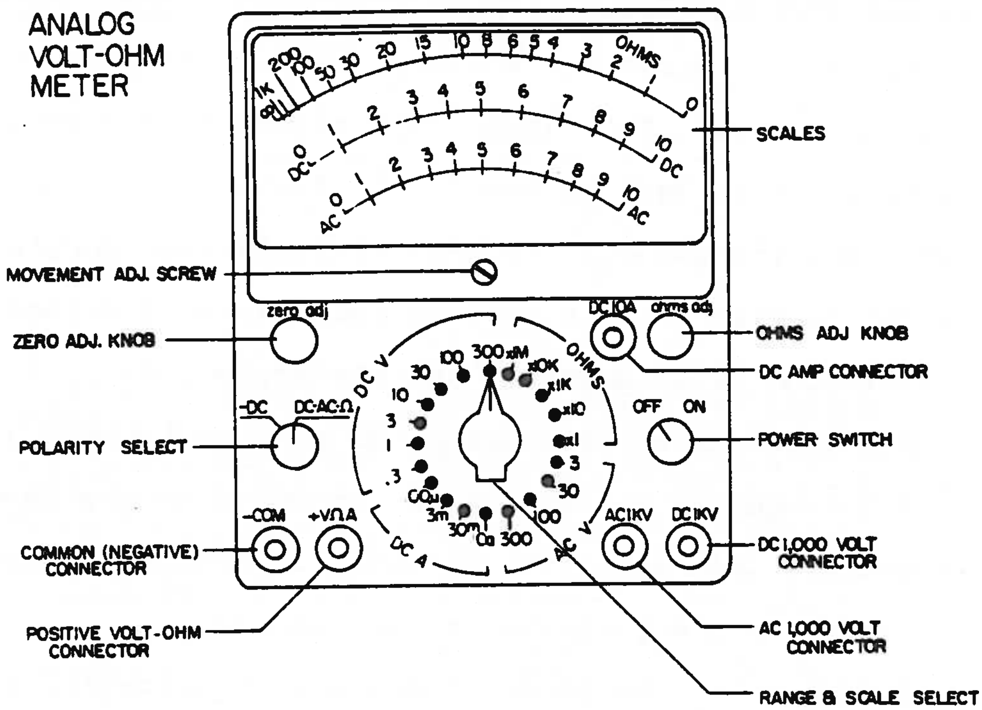
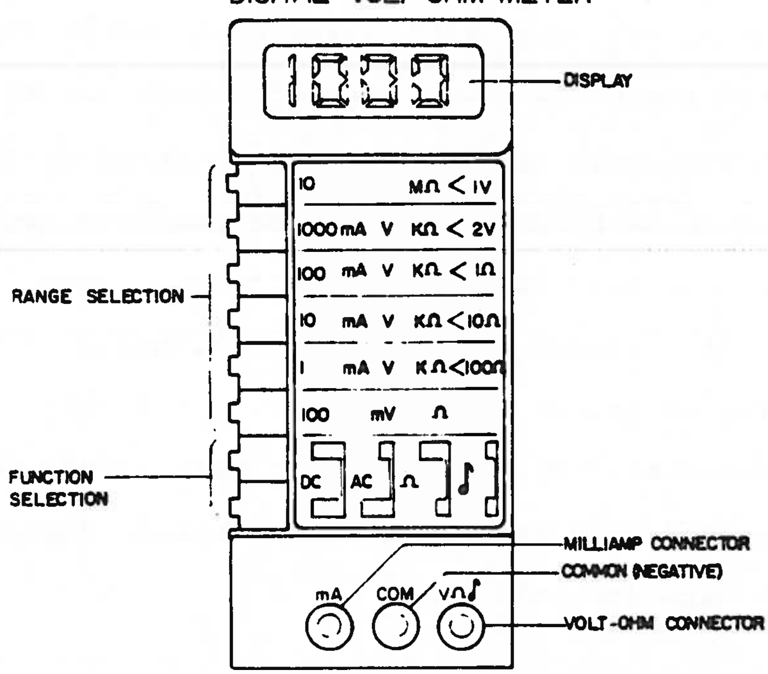
## ANALOG VOLT-OHM METER




## DIGITAL VOLT OHM METER



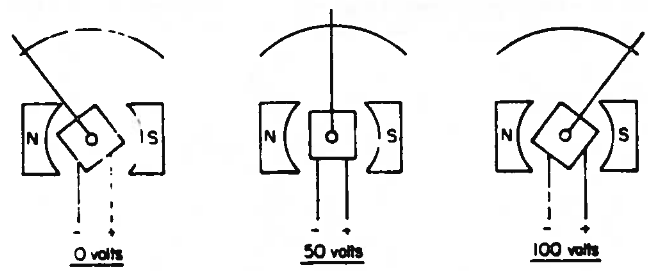
The analog VOM consists of four main parts; the meter movement, the scale and pointer, the range/scale selector, and the probes. The range/scale selector is a rotary switch. It is used to select the function (AC, DC and OHMS) and the range of voltage or resistance applied. The switch selects a predetermined resistance in series between the meter movement and the probes.

The probes are color coded red and black. The black lead is negative and should be connected to the common (negative) terminal. The red lead is positive and should be connected to the positive (+) DC terminal.

Before using the meter to measure DC voltages, there are some precautions to be aware of:

1. Be sure to switch the meter on.

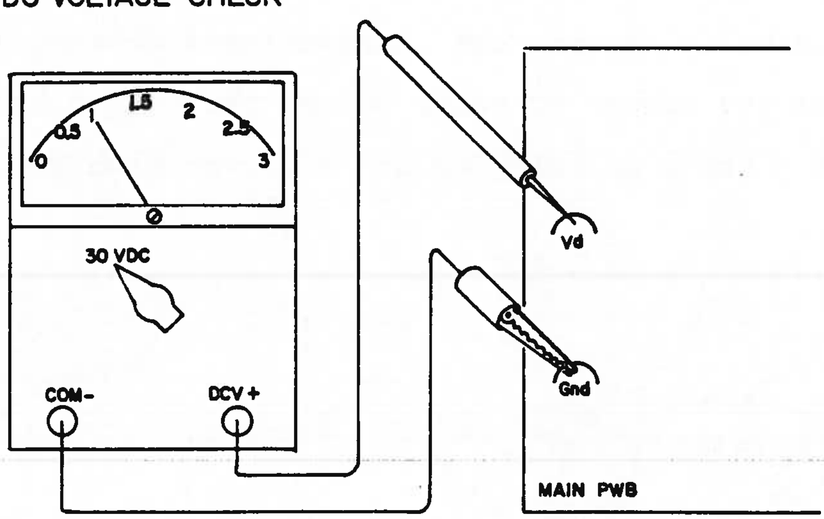
2. Select the appropriate range and voltage. When measuring an "unknown" voltage, set the meter to read the highest voltage range. This will protect the meter from over voltage damage. When measuring a known low voltage, select the range that will be the most accurate. Analog meters are most accurate when the readings are taken at mid-scale. For example, a 10volt potential read on the 10VDC scale will produce a full scale deflection of the pointer. If the true potential value is 10.5 or 9.5 VDC, the reading may be inaccurate. By selecting the next higher scale (30VDC) the pointer will reflect a more accurate representation of the voltage applied.




Voltmeter set to 100v D.C.range

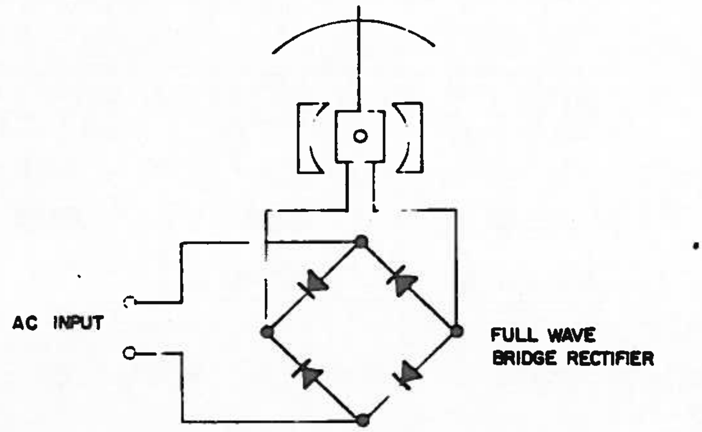
3. Always observe polarity. When taking voltage measurements, DC is measured against a ground reference. To take a test point measurement, the black (common) lead should be connected to the circuit board ground (not frame ground).

DC VOLTAGE CHECK



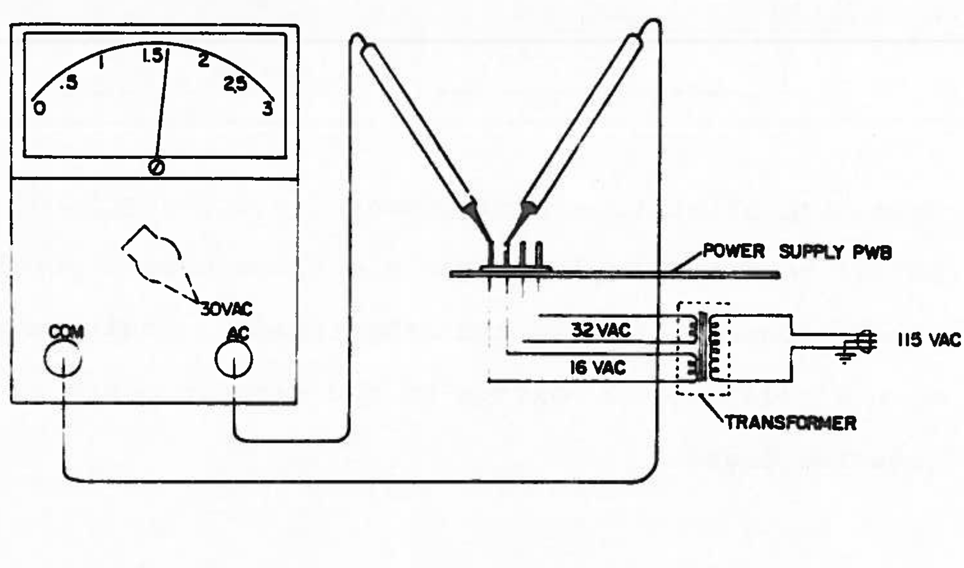

This type of voltage arrangement (negative ground) is called positive logic. When a machine uses a positive common ground, reverse the meter leads. Positive ground with a negative DC voltage on the circuit board is called negative logic.

## AC VOLTMETER




AC measurements are always made across the AC circuit in question. Never read an AC circuit against ground. Select the proper AC range before performing any voltage tests. Probe polarity is not a factor when checking AC.

## AC VOLTAGE CHECK



## THE OHMMETER

The two applications for the ohmmeter are resistance measurements and continuity checks. The ohmmeter has a self-contained, reference voltage battery. When testing a component or circuit, the meter reading will indicate the total amount of resistance to the battery voltage applied. Whenever the ohmmeter is used, no other source of electricity may be present. It is a good practice to disconnect the power cord before using the ohmmeter. Failure to do so may result in damage to the meter.

Ohmmeters have several different resistance ranges. To obtain an accurate reading of the component in question, select the range that will produce a midscale reading. The range selector provides the multiplying factor of the readings:

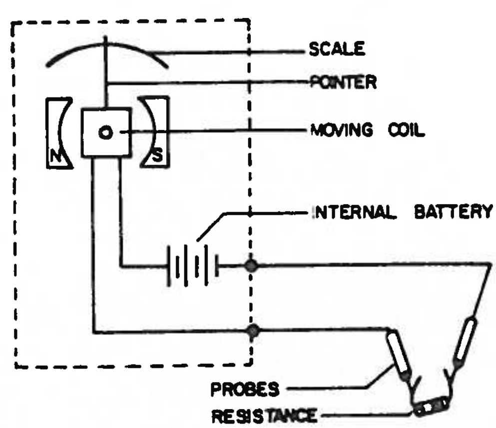
X1 = multiply the reading times one

X10 = multiply the reading times ten

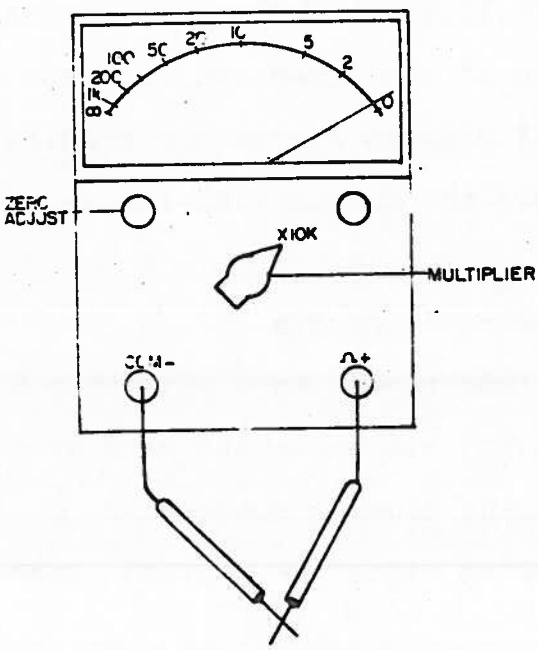
X1k = multiply the reading times one thousand (K=Kilohm=1,000)

X10k = multiply the reading times ten thousand

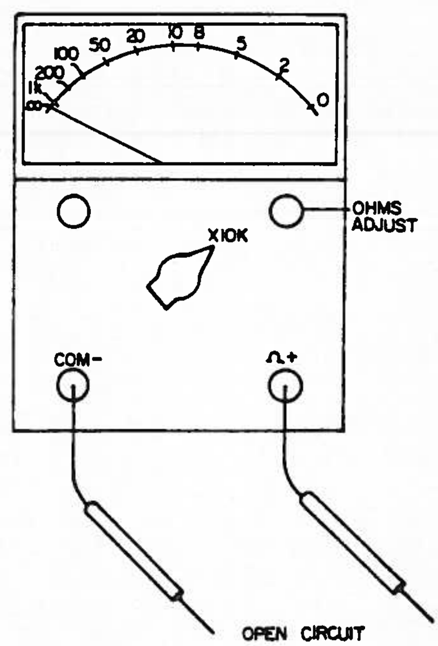
1M = multiply the reading times one million (M=Megohm=1,000,000)



Before applying an analog ohmmeter to a circuit, select the appropriate range and touch the tips of the test leads together. Adjust the meter to read zero (0 ohms, no resistance). Each time the range selector is changed, the analog ohmmeter must be recalibrated in this manner. Inability to zero the meter is usually indicative of a weak battery.

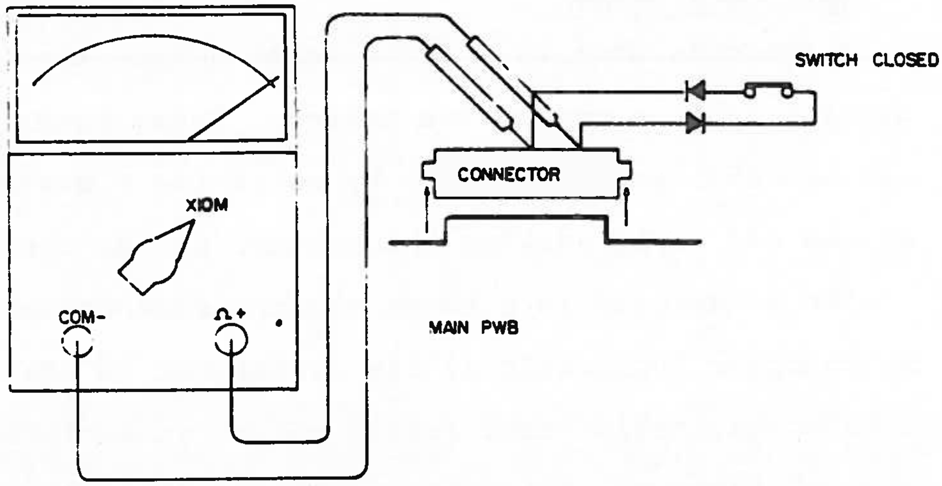



SHORTED CIRCUIT




OPEN CIRCUIT

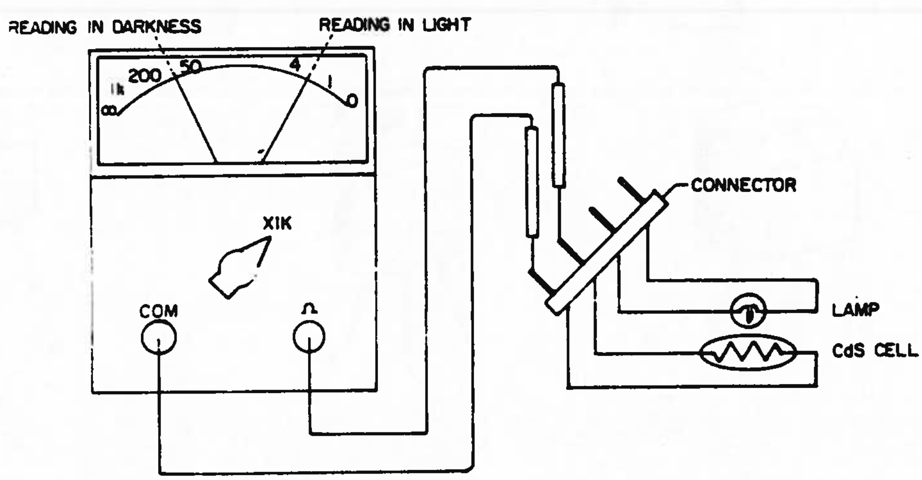
CHECKING A SWITCH CIRCUIT WITH AN OHMMETER (CONTINUITY)




When checking circuits that contain diodes, there are two considerations: the polarity of the meter leads (diodes only conduct in one direction) and the range. A higher ohm scale is necessary to read across the diode. The diode may present some resistance even when the meter leads are correctly connected.

After using the ohmmeter, be sure to reset the range selector to a non-resistance range. This will prevent excessive battery drain.

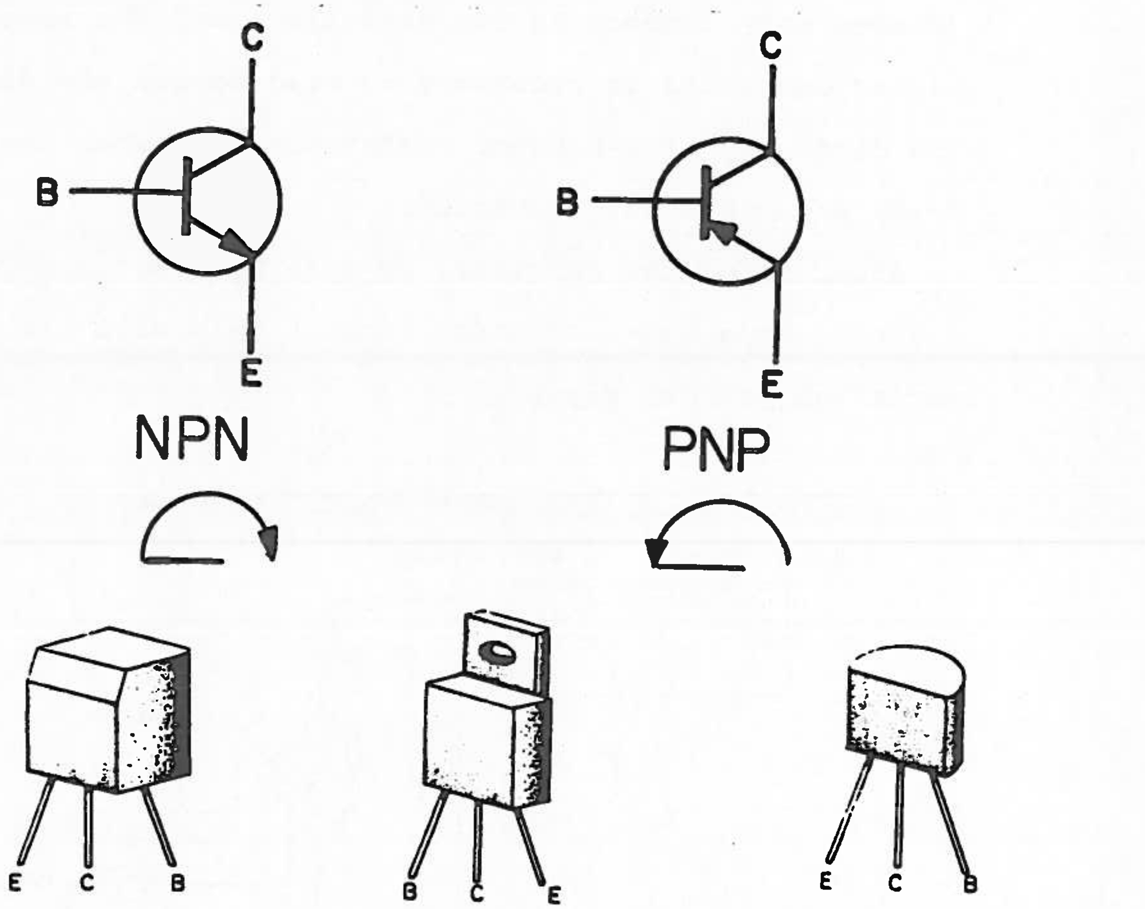
CHECKING A CdS CELL with an OHMMETER (RESISTANCE)



## Semiconductors

A semiconductor is a solid state device that has conductive and non-conductive states. These conditions (on and off) are controlled by switching a control lead on and off or by varying the voltage on the control lead.

The transistor is a three element semiconductor. In photocopier applications, the transistor is used as a high-speed, solid-state switch and as an amplifier. There are two types of transistors, NPN and PNP. The three leads of the transistor are called: Base, Collector and Emitter. The emitter arrow pointed to the base is the PNP. The emitter arrow pointed away from the base is NPN.

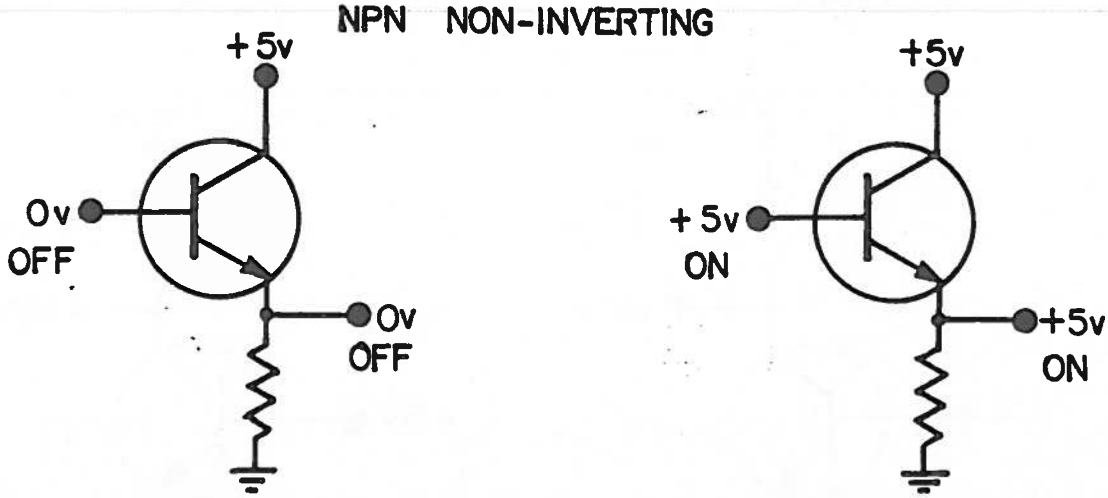


NPN TRANSISTORS:

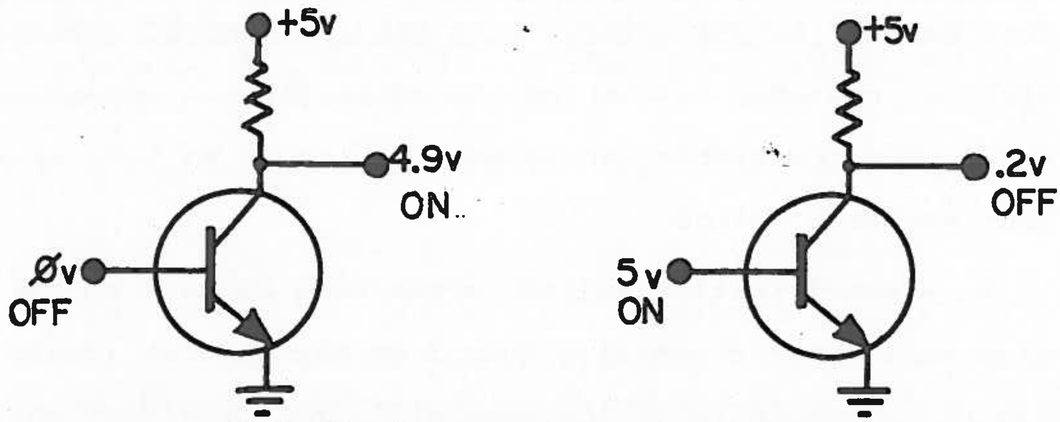
When the NPN is used as a switch, or an amplifier, the emitter lead is connected to the negative side of the circuit (ground) and the collector lead is connected to the positive side (+DC). The DC voltages on the base lead will cause the transistor to switch on or off, conducting from emitter to collector. With the addition of a current limiting resistor (either on the collector (+) or emitter (-) side) the transistor can be made to act as an inverting or non-inverting switch.

As a non-inverting switch, a positive voltage on the base lead will cause a positive output on the emitter (conductive state). Zero volts on the base will produce a zero volt condition on the emitter (non-conductive state). The current limiting resistor is between the emitter and ground (for non-inverting states).

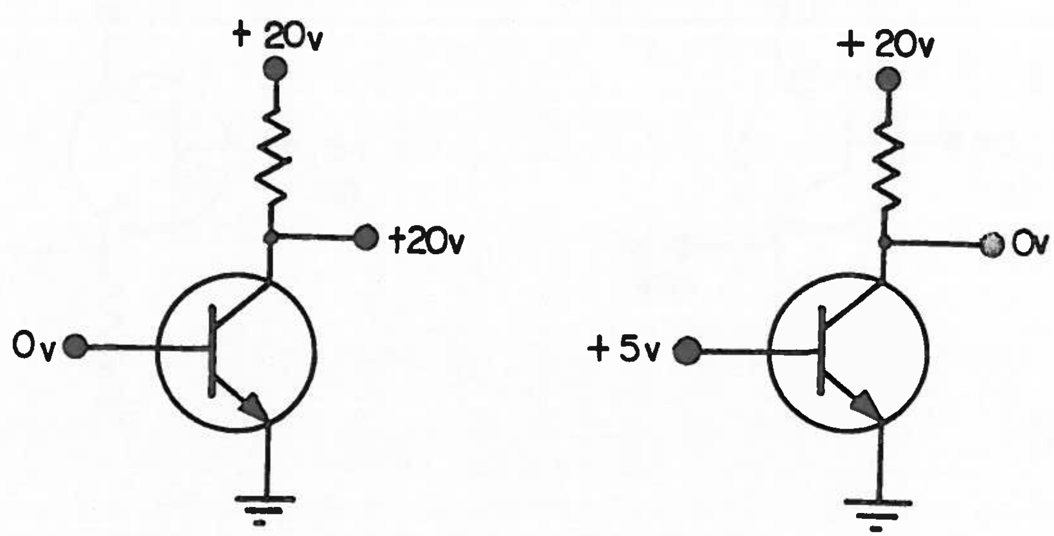
NPN NON-INVERTING



As an inverting switch, the current limiting resistor is located between the positive voltage source and the collector lead. When the base is at zero volts, current no longer flows across the transistor, and voltage is present at the collector. When voltage is applied to the base, the transistor conducts and the output at the collector drops to nearly zero.

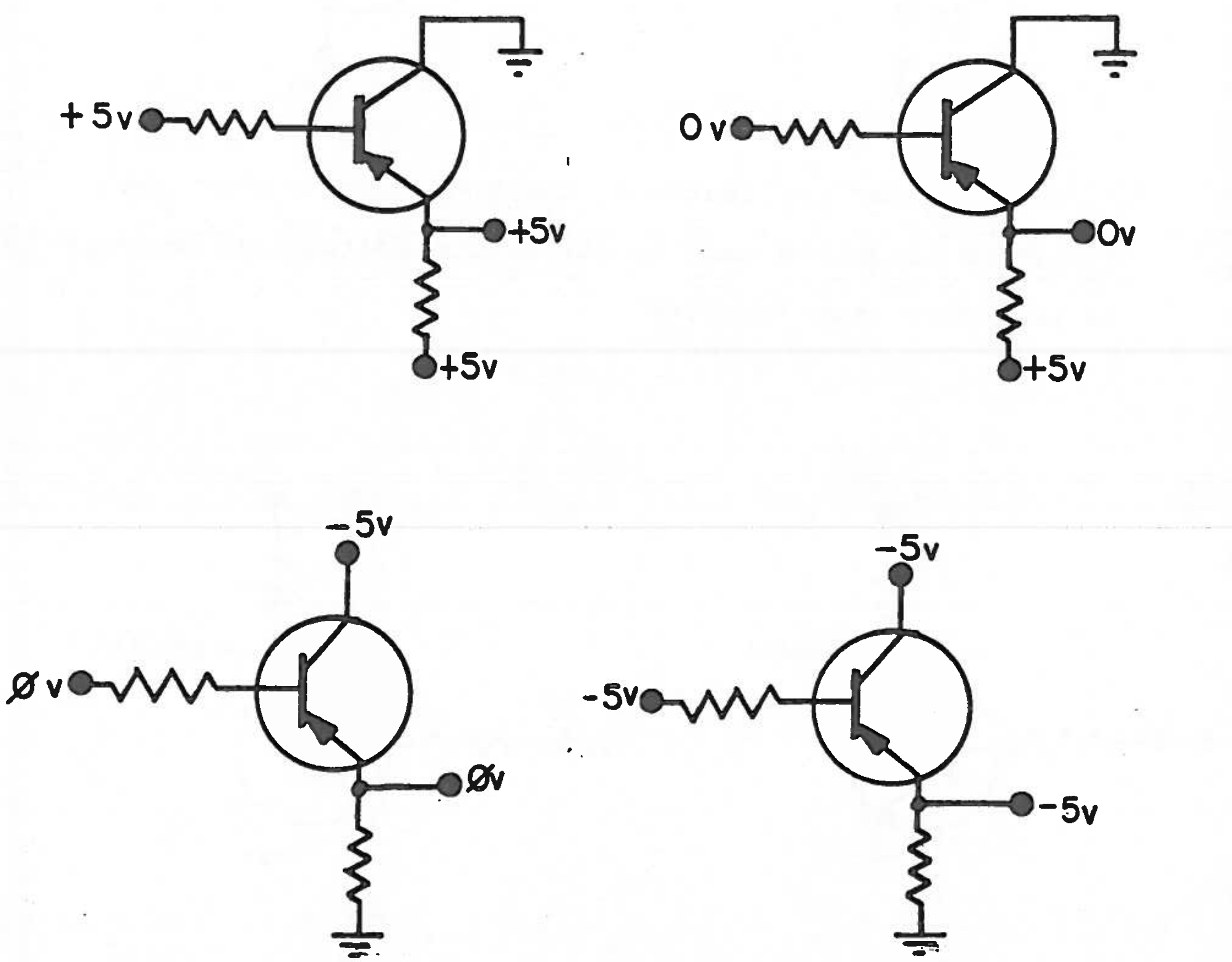



In amplifier applications, the source voltage at the collector is increased. Using the same low base voltages at the input, a much higher output is present at the collector. This arrangement can also be made inverting or non-inverting.

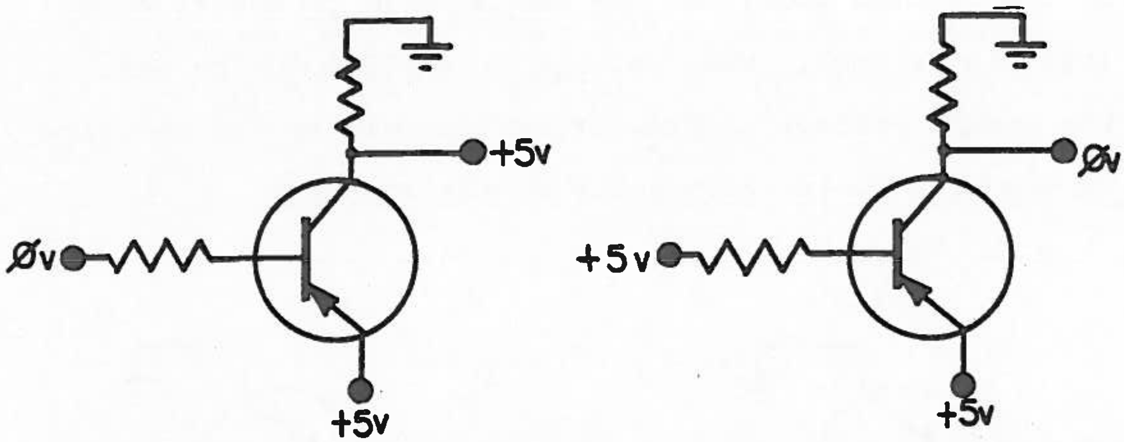


PNP TRANSISTORS:

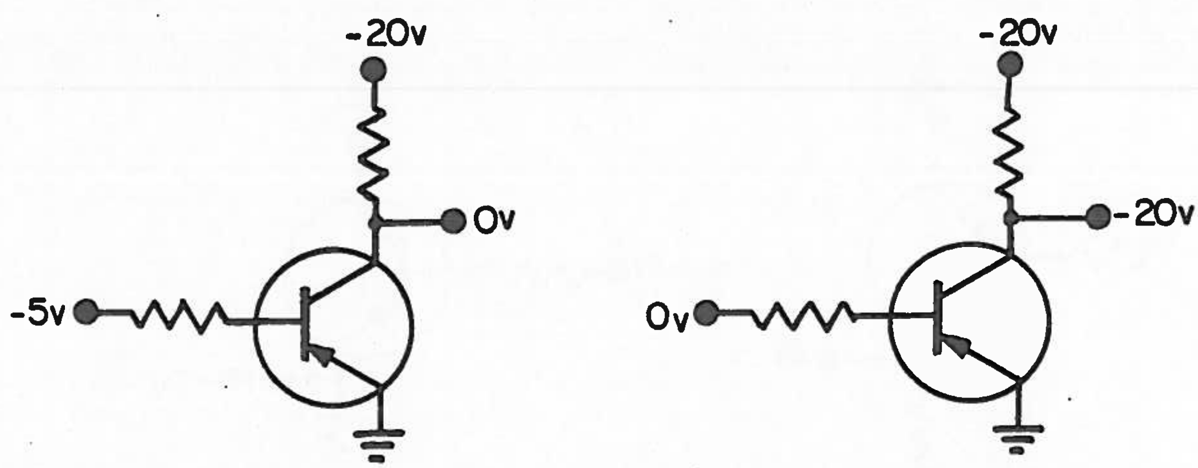
The PNP operates in an opposite manner from the NPN. All the polarities are reversed. The emitter lead is connected to the positive side of the circuit and the collector lead to the negative side. With the current limiting resistor on the emitter side, the PNP can be made to act as a non-inverting switch. When voltage is applied to the base, the source voltage is present at the emitter. Zero volts on the base yields zero volts at the emitter.



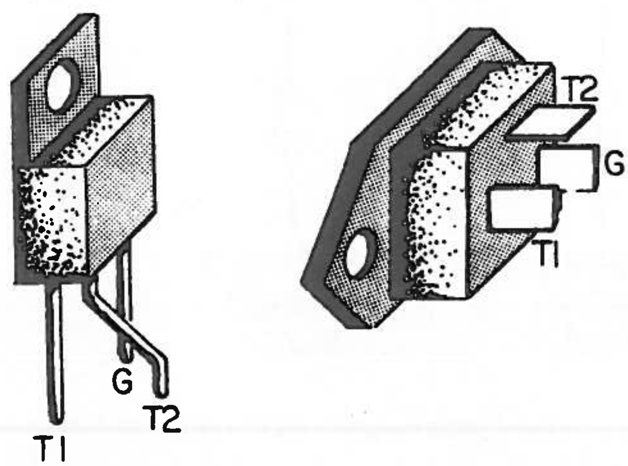
As an inverter, the limiting resistor is positioned between the collector and ground. When zero volts is present at the base, the source voltage is felt at the collector. As base voltage is made more positive, the transistor switches off and zero volts is present at the collector.

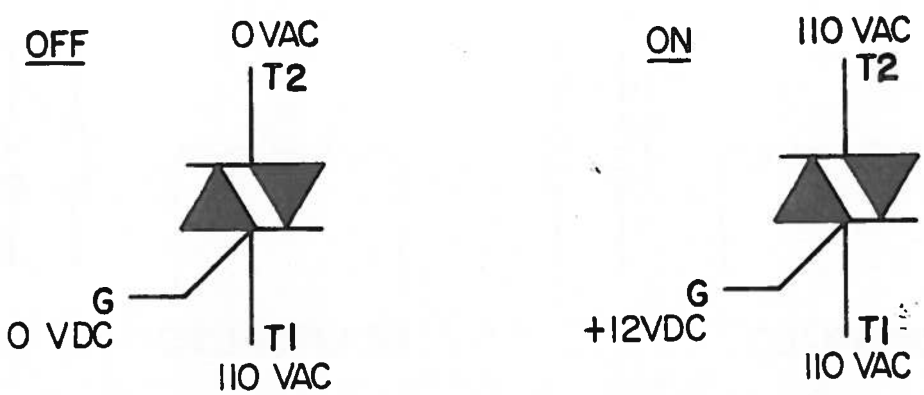



In amplifier applications, the source voltage at the collector (inverted amp) or the source voltage at the emitter is increased (non-inverted).



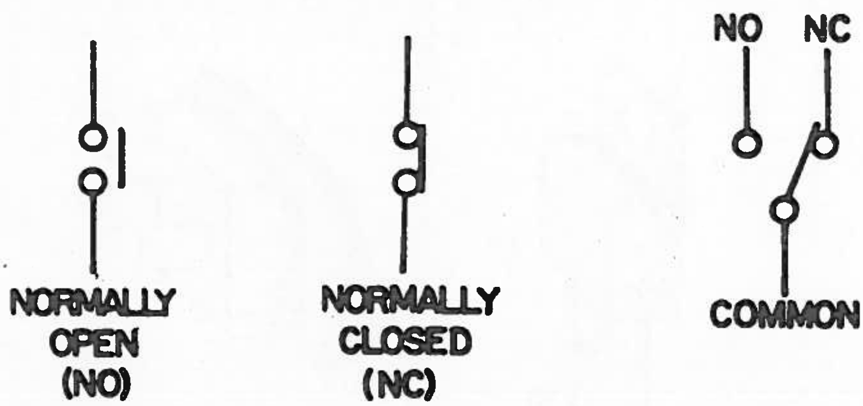
The triac is also a three terminal device. It is used to control an AC device by using a DC signal. The three leads are called T1, T2 and Gate (G). When DC current (pulsating full wave) is applied to the gate, the barrier between T1 and T2 breaks down allowing AC current to pass through the triac. When the gate current is switched off, the barrier is restored and the triac stops conducting.



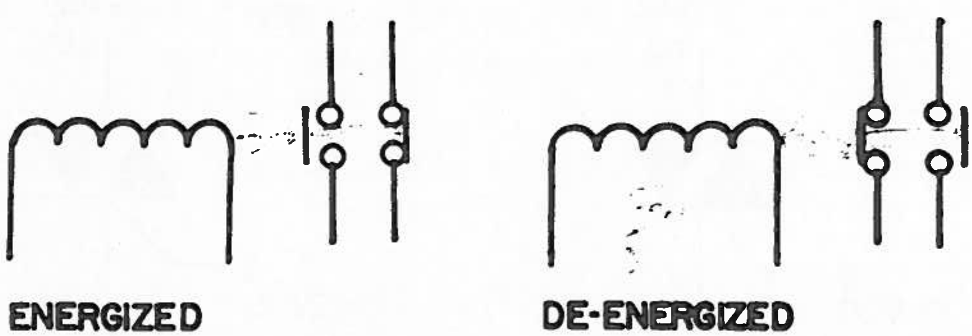



## Relays

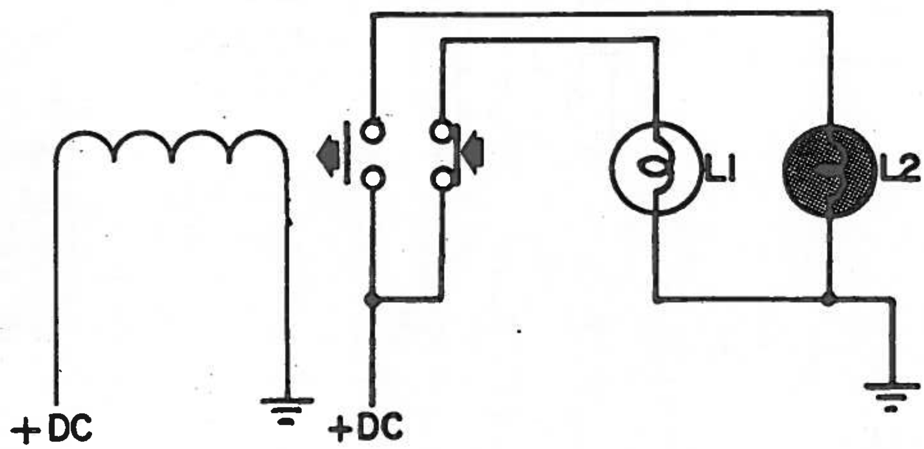
A relay is an electromagnetic switch. The switch contacts are operated by a magnetic field. The magnetic field is generated when current is passed through the coil of the relay. When the current is switched off, the return spring resets the contacts to their "normal" positions. The term "normal" refers to the contact position when the relay is off (de-energized).



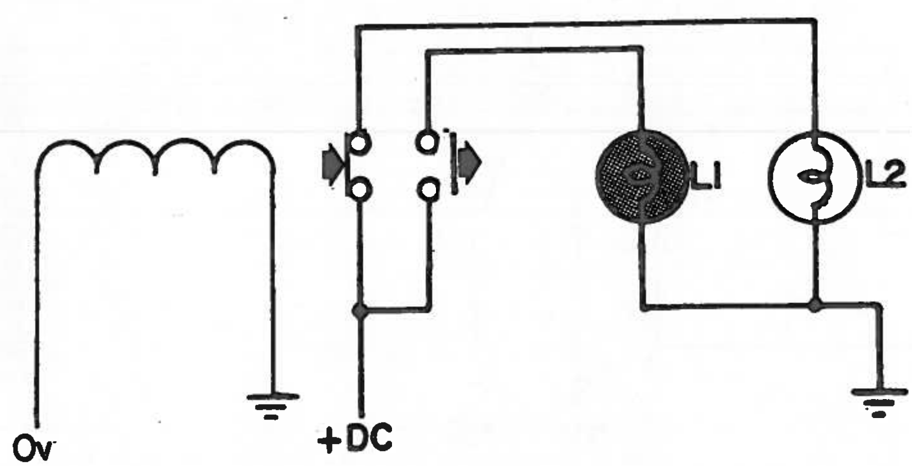

Normally open contacts will close when the relay coil is energized. Normally closed contacts will open when the relay coil is energized. Many different contact arrangements are possible. The contacts could be all normally open, all normally closed, or in any combination.

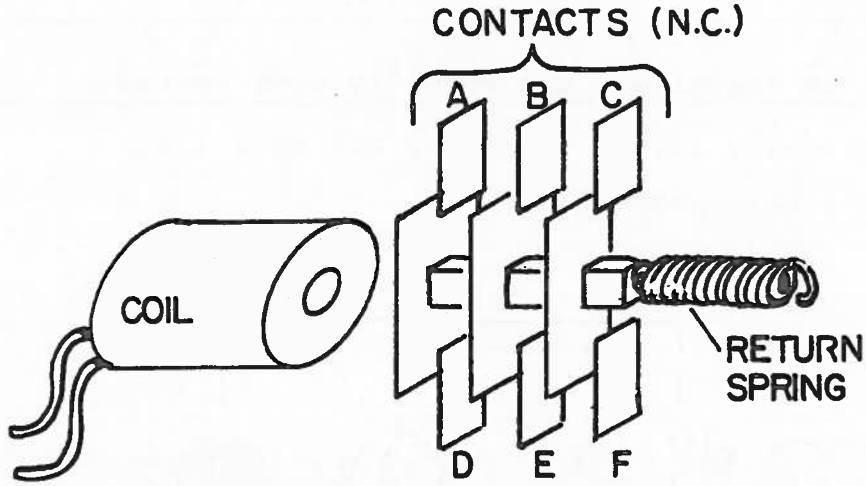


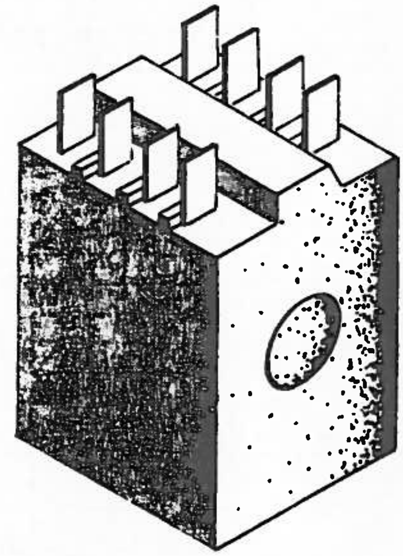
When the coil is energized, the normally open contact closes and the normally closed contacts are open (lamp 1 goes on and lamp 2 goes off).

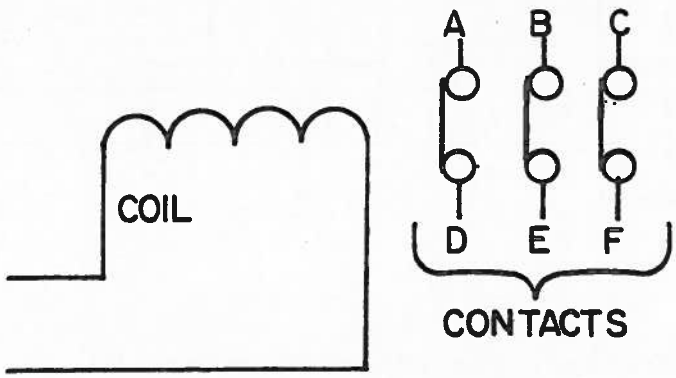


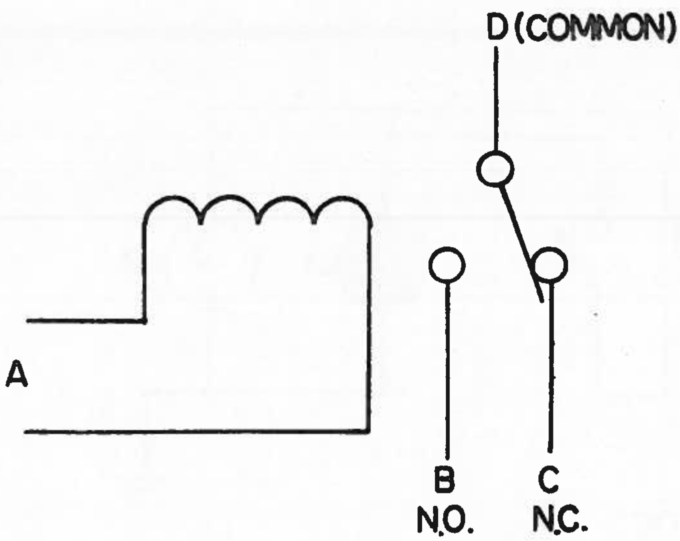

When the coil is de-energized, the contacts return to their normal positions (lamp 1 goes off and lamp 2 goes on).

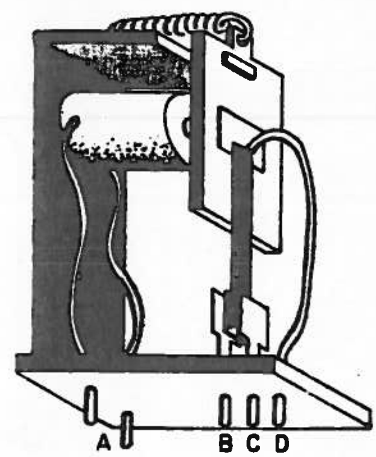



CONTACTS (N.C.)
A
B
C
COIL
RETURN SPRING
D
E
F




A
B
C
COIL
D
E
F
CONTACTS


D (COMMON)
A
B
N.O.
C
N.C.


A
B C D

## Logic Devices

For any electronic device, only two states of action are possible: ON (high) and OFF (low). This dual nature is known as Binary and the application of binary is called Digital Logic. The term digital refers to representing the "on" state as a 1, and the "off" state as a 0.

Composed of chains of transistors and diodes, logic devices are used to control the Electromechanical functions of the photocopier. Logic device units are called "gates", and there are five basic units: AND, OR, NAND, NOR and INVERTER. Logic gates are represented by their logic symbols and not by their internal component arrangements. All the inputs and outputs can be represented by logic 1 (high) or logic 0 (low). This simplifies the understanding of logic operations.

THE AND GATE

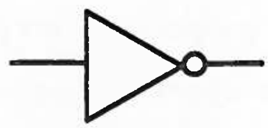
An AND gate is composed of two or more inputs and one output. Only when <u>all</u> the inputs are at logic 1 will the output be at a logic 1. <u>Any</u> 0 input will produce a 0 output.

THE OR GATE

An OR gate is composed of two or more inputs and one output. If any input lead is at logic 1, the output will be logic 1. When all the input leads are at logic 0, the output will be logic 0.


THE INVERTER

An inverter is composed of one input and one output. When the input is at logic 1, the output will be at logic 0. When the input is at logic 0, the output will be at logic 1.



INVERTER

THE NAND GATE

Adding an inverter to the output of an AND gate, produces a NAND gate (NOT-AND). The output of the AND gate is inverted. Any (or all) logic 0 inputs yield a logic 1 output. When all inputs are at logic 1, the output will be logic 0.

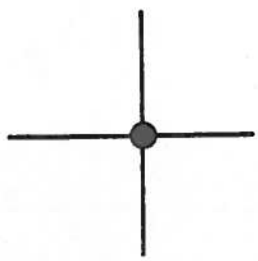

THE NOR GATE

Adding an inverter to the output of an OR gate produces a NOR gate (NOT-OR). The output of the OR gate is inverted. Any or all inputs at logic 1 will produce a logic 0 at the output. When all the inputs are at logic 0, the output will be a logic 1.

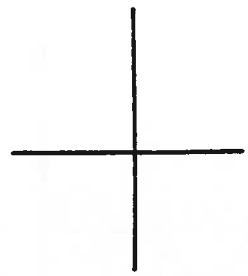
# SCHEMATIC SYMBOLS

## CONDUCTORS

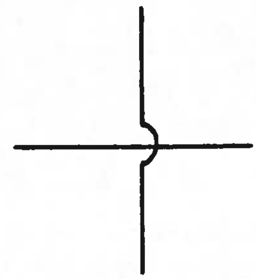
CONNECTED



NOT CONNECTED



OR

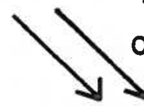


## GROUND

FRAME

EARTH (PWB)

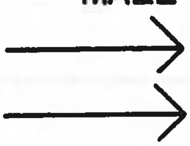
## LIGHT AND HEAT



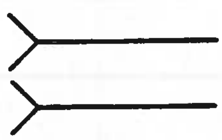
or

## CABLE TERMINATION

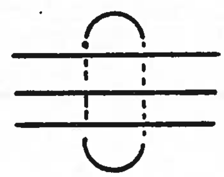
MALE



FEMALE

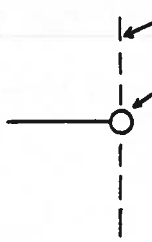


## CABLE, SHIELDED



EDGE OF PWB

CONNECTOR PIN

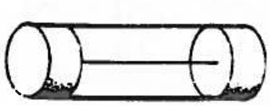


a

CONTINUATION OF THE SAME CIRCUIT

a

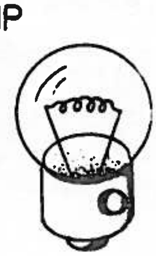
FUSE

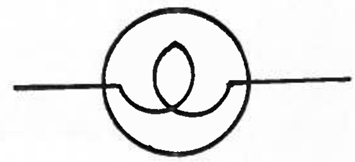


or

or

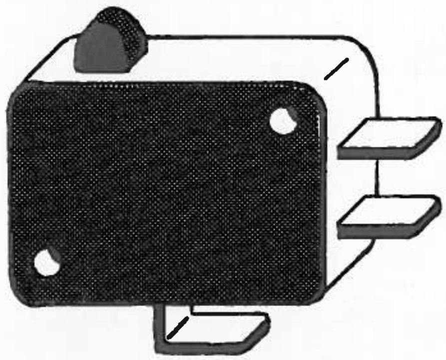
LAMP



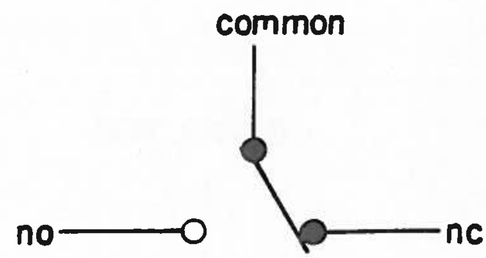


# SWITCHES

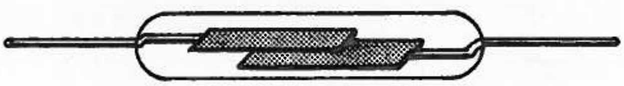
MICROSWITCH



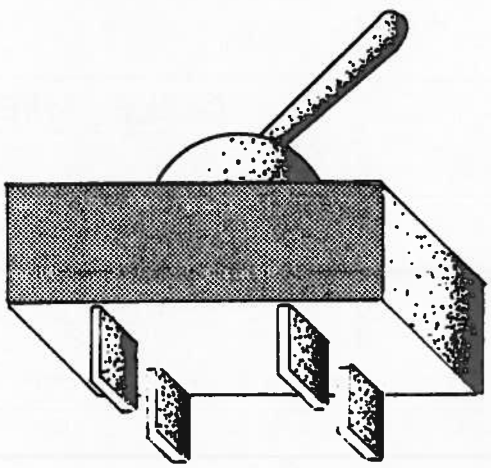
SCHEMATIC SYMBOL

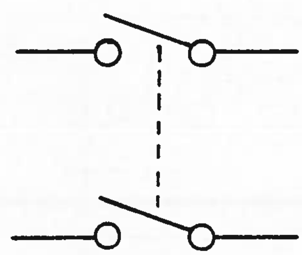



REED SWITCH (magnet actuator)

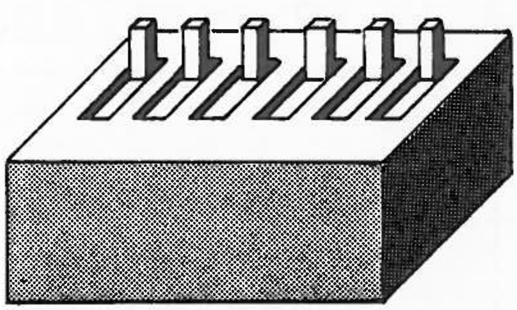


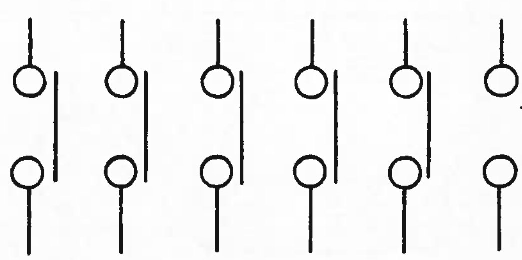
TOGGLE SWITCH (DPST)





DUAL IN LINE PACKAGE (DIP)

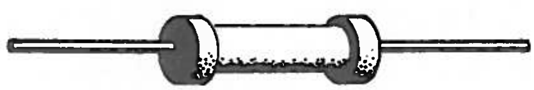




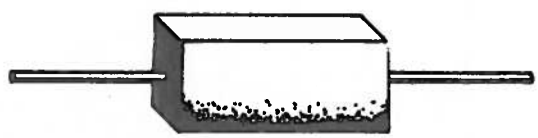
# RESISTORS

CARBON

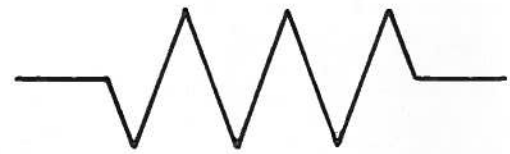
WIRE WOUND (PRECISION)



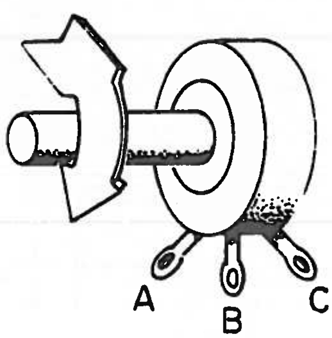
CERAMIC



SCHEMATIC SYMBOL

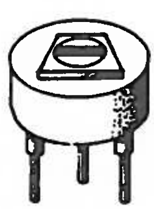


VARIABLE RESISTORS (POTENTIOMETERS)

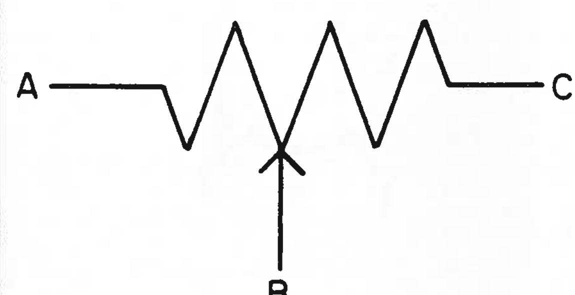



chasis mounted


OR

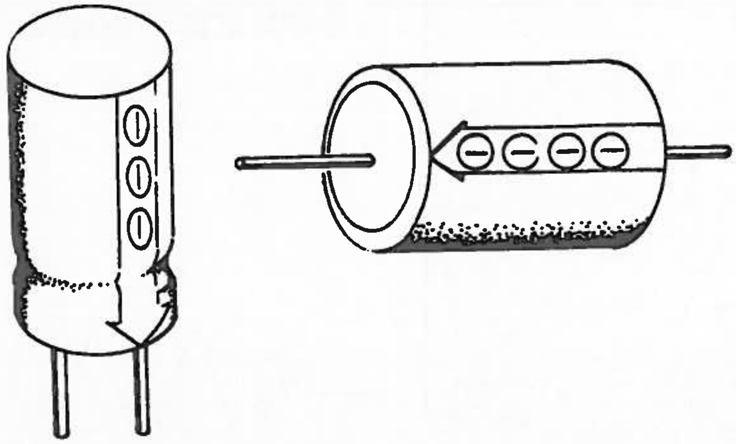


circuit board mounted



# CAPACITORS

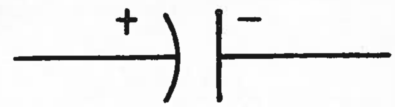
## ELECTROLYTIC



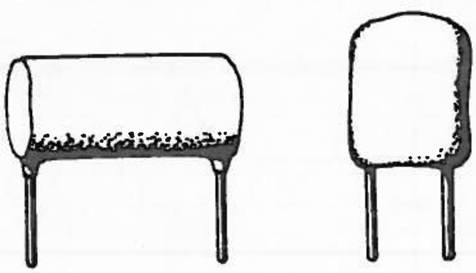
## TANTALUM

## SCHEMATIC SYMBOL

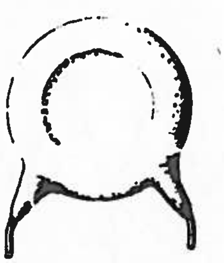
OR




## MYLAR

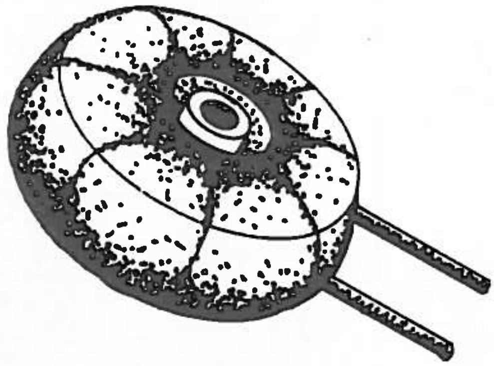


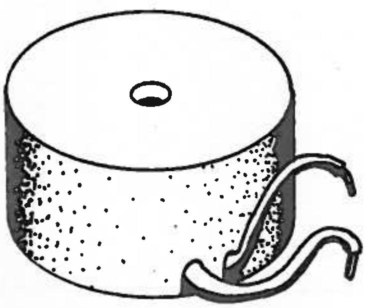
## CERAMIC

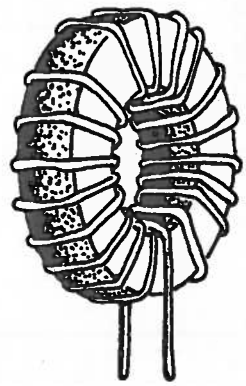


# COILS

TOROIDIAL

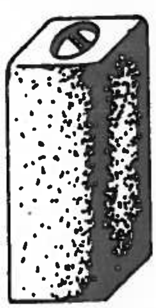


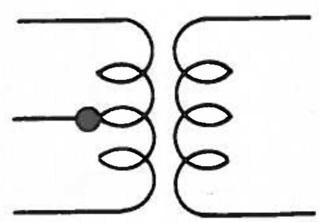




SCHEMATIC SYMBOL

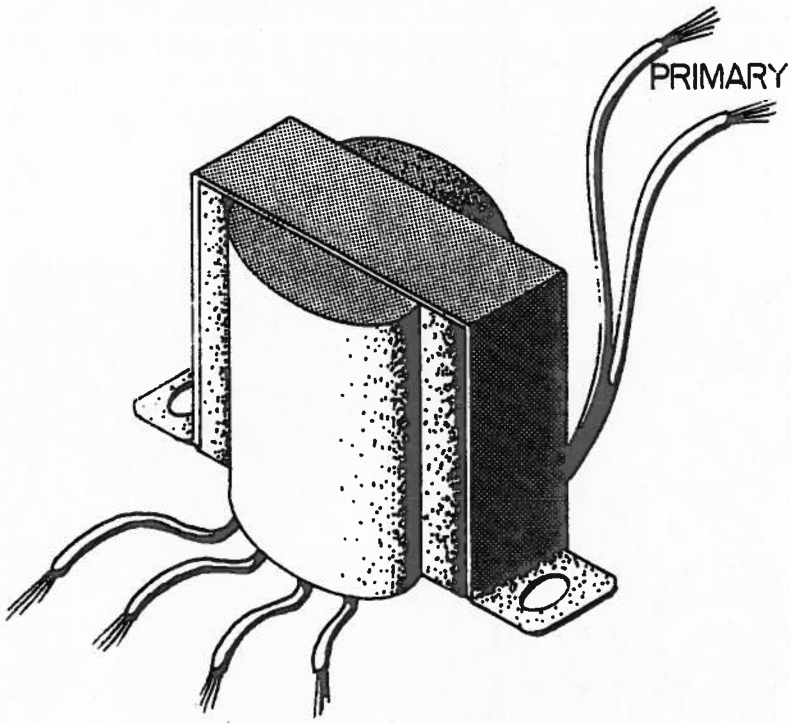
INDUCTION



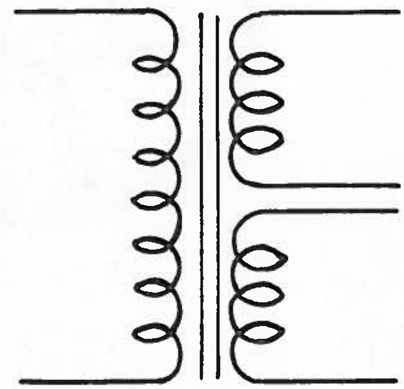


# TRANSFORMERS

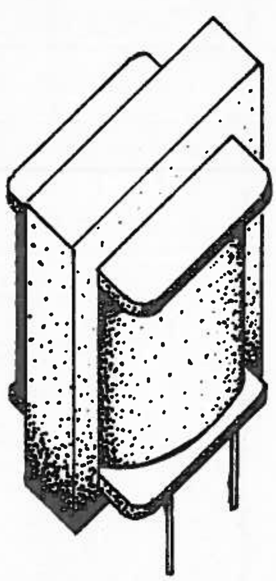
POWER

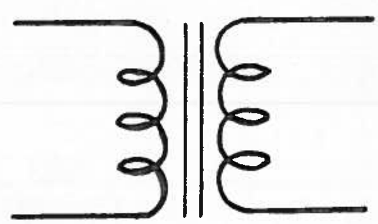



SCHEMATIC SYMBOL

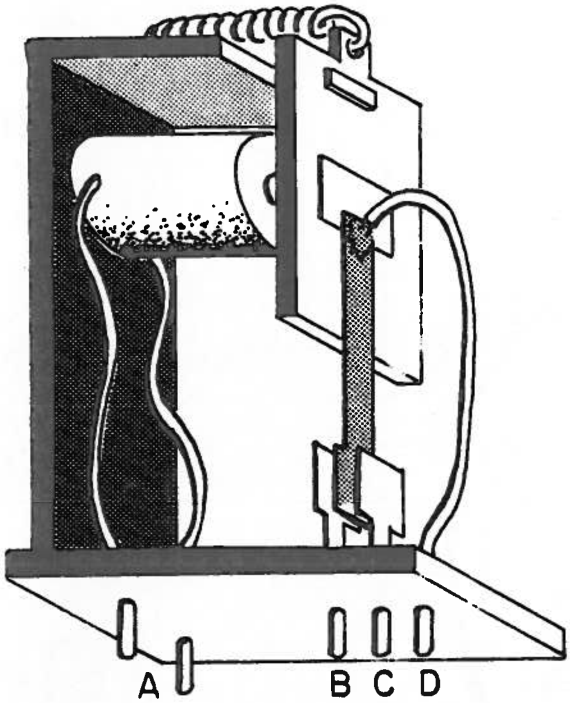


ISOLATION

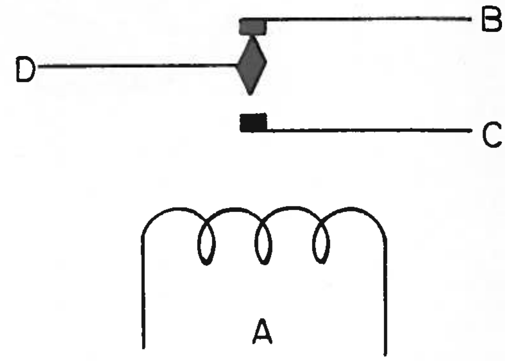


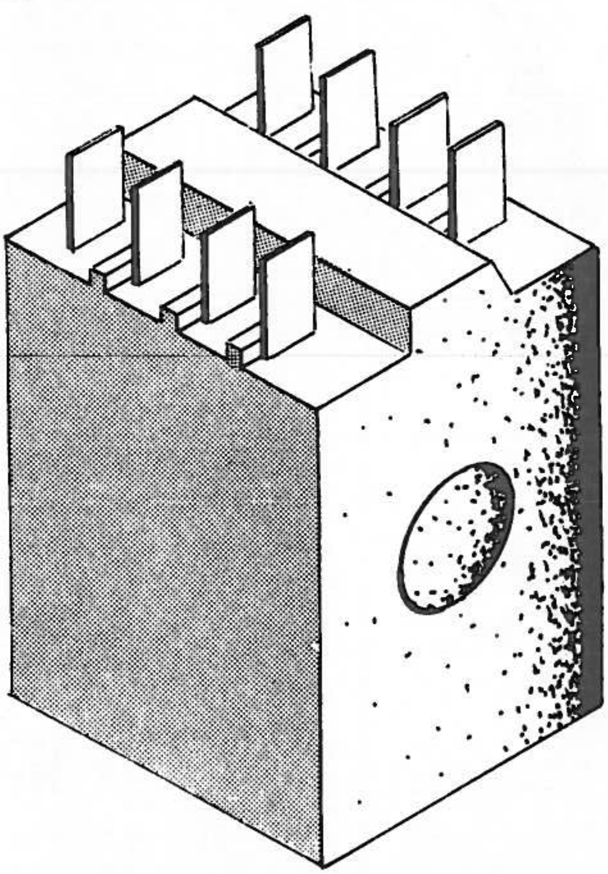


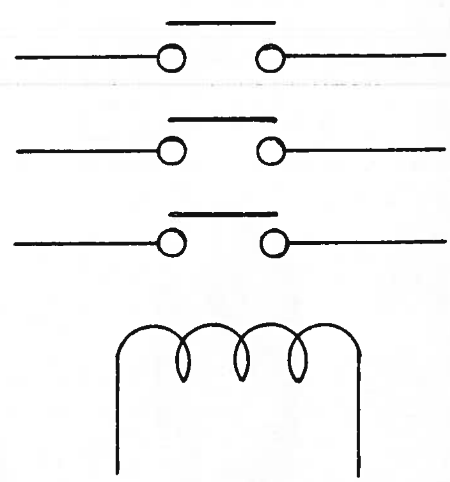
# RELAYS



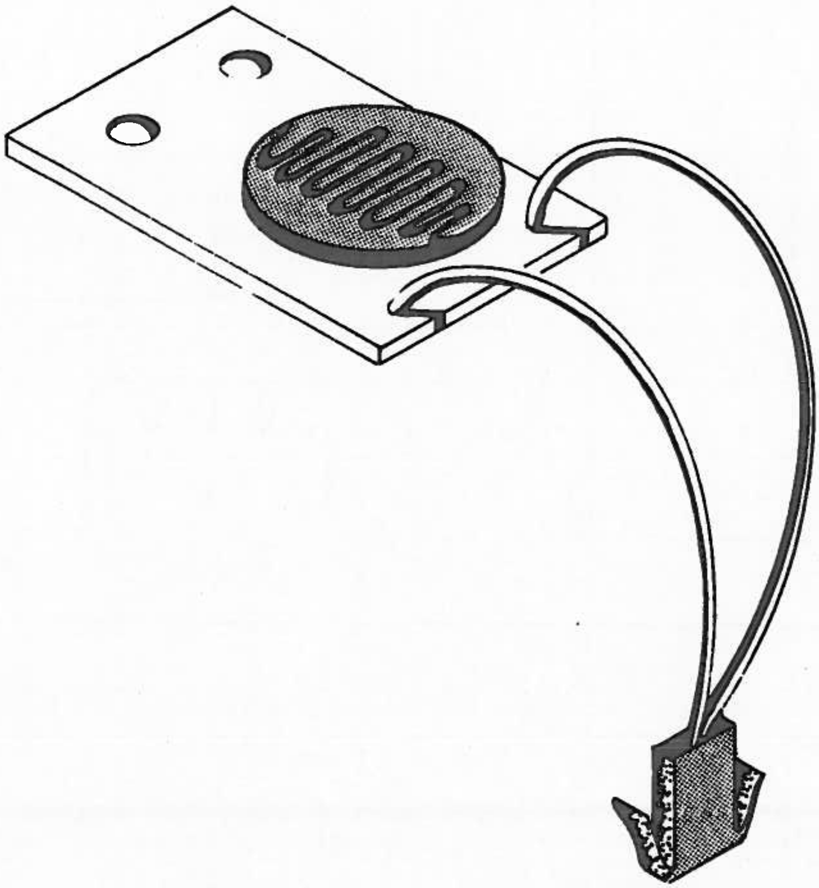

SCHEMATIC SYMBOL



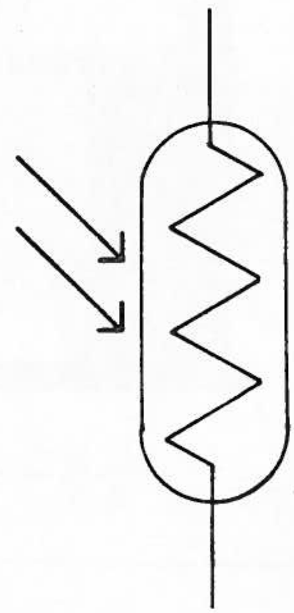





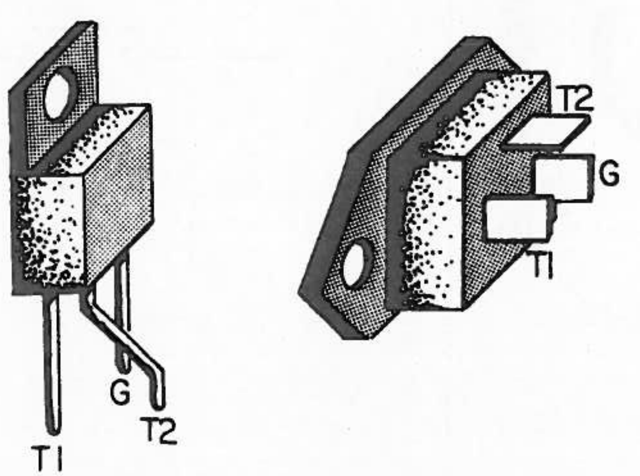
# CdS CELL (Cadmium Sulfide)

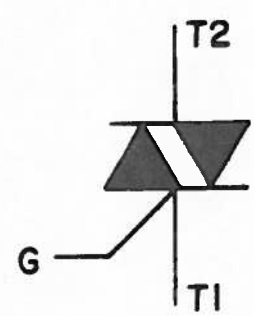


SCHEMATIC SYMBOL



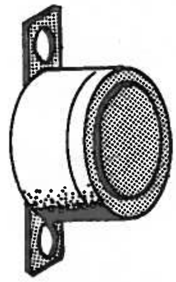
# TRIACS



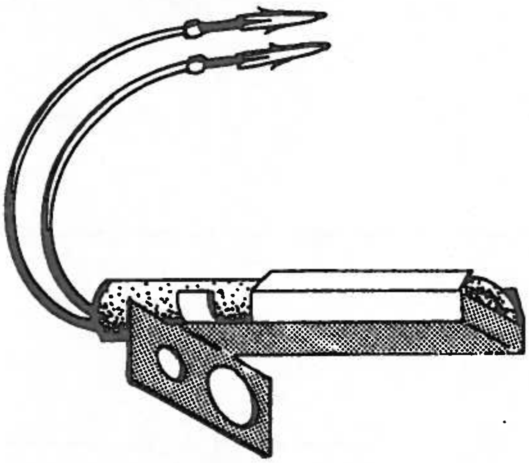
# THERMAL DEVICES

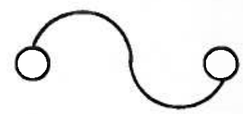
## THERMAL SWITCH



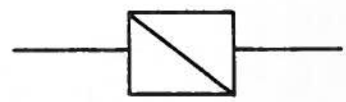
## SCHEMATIC SYMBOL

## THERMAL FUSE

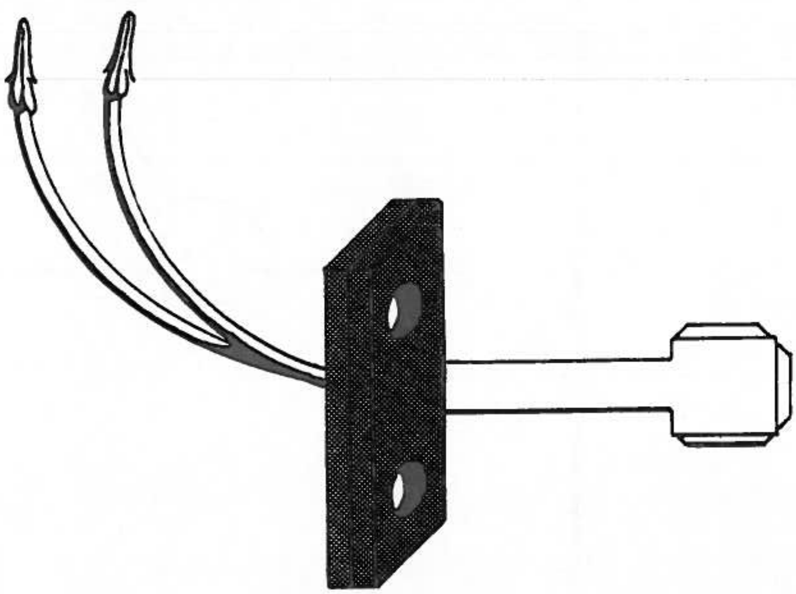


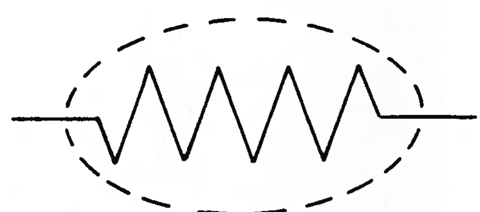


or



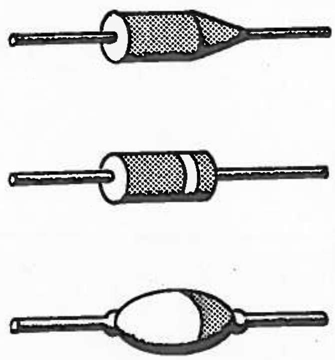
## THERMISTOR



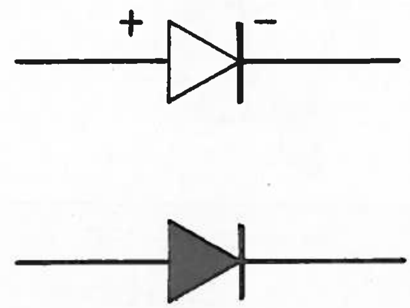


# DIODES

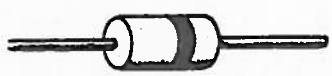
## SILICON and GERMAINIUM

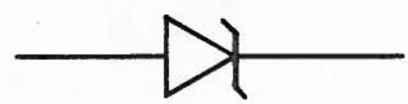


## SCHEMATIC SYMBOL

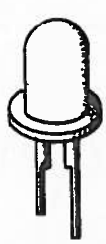


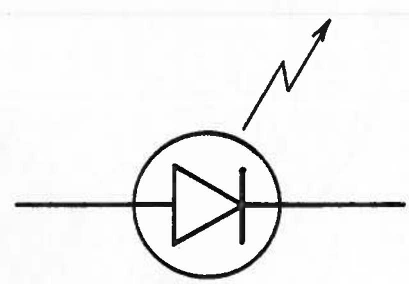

## ZENER



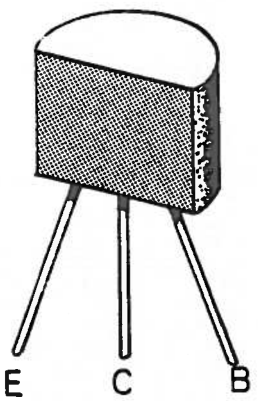


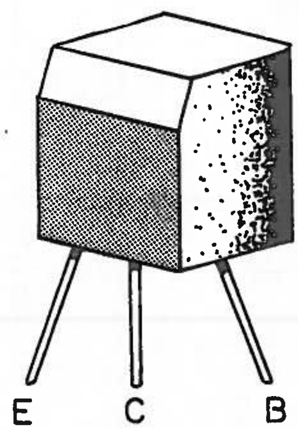
## LIGHT EMITTING (LED)

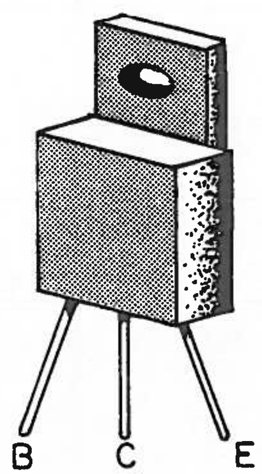




# TRANSISTORS

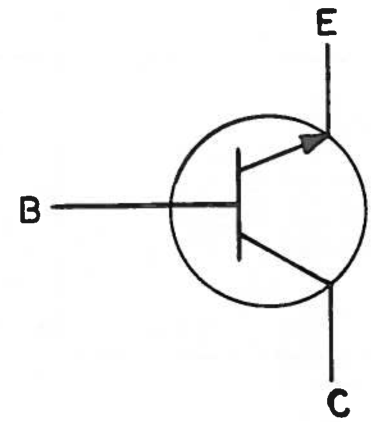


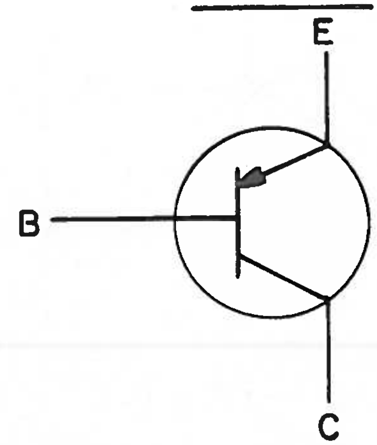




SCHEMATIC SYMBOL

NPN TYPE




PNP TYPE




E=EMITTER

B=BASE

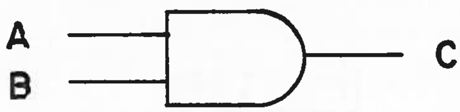
C=COLLECTOR

# LOGIC DEVICES

TRUTH TABLES

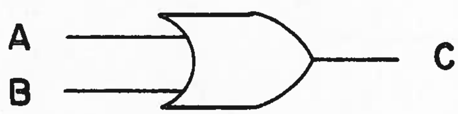
1=ON-HIGH
0=OFF-LOW

## AND GATE



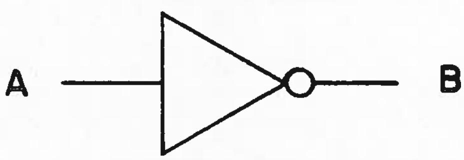

| INPUTS A | B | OUTPUT C |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 0 | 0 |
| 0 | 1 | 0 |
| 0 | 0 | 0 |

## OR GATE



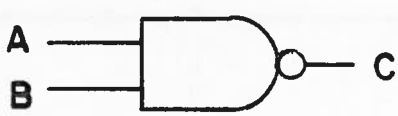

| A | B | C |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 0 | 0 | 0 |

## INVERTER



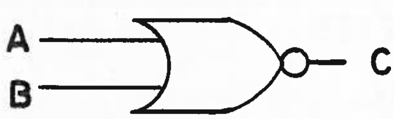

| A | B |
|---|---|
| 1 | 0 |
| 0 | 1 |

## NAND GATE



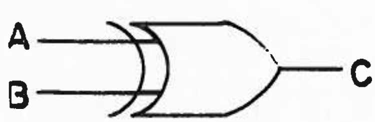

| A | B | C |
|---|---|---|
| 1 | 1 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 0 | 0 | 1 |

## NOR GATE




| A | B | C |
|---|---|---|
| 1 | 1 | 0 |
| 1 | 0 | 0 |
| 0 | 1 | 0 |
| 0 | 0 | 1 |

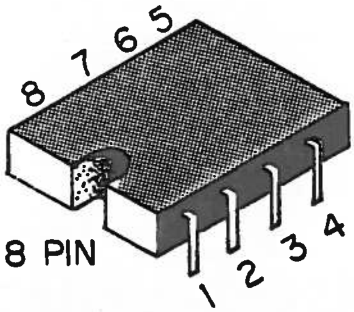
## EXCLUSIVE OR



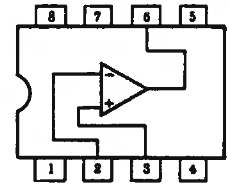

| A | B | C |
|---|---|---|
| 1 | 1 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 0 | 0 | 0 |

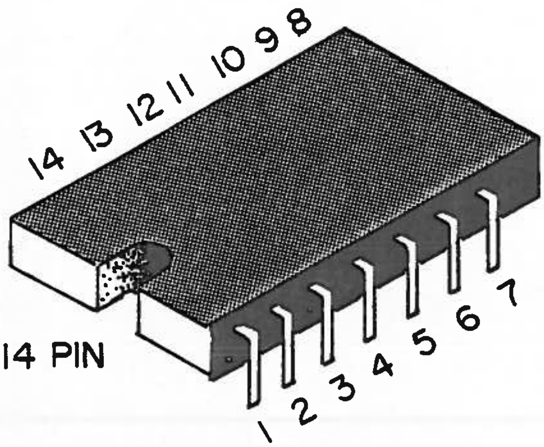
# INTERGRATED CIRCUITS

POSSIBLE INTERNAL ARRANGEMENTS

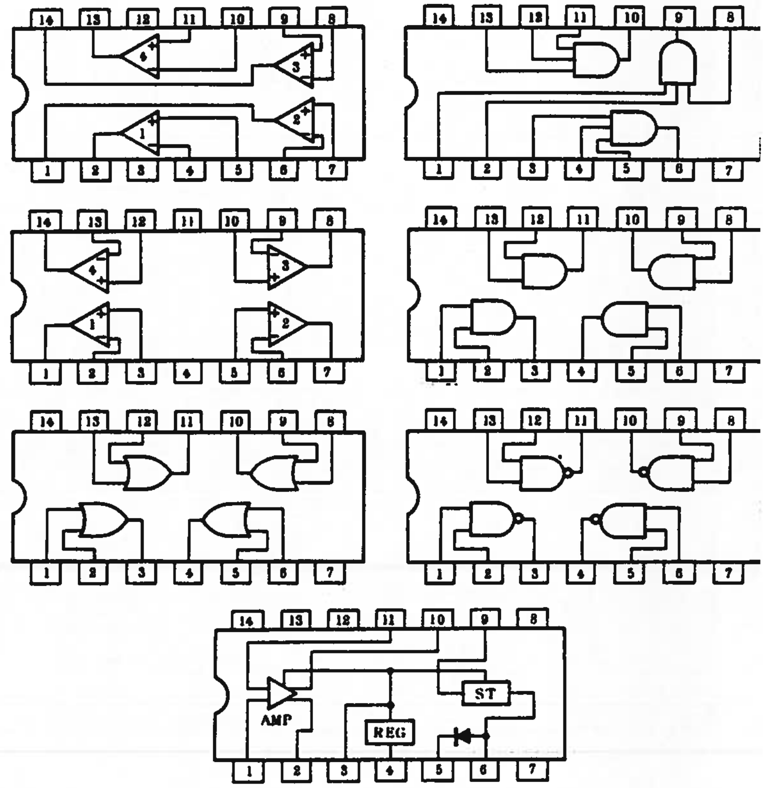


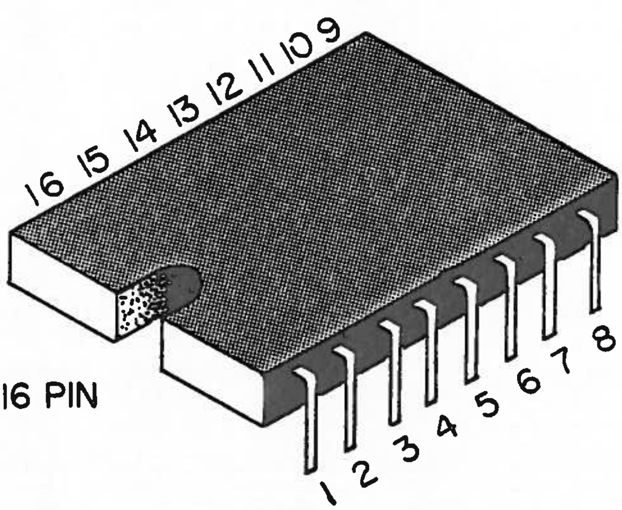
8 PIN



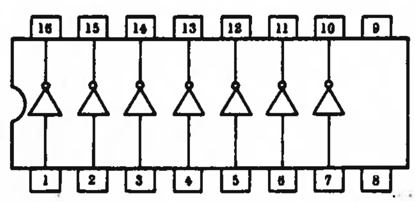


14 PIN

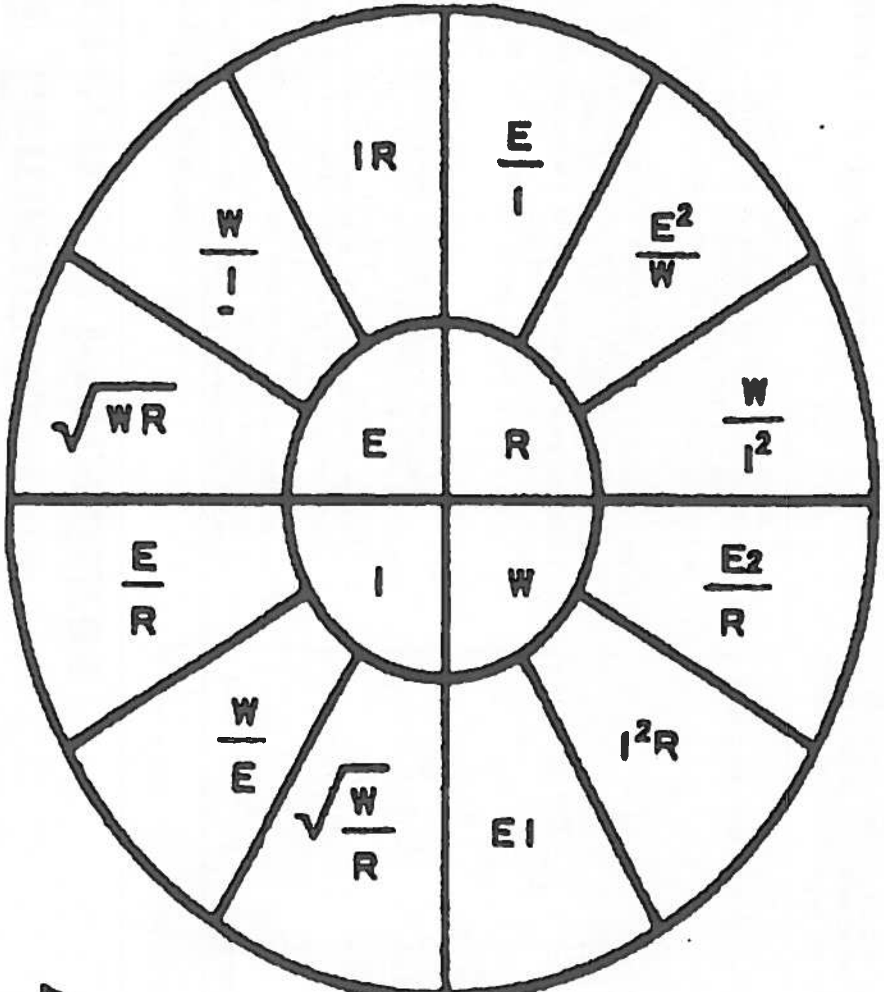


16 PIN



# OHM'S LAW-DIRECT CURRENT




W = WATTS (POWER)

I = CURRENT (AMPERES)

R = RESISTANCE (OHMS)

E = ELECTROMOTIVE FORCE (VOLTS)

COLOR CODE

<u>RADIO</u>

0 - BLACK  2 - RED  4 - YELLOW  6 - BLUE  8 - GRAY

1 - BROWN  3 - ORANGE  5 - GREEN  7 - VIOLET  9 - WHITE

$$\frac{R_1 \times R_2}{R_1 + R_2} = \text{RESISTORS IN PARALLEL}$$

FOR CAPACITORS IN SERIES SUBSTITUTE C FOR R

# ECG® Semiconductors — Replacement Procedures

## Universal Replacements

1. ECG Semiconductors can be used with confidence because they are specially selected prime parts whose specifications generally exceed those of the original part or application. A maximum number of replacement requirements can be satisfied with a minimum inventory of ECG Semiconductor devices. For example, ECG125 diode can be used to replace more than 625 JEDEC (1N) types (1N867, 1N4001, 1N4003, 1N4011, etc.) and ECG123A transistor can be used to replace more than 200 (2N) types (2N708, 2N708A, 2N2096A, 2N3115, etc.) plus thousands of other standard industry transistor types.
2. The frequency of equipment repair can be reduced by upgrading with ECG Semiconductors. For example, if a 100 volt, 15 amp rectifier is frequently replaced in an important control unit, replace it with a higher voltage and/or higher current part, as explained in rectifier replacement section. Or, if the device is overheating, additional heat sinking may be required.
3. ECG Replacement Semiconductors are available through an international network of electronic distributors. These distributors provide local availability of ECG replacement semiconductors to help keep equipment downtime at a minimum.

## Replacement Techniques

### Forming Pins

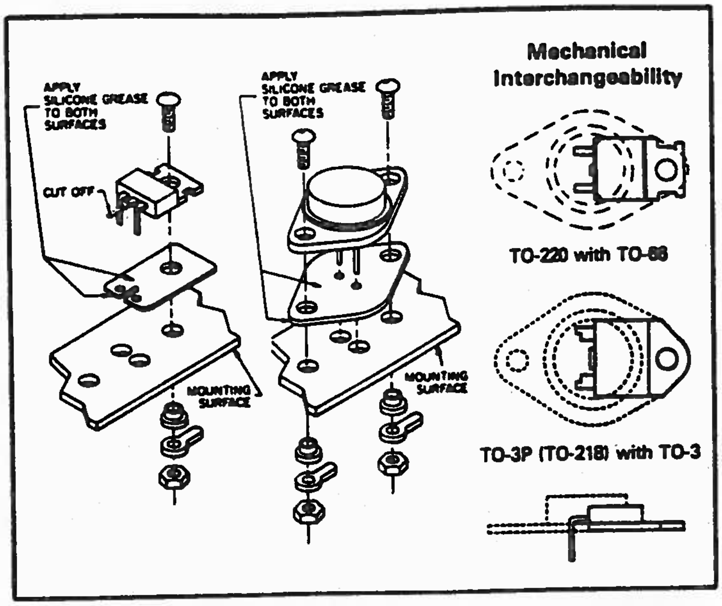
When replacing the original device with an ECG unit, certain mechanical and electrical requirements must be observed. Compare the lead or terminal arrangement of the original part with the ECG replacement. If necessary, bend the leads to the proper basing arrangement and insulate them to prevent possible shorts. For socketed devices, cut the leads on the replacement to proper length. Check the outline dimensions of the replacement if mounting space is a problem. Replacement in untuned stages can generally be made with a minimum of effort.

1. To avoid pulling when bending a plastic device pin, always restrain the pin firmly by holding with a pair of needle-nosed pliers or tweezers located at least 1/8-inch away from the device body. Internal connections of the pins to their junctions may be disrupted if this procedure is not observed.
2. If pins must be spread apart, bend the pin only in the narrow portion of its length, again restraining the pin during bending as per Step 1.
3. Maintain a bend radius of at least 1/16-inch.
4. Do not repeatedly bend pins. Insulate pins if necessary to avoid short circuits.
5. Mount the device before soldering to leads.

### Mounting

(See Illustration)

1. Use the proper mounting hardware, such as insulating bushings, insulating washers, etc., called for by the specific application.
2. To promote efficient heat transfer, insulating washers, when required, should be thin (typically three mils for a mica washer). Use a thin, even layer of ECG424 Heat Sink compound on both sides of the washer.
3. Exercise care that the tool used to tighten the transistor retaining nut or bolt does not contact the device body.
4. Unless otherwise specified do not exceed six inch-pounds torque (an average male can exert about 50-inch pounds torque with a screwdriver).




5. Avoid exerting pull of the device pins while connecting them to their circuit connections. Provide a means of strain relief if these connections tend to place pulling forces on the pins.
6. To extend transistor life in high-power dissipation applications where a large thermal interface is not provided by the original equipment, the use of a heat sink is recommended when space permits. The ECG line includes a variety of transistor heat sinks, insulator kits, and heat sink compound for this purpose.

### Soldering

1. Solid-state circuitry is generally miniaturized and is most often fabricated on a printed-circuit board. Any repairs to this type of circuitry require a well-tinned, pencil-type soldering iron. Care must be taken in soldering, both to prevent damage to the printed circuit board and to make sure that the solid-state device itself is not overheated. A good quality 60/40 (60% tin, 40% lead) solder helps to make joints quickly with a minimum of heat. When solid-state devices must be removed or installed, some means must be provided to conduct heat away from their junctions. Long-nose pliers or hemostats may be used as a heat sink.
2. Leakage between the heating element and the soldering-iron tip can cause the tip to be above ground potential. This leakage voltage may cause transistor damage if the chassis has a return to ground. To be on the safe side when soldering or unsoldering solid-state devices (especially non-gate protected MOSFET's), it is recommended that a flexible grounding strap be connected from the metal neck of the soldering iron to a good ground.
3. The same considerations about line leakage also apply to the use of oscilloscopes and signal generators. Even though the equipment may have a power transformer, the "line-filter" capacitors which are usually connected between the transformer primary and chassis ground permit an ac flow between chassis ground and earth ground. Therefore, if you connect the ground lead of such test equipment to a sensitive point in transistorized equipment having an earth ground, damage may result.
4. After soldering the connections using good solid-state practice, complete the replacement job with a check of the bias, following the procedures provided by the equipment manufacturer.

# Mosfet Handling Precautions

In handling non-gate protected MOSFETS, such as the ECG220 and ECG221, the following precautions should be observed:

Prior to assembly into a circuit, all leads should be kept shorted together with the metal spring.

When devices are handled, the hand being used should be at ground potential.

Tips of soldering irons should be grounded.

Devices should never be inserted into or removed from circuit with power on.

Gate-protected devices, such as the ECG222, incorporate special back-to-back diodes that are diffused directly into the M.O.S. pellet and are electrically connected between each insulated gate and the FET's source. These diodes effectively bypass any voltage transients which exceed approximately ± 10 volts and protect the gates against damage in all normal handling and usage.

# CMOS Handling Precautions

The input protection networks incorporated in all CMOS devices are effective in a wide variety of device handling situations. To be totally safe, however, it is desirable to restate the general conditions for eliminating all possibilities of device damage.

CMOS devices may be damaged if exposed to high static charges. The handling procedure shown below should be followed in order to assure against damaging the devices:

1. The leads of the devices should be shorted out with some type of conductive material except when being tested or when actually in the circuit. This will prevent build up of static charges.
2. All tools, jigs and fixtures, soldering-irons and any type of handling device should be grounded.
3. Transient voltages can damage CMOS too. Therefore, units should not be plugged into, or removed from, circuits while power is still on. Signals should not be applied if the power to the device is off.
4. If a lead is not used, it must be either grounded or connected to the device power supply. Which one will depend on the logic circuit involved.

   Table I indicates general handling procedures recommended to prevent damage from static electrical charges.

   Total protection results when personnel and materials are all at the same or ground potential.

**Table I**

| | Should Be Conductive | Should Be Grounded to Common Point |
|---|---|---|
| Handling Equipment | X | |
| Metal Parts of Fixtures and Tools | | X |
| Handling Trays | X | X |
| Soldering Irons | | X |
| Table Tops | X | X |
| Transport Carts | | (Static Discharge Straps) |
| Manufacturing Operating Personnel | | *(Utilize Grounded Metal Wrist Straps) |
| General Handling of Devices | | *(Utilize Grounded Metal Wrist Straps) |

* 470 Kohm series resistor

Dry weather (relative humidity less than 30%) tends to multiply the accumulation of static charges on any surface. Conversely, higher humidity levels tend to reduce the magnitude of the static voltage generated. In a low-humidity environment, the handling precautions listed above take on added importance and should be adhered to without exceptions.

# Selecting a Bi-Polar Transistor For An Unlisted Type

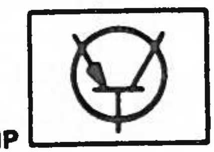
If the transistor to be replaced is unmarked or not listed in the ECG Replacement Guide, the following procedure can be used to make an accurate replacement selection.

Step-by-step determine each of the following parameters:

1. Polarity NPN or PNP
2. Type of material - silicon or germanium
3. Operating frequency range
4. Maximum voltage, collector to emitter
5. Maximum voltage, collector to base
6. Maximum collector current
7. Maximum power dissipation
8. Current gain
9. Case packaging
10. Lead configuration

### Step 1

Is it an NPN or PNP device? Your first source of information would be the schematic drawings. If the arrow on the emitter of the transistor symbol is pointing toward the base, you know it is a PNP device, or if it is pointing away from the base, it is an NPN.

PNP  NPN 

Now let's say for argument sake that the schematic has been drawn incorrectly or suppose you have no schematic, your next clue would be to determine the polarity of the voltage between the emitter and collector.

If the collector voltage is positive with respect to the emitter voltage, then it is a NPN device. If the collector voltage is negative with respect to the emitter voltage then it is a PNP device. Therefore, if the $V_{CE}$ (collector to emitter voltage) is positive, it's NPN, or if the $V_{CE}$ is negative, it's PNP. An easy way to remember the polarity of the collector voltage for each type is:

**NP** OSITIVE **N**

**PN** EGATIVE **P**

### Step 2

Next you must decide whether the device is silicon or germanium. This is most effectively done by the use of a schematic drawing. If you find that the D.C. bias voltage level between the base and emitter is 0.2 volts or less, it is probably a germanium device. Now, if you get a bias voltage reading of 0.4 volts or more, it is probably a silicon device. There will, of course, be some cases where there will be either no bias or reverse bias voltage present. This would be the case in oscillator and sync clipper circuits.

Another way of determining the type of material of a transistor is to look at the complexity of the circuit with respect to the number of components in a single stage. Germanium circuits are much more complex due to germanium's unstable nature with respect to temperature changes and its high leakage currents, therefore, several components are required per stage to make it stable. Voltage dividers are used to compensate the bias voltage and an emitter limiting resistor is always used.

A silicon device, however, is very stable with respect to gain when temperature changes and silicon has very low leakage currents. Therefore, a single silicon amplifier stage may only consist of one resistor for base bias and one load resistor. Some circuits using silicon still have more compensating components than they require but as design engineers have become more aware of the stability of silicon, circuits have become simpler.

### Step 3

After you have determined the polarity and type of material of a device, you next determine the operating frequency range of the circuit in which it is used. This is done mainly by identifying the type of circuit and whether it is working in the audio range, the kilohertz range or the megahertz range.

### Step 4

Next you look at the schematic or the circuit and determine the maximum collector to emitter voltage present in the circuit. In most cases, it is best to use the supply voltage figure as your reference. This figure will then be used to select a replacement device, which has a collector to emitter breakdown voltage at least slightly higher than the supply voltage. Preferably the higher the collector to emitter breakdown voltage, the better.

### Step 5

Next the collector to base maximum voltage must be determined. If you have determined the collector to emitter maximum voltage requirements, then you can use this figure for the collector to base maximum voltage requirements.

### Step 6

The sixth step is to determine the maximum collector current. To do this you would consider the DC condition with the device fully on, which of course would give you the highest current required of the device.

### Step 7

Now that you have determind the maximum voltage and collector current requirements, you can use them in determining the maximum power requirements. However, the type of circuit where the device is used is the major factor with respect to power dissipation. Here we have some general wattage ranges for different circuit types.

1. Input stages, AF or RF, 50-200 milliwatts
2. IF stages and driver stages, 200 MW - 1 watt
3. Higher power output stages 1 watt and up

### Step 8

Next you determine the gain expected from the circuit. This is determined primarily by its application in a circuit. Some typical gain categories are:

| | |
|---|---|
| RF, Mixers, IF and AF | 80 - 150 |
| RF and AF Drivers | 25 - 80 |
| RF and AF Output | 4 - 40 |
| High Gain Preamps and Sync Separators | 150 - 500 |

### Step 9

Next you determine the case packaging and over-all dimensions. (Case type and size need only be considered where an exact mechanical fit is required. Otherwise, if you can fit the device into place even though it is not the exact case, it will probably do the job as well as the original. Some high frequency circuits may require exact replacements but even these circuits will require some alignment touch-up, especially in the case of UHF circuits.)

### Step 10

Lastly you note the lead configuration. (Lead configuration generally is not a prime consideration for replacement transistors although it may be desirable for ease of insertion and appearance.)

With the above 10 parameters determined, the application selector guides in the transistor section can be used to find an accurate replacement device.

In an emergency situation where a replacement is listed in the ECG Semiconductor Guide but you do not have the recommended type in stock, this procedure could be used to determine alternate ECG replacements with higher ratings or different case or lead configurations.

## SCR, Triac, Rectifier and Bridge Replacement

A substitute rectifier, SCR, triac or bridge can be used as long as it is:

1. Equal to or greater in current rating
2. Equal to or greater in voltage rating
3. In a similar case
4. Has (for SCR's and triacs) the same or lower $I_{GT}$ rating
5. Has equal or faster switching speed

The important factor in point 3 is that for proper heat transfer, substitutes for stud type devices should have the same stud size - this, so you can simply take out the defective device and install the new device without having to drill a new size hole in the heat sink. In the case of axial lead devices, however, you may substitute if the case is equal to or smaller than the original device.

Not all ECG devices can be substituted in the above manner. The above-mentioned five substitution factors apply to SCR's, triacs, rectifiers, and bridges only. Voltage regulation zener substitutions are somewhat less flexible, since each zener is manufactured for, and used as, a specific voltage regulator you cannot substitute a different zener voltage.

## Personalized Service For Unlisted Types

Upon the user's request, the ECG Semiconductor Field Engineering Department will try to cross reference any type number or part number not in this ECG Semiconductor Replacement Guide. Sometimes this is possible, sometimes not. However, the chance of success is greatly increased as the amount of information to work with goes up. Therefore, when requesting a new cross reference, please give as much of the information requested in Table II as possible.

**Table II**

1. Type Number
2. Part Number
3. Number on Device
4. Type of Device (i.e., Diode, Rectifier, PNP or NPN Transistor-Silicon or Germanium, SCR, Triac, Integrated Circuit, etc.)
5. If IC, Specify Digital, Linear, or Other Description
6. Case Style (i.e., TO-5, DIP, 3/8" Stud, etc.)
7. Number of Leads
8. Application of Device (i.e., TV, Motor Control, Battery Charger, Arc Welder, Tape Deck, CB, Scanner, Auto Radio, etc.)
9. Manufacturer's Name
10. Trade Name
11. Chassis Number
12. Model Number
13. Description of Device Function

Inquiries for such cross reference information should be sent to:

ECG Semiconductor, Field Engineering
Philips ECG
1025 Westminster Drive
Williamsport, Pennsylvania 17701

## Testing Solid-State Devices

### Precautions

**Ohmmeters** - Ohmmeters must be used with great care in transistor circuits. It must be remembered that the ohmmeter has an internal voltage source. Also, some instruments are capable of delivering high currents.

Meter test probes with sharp points facilitate checks on printed-circuit boards. They minimize the danger of accidentally bridging adjacent conductors. Also, the needle points easily pierce resin, varnish, or surface corrosion on the conductors. False readings are often the result of not making good connections on the printed-circuit board.

In-circuit measurements are often misleading because of the shunt paths provided by transistor junctions that become forward biased by the ohmmeter's supply. An example is shown in Fig. A. With the ohmmeter connected in this fashion, the internal battery places a forward bias on the emitter junction of the transistor. This effectively places $R_E$ in shunt with R2.

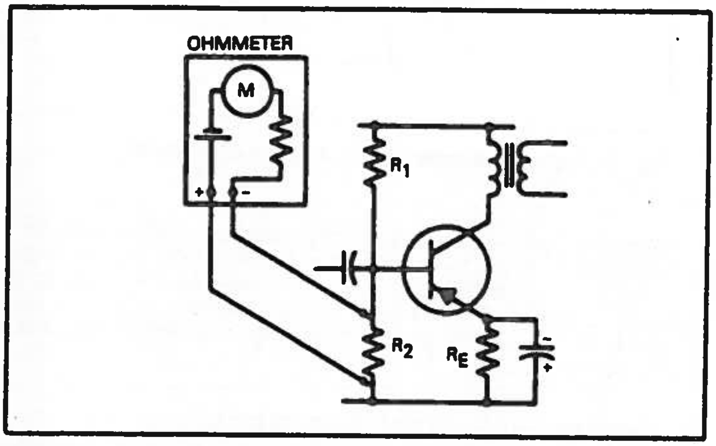



**Fig. A. False resistance reading caused by forward-biased emitter junction.**

In addition to shunt paths provided by transistor junctions, the physically small electrolytic capacitors employed as coupling and bypass capacitors also provide low-resistance shunt paths if the ohmmeter's internal supply should polarize them incorrectly. These components can be permanently damaged by even a low voltage of incorrect polarity. Damage can also be caused if the polarity is correct, but the working voltage of the capacitor is exceeded by the ohmmeter's supply. Some capacitors are rated at only 3 volts, while the internal supply of many ohmmeters is 7.5 volts and may run as high as 30 volts. (Most electronic VOM's employ a 1.5-volt supply and are therefore always safe as far as voltage breakdown is concerned.)

As a general rule, ohmmeter measurements in the transistor circuit should be made by disconnecting one lead of the component to be checked. This removes any possibility of a shunt path. However, the reading in Fig. A. could be made if the ohmmeter leads are reversed, in which case the emitter junction becomes reverse biased. This requires a knowledge of the polarity of the ohmmeter voltage at the meter's test leads.

Ohmmeter connections that reverse-bias transistor junctions sometimes run the risk of exceeding the breakdown potential of the junction. This is particularly true in the case of the emitter junction, which breaks down at lower reverse voltages. If the $V_{(BR)EBO}$ of the transistor is not known and if a battery voltage of several volts or more is used in the ohmmeter, it is best to disconnect the transistor.

Ohmmeter readings that intentionally or accidentally forward bias a transistor junction also run the risk of causing excessive current flow through the transistor. The forward-biased junction is practically a short, so that the total current flowing is determined mainly by the ohmmeter's voltage supply and its internal resistance. Many ohmmeters, including electronic VOM's, supply a short-circuit current of 100 mA when used on the Rx1 scale. This current can damage many transistors. To prevent any danger of damage, only use those resistance ranges where the short circuit current is below 1 mA. For most service-type instruments, use of the Rx100 and Rx10k ranges is safe. Do not read forward-bias currents on the Rx1 scale.

Summing up, ohmmeter readings require some judgment before they are made. You need to know three things about the ohmmeter before making measurements: the polarity of the voltage at the leads, the voltage of the internal battery, and the short-circuit current. Also, unless shunt paths can be definitely eliminated by proper polarization, one lead of the component to be checked must be disconnected.

**Identifying Leads on Unmarked Transistors** — Occasionally, identifying marks may be obliterated on the transistor case. The leads may then be identified with the few ohmmeter checks shown in Fig. B. In Step 1, ohmmeter checks are made between each pair of leads in both the forward and reverse directions. Low readings (below 500 ohms) will be found when the ohmmeter places a forward bias across emitter and collector junctions. The highest forward reading is obtained when the meter is placed across the emitter and collector leads. This check establishes the base lead as the one that is not involved in the high forward-resistance reading.

Step 2 identifies the transistor type. An ohmmeter check is made between the base and one other lead. If a low-resistance reading is obtained when the negative side of the ohmmeter is connected to the base, the transistor is a PNP type. A low resistance reading when the base is positive indicates an NPN unit.

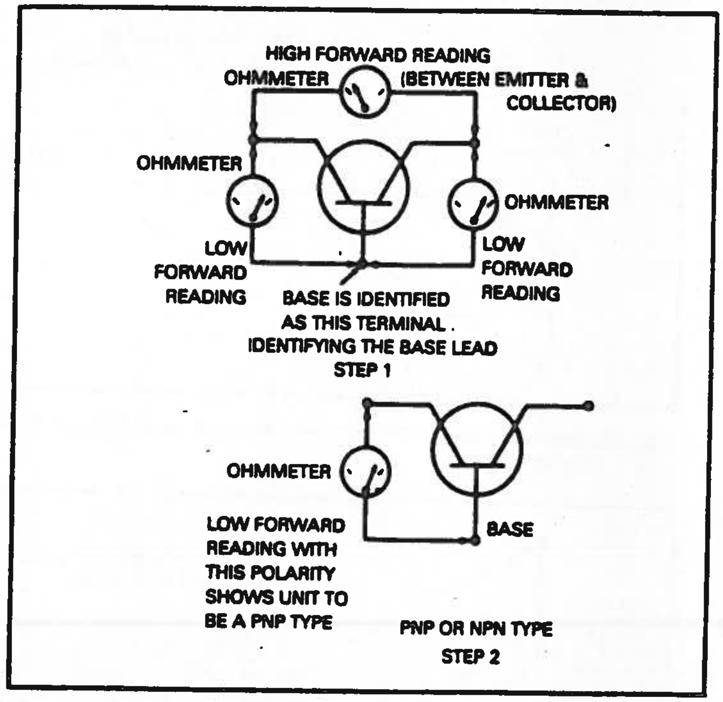



**Fig. B. Hookup arrangement for identifying leads.**

## Testing Bipolar Transistors

A transistor that is operated within its ratings with respect to voltage, power dissipation, and temperature is normally expected to have an almost unlimited life. Failures in transistorized circuits are more often the result of damage or malfunctioning of some other component. This is particularly true when miniature transformers and electrolytic capacitors are employed. Despite the reliability of the transistor itself, failures occur due to shorts or opens in the bias circuitry, temporary overloads, physical damage, or even mishaps while servicing.

A great number of transistor testers and analyzers are available. Some only check leakage and current gain, while others are capable of measuring all of the transistor parameters. From a servicing viewpoint, a few simple tests are enough to reveal a great majority of troubles. These tests, to be described, reveal shorts, opens, excessive leakage, and provide a rough check of current gain. Fortunately, little equipment is required. Some of the tests require only an ohmmeter. The more elaborate checks can be made with just a few additional components.

**Testing the Junctions** — The transistor contains two p-n junctions or diodes. Most of the characteristics of the transistor are tied in with the behavior of the junctions, while the rest of the device simply serves as connective material. Damage to the transistor, therefore, almost always shows up as a malfunctioning of one of the rectifying junctions. The fault may be an open or

A rough but useful check of the condition of the junctions may be made with an ohmmeter. First, the forward resistance of each junction is measured, as shown in Fig. C. In this figure, the connections for a PNP transistor are shown. The negative terminal of the ohmmeter is connected to the base. The forward resistance of both junctions is checked by touching the emitter and then the collector terminal in turn with the positive lead. A high reading indicates an open junction. A normal unit should show a reading below 500 ohms. Observe the precautions given earlier for using the ohmmeter. The forward resistance of the junctions of an NPN unit is checked with the same setup shown in Fig. C, but with the leads to the ohmmeter reversed.

To check for shorts or excessive leakage, reverse the ohmmeter connections and switch to a higher resistance scale, as shown in Fig. D. Now the ohmmeter places a reverse bias on each junction in turn, and leakage current is registered on the meter. A low resistance reading indicates a shorted or leaky junction. Low- and medium-power germanium transistors should show a resistance reading of at least 500 kilohms.

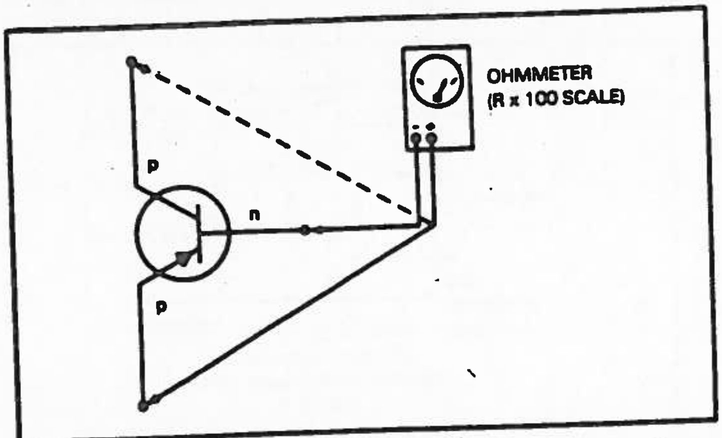



Fig. C. Method of checking the forward resistance of both junctions.

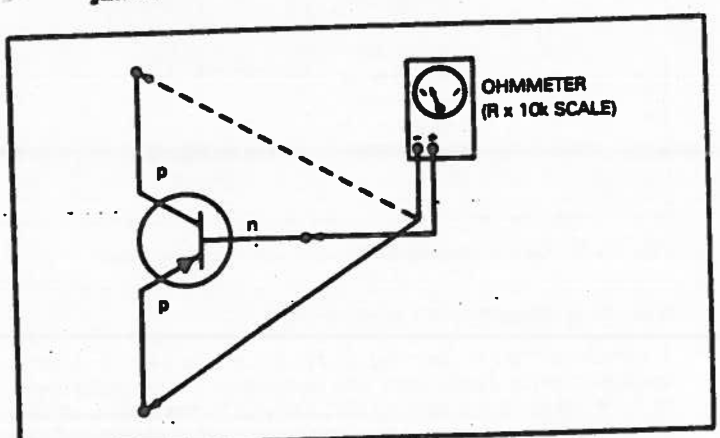



Fig. D. Method of checking the reverse resistance of both junctions.

Typical readings taken with an ohmmeter on the Rx10k scale are 700 kilohms to 1.5 megohms. Silicon transistors give much higher resistance readings. Power transistors have larger junctions and therefore greater leakage currents. Reverse-bias resistance readings should be 50 kilohms or greater for power transistors.

Reverse-resistance checks on NPN transistors are made by reversing the ohmmeter leads so they are opposite to that shown in Fig. D. Note that the actual numerical reading in ohms is meaningless, because the ohmmeter can only measure linear resistances. The specific ohms-reading changes from meter to meter and is not the same for different settings of the range switch. The minimum and maximum values given here apply in the majority of cases. To increase the accuracy of the ohmmeter check, the readings should be compared with those made on a known good transistor of the same type.

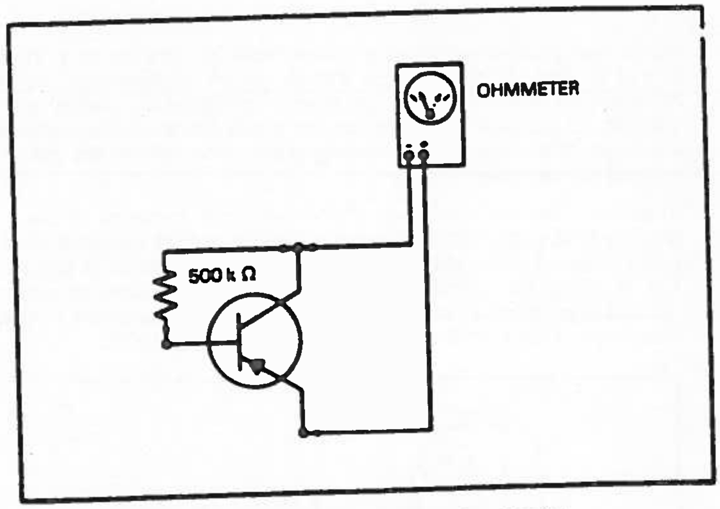



Fig. E. Gain measurement using an ohmmeter.

**Current Gain** — Transistor action may be checked with an ohmmeter by means of the setup shown in Fig. E. The meter registers $I_{CEO}$ before the 500-kilohm resistor is touched to the base. Connecting the resistor allows a small base bias to be applied, and the meter shows an increase in current (decrease in resistance reading).

## Testing Field-Effect Transistors

Testing field-effect devices is somewhat more complicated than testing bipolars and must take into account the following:

1. Is the device a JFET or MOSFET?
2. Is the FET an n-channel or p-channel type?
3. If the device is a MOSFET, is it an enhancement or depletion type?

Do not attempt to remove from the circuit or handle a FET unless certain that the device is a JFET or an insulated-gate-protected MOSFET. This verification is essential, because an uninsulated-gate-protected MOSFET may be damaged unless proper handling precautions are taken. When handling or inserting or removing this type of MOSFET, the following should be observed:

1. Prior to assembly into a circuit, all leads should be kept shorted together by either the use of metal shorting springs attached to the device by the vendor, or by the use of a conductive foam. Note.- polystyrene "snow" should not be used because it can acquire high static charges.
2. When devices are removed by hand from their carriers, the hand being used should be at ground potential.
3. Tips of soldering irons should be grounded.
4. Devices should never be inserted into or removed from circuits with the power on.

**Testing the JFET** — The forward resistance of a JFET can be checked with a low-voltage ohmmeter, preferably on the Rx100 scale. Connect the positive lead to gate and the negative lead to the drain or source, if an n-channel JFET. Reverse the leads if a p-channel type.

To test the reverse resistance of an n-channel JFET, connect the negative lead of the ohmmeter to the gate and the positive lead to the drain or source. The device should show almost infinite resistance. Lower readings indicate either leakage or a short. Reverse the leads to test a p-channel device.

**Testing the MOSFET** — The forward resistance and reverse resistance can be checked with a low-voltage ohmmeter on the highest "R" scale. The insulated-gate MOSFET has an extremely high input resistance. Hence, we should obtain almost infinite resistance readings for both forward and reverse resistance test between gate and drain or source. Lower readings indicate a breakdown in the insulation between gate and drain or source.

## Testing Diodes

**Diodes and Rectifiers** — Because diodes and rectifiers are non-amplifying devices, simple tests for shorts, opens, or excessive leakage are useful methods to determine if they are functioning properly. The following tests are not applicable to the special case of focus diodes and high-voltage triplers, however. The forward resistance of a diode or rectifier is checked by connecting the positive and negative leads of an ohmmeter, preferably set to the Rx100 scale, to their respective positive (anode) and negative (cathode) terminals. A reading of about 500 to 600 ohms is normal for silicon types, about 200 to 300 ohms for germanium types, and for larger-type rectifiers (germanium or silicon) the resistance is somewhat lower than their respective diode types. Because high-voltage types may have several diodes in series, higher resistance readings can be expected.

As a quick go/no-go test, the ohmmeter procedure just described is a good technique.

To check for shorts or excessive leakage, switch to a higher resistance scale and reverse the ohmmeter leads. A low resistance reading indicates a short or leaky device. Germanium diodes should show a resistance reading from about 100 kilohms to 1 megohm. Silicon diodes show higher resistance readings and can go up to 1000 megohms. However, some diodes may show lower resistances but function satisfactorily in some circuits. Rectifiers, because they generally have larger junctions, have higher leakage currents.

**Zener Diodes** — To quickly determine if Zeners have opens, shorts, or leakage, connect an ohmmeter in the forward direction in the same manner as described for standard diodes.

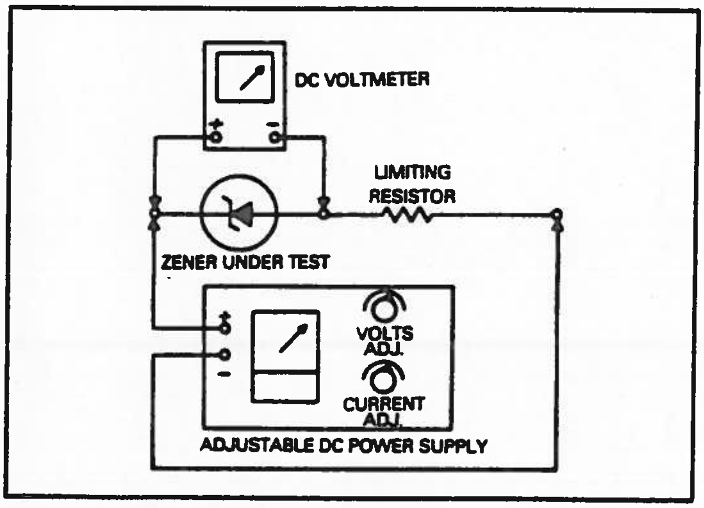



**Fig. F. Hookup arrangement for testing Zener diodes.**

However, these tests, although helpful, do not provide the primary information needed for a Zener diode, namely, is the device regulating at its rated value? A regulation test is accomplished with a metered adjustable power supply that preferably indicates voltage and current.

Connect the output of the power supply through a limiting resistor in series with the Zener diode to be tested and slowly increase the output voltage until the specified current is flowing through the Zener (see Fig. F). Now connect a voltmeter across the Zener to monitor the Zener voltage. Fluctuate the current on either side of the specified Zener current; if the Zener is operating properly, the voltage should remain constant.

## Testing SCRs and TRIACs (Thyristors)

The functional testing of SCRs and TRIACs usually requires test equipment capable of supplying the specified gate current ($I_{GT}$) and minimum hold current of the Thyristor. These parameters are given in chart form in the SCR and TRIAC sections of this book.

Testing with an ohmmeter is not recommended for high current Thyristors and should only be used for relative indications in low current Thyristors. The $I_{GT}$ and $I_{Hold}$ parameters of the Thyristor may exceed the source current capability of the ohmmeter causing false readings and therefore, may not always indicate the true function of the device.

However, a simple ohmmeter test on low power Thyristors may provide an approximate evaluation of their gate-firing capabilities by connecting an ohmmeter as shown in Fig. G. The negative lead is connected to cathode and the positive lead is connected to anode.

Using the Rx1 scale, short the gate to the anode. A reading of approximately 15 to 50 ohms is normal. **Note:** When the gate-to-anode short is removed, the same reading should still show on the meter until the leads are removed from cathode or the anode. Now, reconnecting the meter leads to cathode and anode should show no reading until the gate is again shorted to the anode.

Testing of Gate turn off SCRs requires special test equipment. Field testing of these SCRs is difficult and typically provides erroneous results.

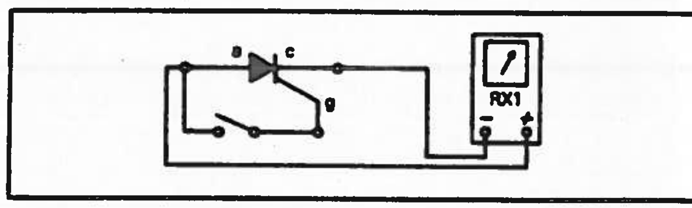



**Fig. G. Hookup arrangement for testing thyristors with an ohmmeter.**