Packaging, Handling, and Mounting

RCA power transistors are supplied in both hermetic packages (metal and/or ceramic) and plastic packages.The photographs in Fig. 32 show the packages that are used for these devices.

The volume and area of the package are important in determining the power dissipation capability of a power transistor; chip mounting and encapsulation are also factors. The maximum allowable power dissipation in the device is limited by its junction temperature, which depends upon the ability of the thermal circuit to conduct heat away from the chip. The predominant mode of heat transfer is conduction through the silicon chip and through the case; the effects of internal free convection and radiation and lead conduction are small and may be neglected. The **thermal resistance** from pellet to case depends upon the pellet dimensions and the package configuration.

When the device is operated in free air, without a heat sink, the steady-state thermal circuit is defined by the junction-to-free-air thermal resistance. Thermal considerations require that there be a free flow of air around the device and that the power dissipation be maintained below that which would cause the junction temperature to rise above the maximum rating. When the device is mounted on a heat sink, however, care must be taken to assure that all portions of the thermal circuit are considered.

Fig. 33 shows the thermal equivalent circuit for a heat-sink-mounted device. This figure shows that the junction-to-ambient thermal circuit includes three series thermal-resistance components, i.e., junction-to-case, $R_{\theta JC}$; case-to-heat-sink, $R_{\theta CS}$; and heat-sink-to-ambient, $R_{\theta SA}$. The junction-to-case thermal resistance of the various device types is given in the individual technical bulletins on specific types. The heat-sink-to-ambient thermal resistance can be determined from the technical data provided by the heat-sink manufacturer, or from published heat-sink nomographs. The case-to-heat-sink thermal resistance depends on several factors, which include the condition of the heat-sink surface, the type of material and thickness of the insulator, the type of thermal compound, the mounting torque, and the diameter of the mounting hole in the heat-sink.

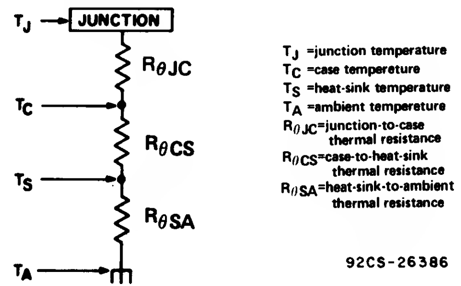


Fig. 33 - Thermal equivalent circuit for a solid-state device mounted on a heat sink.

HERMETIC PACKAGES

The selection of a particular method for mounting and connection of power transistors in equipment depends on the type of package involved; on the equipment available for mounting and interconnection; on the connection method used (soldered, welded, crimped, etc.); on the size, shape, and weight of the equipment package; on the degree of reliability and maintainability (ease of replacement) required; and, of course, on cost considerations.

In the following discussion, the information given applies to the package rather than the device unless otherwise specified. In other words, the discussion of handling and mounting of the TO-5 package is understood to cover mounting of the transistors.

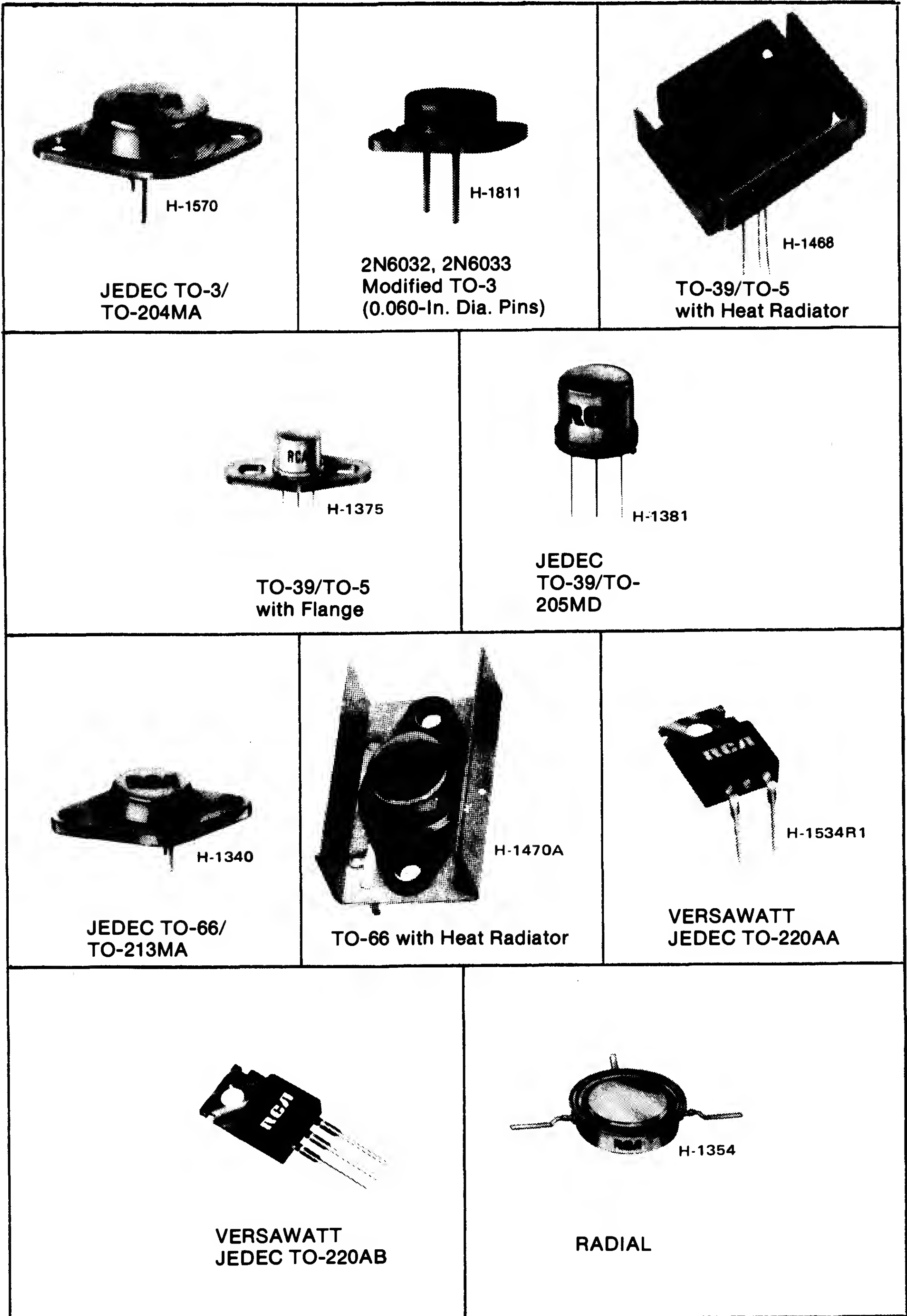


Fig. 32 - RCA power transistor packages.

Packages with Flexible Leads

Some power transistor packages have flexible leads; these leads are usually soldered to the circuit elements. In all soldering operations, some slack or an expansion elbow should be provided in each lead to prevent excessive tension on the leads. Excessive heat should be avoided during the soldering operation to prevent possible damage to the devices. Some of the heat can be absorbed if the flexible lead of the device is grasped between the case and the soldering point with a pair of long-nosed pliers.

Although flexible leads can be bent into almost any configuration to fit any mounting requirement, they are not intended to take repeated bending. In particular, repeated bending at the point at which the lead enters the case should be avoided. The leads are not especially brittle at this point, but the sharp edge of the case produces an excessively small radius of curvature in a bend made at the case. Repeated bending with a small radius of curvature at a fixed point will cause fatigue and breakage in almost any material. For this reason, right-angle bends should be made at least 0.020 inch from the case. This practice will avoid sharp bends and maintain sufficient electrical isolation between lead connections and header. A safe bend can be assured if the lead is gripped with pliers close to the case and then bent the requisite amount with the fingers, as shown in Fig. 34. When the leads of a

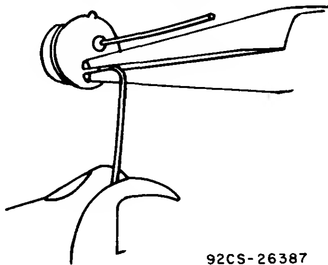


Fig. 34 - Method of bending leads on a flexible-lead package.

number of devices are to be bent into a particular configuration, it may be advantageous to use a lead-bending fixture to assure that all leads are bent to the same shape and in the correct place the first time, so that there is no need for the repeated bending.

Transistors should be mounted on heat sinks when they are operated at high power levels. An efficient heat-sink method for transistors in JEDEC TO-39 packages is to provide intimate contact between the heat sink and at least one-half of the base of the device opposite the leads. TO-39 packages can be mounted to the heat sink mechanically, with glue or an epoxy adhesive. Transistors should not be soldered to the heat sink.

Packages with Mounting Flanges

The mounting flanges of packages such as the JEDEC-type TO-3 or TO-66 often serve as the collector terminal. In such cases, it is essential that the mounting flange be securely fastened to the heat sink, which may be the equipment chassis. Under no circumstances, however, should the mounting flange be soldered directly to the heat sink or chassis because the heat of the soldering operation could permanently damage the device.

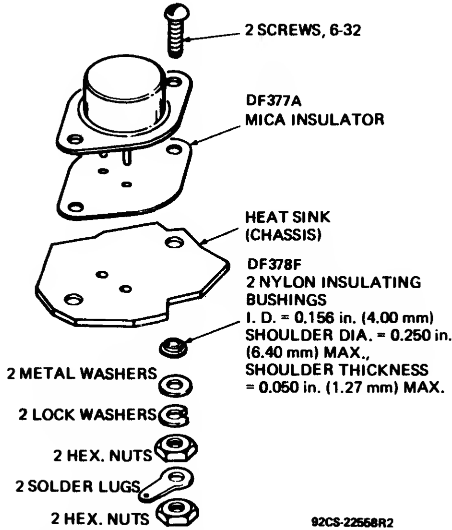
Such devices can be installed in commercially available sockets. Electrical connections may also be made by soldering directly to the terminal pins. Such connections may be soldered to the pins close to the pin seats provided care is taken to conduct excessive heat away from the seals; otherwise, the heat of the soldering operation could crack the pin seals and damage the device.

During operation, the mounting-flange temperature is higher than the ambient temperature by an amount which depends on the heat sink used. The heat sink must provide sufficient thermal conduction to the ambient environment to assure that the temperature of the device mounting flange does not rise above the rated value. The heat sink or chassis may be connected to either the positive or negative supply.

Fig. 35 shows methods of mounting flanged packages. Zinc-oxide-filled silicone grease should be used between the device and the heat sink to eliminate surface voids and to help conduct heat across the interface. Although glue or epoxy adhesive provides good bonding, a significant amount of thermal resistance may exist at the interface. To minimize this interface resistance, an adhesive material with low thermal resistance, such as Hysol* Epoxy Patch Material No. 6C or Wakefield* Delta Bond No. 152, or their equivalent, should be used.

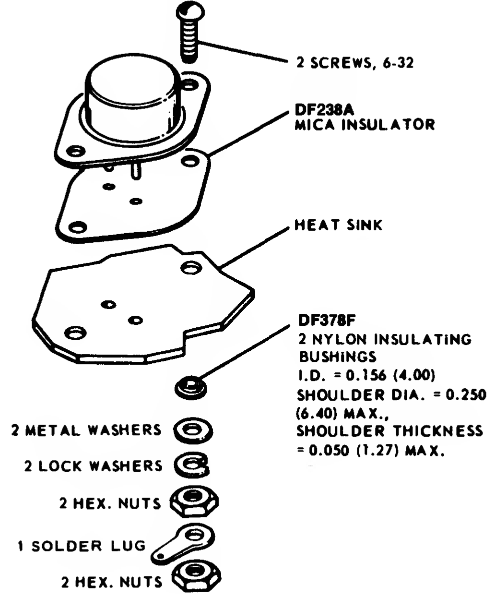
*Products of Hysol Corporation, Olean, New York, and Wakefield Engineering, Inc., Wakefield, Massachusetts, respectively.

TO-204MA/TO-3

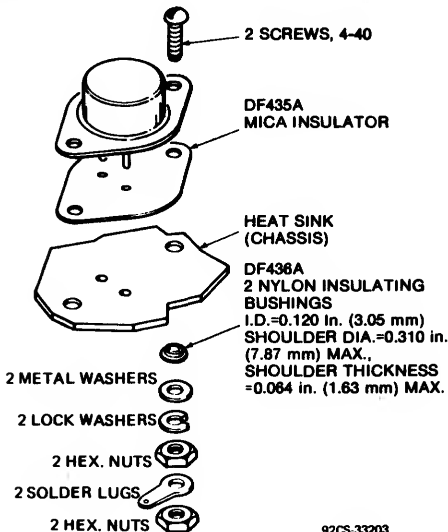


NOTE: MAXIMUM TORQUE APPLIED TO MOUNTING FLANGE IS 12 in.-lbs. (0.14 kgf m).

MODIFIED TO-3

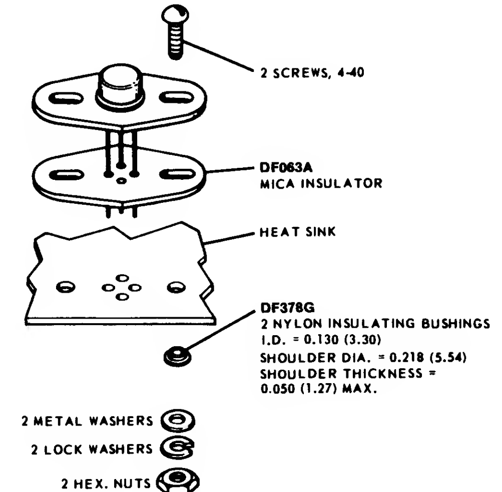


TO-204MA/TO-3 With 200-mil diameter pin isolation



NOTE: MAXIMUM TORQUE APPLIED TO MOUNTING FLANGE IS 8 in.-lbs. (0.09 kgf m).

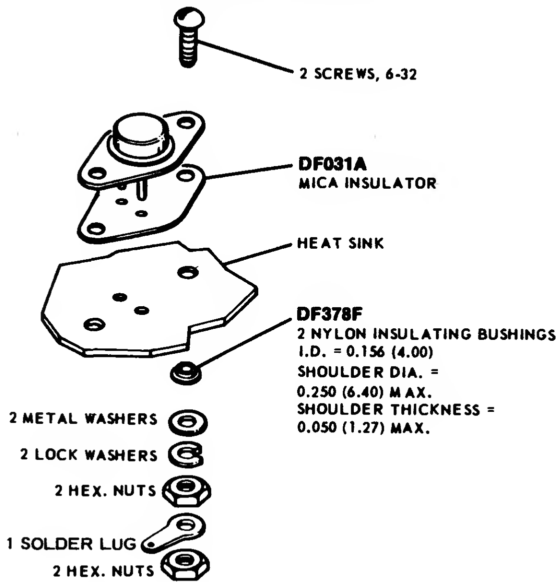
TO-205MA/TO-5 TO-205MD/TO-39 With Flange



Note: Maximum torque applied to mounting flange is 8 in.-lb. (0.09 kgfm).

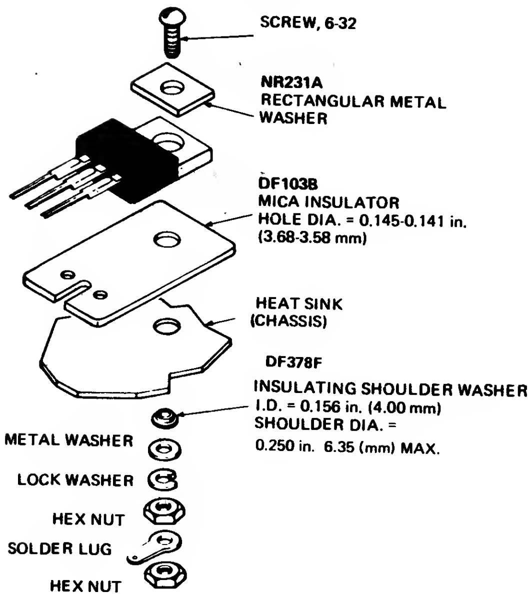
Fig. 35 - Methods of mounting flanged-packaged types.

TO-213MA/TO-66



Note: Maximum torque applied to mounting flange is 12 in.-lb. (0.14 kgfm)

TO-220AB



NOTE: MAXIMUM TORQUE APPLIED TO MOUNTING FLANGE IS 8 in.-lb. (0.09 kgf-m)

TO-220AA

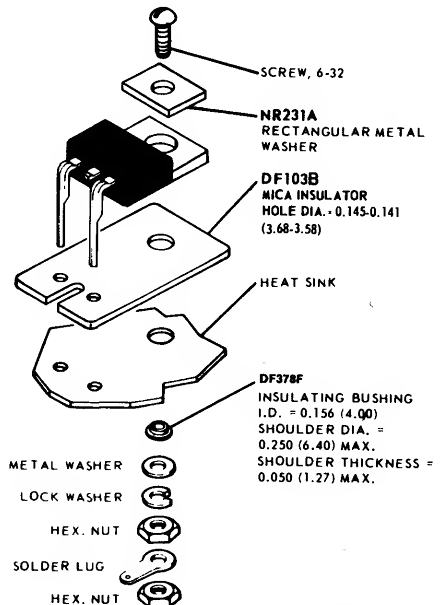


Fig. 35 - Methods of mounting flanged-packaged types (cont'd).

MOLDED-PLASTIC PACKAGES

RCA power transistors in molded-silicone-plastic packages are available in a wide range of power-dissipation ratings and a variety of package configurations.

The most common type of molded-plastic package is the RCA VERSAWATT (JEDEC TO-220) package for medium-power applications, specifically designed for ease of use in many applications. Each basic type offers several different lead options, and the user can select the configuration best suited to his particular application.

Fig. 36 shows the options currently available for devices in RCA VERSAWATT packages.

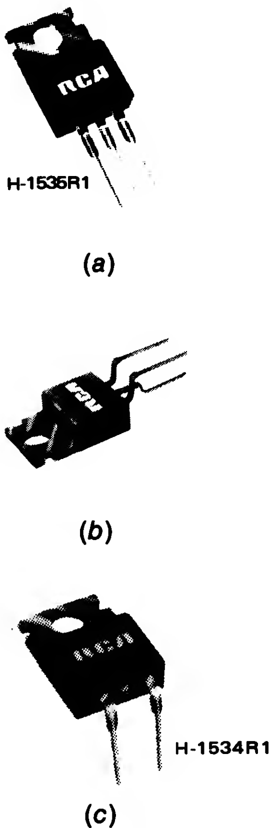


Fig. 36 - RCA VERSAWATT transistor packages: (a) JEDEC No. TO-220AB in-line lead version; (b) configuration designed for mounting on printed-circuit boards; (c) JEDEC No. TO-220AA version, which may be used as replacement for JEDEC No. TO-66 metal packages in JEDEC TO-66 sockets.

The JEDEC Type TO-220AB in-line-lead version, shown in Fig. 36(a), represents the basic style. This configuration features leads that can be formed to meet a variety of specific mounting requirements. Figs. 36(b) and 37 show a package configuration that allows a VERSAWATT package to be mounted on a printed-circuit board with a 0.100-inch grid and a minimum lead spacing of 0.200 inch. Fig. 36(c) shows a JEDEC Type TO-220AA version of the VERSAWATT package. The dimensions of this type of transistor package are such that it can replace the JEDEC TO-66 transistor package in a commercial socket or printed-circuit board without retooling. The TO-220AA VERSAWATT package can also be obtained with an integral heat sink.

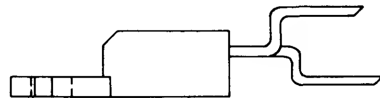


Fig. 37 - Method of configuring VERSAWATT transistor leads for connection to printed-circuit boards and to provide relief in mounting arrangements in which forces are imposed on the package leads.

Lead-Forming Techniques

The RCA VERSAWATT plastic package is both rugged and versatile within the confines of commonly accepted standards for such devices. Although these versatile packages lend themselves to numerous arrangements, provision of a wide variety of lead configurations to conform to the specific requirements of many different mounting arrangements is highly impractical. However, the leads of the VERSAWATT in-line package can be formed to a custom shape, provided that they are not indiscriminately twisted or bent. Although these leads can be formed, they are not flexible in the general sense, nor are they sufficiently rigid for unrestrained wire wrapping.

Before an attempt is made to form the leads of an in-line package to meet the requirements of a specific application, the desired lead configuration should be determined, and a lead-bending fixture should be designed and constructed. The use of a properly designed

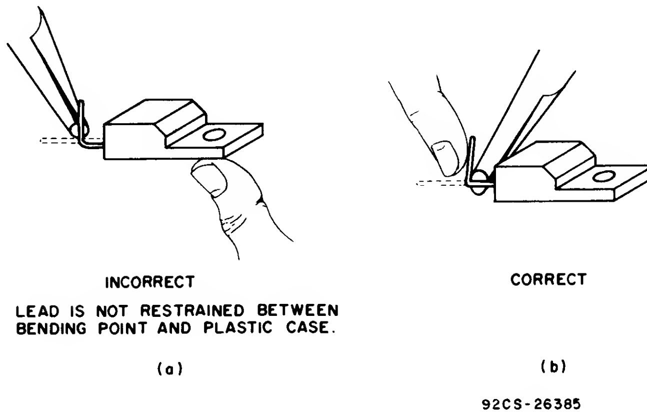


Fig. 38 - Use of long-nosed pliers for lead bending: (a) incorrect method; (b) correct method.

fixture for this operation eliminates the need for repeated lead bending. When the use of a special bending fixture is not practical, a pair of long-nosed pliers may be used. The pliers should hold the lead firmly between the bending point and the case, but should not touch the case. Fig. 38 illustrates the use of long-nosed pliers for lead bending. Fig. 38(a) shows a technique that should be avoided; Fig. 38(b) shows the correct method.

When the leads of an in-line plastic package are to be formed, whether by use of long-nosed pliers or a special bending fixture, the following precautions must be observed to avoid internal damage to the device:

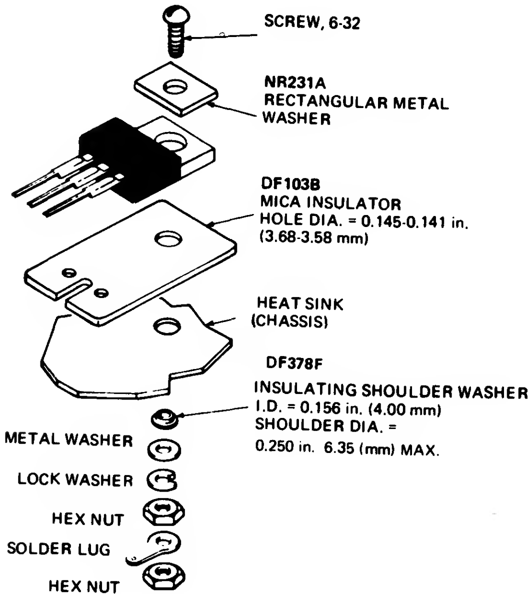
1. Restrain the lead between the bending point and the plastic case to prevent relative movement between the lead and the case.
2. When the bend is made in the plane of the lead (spreading), bend only the narrow part of the lead.
3. When the bend is made in the plane perpendicular to that of the leads, make the bend at least ⅛ inch from the plastic case.
4. Do not use a lead-bend radius of less than 1/16 inch.
5. Avoid repeated bending of leads.

The leads of the TO-220AB VERSAWATT in-line package are not designed to withstand excessive axial pull. Force in this direction greater than 4 pounds may result in permanent damage to the device. If the mounting arrangement tends to impose axial stress on the leads, some method of strain relief should be devised. Fig. 38 illustrates an acceptable lead-forming method that provides this relief.

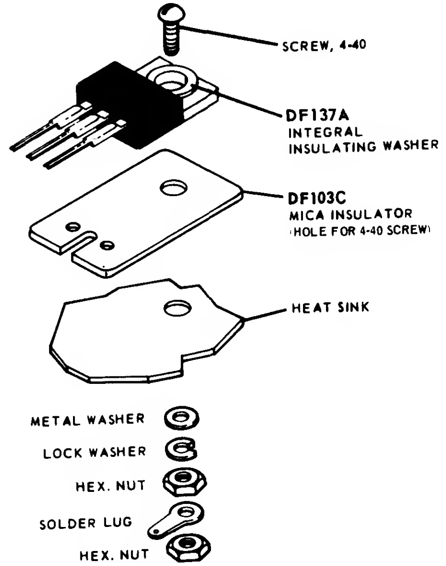
Wire wrapping of the leads is permissible, provided that the lead is restrained between the plastic case and the point of the wrapping. Soldering to the leads is also allowed; the maximum soldering temperature, however, must not exceed 235°C and must be applied for not more than 10 seconds at a distance greater than ⅛ inch from the plastic case. When wires are used for connections, care should be exercised to assure that movement of the wire does not cause movement of the lead at the lead-to-plastic junctions.

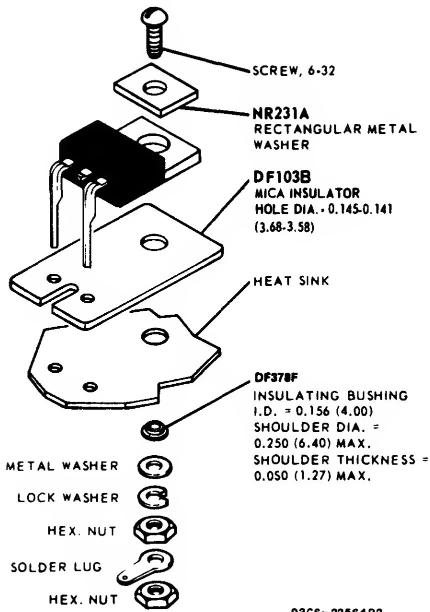
Mounting Considerations

Fig. 39 shows recommended mounting arrangements and suggested hardware for VERSAWATT devices. The rectangular washer (NR231A) shown in Fig. 39(a), (c) and (d) was designed to minimize distortion of the mounting flange when the device is fastened to a heat sink. Excessive distortion of the flange could cause damage to the device. The washer is particularly important when the size of the mounting hole exceeds 0.140 inch (6-32 clearance). Larger holes are needed to accommodate insulating bushings; however, the holes should not be larger than necessary to provide hardware clearance and, in any case, should not exceed a diameter of 0.250 inch. Flange distortion is also possible if excessive torque is used during mounting. A maximum torque of 8-inch-pounds is recommended. The tool used to drive the mounting screw should never come in contact with the plastic



NOTE MAXIMUM TORQUE APPLIED TO MOUNTING FLANGE IS 8 in. lb. (0.09 kgf m)





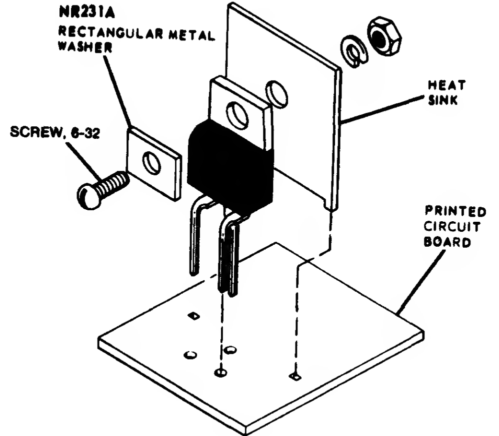


Fig. 39 - Recommended mounting arrangements and suggested hardware for use with VERSAWATT devices.

body during driving operation. Such contact can result in damage to the plastic body and internal device connections. An excellent method of avoiding this problem is to use a spacer or combination spacer-isolating bushing which raises the screw head or nut above the top surface of the plastic body, as shown in Fig. 40. The material used for such a spacer or spacer-isolating bushing should be carefully selected to avoid cold-flow and consequent reduction in mounting force. Suggested materials for these bushings are diallphthalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate. Unfilled nylon should be avoided.

Modification of the flange can also result in flange distortion and should not be attempted. The flange should not be soldered to the heat sink by use of lead-tin solder because the heat required with this type of solder will cause the junction temperature of the device to become excessive.

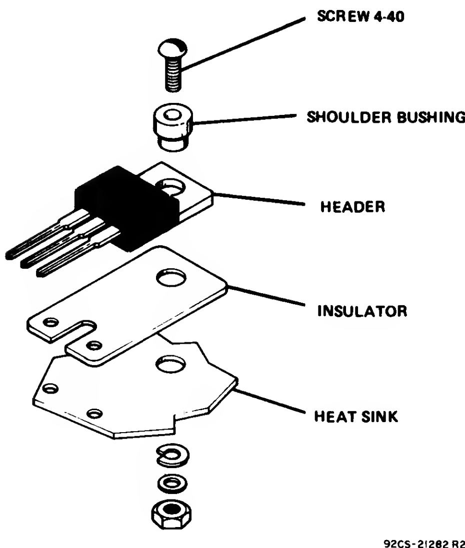


Fig. 40 - Mounting arrangement in which an isolating bushing is used to raise the head of the mounting screw above the plastic body of the VERSAWATT package.

TO-220AA packages can be mounted in commercially available TO-66 sockets, such as UID Electronics Corp. Socket No. PT-4 or equivalent. For testing purposes, the TO-220AB in-line package can be mounted in a Jetron Socket No. CD74-104 or equivalent. Regardless of the mounting method, the following precautions should be taken:

1. Use appropriate hardware.
2. Always fasten the devices to the heat sink before the leads are soldered to fixed terminals.
3. Never allow the mounting tool to come in contact with the plastic case.
4. Never exceed a torque of 8 inch-pounds.
5. Avoid oversize mounting holes.
6. Provide strain relief if there is any probability that axial stress will be applied to the leads.
7. Use insulating bushings made of materials that do not have hot-creep problems. Such bushings should be made of diallphthalate, fiberglass-filled nylon, or fiberglass-filled polycarbonate.

Many solvents are available for degreasing and removal of flux from device and printed-circuit board after the device has been mounted. The usual practice is to submerge the board in a solvent bath for a specified time. From a reliability standpoint, however, it is extremely important that the solvent, together with other chemicals in the solder-cleaning system (such as flux and solder covers), not adversely affect the life of the device. This consideration applies to all non-hermetic and molded-plastic devices.

It is, of course, impractical to evaluate the effect on long-term device life of all cleaning solvents, which are marketed under a variety of brand names with numerous additives. Chlorinated solvents, gasoline, and other hydrocarbons cause the inner encapsulant to swell and damage the transistor. Alcohols are acceptable solvents and are recommended for flux removal whenever possible. Several examples of suitable alcohols are listed below:

1. methanol
2. ethanol
3. isopropanol
4. blends of the above

When considerations such as solvent flammability are of concern, selected freon-alcohol blends are usable when exposure is limited. Solvents such as those listed below should be safe when used for normal flux removal

operations, but care should be taken to assure their suitability in the cleaning procedure:

1. Freon TE
2. Freon TE-35
3. Freon TP-35 (Freon PC)

These solvents may be used for a maximum of 4 hours at 25° C or for a maximum of 1 hour at 50° C.

Care must also be used in the selection of fluxes in the soldering of leads. Rosin or activated-rosin fluxes are recommended; organic fluxes are not.

SPECIAL HANDLING CONSIDERATIONS

The generation of static charge in dry weather is harmful to all transistors, and can cause permanent damage or catastrophic failure in the case of high-speed devices. The most obvious precaution against such damage is humidity control in storage and operating areas. In addition, it is desirable that transistors be stored and transported in metal trays rather than in polystyrene foam "snow". During testing and installation, both the equipment and the operator should be grounded, and all power should be turned off when the device is inserted into the socket. Grounded plates may also be used for stockpiling of transistors prior to or after testing, or for use in testing ovens or on operating life racks. Further protection against static charges can be provided by use of partially conducting floor planes and non-insulating footwear for all personnel.

Environmental temperature also affects performance. Variations of as little as 5 per cent can cause changes of as much as 50 per cent in the saturation current of a transistor. Some test operators can cause marked changes in measurements of saturation current because the heat of their hands affects the transistors they work on. Precautions against temperature effects include air-conditioning systems, use of finger cots in handling of transistors (or use of pliers or "plug-in boards" to eliminate handling), and accurate monitoring and control of temperature near the devices. Prior to testing, it is also desirable to allow sufficient time (about 5 minutes) for a transistor to stabilize if it has been subjected to temperature much higher or lower than normal room temperature (25° C).

Although transient rf fields are not usually of sufficient magnitude to cause permanent damage to transistors, they can interfere with accurate measurement of characteristics at very low signal levels or at high frequencies. For this reason, it is desirable to check for such radiation periodically and to eliminate its causes. In addition, sensitive measurements should be made in shielded screen rooms if possible. Care must also be taken to avoid the exposure of transistors to other ac or magnetic fields.

Many transistor characteristics are sensitive to variations in temperature, and may change enough at high operating temperatures to affect circuit performance. Fig. 41 illustrates the effect of increasing temperature on the common-emitter forward current-transfer ratio (beta), the dc collector-cutoff current, and the input and output impedances. To avoid undesired changes in circuit operation, it is recommended that transistors be located away from heat sources in equipment, and also that provisions be made for adequate heat dissipation and, if necessary, for temperature compensation.

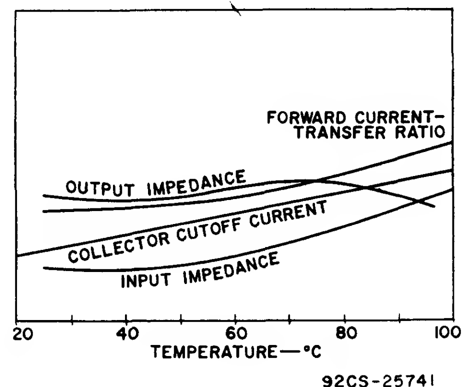


Fig. 41 - Variation of transistor characteristics with temperature.