750 2500	❺	3500 8000	❻	❼
P1029	146	Norm	P	5000			.003	50

Fig. 19. FET Section of Reference Book

1. **FET** - Numerical listing of all Field Effect Transistors.

2. **BASE** - The number listed in this column corresponds to the correct basing diagram for the transistor shown at the rear of the book. (Basing information was not available for some transistors. Rather than omit the transistor for this reason, the number 500 was entered to indicate that basing information is not included.)

3. **BIAS** - This column denotes whether the transistor is a depletion or enhancement type. The entry NORM indicates a depletion type using reverse bias on the gate with respect to source. POS indicates an enhancement type with positive or forward bias on the gate with respect to source.

4. **CHAN** - The letter listed in this column indicates transistor composition. N indicates an N-channel type, P indicates a P-channel type.

5. **GAIN** - Listing of available information regarding minimum, average, or maximum mutual conductance, Gm, in micromhos.

6. **LEAK** - Maximum allowable I_{GSS} leakage (source/gate current with drain shorted to source) for the transistor type. Transistors exhibiting a greater leakage value than specified should be considered defective.

7. I_{DSS} - Maximum zero bias current (source to drain current with gate shorted to source). Used for matching or culling FET's.

CHECKING DIODES AND RECTIFIERS

The TF166 will check signal diodes, power rectifiers, and zener diodes, in circuit, for both opens and shorts. To test a diode in circuit, proceed as follows:

1. Depress the LOW PWR, "N" POLARITY, and AC IN CIRCUIT pushbuttons.

2. Connect the E lead of the TF166 to the cathode of the diode, and the B lead to the anode of the diode as shown below.

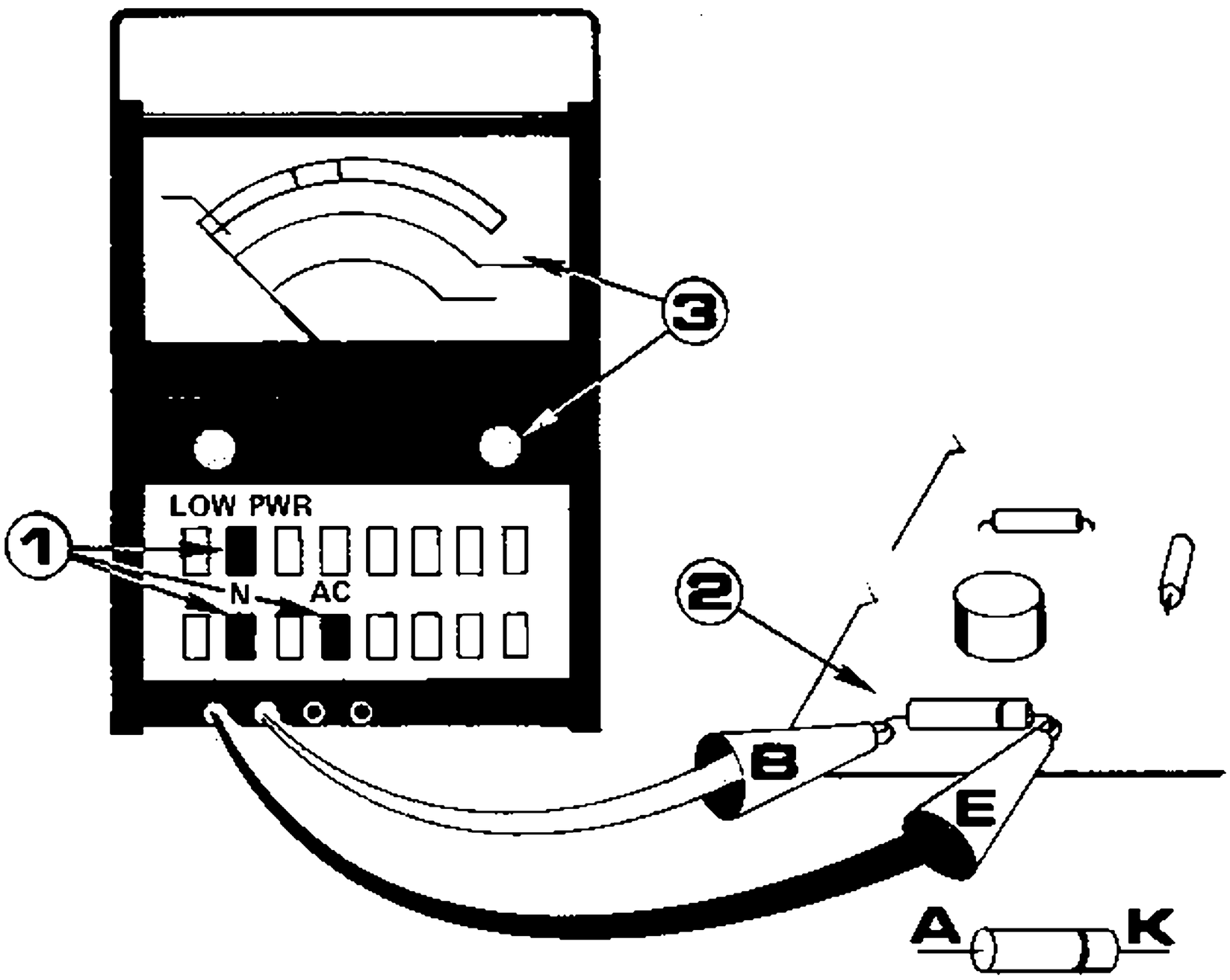


Fig. 20. In Circuit Diode and Rectifier Test

3. Rotate the GAIN CAL control fully clockwise. If the meter reads up scale, the device has good diode action. If the meter does not move, or moves in the negative direction, the diode may be open, shorted, or the leads reversed. (Diodes shunted with a low impedance or a defective component will check Bad in-circuit. Remove the diode from the circuit, and recheck using the OUT OF CIRCUIT test as a final check).

CHECKING DIODES AND RECTIFIERS OUT OF CIRCUIT

A more accurate check on a diode or rectifier may be made out of circuit with the leakage test on the TF166. The reverse current or leakage can be measured and compared with the forward current to find the actual front to back ratio of the diode. To test a diode out of circuit, proceed as follows:

1. Connect the C lead of the TF166 to the cathode of the diode, and the B lead to the anode.

2. Press the N polarity and LEAKAGE buttons, and observe the LEAKAGE scale on the meter. The meter will indicate the reverse or leakage current of the diode, and should read near zero.

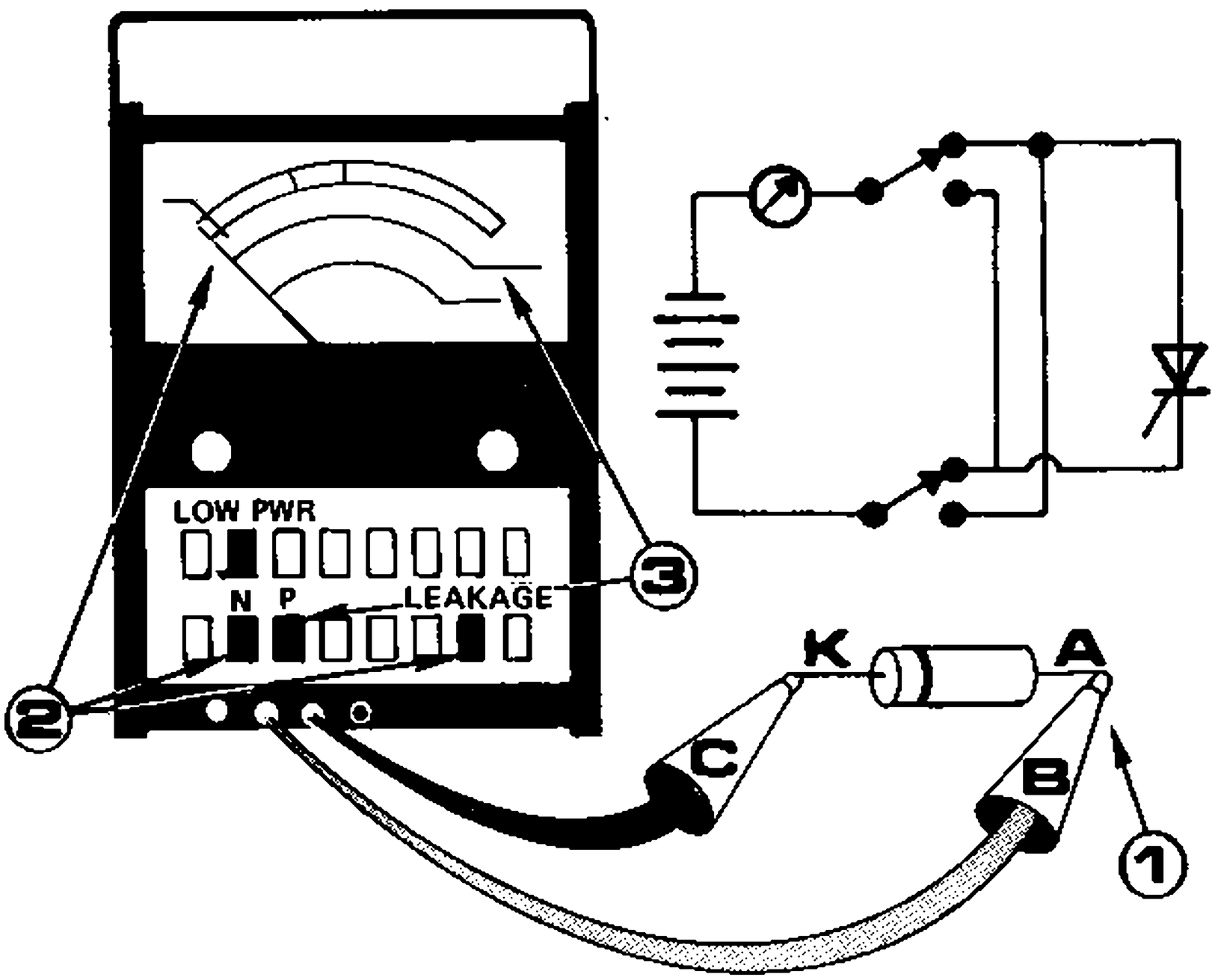


Fig. 21. Out of Circuit Diode and Rectifier Test

3. Press the P polarity and LEAKAGE buttons, and observe the LEAKAGE scale on the meter. The meter will indicate the forward current of the diode, and should read near full scale.

MATCHING DIODES IN OR OUT OF CIRCUIT

Matched diodes are used in applications such as phase detectors in the horizontal oscillator circuits, and 3.58MHz reference oscillator circuits in color TV. They are also used in ring modulators and demodulators, as well as the stereo decoder in FM stereo receivers. To match diodes in or out of circuit, proceed as follows:

1. Set up and connect the TF166 to one of the diodes to be matched the same as for CHECKING DIODES IN CIRCUIT.

2. Adjust the GAIN CAL control to position the meter pointer to 10 on the Beta GAIN scale (break between "?" and GOOD).

3. Without touching the GAIN CAL control, connect the TF166 to the diode or other diodes to be matched. For proper matching the meter should indicate within 10% (between 9 to 11 on the Beta scale).

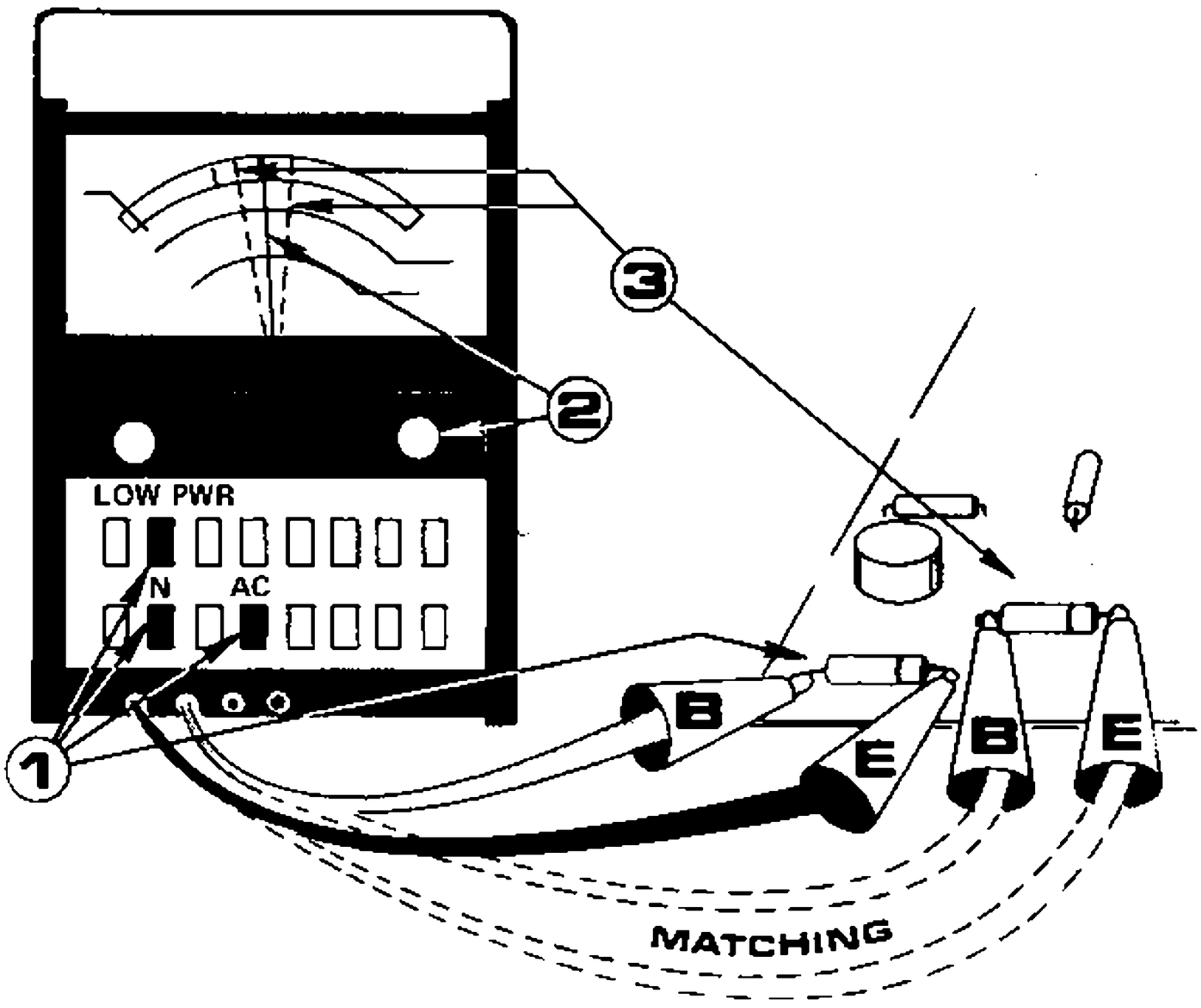


Fig. 22. Matching Diodes In or Out of Circuit

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ZENER DIODES

Zener diodes may be checked for opens or shorts with the TF166, but the results will not indicate the regulating point of the diode. Zener diodes above eight volts will exhibit no leakage and will show good forward conduction on the out of circuit test. A zener diode in the six volt range will have a reverse leakage of better than three quarters full scale (around 2000 microamps) and a zener diode of less than five volts will read the same in both directions, due to the zener effect.

VARICAP DIODES

A varicap diode will exhibit the same diode action as a regular silicon diode, and should be tested with the same procedure. The only difference between the two is that the varicap diode has a controlled capacity effect. The reverse current or leakage will be one of the most important checks on this type of diode. Excessive reverse leakage current will cause the Q of the varicap to be lower than normal, which will reduce the sensitivity of a receiver or reduce the output of an oscillator circuit.

CHECKING OTHER SEMICONDUCTOR DEVICES

Devices such as the SCR, TRIAC, and UJT are making their appearance in power supplies and TV receiver sweep circuits. These devices do not exhibit gain as such, and therefore can not be tested with the in circuit gain tests on the TF166. Leakage, however, is an important parameter on these devices, and the TF166 is ideal to measure this leakage.

CHECKING SCR'S AND TRIACS

TESTING FOR I_{KAO} AND I_{AKO}

I_{KAO} is the current that flows when a voltage is applied between anode and cathode, with the gate open, and the anode positive with respect to the cathode. It is a measure of the SCR's ability to block forward current in its normal off state. I_{AKO} is the current that flows when a voltage is applied between anode and cathode, with the gate open, and the anode negative with respect to the cathode. It is a measure of the SCR's reverse blocking characteristics. To test for I_{KAO} and I_{AKO}, proceed as follows:

1. Connect the C lead of the TF166 to the anode of the SCR and the B lead to the cathode. Leave the E lead of the TF166 and the gate of the SCR open and unconnected.

2. Press the N polarity and LEAKAGE buttons and observe the LEAKAGE scale on the meter. The meter will indicate I_{AKO}, and should read near zero.

3. Press the P polarity and LEAKAGE buttons, and observe the LEAKAGE scale on the meter. The meter will indicate I_{AKO}, and should read near zero.

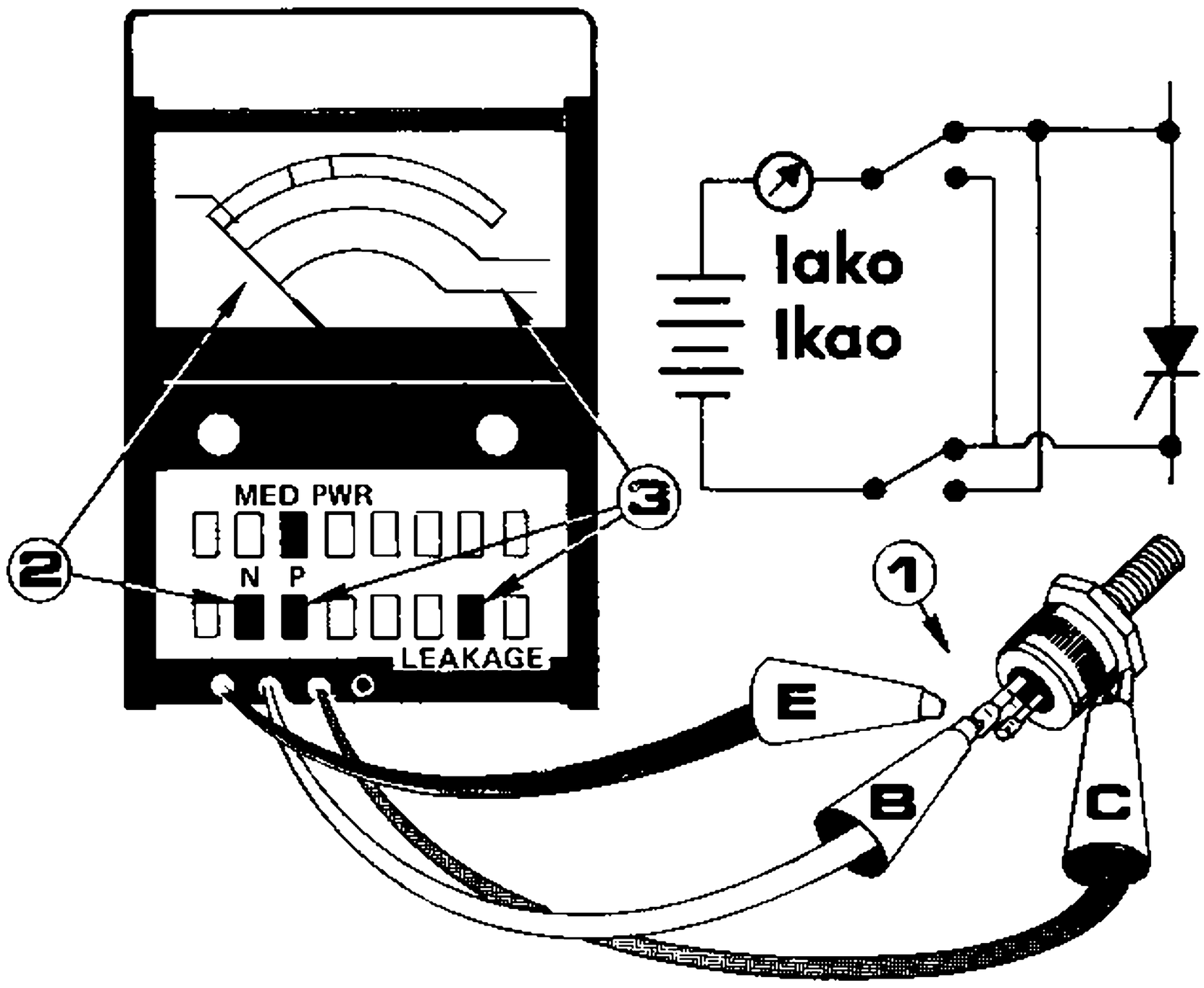


Fig. 23. I_{KAO} and I_{AKO} Test for SCR's

TESTING FOR I_{AGO} (SCR'S ONLY)

I_{AGO} is the leakage current that flows when a voltage is applied between anode and gate with the cathode open, and the anode positive with respect to the gate. I_{AGO} will tend to turn the SCR on, and will limit the maximum impedance between gate and cathode at which the SCR can be operated. To test for I_{AGO}, proceed as follows:

1. Press the N polarity and one of the regular transistor type buttons.

2. Connect the C lead of the TF166 to the anode of the SCR, the B lead to the gate, and the E lead to the cathode.

3. Press the LEAKAGE button, and observe the leakage scale on the meter. The meter will indicate I_{AGO} and should read zero for small (under 5 amp) SCR's, and no more than a few microamps for larger SCR's.

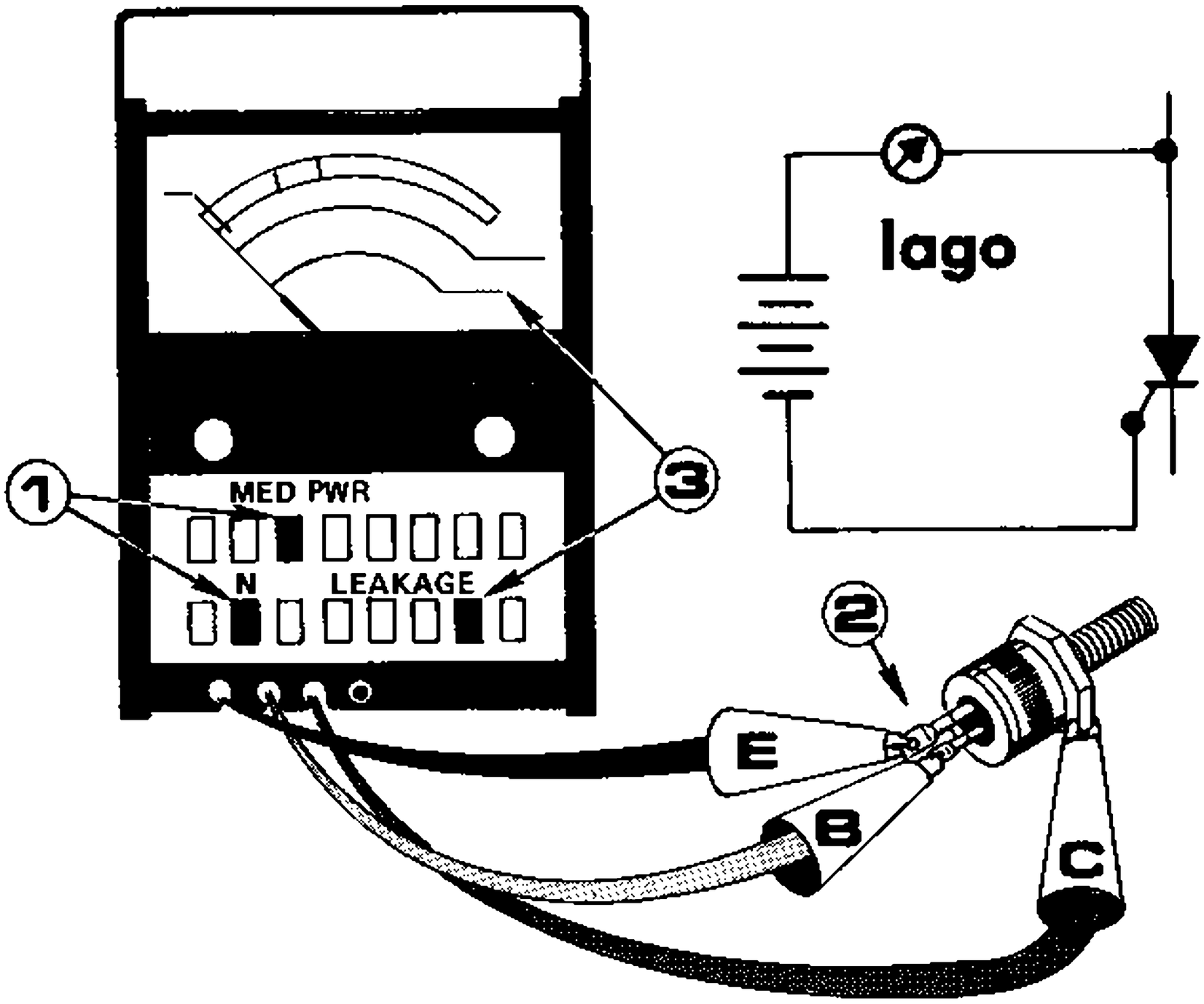


Fig. 24. I_{AGO} Test for SCR's

TESTING UNIJUNCTION TRANSISTORS FOR I_{EB_1S}

I_{EB_1S} is the leakage current that flows when a voltage is applied between emitter and base 1, with base 2 shorted to base 1, and the emitter negative with respect to base 1 and base 2. I_{EB_1S} will affect the stability of

any circuit using the UJT, and will limit the maximum emitter time constant that the UJT will operate at. To test for I_{EB_1S}, proceed as follows:

1. Press the GATE 1, NORM, and N polarity buttons on the TF166.

2. Connect the GATE lead of the TF166 to the emitter of the UJT, the DRAIN lead to base 1, and the SOURCE lead to base 2.

3. Press the LEAKAGE button and observe the LEAKAGE scale on the meter. The meter will indicate I_{EB_1S} and should read at or near zero.

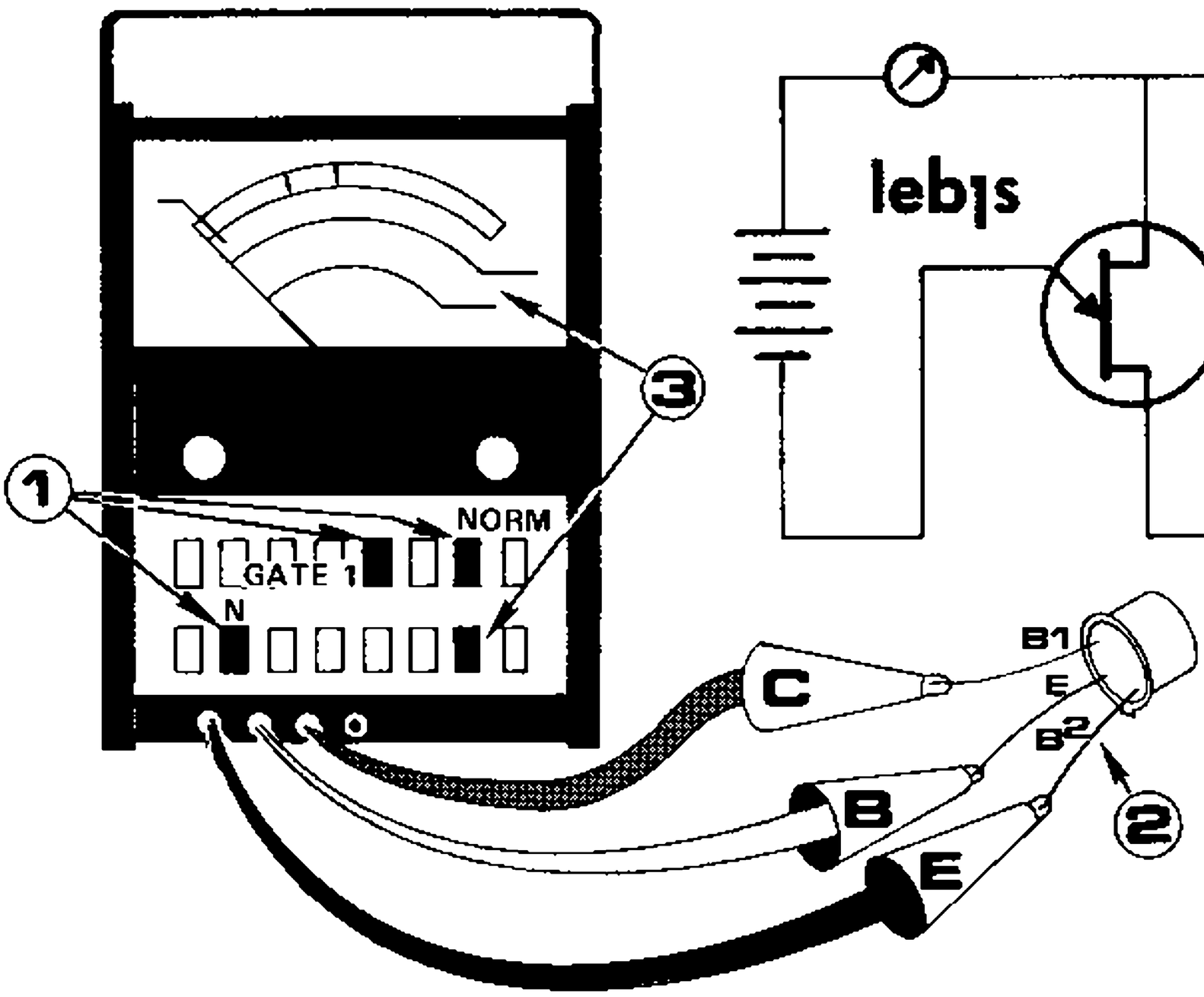


Fig. 25. I_{EB_1S} Test for Unijunction Transistors

CIRCUIT DESCRIPTION

The heart of the TF166 Automatic Transistor Analyzer is the meter amplifier shown in Fig. 26. IC1, a 741 high gain operational amplifier, amplifies the small currents and voltages used to test the transistor or FET to a level that will drive the meter. The sensitivity of this amplifier is .2mV for the GAIN CAL line on the meter. This would represent a full scale sensitivity of 4mv, except that compression is provided by diodes CR104 - CR106, R105 and R106 to lower the full scale sensitivity to 100mv. This compression allows the TF166 to measure transistor beta from 1 to 500 on the same scale, without complicated range switching.

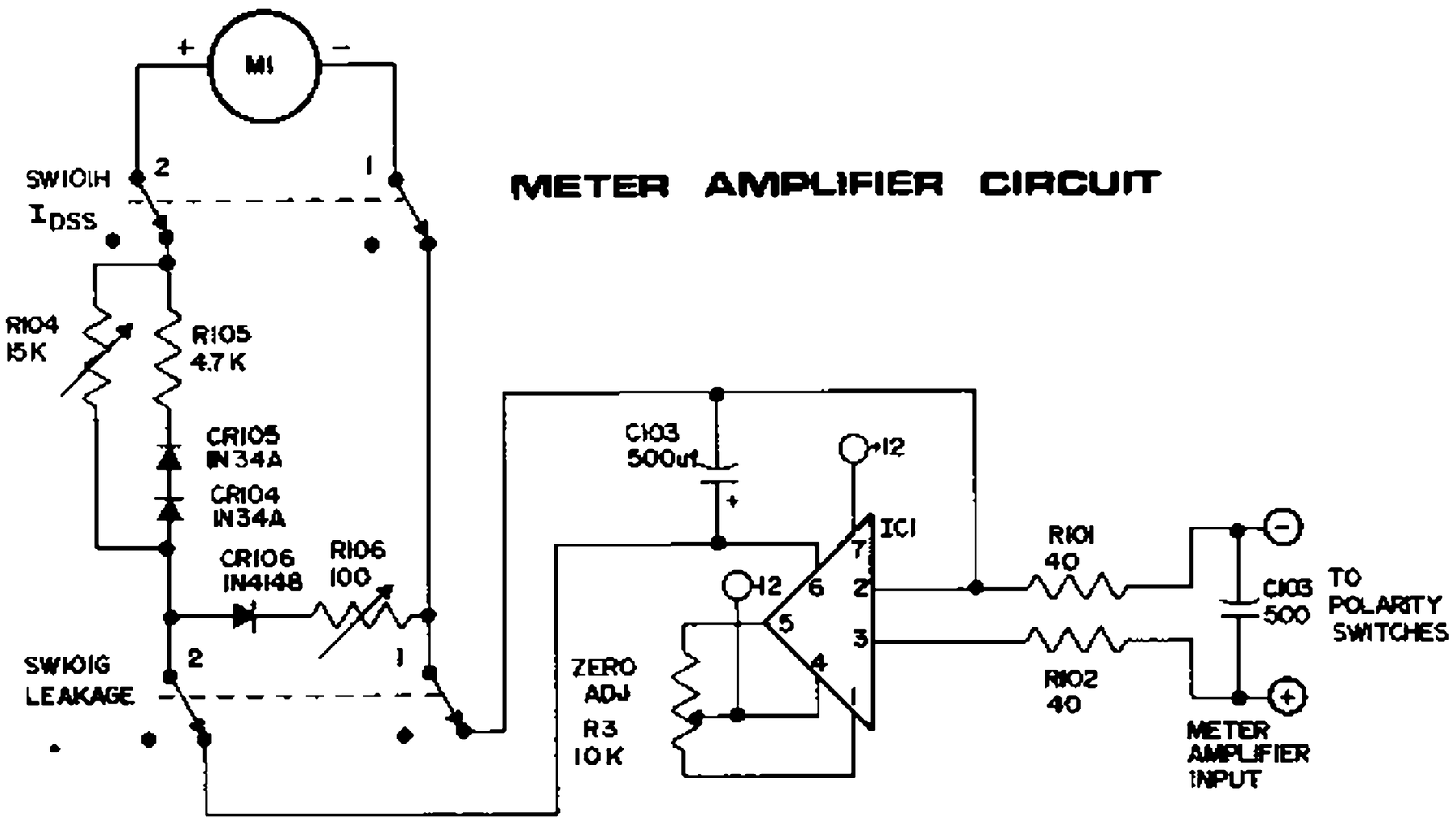


Fig. 26. TF166 Meter Amplifier Circuit

AC IN CIRCUIT TEST

Fig. 27 is a simplified drawing of the AC IN CIRCUIT test. The RF-IF, NPN, and AC IN CIRCUIT buttons are pushed, and the gain test button is shown in the normal out position. Shunt resistor R201 to R204, as selected by section 3 of SW201A, B, C, and D, is connected in series with the base lead. Resistor R206 to R209, as selected by section 4 of SW-201A, B, C, and D, is connected in series with the emitter lead. The 40 ohm shunt resistors shown selected provide the maximum sensitivity of the RF - IF position. The meter amplifier IC1 is connected across the

resistor in series with the base lead, and R108 the 40 ohm resistor that matches the meter input resistance is connected across the resistor in series with the emitter lead.

With a transistor connected to the "E", "B", and "C" leads R1A, the front panel GAIN CAL control, is adjusted so the current flow through the base resistor causes a .2mv drop, corresponding to the GAIN CAL line on the meter. The base currents necessary for GAIN CAL are as follows: RF-IF (40 ohm) 10uA, LOW PWR (8 ohm) 30uA, MED PWR (2.1 ohm) 100uA, and HI PWR (.67 ohm) 300uA. When the GAIN button is pushed, the meter amplifier is connected across the resistor in series with the emitter lead, and R108 is connected across the base resistor. (The switching of R108 and the meter amplifier is necessary to maintain a constant 40 ohm resistance across the base and emitter resistors.)

The meter amplifier now measures the voltage drop across the emitter

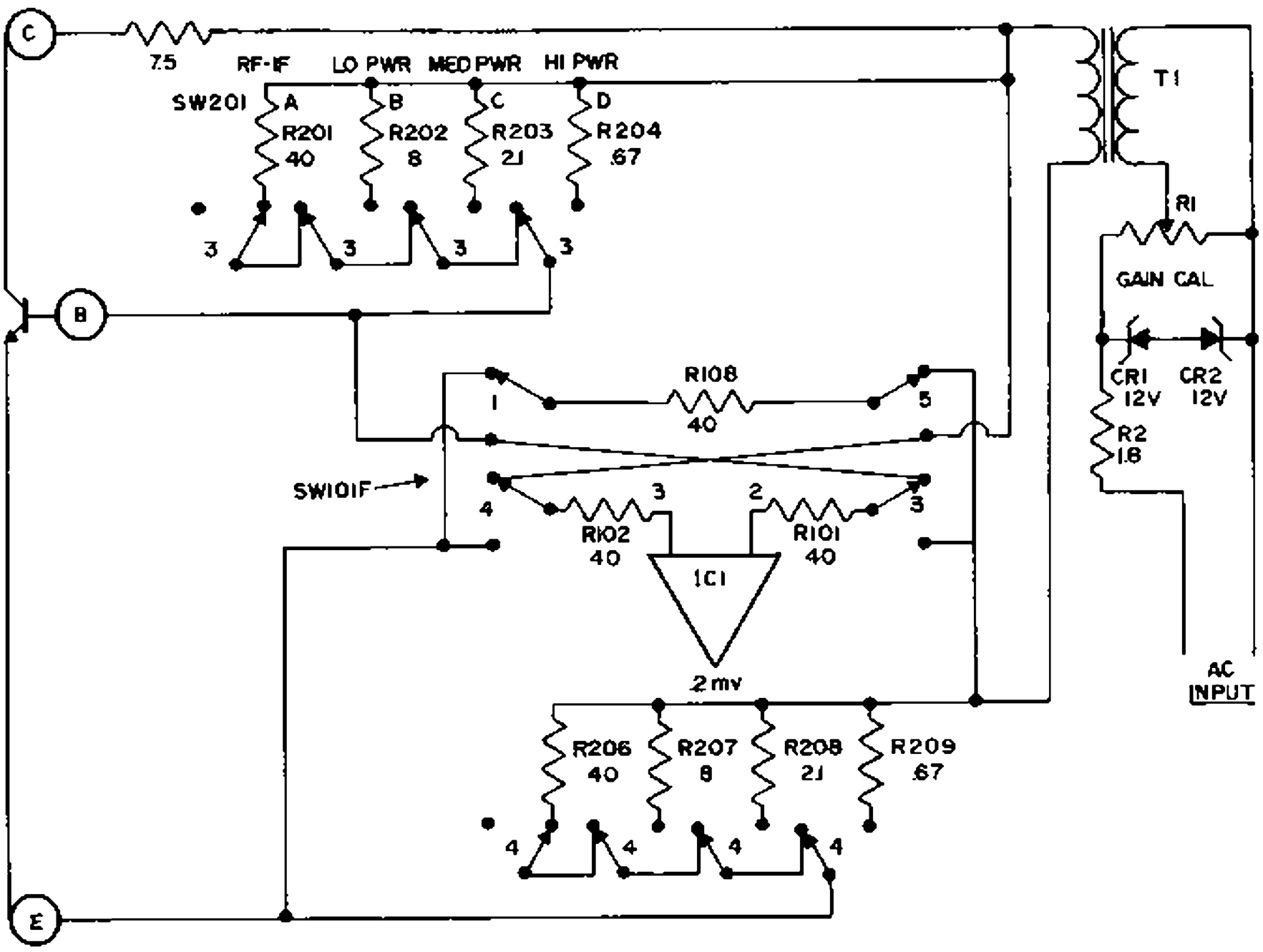


Fig. 27. TF166 AC In Circuit Test

resistor, caused by the emitter current in the transistor. This voltage represents the combined IR drop caused by the reference level of base current and the collector current it causes. The up scale reading of the meter is calibrated to correspond to the ratio of collector current to base current, or Beta.

The only difference between NPN test and the PNP test is that the 2 and 3 inputs of the meter amplifier would be reversed allowing it to measure opposite polarity transistor currents.

DC OUT OF CIRCUIT TEST

Fig. 28 is a simplified drawing of the DC OUT of CIRCUIT test. The test for DC is basically the same as for AC. The only differences are: CR101 added as a rectifier in series with the output of T1, making the test DC instead of AC; the 7.5 ohm resistor removed from the collector lead, and a 1K resistor added to the base lead. The switches are shown in the DC, NPN, and MED PWR positions, with the gain test button in the normal "out" position. To change polarity from NPN to PNP, CR101 is reversed to provide an opposite DC output, and the 2 and 3 inputs of the meter amplifier are reversed to measure the opposite polarity transistor currents.

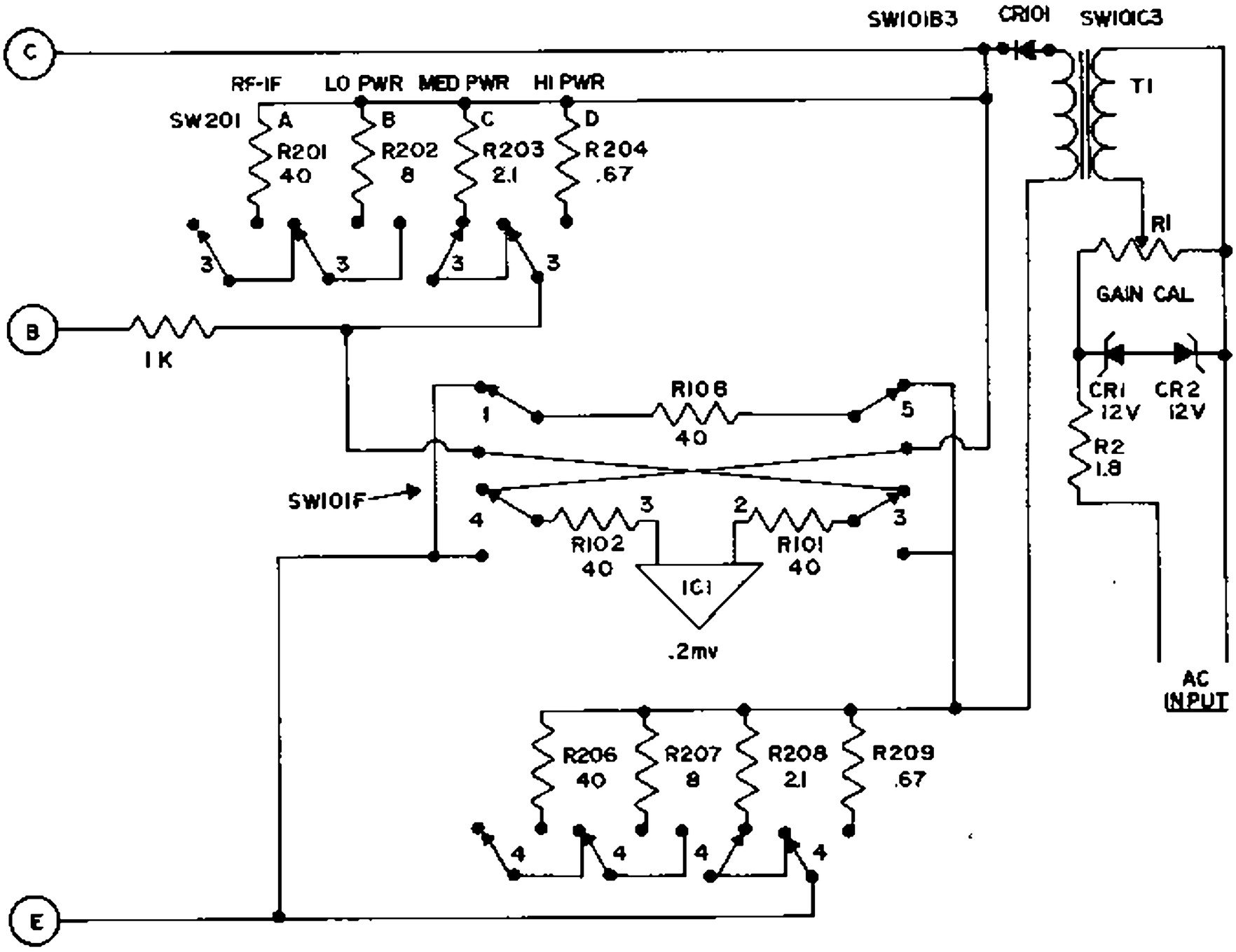


Fig. 28. TF166 DC Out of Circuit Test

FET Gm TEST

Fig. 29 is a simplified drawing of the FET Gm test. The GATE 1, NORM, and "N" POLARITY buttons are shown depressed, and the GAIN test button is shown in the normal "out" position. The source of the FET under test is connected to the negative output of the 6.2 volt power supply, and the drain is connected to the positive output of the current sensing bridge. The bridge current will flow through TR101 during the first half cycle of the applied AC voltage when its base is positive, and through TR102 during the next half cycle, when its base is positive.

Any difference in the output current from the bridge during alternate half cycles would unbalance the bridge and cause the meter to deflect. With the gate of the FET under test connected to the source as shown the current flow from source to drain in the FET under test will be approximately equal during both half cycles of the applied AC voltage. R5, the front panel GAIN CAL control, is adjusted so that the bridge is balanced to the GAIN CAL line on the meter.

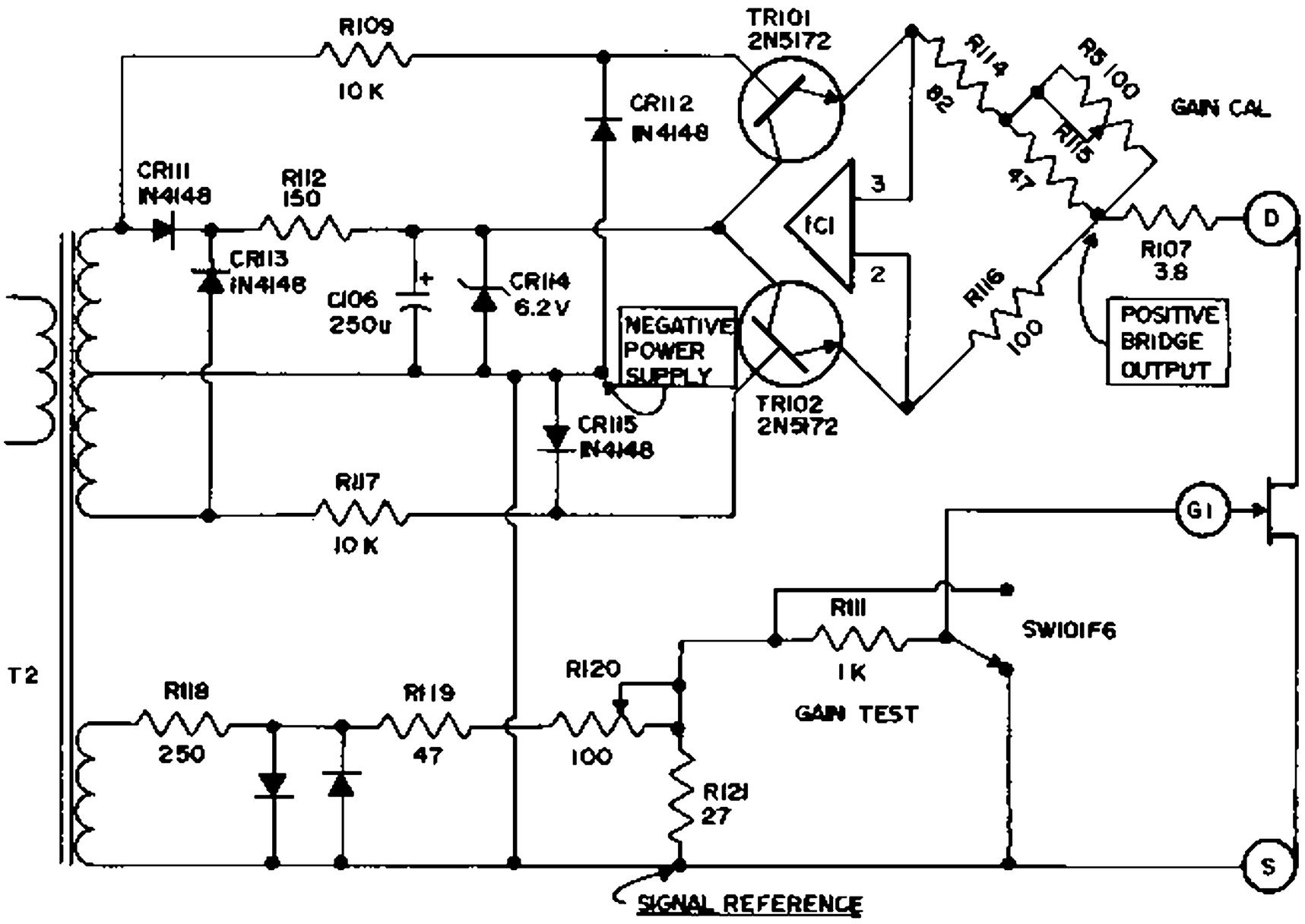


Fig. 29. TF166 FET Gm Test

When the GAIN button is pushed, the gate to source connection of the FET under test is removed, and the gate is connected to the 60Hz square wave test signal developed by the lower winding of T2. R111 (1K) is in the circuit to keep the gate of the FET from floating during the time that the gain button is being pushed, preventing possible damage to the FET.

Fig. 30 is a photograph of the source/drain signal on the top trace, and the gate signal on the bottom trace. The gate signal will be positive at the same time as the base of TR101, and bridge current is flowing through TR101, R114, R115, and R5 (Time A). The gate signal will be negative when the base of TR102 is positive, and bridge current is flowing through TR202 and R116 (Time B). The drain current of the FET under test will increase when its gate is positive, and decrease when its gate is negative, causing the current sensing bridge to be unbalanced. The unbalance in the bridge will cause the emitter of TR101 to be positive with respect to the emitter of TR102, resulting in an up scale deflection of the meter. This up scale deflection is calibrated in Gm for the gain of the FET.

The test for a P channel FET is basically the same as for an N channel, with the following exceptions: Inputs 2 and 3 of the IC op amp are reversed; the negative power supply lead is connected to the drain of the

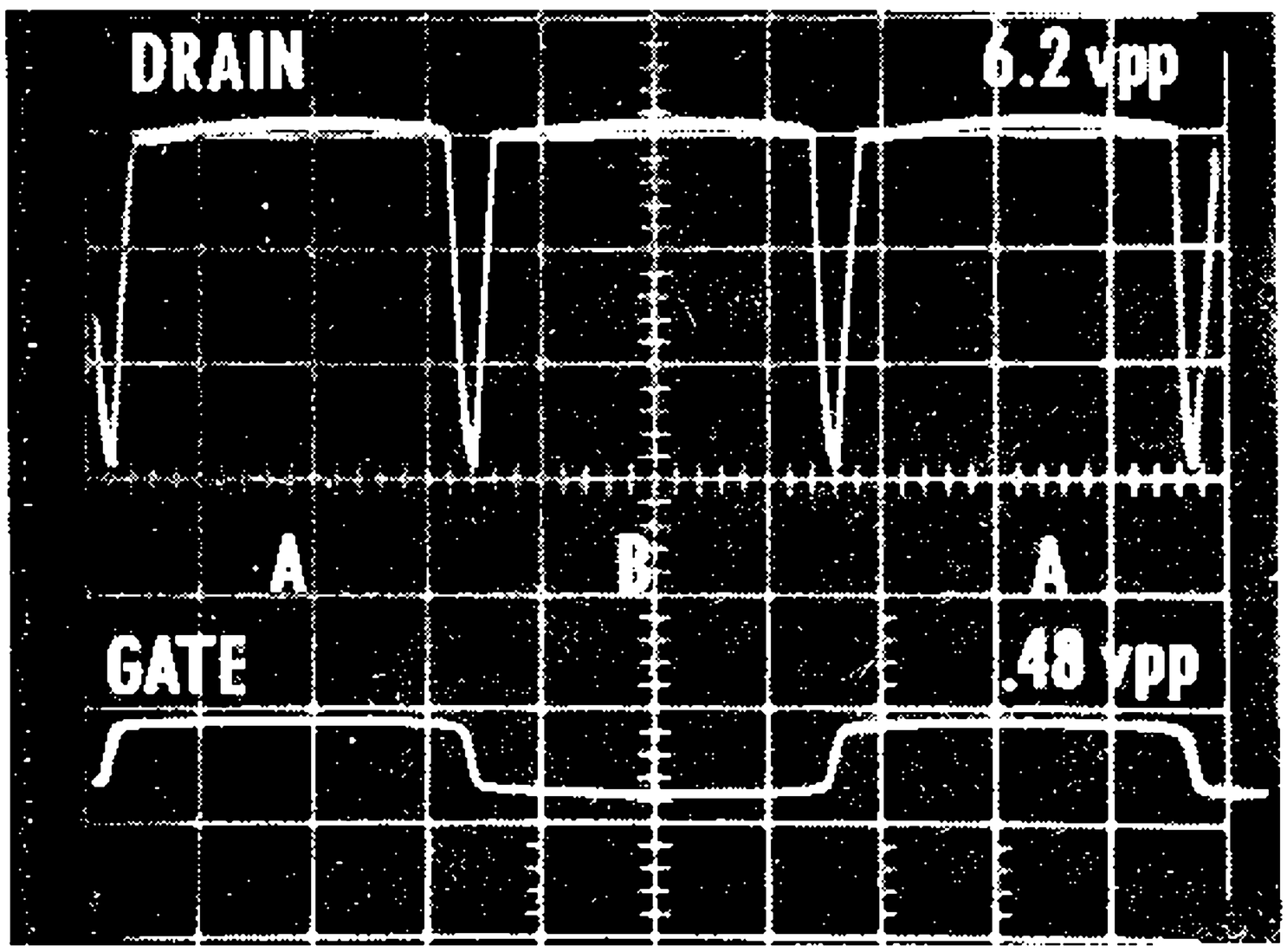


Fig. 30. FET Test Signals of TF166

FET, and the positive bridge output with R107 (3.8 ohms) in series is connected to the source.

The test for enhancement FET's is the same as for normal (depletion) types, except the signal reference is connected to the drain instead of the source.

LEAKAGE TEST

Fig. 31 is a simplified drawing of the I_{CBO} test for an NPN transistor. The base of the transistor under test is connected to the negative lead of the 6.2 volt power supply, and the collector lead is connected through the meter circuit to the 4 volt tap (junction to R113 and R110) on the supply. In order to provide maximum sensitivity at low leakage currents, and still maintain sufficient range for higher leakage currents, the higher leakage currents are shunted from M1 by CR106 and R106, compressing the upper part of the scale on M1. Any leakage current present in the transistor under test will flow from the negative power supply lead,

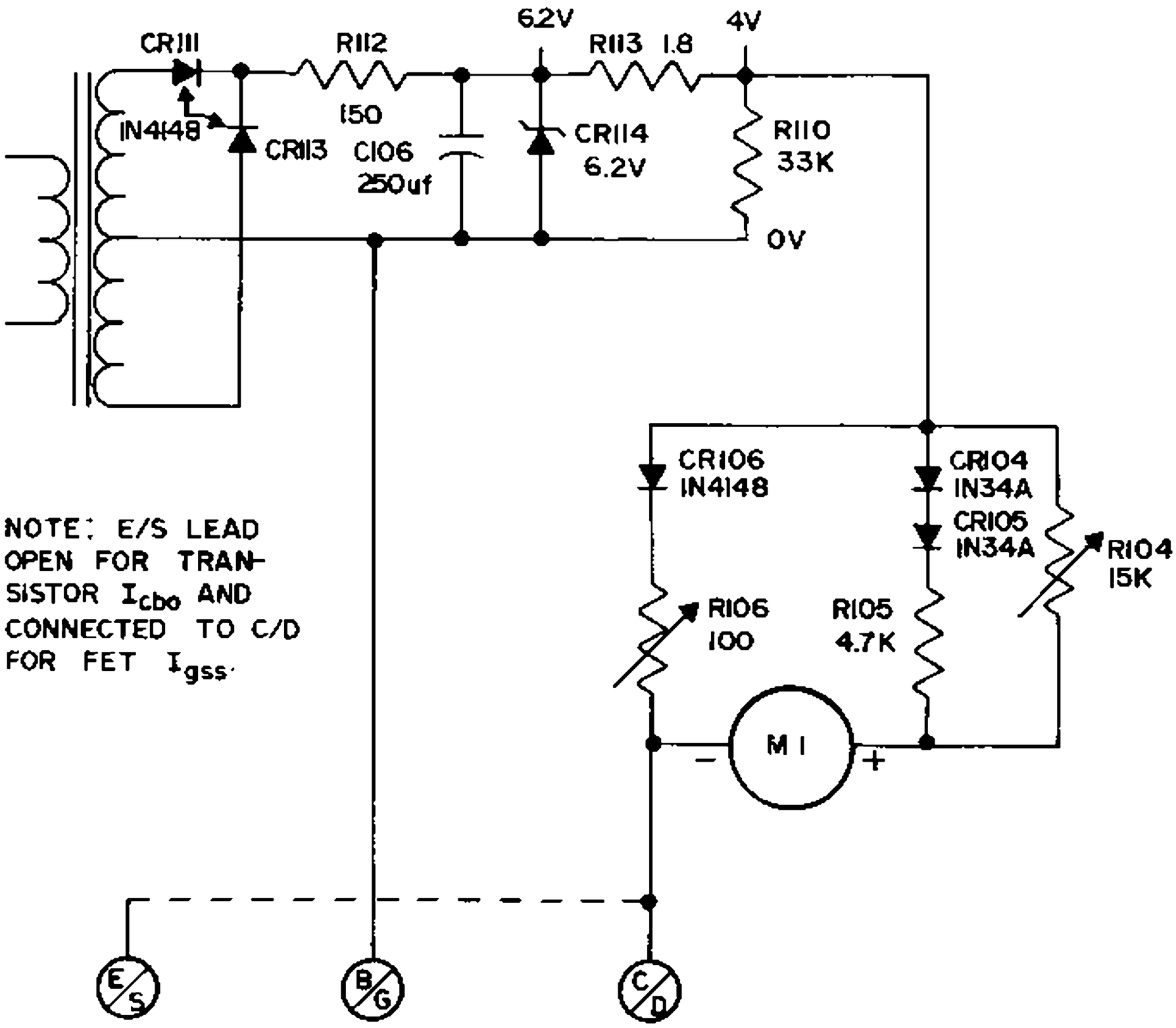


Fig. 31. TF166 I_{CBO} Test

through the base collector junction, through the meter and associated circuitry, and to the positive power supply lead.

The leakage test for a PNP transistor is the same as for the NPN, except that the negative power supply lead is connected to the collector lead, and the positive 4 volt tap is connected to the base lead through the meter circuit.

The leakage test for an N or P channel FET (I_{GSS}) is the same as for a NPN or PNP transistor, except for the FET test the source lead is tied to the drain lead.

I_{DSS} TEST

Fig. 32 is a simplified drawing of the FET I_{DSS} test, with the GATE 1, "N" POLARITY and I_{DSS} buttons pushed. This test uses the same bridge circuit used for the Gm test, except that the meter is removed from across the op amp, and connected in series with the positive output of the bridge. The drain of the FET under test is connected to the negative side of the meter, so the meter measures the drain current. The source and gate are connected to the negative output of the 6.2 volt supply.

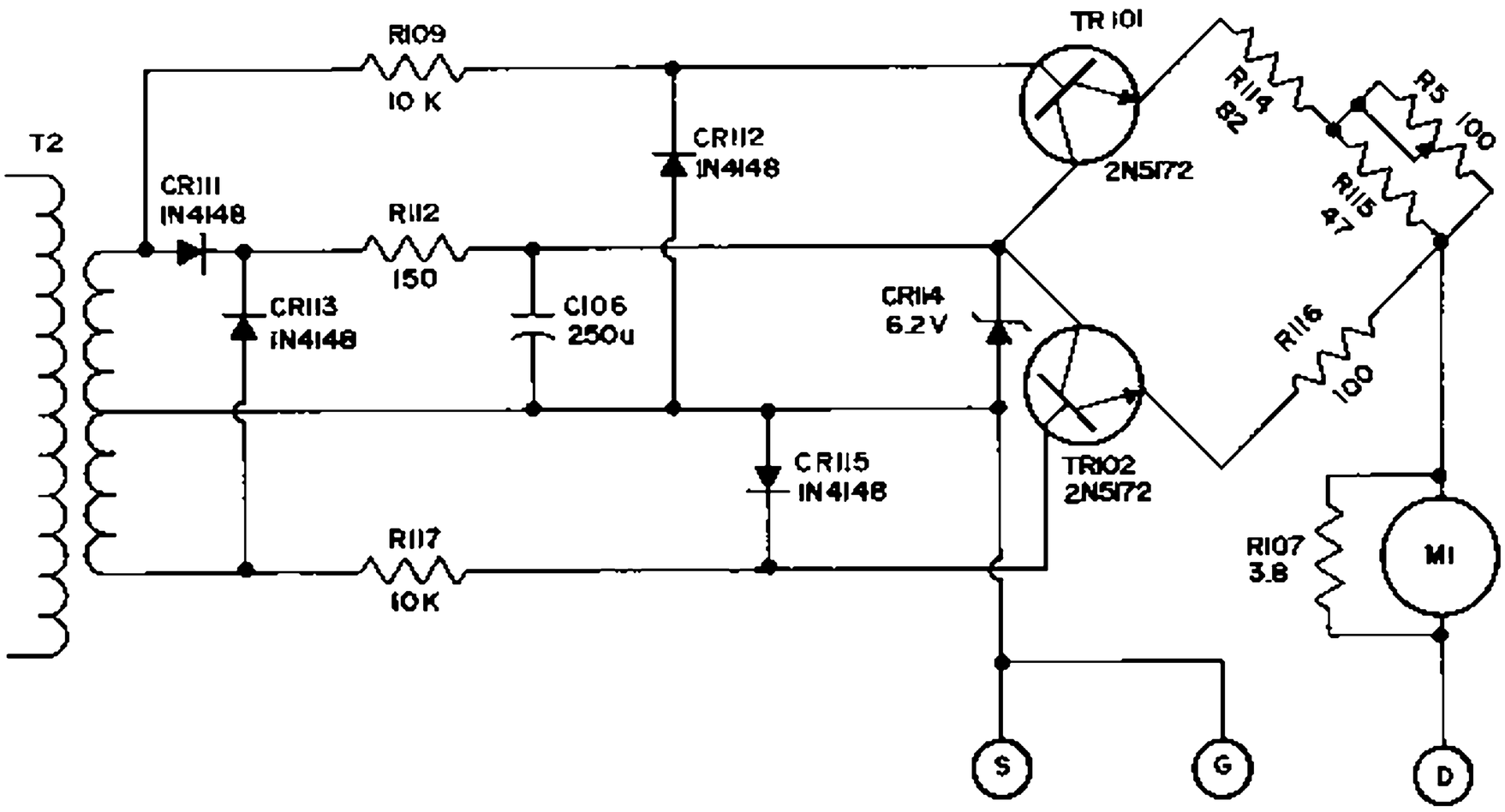


Fig. 32. TF166 I_{DSS} Test

The test for a P channel FET is the same as for the N channel, except that the drain is connected to the negative output of the 6.2 volt supply, and the source and gate are connected to the negative side of the meter.

SERVICING YOUR TF166

DISASSEMBLY INSTRUCTIONS

Place the TF166 face down on a soft cloth, and remove the screws from the top rear of the case, and from the bottom of the case. Turn the TF166 on its back, and lift the front panel from the case. It may be necessary to lift alternately on the top and bottom of the front panel. Once the front panel is loose from the case, set the TF166 on its bottom, and pull the front panel away from the case. Take care to guide the line cord through the opening in the rear of the case. To reassemble the TF166 reverse the above procedure.

CALIBRATION INSTRUCTIONS

NOTE: Calibration adjustments must be made in proper sequence to obtain accurate results.

METER ZERO ADJUSTMENT

1. Remove the TF166 from its case.

2. Lay the TF166 on its right side, and adjust the static meter zero to position the meter pointer to the zero on the left edge of the meter.

TRANSISTOR BETA CALIBRATION

1. Plug the TF166 into a properly grounded AC outlet, press the RF-IF, N polarity, and DC OUT CIRCUIT buttons, and adjust the front panel ZERO ADJUST control to position the meter pointer to the zero on the left edge of the meter.

2. Turn the front panel GAIN CAL control fully counter-clockwise, and connect a milliameter, (such as a Sencore FE16), positive lead to the collector lead of the TF166 and negative lead to the emitter lead of the TF166.

3. Press the front panel GAIN button, and adjust the front panel GAIN CAL control until the external milliameter measures .5mA of

current. It will be normal for the milliameter needle to vibrate slightly.

4. Keep the GAIN button depressed, and adjust the internal BETA 50 CAL control (R104) until the TF166 meter indicates a beta of 50.

5. Press the front panel GAIN button, and adjust the front panel GAIN CAL control so that the external milliameter measures 5mA of current. It will be normal for the milliameter needle to vibrate slightly.

6. Keep the GAIN button pushed, and adjust the internal BETA 500 CAL control (R106 so that the TF166 meter indicates a beta of 500.

7. Repeat steps 3, 4, 5, and 6 until the TF166 is accurately calibrated at a beta of 50 and 500.

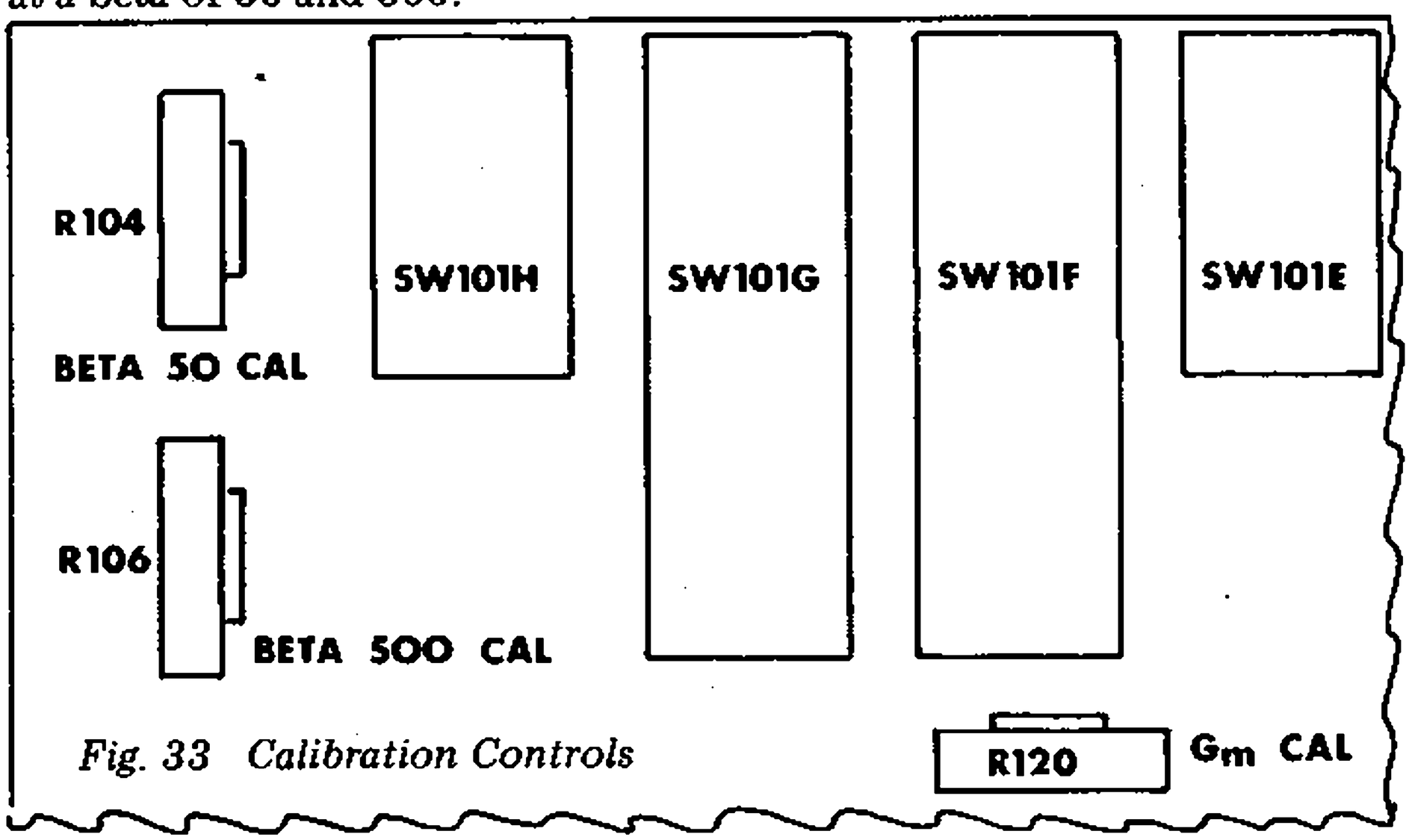


Fig. 33 Calibration Controls

FET Gm CALIBRATION

1. Press the GATE 1, NORM, N POLARITY, and AC IN CIRCUIT buttons.

2. Connect an oscilloscope (such as a Sencore PS163) ground lead to the source lead of the TF166, and signal lead to the gate lead of the TF166.

3. Press the front panel GAIN button, and adjust the internal Gm CAL control (R120) for exactly .48 v p-p as measured on the oscilloscope.

TROUBLE SHOOTING CHARTS

FET GM INOPERATIVE

Press GATE 1, NORM, "N" POLARITY, and IN CIRCUIT AC buttons. Connect scope ground to source lead, and signal lead to drain lead. Does waveform match upper trace in Fig. 30 on page 41 (6.2V p-p)?

NO

Is this waveform present at the emitters of TR101 and TR102?

Conclusion:
Suspect TR101, TR102, and associated circuits.

NO

Conclusion:
Suspect CR116, CR117 and associated circuits.

YES

Move scope signal lead to gate lead. Press gain button. Does signal match bottom trace? (.48 v p-p)

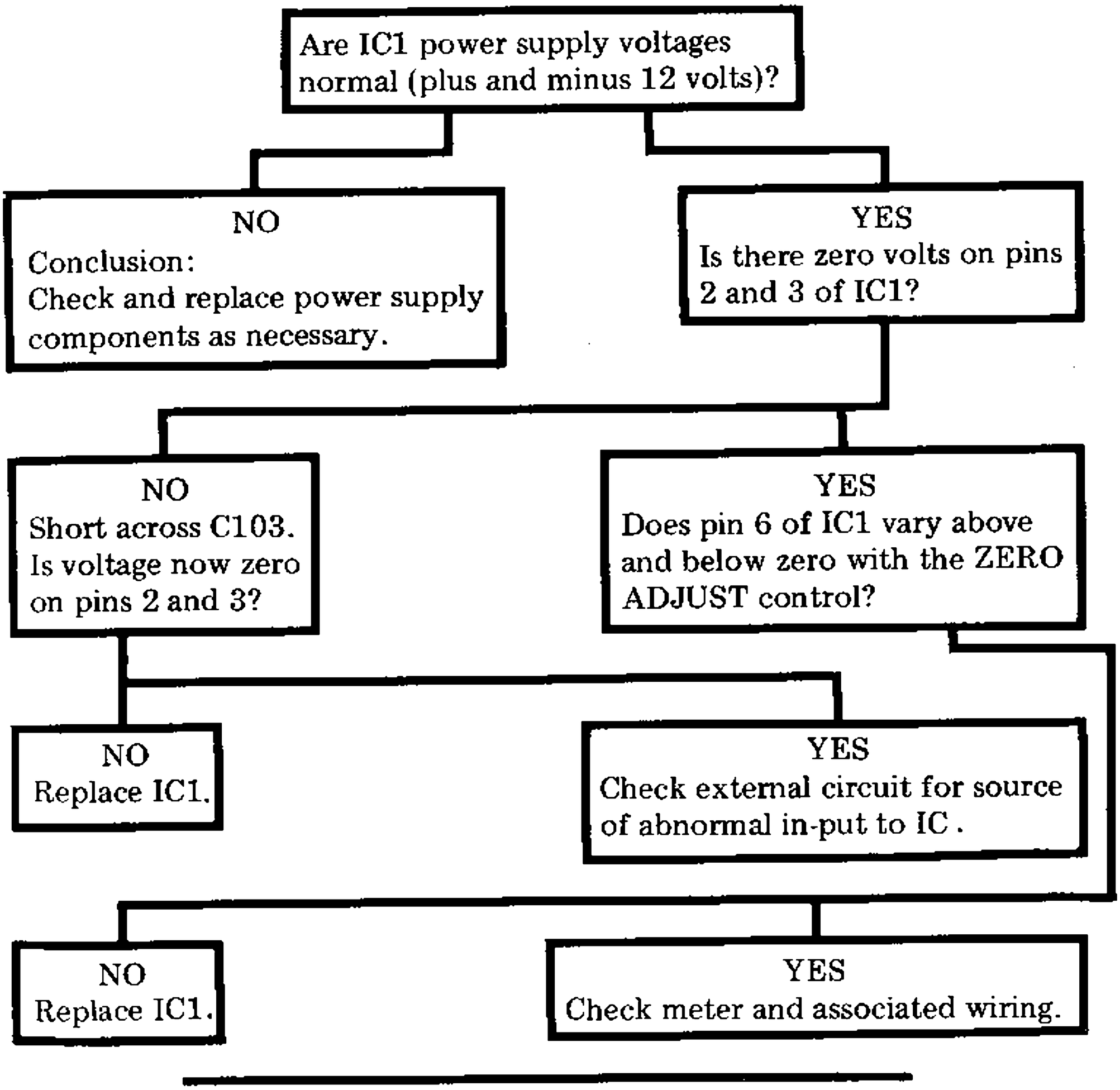
YES

Conclusion:
Suspect wiring between emitter and drain lead.

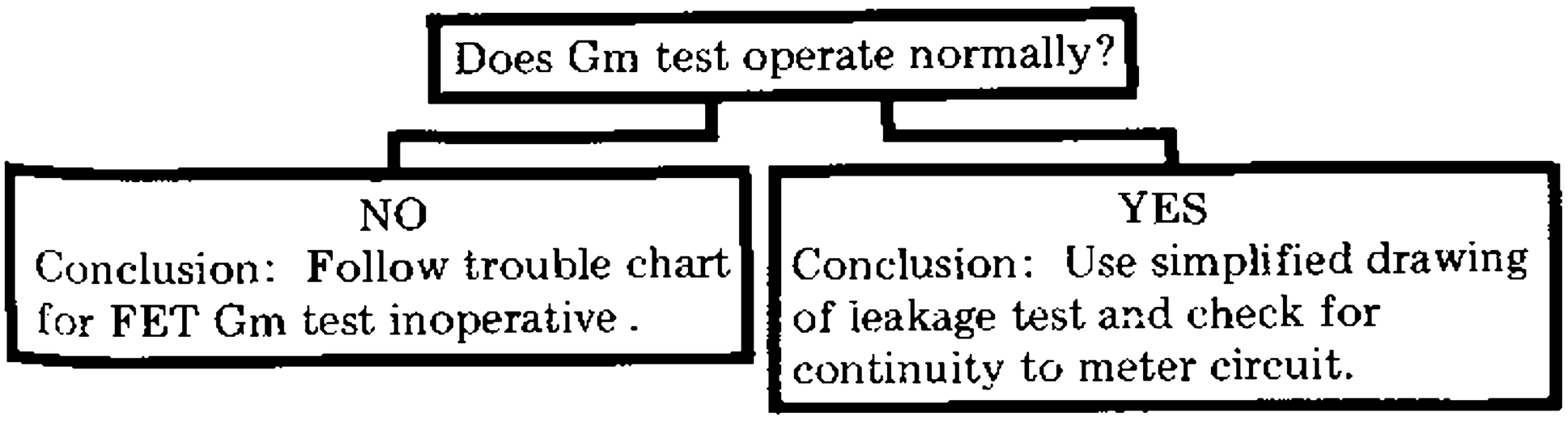
YES

Conclusion:
Turn off TF166 and check for continuity from pin 3 of TR101, and from pin 2 of IC1, to emitter of TR102; also from GATE 2 lead to drain.

METER PINS LEFT OR RIGHT, ZERO ADJUST CONTROL HAS NO EFFECT



LEAKAGE (I_{CBO} or I_{GSS}) INOPERATIVE



TRANSISTOR BETA DC ONLY INOPERATIVE

Press RF-If, N POLARITY, and DC OUT CIRCUIT buttons. Connect negative lead of ohmmeter to collector lead, and positive lead to terminal 1 of connector on 43A51 PC board. Should measure forward diode (low) resistance. Press "P" polarity button; should measure reverse diode (very high) resistance. Does this check out properly?

NO

Conclusion:
Suspect CR101 and associated wiring.

YES

Check for 1,000 ohms from base to collector lead. Is this resistance present?

NO

Conclusion:
Suspect R202 and associated wiring.

YES

Conclusion
Follow check out procedure for TRANSISTOR BETA AC INOPERATIVE.

I_{DSS} TEST INOPERATIVE

Does Gm test operate normally?

NO

Conclusion: Follow check out procedure for FET gm test inoperative.

YES

Conclusion: Use simplified drawing of I_{DSS} circuit, and check for continuity to meter circuit.

TRANSISTOR BETA AC INOPERATIVE

Connect oscilloscope ground lead to emitter lead, and signal lead to collector lead. Connect 1K resistor in parallel with scope leads. Press RF-IF, N POLARITY, and AC IN CIRCUIT buttons. Turn GAIN CAL control fully clockwise. Do you see 8 v p-p square wave?

NO

Is 8 v p-p square wave present between terminals 1 and 2 (red transformer leads) on connector to 43A51 PC board?

NO

Pull connector from terminals 1 and 2. Is 8 v p-p signal present between red transformer leads?

NO

Check wiring of T1 and associated circuits.

YES

Conclusion:
Suspect short circuit between terminals 1 and 2

YES

Move scope signal lead and lead of 1K resistor to base lead. Is 8 v p-p present at base lead?

YES

Conclusion:
Turn TF166 off and check for 7.5 ohms from collector lead to terminal 1, and 20 ohms from emitter to terminal 2.

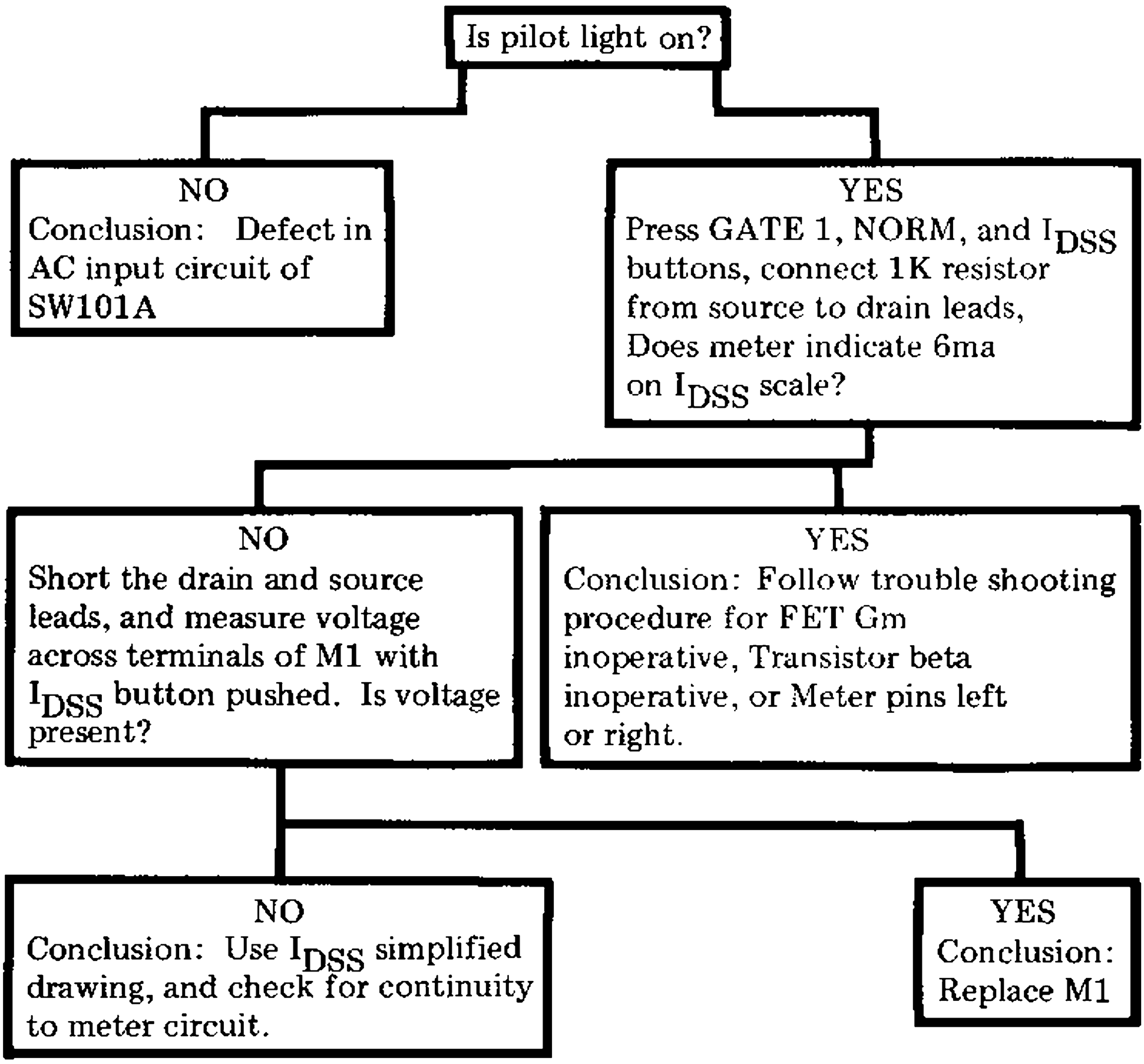
NO

Conclusion:
Turn TF166 off and check for 20 ohms from base lead to terminal 1.

YES

Conclusion:
Turn off TF166 and check for continuity from base lead to pin 2 of IC1, from terminal 1 on connector to pin 3 of IC1.
Press gain button, and check for continuity from emitter lead to pin 3 of IC1, and from terminal 1 on connector to pin 2 of IC1.

TF166 COMPLETELY DEAD



BOARD LAYOUTS

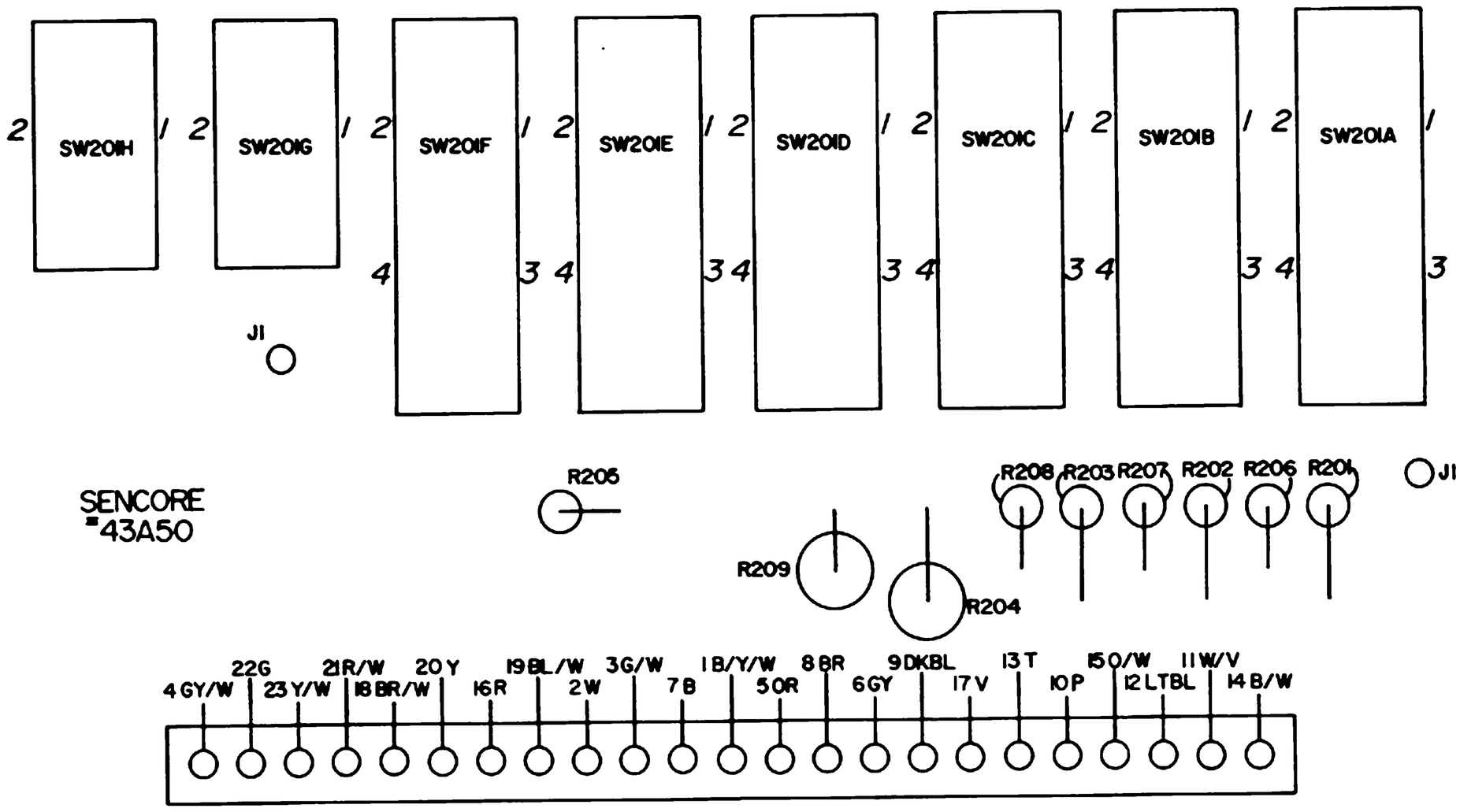


Fig. 34 Component Side View of 43A50 Board

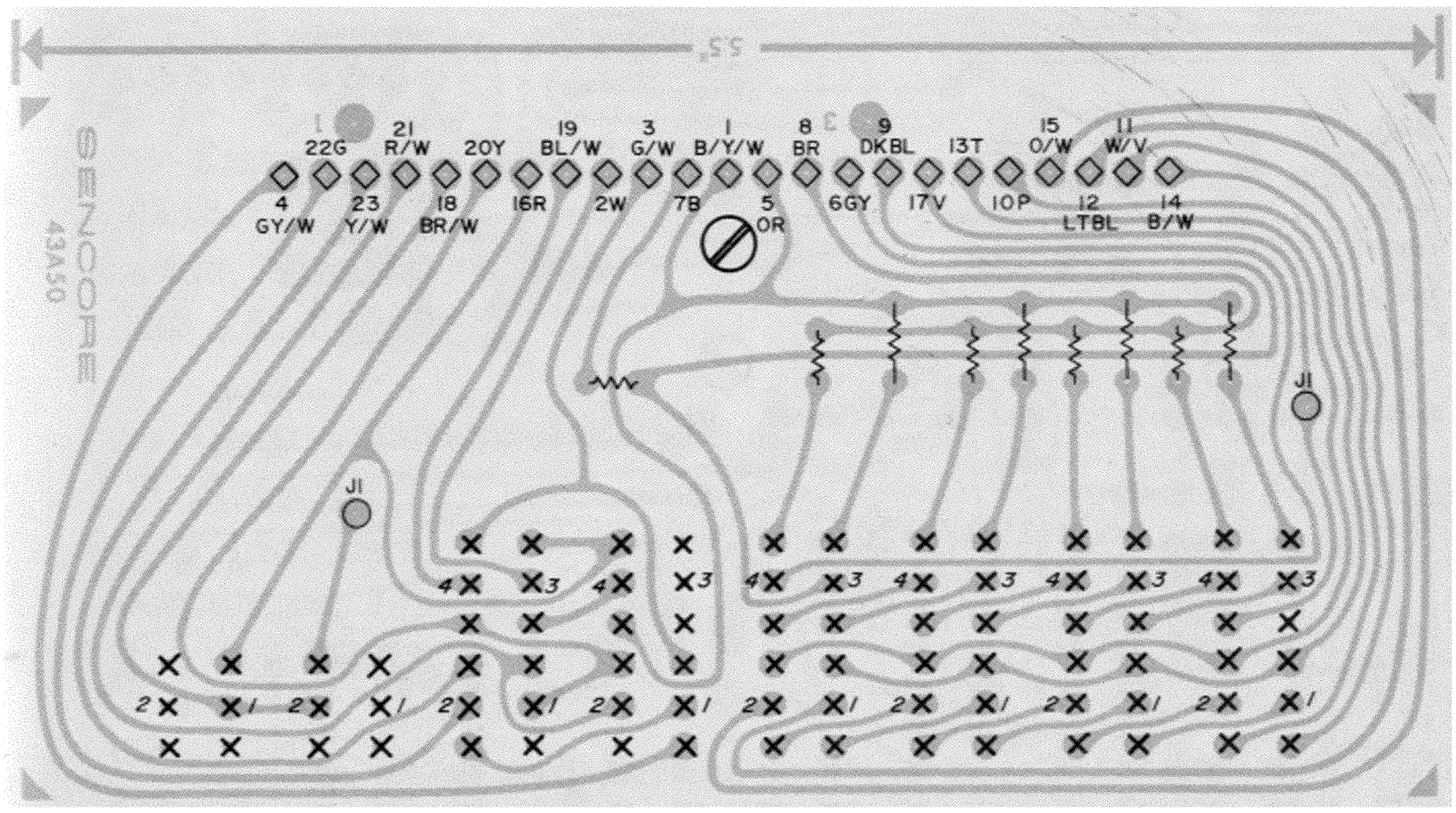


Fig.35 Foil Side View of 43A50 Board

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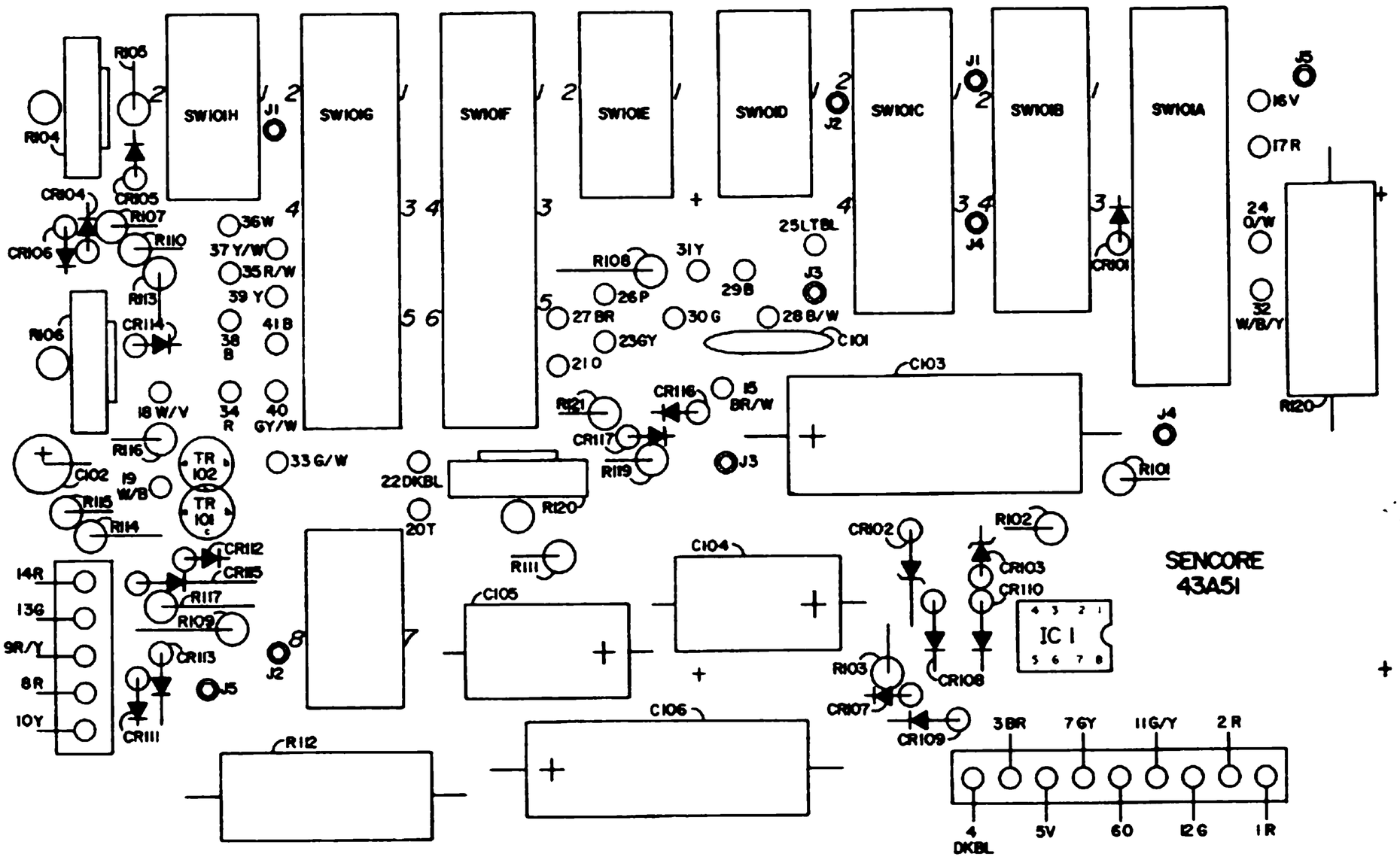

Fig. 36 Component Side View of 43A51 Board

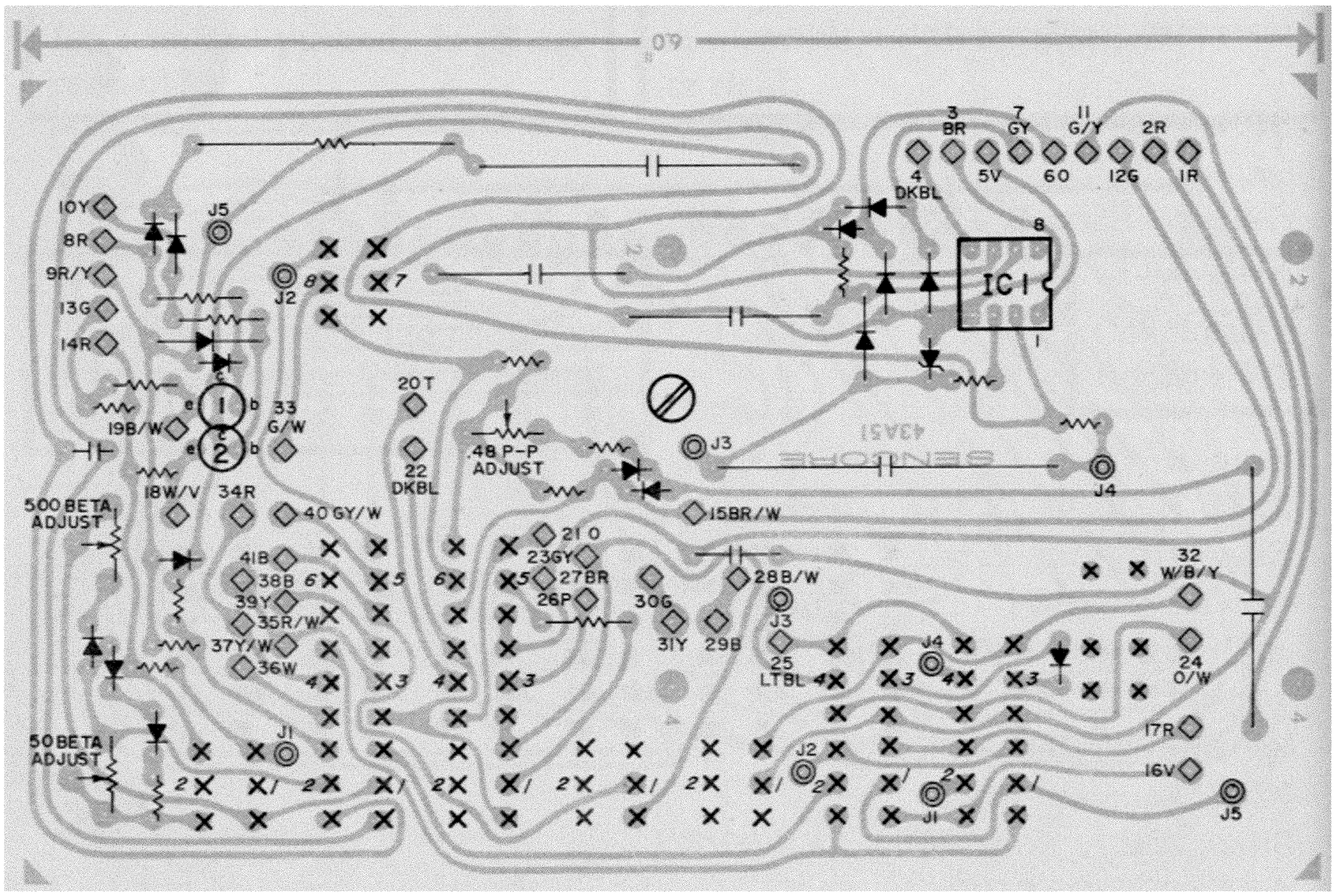

Fig. 37 Foil Side View of 43A51 Board

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SERVICE AND WARRANTY

You have just purchased the only transistor analyzer on the market today. The Sencore TF166 has been inspected and tested twice at the factory and has passed a rugged use test by our Quality Assurance Department to insure the best quality instrument to you. If something should happen, the TF166 is covered by a standard 90 day warranty as explained on the warranty policy enclosed with your instrument.

Sencore has three regional offices to serve you. Instruments to be serviced should be returned to the nearest regional office by UPS if possible. Parcel post should only be used as a last resort. Instruments should be packed with the original packing materials or equivalent, and double boxed to insure safe arrival at the regional office. The blue and white display carton IS NOT an acceptable shipping container. When returning an instrument for service, be sure to state the nature of the problem to insure faster service.

If you wish to repair your own TF166 Transistor Analyzer, we have included a schematic, trouble chart, and parts list. Any of these parts may be ordered directly from the regional office nearest you.

We reserve the right to examine defective components before an in warranty replacement is issued.

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