TRANSISTORS and DIODES

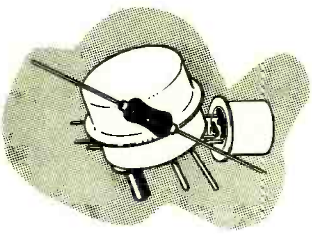
A guide in use and handling

Western Electric

BELL SYSTEM

TRANSISTORS and DIODES

A Guide In Use and Handling



Contents

Introduction

> "A tiny device that serves nearly all the functions of a conventional vacuum tube, and holds wide promise for radio, telephone and electronics, was demonstrated yesterday by Bell Telephone Laboratories scientists who developed it. Known as the transistor ..."
>
> - New York Herald Tribune, June 1, 1948

The news of the invention of the transistor made the front page of only a few newspapers... but the announcement stirred the scientific and technological world. It heralded a new era in electronics... the electronic revolution had begun.

It is not the purpose of this book to review the evolution of the transistor. Rather, it is intended to set forth the correct and accepted handling, assembling and testing considerations needed to properly use transistors and diodes. The book is directed to Product Engineers and Shop Section Chiefs.

Observance of the practices covered in this book will protect the essential reliability built into transistors and diodes, and thus help obtain low failure rates in end use system applications. It is important that circumstances contributing to an observed failure be thoroughly examined and the cause determined. Self-correcting measures can then be taken, through use of information outlined in this book. Where failure is attributable to the device manufacturer, feedback of information may be helpful in eliminating future failures due to the same cause.

The invention of the transistor offered the promise of new and exciting improvements in the telephone system. Even in the earliest development stages, scientists said the transistor had the potential of infinitely long life... largely due to the absence of a cathode.

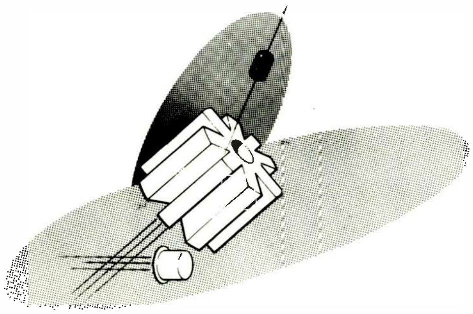
Recent developments in transistor technology and advanced methods of accelerated life testing indicate the transistor may now be expected to operate within its ratings... far in excess of twenty years. However, a very small percentage of these devices have limited life. These are of great concern to the manufacturer because they limit the ultimate reliability of the system in which they are used.

The active region in a miniature electron tube is approximately a million times greater than the volume of the active region in a typical diffused switching transistor. An appreciation of this scale difference is important in translating conventional electron tube practices to the new devices. The key to obtaining stable electrical characteristics in a transistor or diode is surface cleanliness of semiconductor material junctions to an atomic level. Maintaining this cleanliness level over a very long period of time is the function of the glass-metal seal package.

The device user must, therefore, appreciate the minuteness of the active region, the cleanliness level established by the manufacturer, and the importance of protecting the soundness of the package seal. Lack of appreciation can lead to degrading of the essential reliability built into the device and to the possibility of placing potential defects in circuits doomed to fail in operating systems.

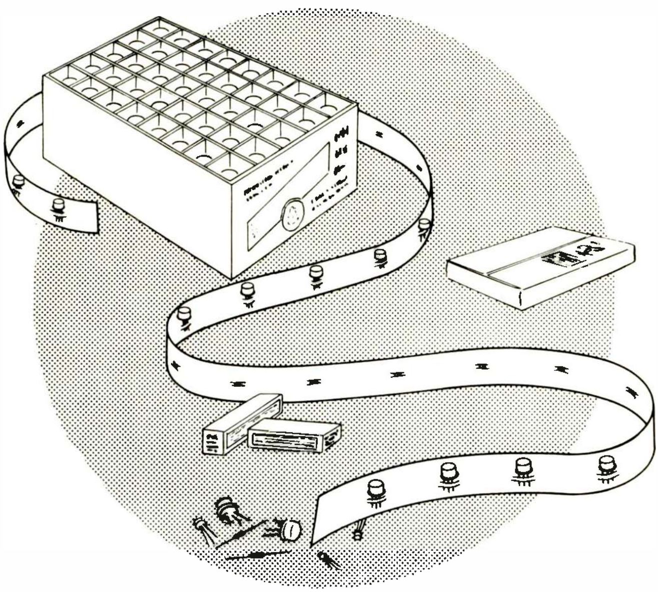
Introduction

The book is divided into four parts to cover various functional activities. Caution regarding the possibility of mechanical shock and static electrical discharge causing damage to semiconductor devices is repeated in several sections. This is done to make each part complete, and to stress the importance of proper handling and testing procedures. A cross-reference list of Western Electric codes and types is included to help the user relate code numbers and types with the text. Illustrations providing some internal construction details are included for information.



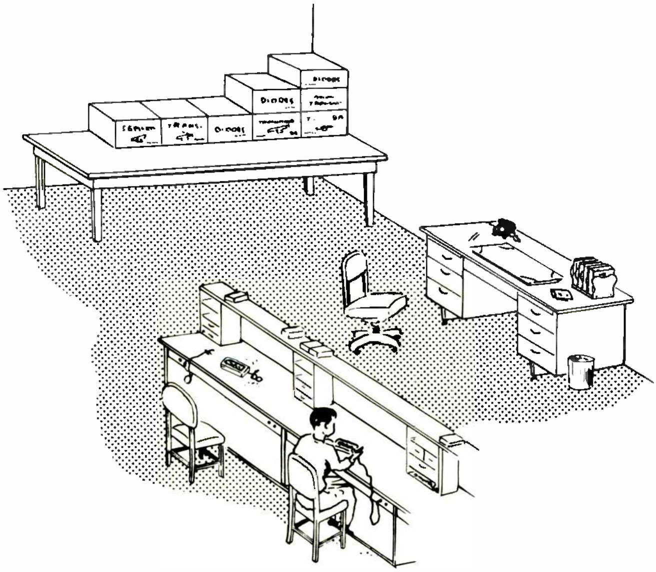
Handling

This section covers the care and handling of semiconductor devices from the time they leave the device manufacturer until they arrive at the assembly position, where they will be incorporated into circuit boards, apparatus, or equipment.



Packing and Unpacking

Semiconductor devices may be packed and shipped in a number of ways, depending on the device requirements and the manner in which they will be used. Diodes may be bulk-packed in "egg crate" cartons, or individually packed in plastic strips or in envelopes. Transistors of the 16-type may be bulk-packed in kimpak-lined cartons of 200 devices each. Power diodes, power transistors, devices supplied with mounting hardware, and matched sets are usually individually packed. If lots must be broken, each group should be repacked in a manner similar to the original packing.

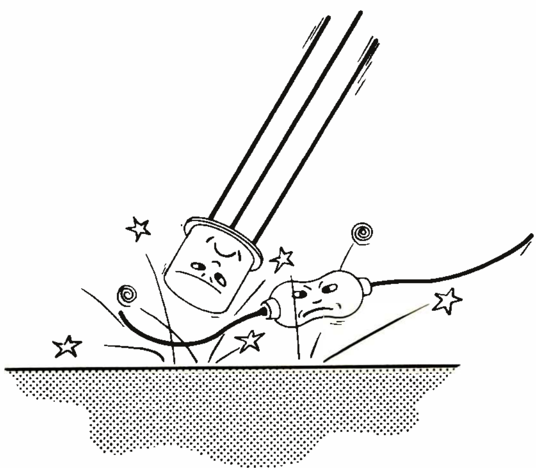


Storage

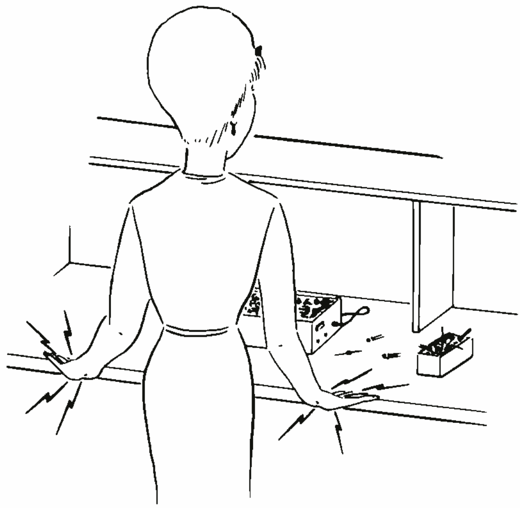
Semiconductor devices should be stored in their shipping containers whenever possible. The containers are specially designed to give the kind of protection needed. Devices should never be dumped out of cartons into bins. This can result in mechanical shock, bent and tangled leads, and cracked glass seals, causing electrical degradation or scratched leads which can start corrosion and make soldering difficult. Transistors and diodes should be dispensed from the storeroom on a "First In - First Out" basis. Prolonged storage may cause oxide to form on the leads, necessitating special cleaning before soldering.

Mechanical Shock

Semiconductor devices should be handled with the same care as a glass electron tube or a good watch. Rough handling or dropping may cause leaks or cracks in the glass seal, damage to the internal wafer, or the small internal wire bonds to open. Although the effects of jolts and jars may not show up immediately, they may shorten the life expectancy by causing potential defects. If mechanical damage, such as cracks in the glass seals, dents in the can (especially the flange), and nicks in the tubulation is noted, do not use the device.



In general, semiconductor devices are capable of withstanding shocks of 2000g. A fall from a bench to the floor may produce a shock as high as 6000g, depending on the device, the position on impact, and the type of floor surface.

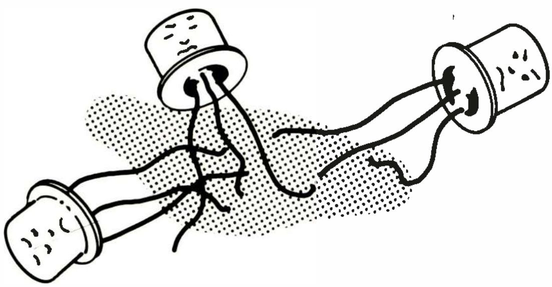


Static Electrical Discharge

A static charge of several thousand volts can easily build up on your body from simply walking about on a nonconductive floor, or moving around in a chair. This is particularly true in low humidity, and when clothing made of wool or certain synthetic fibers, such as nylon, is worn. Ordinarily, this static charge is harmless to people because of its low energy content. However, the charge may be high enough to send a damaging pulse through a semiconductor device when it is touched. Before handling ultra-high frequency transistors, milliwatt NPN germanium alloy transistors, and microwave point-contact diodes, be sure to ground static charges by touching some grounded metal object, such as a metal work bench. In extreme cases, sensitive devices may require handling in a completely shorted condition, and operators may require special grounding facilities.

Leads

Bent and tangled leads, caused by improper handling, may cause slow leaks to develop in glass seals, or may result in broken leads or structural changes that would initiate stress corrosion. Handling of leads should be kept to a minimum, as residues from body oils are likely to cause soldering difficulties.

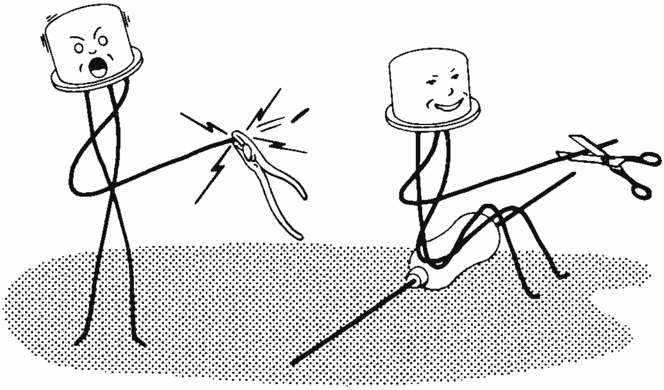


Assembly

Semiconductor devices, as compared to their electron tube counterparts, are quite rugged. This can be attributed to their relatively small mass and solid state structure. But, there is a practical limit to the amount of rough handling they can withstand. They must not be handled as if they were nuts and bolts. It bears repeating that semiconductor devices should be handled as gently as a fine watch or a glass electron tube. This section is of prime interest to those concerned with the assembly or replacement of semiconductor devices in circuit boards or equipment.

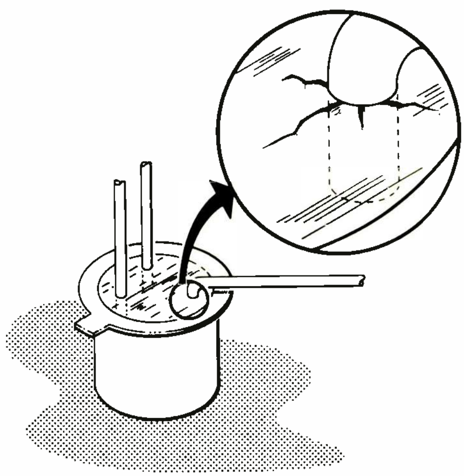
Leads

Cutting of semiconductor device leads can result in a mechanical shock wave which may travel through the lead into the device and degrade the device's electrical properties. Transistors are generally more susceptible to this type of mechanical



damage than diodes. A shearing tool should be used to minimize the possibility of shock damage. Shearing tools of roughly the same size as diagonal pliers are commercially available and should always be used instead of diagonal pliers. When no shearing tool is available, diagonal pliers may be used to nick the lead, which can then be moved back and forth until it breaks.

Nearly all semiconductor devices employ a glass-to-metal seal. The leads of the devices are made with materials such as Kovar and Rodar, to match the thermal expansion of glass. The number of bends to which a lead may be subjected should be kept at a minimum to assure soundness of the seal. Forcing leads into alignment with terminals or posts by twisting or pulling may damage the seal. All bends should be made not closer than 1/16 of an inch (unless otherwise specified) from the surface of the glass seal or, in the case of plastic encapsulated devices, from the body of the device. Closer bends can result in cracking of the seal, with deterioration of the enclosed environment resulting in lower reliability of the device. The cracks may not be apparent even under a 60-power microscope.

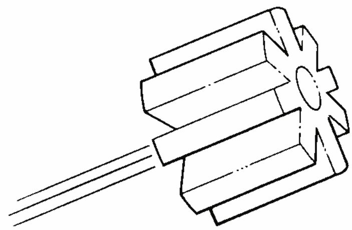


The wirewrapping of semiconductor device leads requires special consideration because of the residual tension and the stress corrosion effects which may develop. This is especially true of gold-plated Kovar or Rodar leaded devices. It is recommended that the appropriate Bell Laboratories Applications Group be consulted before wirewrapping of semiconductor device leads is undertaken.

The use of percussion welding is generally not recommended for semiconductor devices, because of the likelihood of damage due to the high currents generated. Resistance welding may be acceptable, provided care is taken to insure that no destructive transients are introduced into the devices. This is particularly applicable to transistors, which usually have one element connected to the case. Low-power devices, such as ultra-high frequency and NPN alloy transistors, are especially susceptible. The appropriate Bell Laboratories Applications Group should be consulted before introducing welding to semiconductor leads.

Heat Sinks

Heat sinks are classified under two types: (1) the temporary type, which is used in soldering to prevent the introduction of excessive heat to the semiconductor device, and (2) the permanent type, which is installed with the device to improve the dissipation of heat generated within the device itself. The latter can be either a radiator fin-type, which surrounds and is part of the device, or the external type which is mounted to the stud of the device during circuit assembly. The temporary type will be discussed in the section on Soldering.

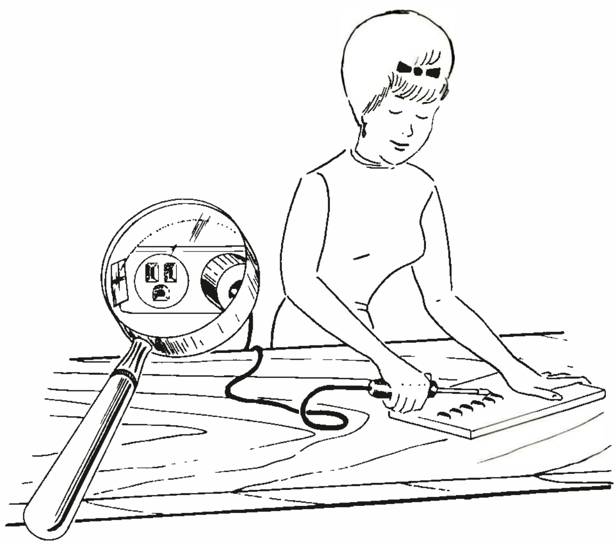


From the electrical standpoint, permanent type heat sinks are used to reduce junction temperature for increased power dissipation capability and reliability. The ability of a semiconductor device to dissipate its rated power is dependent upon (1) internal thermal resistance of the device itself and (2) external factors, such as the size of the heat sink, the thermal resistance between the heat sink and the device, the degree of ambient circulation, and the temperature of the ambient. Device data sheets often contain information concerning these external factors.

The bearing surface upon which a stud-mounted semiconductor device is installed must be flat, clean and free of burrs. This is necessary to insure adequate contact between the heat sink and the device, in order to obtain proper heat flow. Thermal contact is improved with a very thin film of silicone lubricant between the clamped surfaces. Care should be used to insure the torque recommended in the data sheets. When electrical isolation is required between the device and an external heat sink, a thin mica or beryllia washer, coated with silicone lubricant, can be used between the two. Care must be taken not to damage the insulating washer.

Soldering

A soldering iron, properly connected and grounded per Western Electric practices, may still have leakage voltages present on its tip in excess of 1 volt above ground. This voltage can cause damage, particularly to ultra-high frequency transistors which have emitter-to-base breakdown voltages in the range of 1 volt. With such devices, it is desirable to use a working surface isolated from ground. Some soldering guns, even when adequately grounded, produce transient voltages each time the power is turned on or off. These are caused by the inductive reactance in the tool and ground lead. Particularly susceptible to damage from these transients are NPN germanium alloy transistors, ultra-high frequency transistors, and microwave point-contact diodes.



Wave and dip soldering have an advantage over hand soldering because the entire circuit board is maintained at the electrical potential of the molten solder. Thus, destructive transients are not introduced into the devices.

Care must be exercised to insure that solder bath temperatures are uniform, that the duration of immersion is timed properly, and that the devices are not immersed closer than 1/16 of an inch from the glass-to-metal seal. Failure to follow these precautions can result in small changes in electrical characteristics which are not easily detected, and may also cause eventual failure of the device.

The length of time to which a semiconductor device may safely remain in the molten solder is dependent upon the type (whether alloy or diffused), the temperature of the bath, and the distance heat must flow to reach the critical areas of the device.

Temporary heat sinks, such as clamps or pliers, are not required if not specified in the circuit assembly drawings, and if the following recommended procedures are met:

(1) Soldering information which may be included in the device data sheets should be followed.

(2) Higher solder bath temperatures for a shorter time are preferred for better solder-wetting of the leads, and to prevent long heat exposure from affecting the critical areas of the device.

(3) Corrosive fluxes <u>should not be used</u> to facilitate soldering.

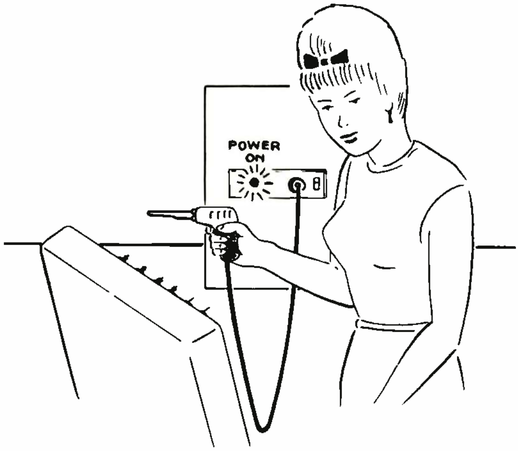
(4) Diffused type devices, except where leads are attached by a soft solder, can withstand higher temperatures for longer periods of time than can alloyed types. As an example, diffused transistors of the 15- or 16-type families can withstand a 575°F bath for a period of 1 minute when immersed to not more than 1/16 of an inch from the seal. The

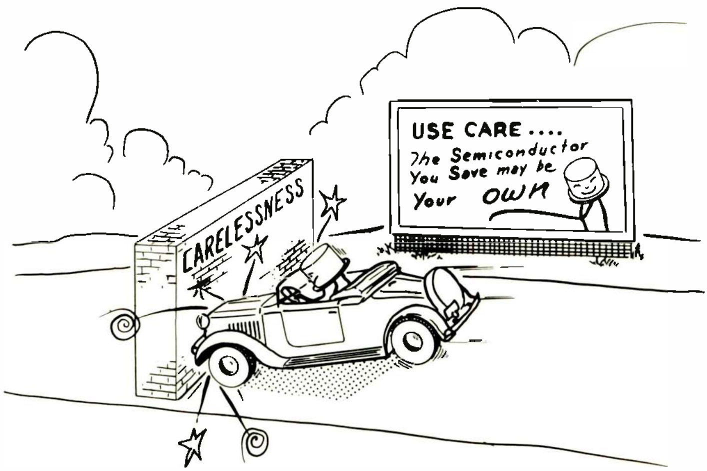
12-type germanium alloy transistor should not remain in the same bath for more than 2 seconds. In hand soldering, somewhat higher iron tip temperatures can be used if only one lead is heated at a time.

Static Charges and Transients

A discussion of possible damage to semiconductor devices by static charges built up on the body, and how this danger can be reduced by grounding, is provided under "Handling" (page 7).

Electric tools, such as screwdrivers and wirewrappers, are frequently used in the assembly of circuit boards containing semiconductor devices. Some devices can be damaged by transients generated by these tools. Air-operated tools are recommended for working on circuits employing ultra-high frequency transistors, milliwatt germanium NPN alloy transistors, and microwave point-contact diodes.



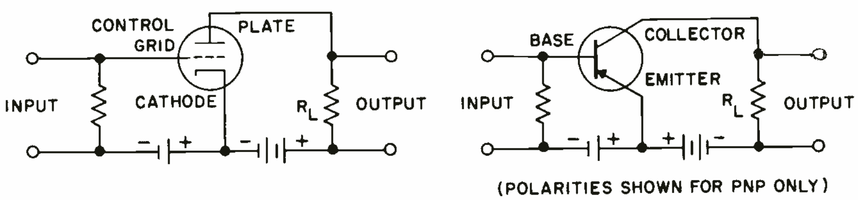


Mechanical Shock

Semiconductor devices are rugged, but they are not indestructible. In a fall from a bench to the floor, a device may receive a shock up to 6000g. By comparison, an automobile striking a solid wall at high speed would generate less than 100g, and yet be completely demolished. Exposure of a transistor or diode to any single jolt or jar probably would not be fatal, but repeated shocks may degrade the electrical performance of the device and shorten its life expectancy. The larger the semiconductor device, the more likely it is to suffer mechanical shock. Microwave point-contact diodes are the most susceptible to shock.

Electrical Testing

The long established procedures for testing electron tube circuits do not directly apply to circuits using semiconductor devices. This is because strict limits are placed on the upper values of applied voltage, current and power for these devices. For example, if breakdown limits are exceeded, an abrupt drop in impedance takes place, which usually results in damage, unless circuits are designed to limit high currents.



TUBE-TRANSISTOR ANALOGY

Circuit Testing

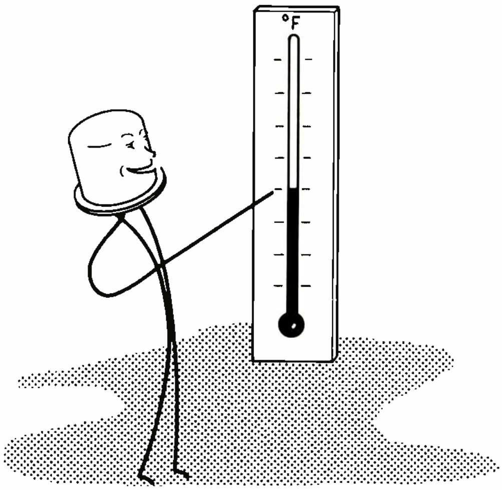
Performance tests on completed circuits must be made in such a way that breakdown voltages and maximum currents will not be exceeded for even very short periods of time. Exceeding maximum limits may cause a sudden and permanent change of operating characteristics, or start a long, slow change which will result in a "sick circuit" and eventual failure.

Transient energy in the form of voltage spikes or current surges may be generated when sudden changes, such as turning a circuit on or off, occur. Similar effects are produced by momentary shorts in live circuits, or connection of a low-impedance probe used in troubleshooting. These undesirable transients may exceed the maximum ratings of semiconductor devices in the circuit and cause damage. Caution should be used to prevent or minimize their occurrence.

It is good practice to turn off the power when connecting or removing circuit boards from a test set. In some cases, it may be necessary to short the test set connector terminals in order to discharge the energy stored in wiring and other capacitance in the test set, even though all power supplies are disconnected.

After all necessary connections are made and test set connector short circuits removed, test voltages can be applied in a particular sequence. The BTL circuit design engineer can provide this sequence.

Consideration must be given to ambient temperature when testing semiconductor circuits, since some device parameters can undergo a 2-to-1 change when the temperature is changed as little as 20° F.



Following the operating tests, all voltages should be returned to zero in a proper sequence. In the special case mentioned above, the test set terminals must be shorted before the circuit under test is removed.

Devices particularly susceptible to test-set transients are microwave point-contact diodes, ultra-high frequency transistors, and germanium NPN alloy transistors. They can be as sensitive to transients as a wrist watch is to the blow of a hammer.

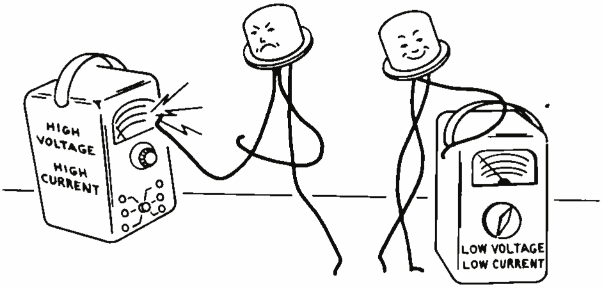
Circuit Troubleshooting

It is normal practice to troubleshoot and repair an assembled circuit which does not operate properly. Many approaches can be used in troubleshooting. It is not within the scope of this book to define methods of locating defects, but rather to offer precautionary suggestions which may apply.

Battery-operated buzzers, often used as continuity testers, are prolific generators of relatively high-energy transients. Destructive transients may be developed, even though the buzzer battery voltage is much lower than the normal voltage applied to the circuit under test. For this reason, buzzers should never be used when troubleshooting circuits containing semiconductor devices, or any other type of circuit connected to a circuit containing transistors or diodes. You wouldn't use 50 kilowatts of energy to test a flashlight bulb.

Wiring continuity tests must be made by use of a selected ohmmeter; that is, one that does not exceed the current or voltage ratings of the devices in the circuits being tested.

It is good practice to remove all power to a circuit when an ohmmeter is used.



Transient voltages can result in connecting or disconnecting an ohmmeter across a transformer winding or other inductive element. Damage to a semiconductor device in an adjacent circuit may result.

Troubleshooting by bias measurement or signal tracing is, of necessity, performed with power on. Connecting or disconnecting test probes may cause damage to a semiconductor device by transients. Probe input capacitances may become charged at one point in the live circuit and then, at the next point of application, discharge destructive energy through a semiconductor device. The practice of shorting the probes between readings, or using a resistance terminated probe, will eliminate this problem.

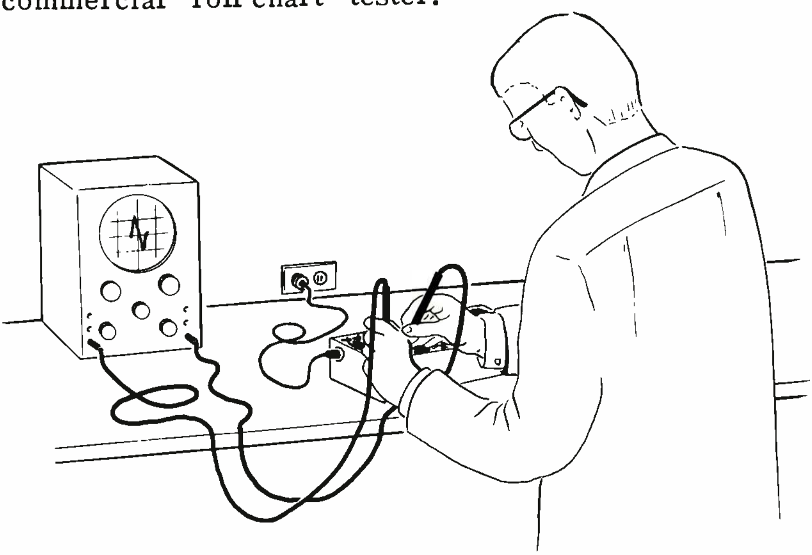
Improper grounding may cause leakage currents from ac line-operated test equipment, which will result in damage to the semiconductor devices in the circuit under test.

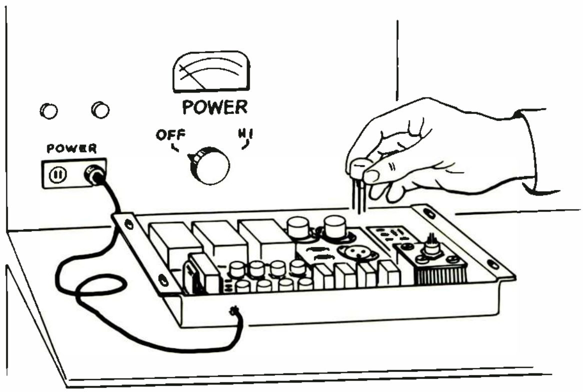
High-voltage static charges which build up on clothing, particularly in low-humidity environments, may be injurious to some lower power semiconductor devices if discharged through them. This can be easily avoided by touching a grounded metal object before handling a semiconductor circuit.

Device Testing

Transistors and diodes can be tested as independent units, in the same manner as electron tubes are usually checked, or while wired into a circuit. Special precautions should be followed to avoid exceeding the device ratings, as described in the sections on Circuit Testing and Troubleshooting.

Available commercially are several general purpose transistor and diode testers which, like commercial tube testers, check a few of the fundamental parameters. A check of the dc leakage currents, breakdown voltages, and current gain (of transistors) normally will tell if the device has opened, shorted or degraded appreciably since the time it was thoroughly tested by the device manufacturer. An ohmmeter, specifically selected to have voltages and currents within the maximum ratings of the device, can be used to indicate opens or shorts. An Allentown test set, SID 320159, has been designed to test many parameters that normally cannot be checked on inexpensive commercial testers. The Hickock Model 870 is an example of a commercial "roll chart" tester.





A common method of making a quick check of a semiconductor device believed to be defective is to insert it into a circuit known to be in working order. All power to the circuit should be removed before inserting the "doubtful" device, to reduce transients. In some circuits it may also be necessary to discharge circuit capacitances, in order to eliminate harmful transients before inserting devices. A device known to be good should never be placed in an inoperative circuit, since a defective circuit component may cause damage to the good device.

When testing a semiconductor device wired into a circuit, refer to the precautions listed for circuit testing and troubleshooting. There are several commercial "in-circuit" testers available, which can make limited checks without removing a device soldered into the circuit. An example is the Hickock Model 890 In-Circuit Beta Tester.

When using commercial testers, be sure to follow the manufacturer's instructions carefully.

Some semiconductor device parameters are extremely dependent upon temperature or bias conditions. Leakage currents may double when the temperature is increased about 20°F. Transistor current gain (common emitter connection) may vary more than 2 to 1, as the emitter current is varied within the ratings of the device. Consult the device data sheets for proper temperature and bias conditions when testing for the manufacturer's specification limits.

Typical Ohmmeter Data

DESCRIPTION	MAX SHORT CIRCUIT CURRENT (Low Ohm Scale)	MAX OPEN CIRCUIT VOLTAGE (High Ohm Scale)	MAX POWER TO DEVICE UNDER TEST
Triplett Model 630-L			
X1 & X10	12 MA	0.14 Volts*	0.42 MW
X1K & X100K	0.34 MA	34 Volts	0.68 MW
Hewlett-Packard Model 412A	10 MA	1 Volt	2.5 MW
Simpson Model 260	75 MA	7.5 Volts	30 MW
Triplett Model 310	80 MA	16 Volts	30 MW
RCA Voltohmyst Model WV-97A	150 MA	1.5 Volts	60 MW
Weston Analyzer Model 980 Mark II	60 MA	4 Volts	90 MW
Triplett Model 630	350 MA	34 Volts	112 MW

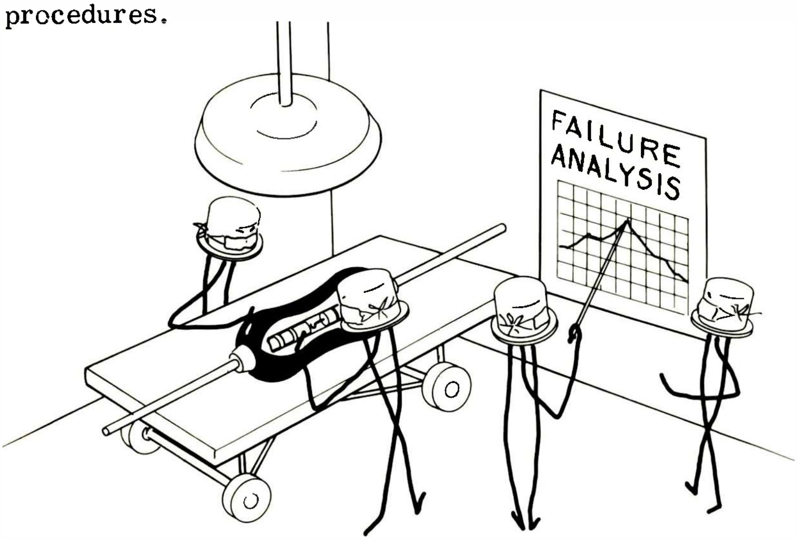
*X1 & X10 Only

Failure Analysis

Failures are classified into four general categories:

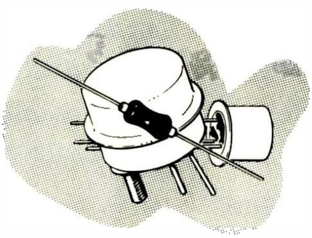
(1) Design	— Inadequate device design for the ratings published.
(2) Manufacture	— Improper device manufacturing techniques and workmanship.
(3) Application	— Incompatability between device and circuit.
(4) Equipment Assembly	— Improper techniques in handling and assembling devices into circuits and systems.

It is important to recognize the failure symptoms and to establish the cause of failure. Through thorough analysis, the cause of many failures can be determined and corrective action taken in the shortest possible time. Experience has shown that most failures result from mishandling and improper testing procedures.



Transistors and Diodes

If there is a Failure Analysis Engineer at your location, contact him for aid in determining the causes of failure. Otherwise, contact the Device Product Engineer at Allentown or Laureldale.



Appendix A

Western Electric Semiconductor Codes

TRANSISTORS

8 B	NPN	MW Ge Alloy
9 A	PNP	High Power Ge Alloy
9 B, D	PNP	Med Power Ge Alloy
12 A-N	PNP	MW Ge Alloy
15 A-D	PNP	MW Ge Diffused *
16 A-E	NPN	MW Si Diffused
16 D	NPN	MW Si Epitaxial
17 A	PNP	MW Ge Alloy
18 A-B	NPN	MW Si Diffused
19 A	NPN	MW Si Diffused
20 B-G	NPN	Med Power Si Diffused
20 D	NPN	Med Power Si Epitaxial
21 A-C	NPN	MW Si Diffused
22 A	NPN	MW Si Diffused
23 A	NPN	Med Power Si Diffused
24 A	NPN	Med Power Si Diffused
24 B	NPN	Med Power Si Epitaxial
25 A	NPN	MW Si Diffused
26 A, B	PNP	MW Ge Diffused *
28 A	PNP	MW Ge Alloy
29 A	NPN	MW Si Epitaxial
30 A	NPN	MW Ge Alloy
31 A	PNP	MW Ge Alloy
32 A	NPN	Med Power Ge Alloy
33 A	NPN	MW Si Diffused
35 A	PNP	MW Ge Alloy

MW (Milliwatt) — under 1/2 watt
Medium Power — 1/2 - 2 watts
High Power — over 2 watts
*Ultra-High Frequency Types

DIODES

400 A-J	MW Ge Point Contact
401 A	MW Ge Point Contact
403 A-C	MW Si Point Contact
404 A-D	MW Si Point Contact
405 B-D	Microwave Si Point Contact
406 A, B	Microwave Si Point Contact
407 A-F	MW Ge Point Contact
408 A-415 A	MW Ge Point Contact
416 C	Microwave Si Point Contact
417 B	MW Si Alloy Junction
418 A	MW Si Point Contact
420 A-T	MW Si Alloy Junction
421 A-E	MW Si Alloy Junction
422 B	MW Si Alloy Junction
424 A	MW Ge Point Contact
425 A-N	High Power Si Diffused Junction
426 A-Y, AA-AH	Med Power Si Diffused Junction
427 A	Microwave Ge Gold Bonded

MW (Milliwatt) — under 1/2 watt
Medium Power — 1/2 - 2 watts
High Power — over 2 watts

Western Electric Semiconductor Codes

DIODES

431 A	Microwave Ge Point Contact
432 A	MW Si Diffused Junction
433 A, B	MW Si Alloy Junction
434 A, B	MW Si Diffused Junction
435 A-H	MW Si Diffused Junction
436 A	MW Si Diffused Junction
437 A, B	MW Si Diffused Junction
438 A	MW Si Diffused Junction
439 A	MW Si Diffused Junction
440 A	Med Power Si Diffused Junction
441 A-J	MW Ge Point Contact
442 A	MW Si Diffused Junction
444 A	MW Ge Point Contact
445 A	MW Ge Gold Bonded
446 A-F	MW Si Diffused Junction
447 A	MW Si Diffused Junction
448 A	MW Si Alloy Junction
449 A	MW Si Diffused Junction

MW (Milliwatt) — under 1/2 watt
Medium Power — 1/2 - 2 watts
High Power — over 2 watts

Appendix B

Semiconductor Device Classification

TRANSISTORS

MW Ge Alloy	PNP	12 A-N, 17 A, 28 A, 31 A, 35 A
Med Power Ge Alloy	PNP	9 B, D
High Power Ge Alloy	PNP	9 A
MW Ge Alloy	NPN	8 B, 30 A
Med Power Ge Alloy	NPN	32 A
MW Ge Diffused	PNP	15 A-D; 26 A, B
MW Si Diffused	NPN	16 A-E; 18 A, B; 19A; 21 A-C; 22 A, 25 A; 33 A
Med Power Si Diffused	NPN	20 B-G, 23 A, 24 A
Si Diffused Epitaxial	NPN	16 D, 20 D, 24 B, 29 A
Ultra-High Frequency Type	PNP	15 A-D; 26 A, B

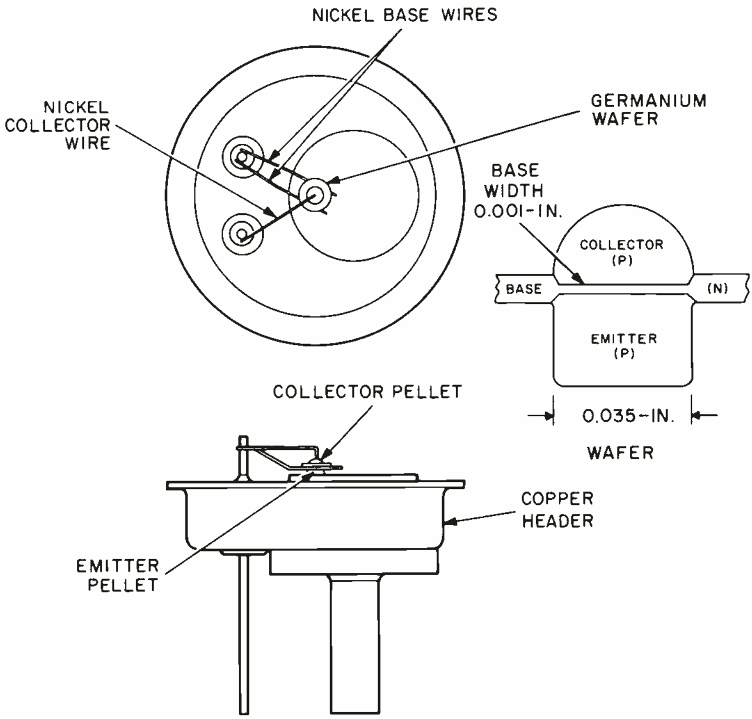
DIODES

Point Contact	400 A-J, 401 A, 403 A-C, 404 A-D, 407 A-F, 408 A-415 A, 418 B, 424 A, 441 A-J, 444 A
Microwave Point Contact	405 B-D; 406 A, B; 416 C; 431 A
Si Alloy Junction	417 B, 420 A-T, 421 A-E, 442 B, 433 A-B, 448 A
MW Si Diffused Junction	432 A; 434 A, B; 435 A-H; 436 A; 437 A, B; 438 A; 439 A, 440 A, 442 A, 446 A-F, 447 A, 449 A
Med Power Si Diffused Junction	426 A-Y, 426 AA-AH, 440 A
High Power Si Diffused Junction	425 A-N
MW Ge Gold Bonded	445 A
Microwave Ge Gold Bonded	427 A

Appendix C

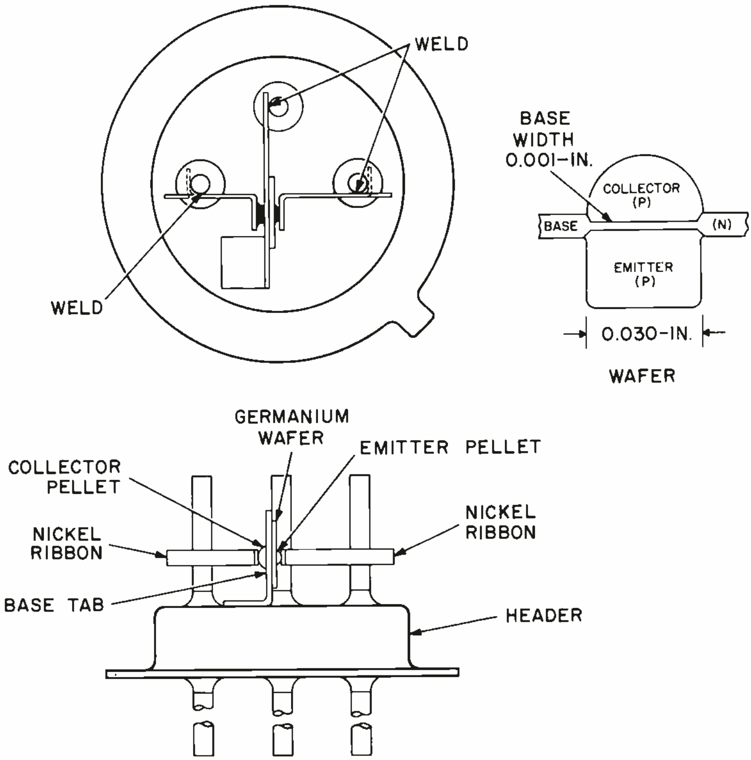
Typical Transistor and Diode Construction

The illustrations on the following pages show the internal construction of some basic transistors and diodes manufactured by the Western Electric Company. Note the minute dimensions of the active regions. Consult the data sheets for electrical ratings. (All dimensions shown on illustrations are approximate.)



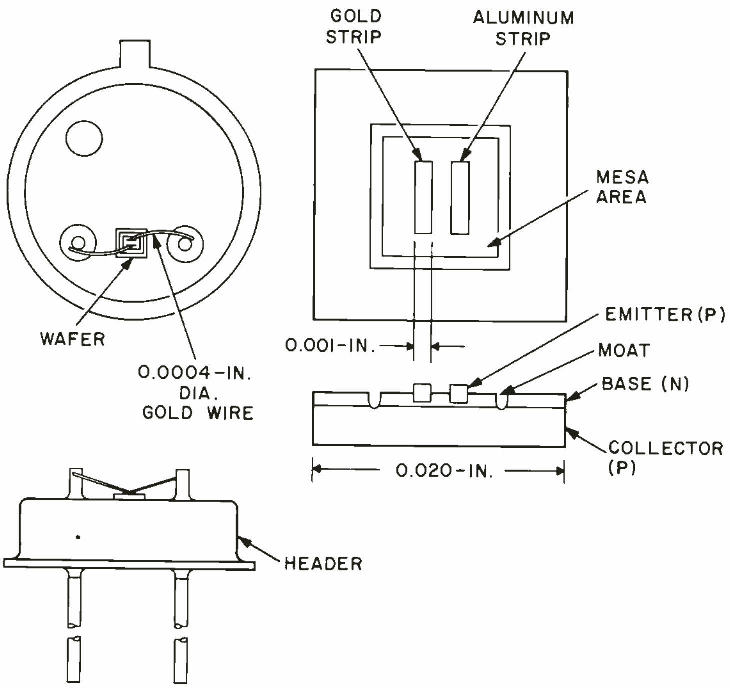
PNP MEDIUM POWER GERMANIUM ALLOY TRANSISTOR - 9 B, D TYPE

The 9 B, D transistor is suitable for use in medium-power, low-distortion amplifier, medium-speed switching and core-driving applications.



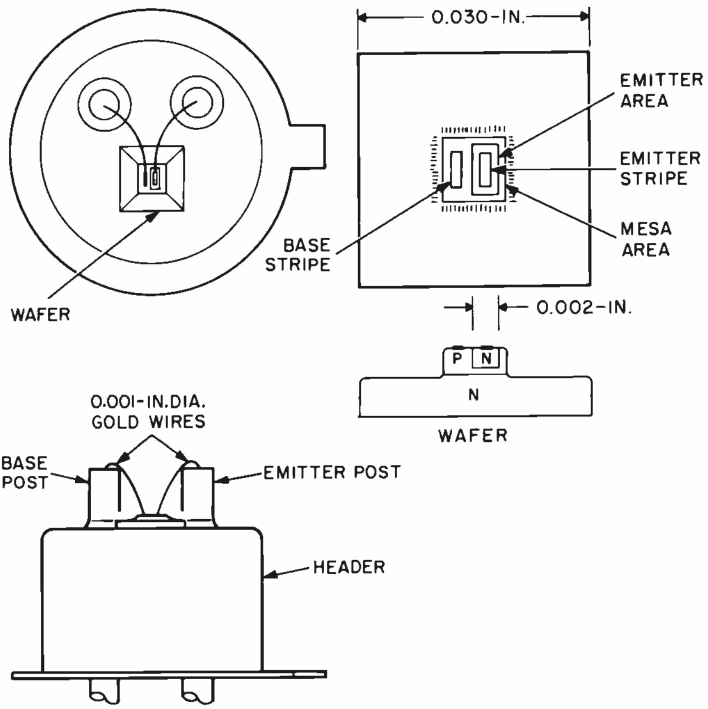
MILLIWATT GERMANIUM ALLOY
PNP TRANSISTOR - 12 TYPE

The 12-type transistor is a 1/4-watt, general purpose, PNP germanium alloy junction transistor. It is used principally as a medium-frequency amplifier or medium-speed switch.



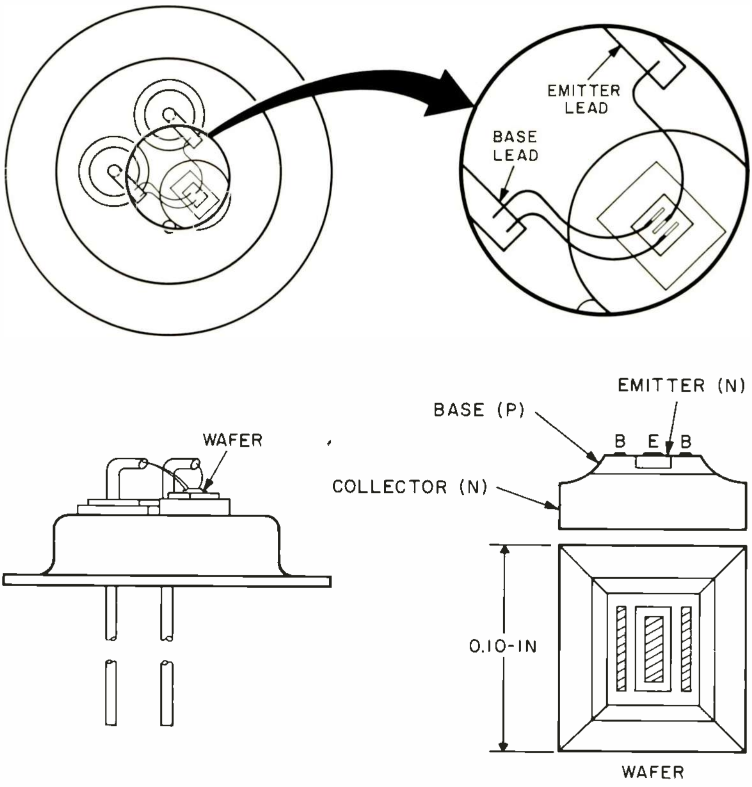
MILLIWATT GERMANIUM DIFFUSED BASE
(ULTRA-HIGH FREQUENCY)
PNP TRANSISTOR - 15 TYPE

The 15-type transistor is used principally as a VHF amplifier or very fast switch.



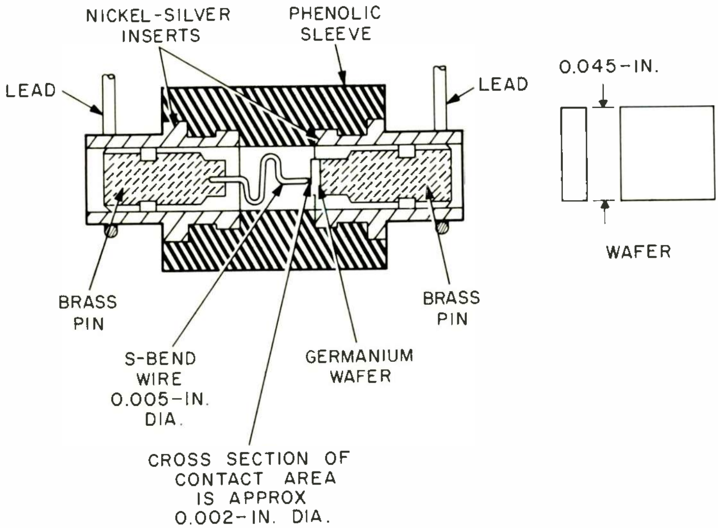
NPN MILLIWATT SILICON DIFFUSED
TRANSISTOR - 16 TYPE

The 16-type transistor is used principally as a general purpose, radio-frequency, small-signal amplifier or high-speed switch.



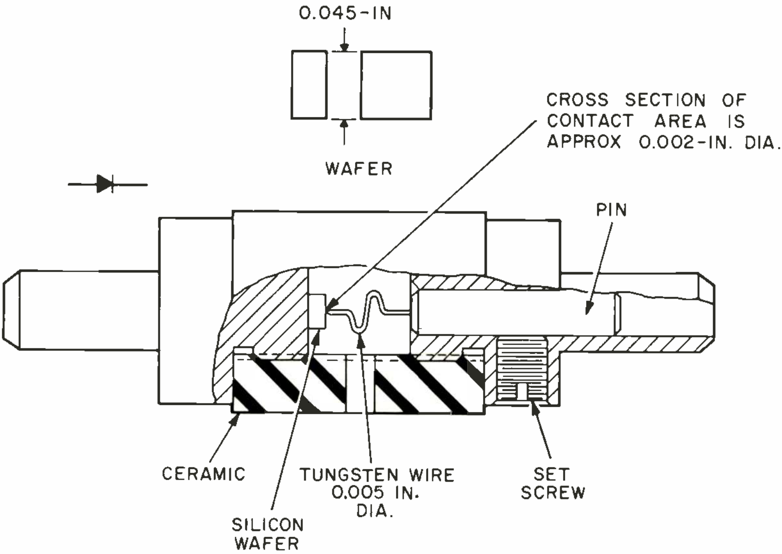
NPN MEDIUM POWER DIFFUSED SILICON
TRANSISTOR - 20 TYPE

The 20-type transistor is used principally as a medium-power amplifier or high-current switch.



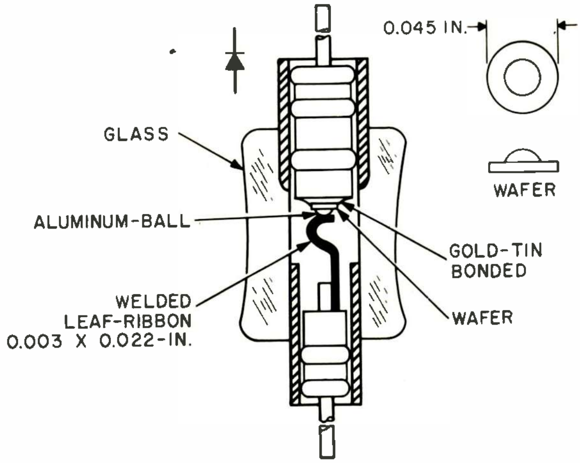
POINT-CONTACT DIODE - 400 TYPE

The 400-type is a general purpose diode used principally as a detector or low-power rectifier. The 441-type diodes are electrically identical to the 400-type, except that they have axial leads.



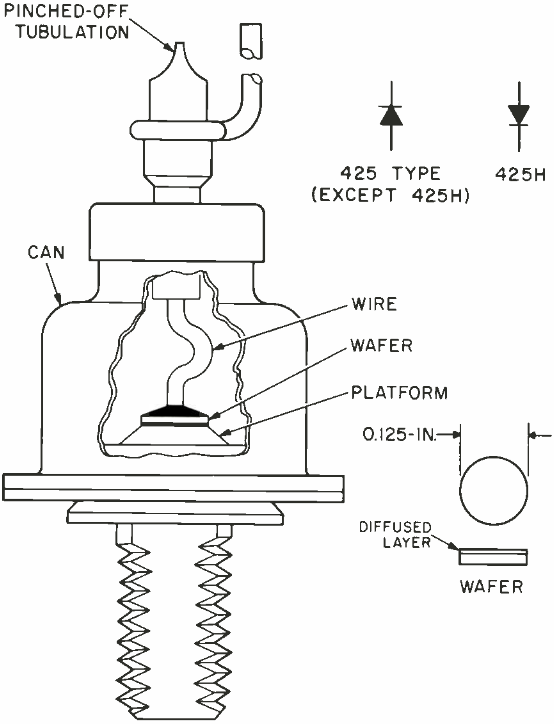
MICROWAVE POINT-CONTACT DIODE - 405C TYPE

The 405-type diode is principally used as a detector of microwave energy.



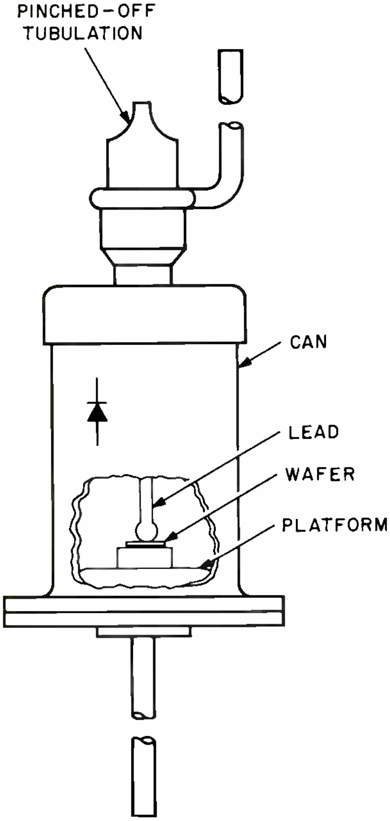
SILICON ALLOY JUNCTION DIODE - 420 TYPE

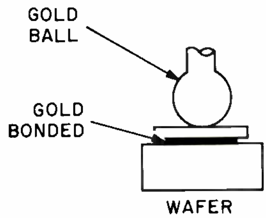
The 420-type diode is used principally as a low-power rectifier with extremely low leakage currents, a voltage reference source or voltage regulator.



HIGH POWER SILICON DIFFUSED JUNCTION DIODE - 425 TYPE

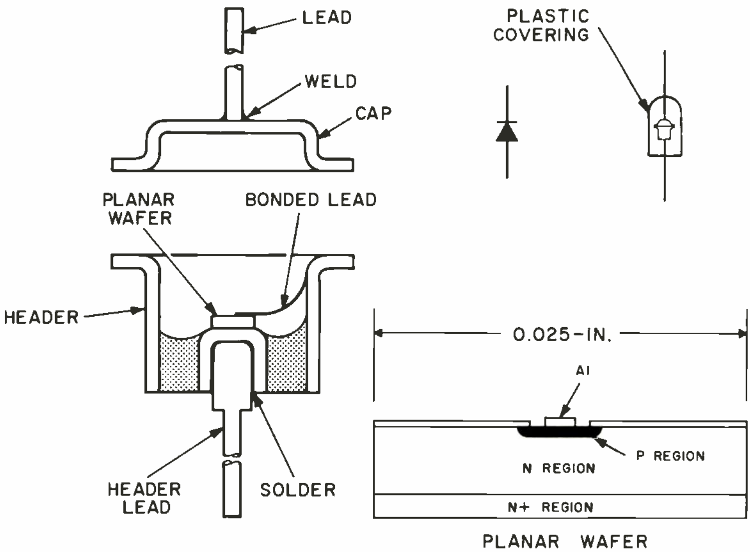
The 425-type diode is used principally as a high-power rectifier or voltage regulator, capable of dissipating 10 watts when properly heat-sinked.





MEDIUM POWER SILICON DIFFUSED JUNCTION
DIODE - 426 TYPE

The 426-type diode is used principally as a medium-power rectifier, or voltage regulator.



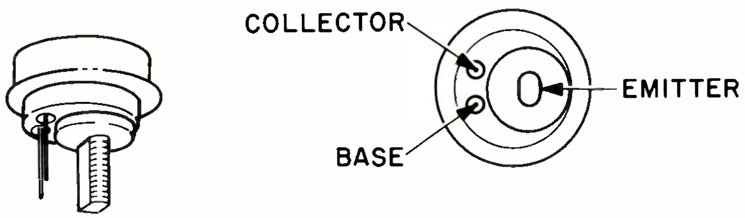
MILLIWATT SILICON DIFFUSED JUNCTION
DIODE - 432 TYPE

The 432-type diode is used principally in low-level,high-speed logic systems.

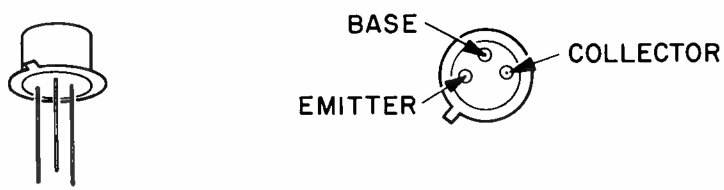
Appendix D

Basing Information

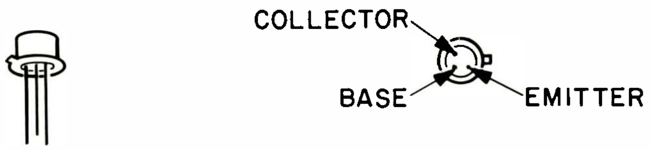
TRANSISTORS



9 TYPE



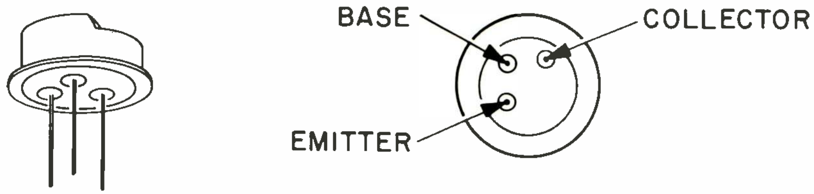
12 AND 15 TYPE



16 AND 21 TYPE

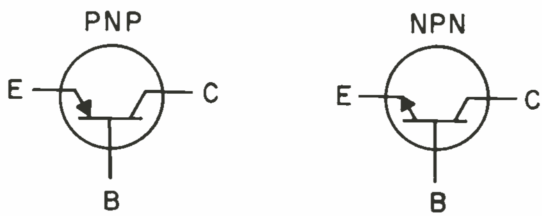
Transistors are shown approximately full size. For further information, see data sheet.

TRANSISTORS
(Continued)



20 TYPE

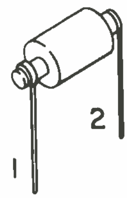
Transistors are shown approximately full size. For further information, see data sheet.



SCHEMATIC REPRESENTATION

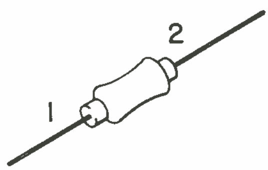
DIODES

400 TYPE

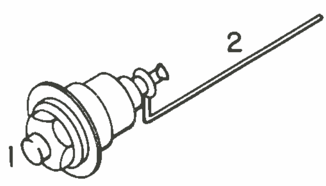


405 TYPE

420 TYPE



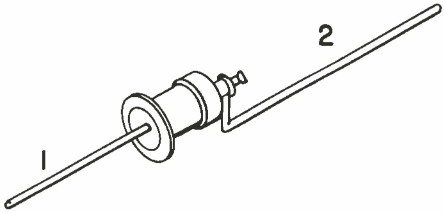
425 TYPE



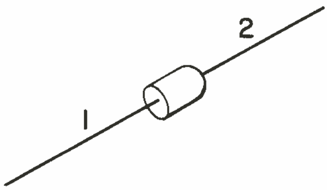
Diodes are shown approximately full size except leads. For further information, see data sheet.

DIODES
(Continued)

426 TYPE

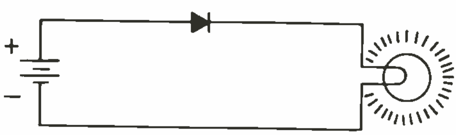


432 TYPE

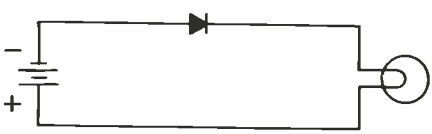


SCHEMATIC

Diodes are shown approximately full size except leads. For further information, see data sheet.



FORWARD

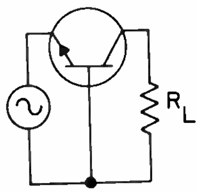
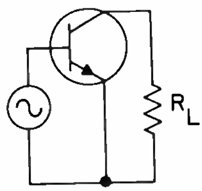
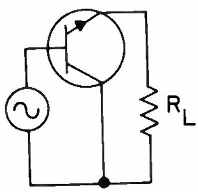


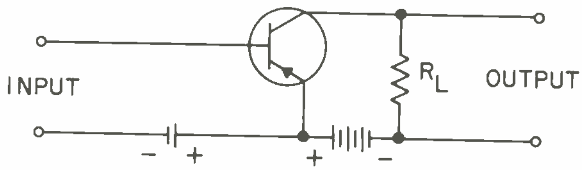
REVERSE

DIODE BIAS CIRCUITS

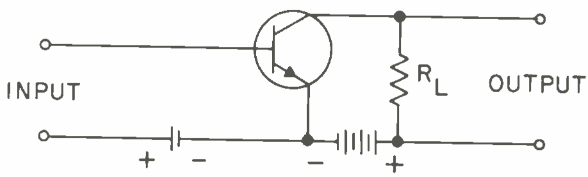
Appendix E

Transistor Circuit Configurations

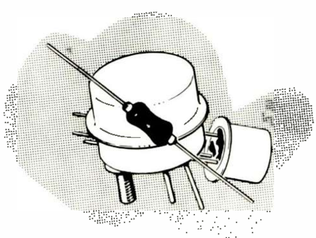
CIRCUIT	CHARACTERISTICS
 COMMON BASE (CB)	Lowest input impedance Highest output impedance Low current gain (<1) High voltage gain Moderate power gain
 COMMON EMITTER (CE)	Moderate input impedance Moderate output impedance High current gain High voltage gain Highest power gain
 COMMON COLLECTOR (CC) (EMITTER FOLLOWER)	Highest input impedance Lowest output impedance High current gain Unity voltage gain Lowest power gain



COMMON EMITTER BIAS CIRCUIT - PNP



COMMON EMITTER BIAS CIRCUIT - NPN



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