AN-956A

Using Surface-Mount Devices

(HEXFET is a trademark of International Rectifier)

by W. Parrish

Summary

Surface-mount technology is gaining increasing acceptance over through-hole mounting. International Rectifier offers HEXFET® power MOSFETs, high voltage gate drivers, Schottky diodes, and ultra-fast recovery diodes in packages suitable for surface mounting. This application note gives details of these packages and their thermal characteristics, as well as handling and mounting details.

Introduction

The electronics industry is continually seeking ways to reduce the size and the cost of its products. Surface mounted components represent a major step in this direction. Surface mounting involves soldering parts onto the surface of the printed circuit board rather than inserting the pins through holes in the board and soldering on the underside. Surface-mount component packages are much smaller than those typically used in through-hole mounting, and the leads are short or folded under the package. The result is a much higher packing density — up to four times as many components can be mounted on a board — and more if components are mounted on both sides of the board. Other benefits to be derived from surface mounting include lower parasitic capacitances and inductances, higher reliability, fewer assembly-related faults, reduced production costs, and simplified handling of components.

To date, most progress in the development of surface-mount components has been concentrated on integrated circuits. However, with surface-mount technology gaining rapid acceptance in all sectors of the electronic industry, there is a growing demand for discrete semiconductor devices in surface-mount packages. International Rectifier has responded by producing a range of surface-mount packages for its product line.

Surface-Mount Packages

Table 1 lists International Rectifier's present range of surface-mount packages. More information about specific International Rectifier HEXFET power MOSFET surface-mount devices is available in the HEXFET Designer's Manual, HDM-1, Volume II. For suggested PC board pad sizes, see Figure 2. Several Hi-Rel/Mil devices are also available; for more information, contact IR's Hi-Rel/Mil Department.

Table 1. Surface-Mount Packages

Product	Package Type
HEXFET Power MOSFET HEXFET Power MOSFET HEXFET Power MOSFET	TO-243AA (SOT-89) TO-252AA (D-Pak) TO-220 with lead form
High Voltage Gate Drivers	LCC
Ultra-Fast Recovery Rectifier Ultra-Fast Recovery Rectifier	D-64 TO-252AA (D-Pak)
Schottky Rectifier Schottky Rectifier	D-64 TO-252AA (D-Pak)

Figure 1. D-Pak Transistor Package

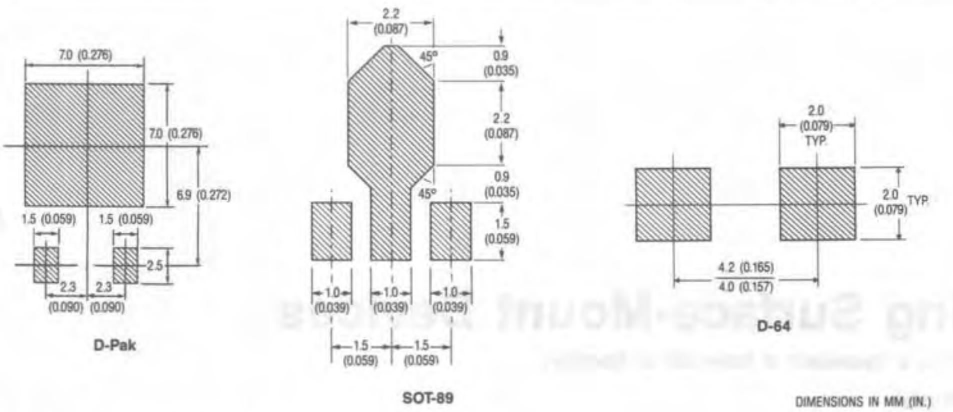

Figure 2. Suggested PC Board Pad Sizes

Thermal Data

As with any power semiconductor device, the current carrying capability is determined by the ability of the package to dissipate heat. The peak junction temperature can be calculated as follows:

$$T_j = T_a + P_t\,(R_{\theta JC} + R_{\theta CS} + R_{\theta SA})$$
$$= T_a + P_t \cdot R_{\theta JA}$$

where:

- T_j = junction temperature
- T_a = ambient temperature
- P_t = total power dissipation in the device (conduction losses, switching losses, leakage losses, etc.)
- $R_{\theta JC}$ = thermal resistance, junction-to-case
- $R_{\theta CS}$ = thermal resistance, case-to-sink
- $R_{\theta SA}$ = thermal resistance, sink-to-ambient
- $R_{\theta JA}$ = thermal resistance, junction-to-ambient

Conversely, fixing the peak junction temperature permits the allowable power dissipation to be calculated.

Table 2 shows the thermal resistance values for the packages listed in Table 1.

In the case of surface mounted devices, the heatsink is usually the printed circuit board or ceramic substrate to which the device is soldered. The sink-to-ambient thermal impedance will depend on the board or substrate material, the pad area available for heat spreading, the proximity of other additional thermal loads on the board, and the velocity of air flow (in the case of forced cooling). Figure 3 shows how the thermal resistance of a three-inch square printed circuit board varies with pad area and air velocity. The data given in this graph should be used with caution, since local air flow can be modified by the shadowing effect of other components. Often, only prototype testing can prove the adequacy of a particular thermal design.

The heat sinking capacity of the board or substrate depends on the thermal conductivity of the board material. Table 3 lists the thermal conductivity of a variety of commonly used materials. The reduction in thermal resistance that can be obtained depends on the material, the thickness of the material, and on the effective area of the board, as well as the air velocity. These factors can interact in a non-linear manner.

Table 2. Thermal Resistance of Surface-Mount Packages

Package	$R_{\theta JC}$ (max)	$R_{\theta CS}$ (typical)	$R_{\theta SA}$	$R_{\theta JA}$ (max)
TO-243AA (SOT-89)	35	5	(Note 1)	110
TO-252AA (D-Pak)	(Note 2)	1.7	(Note 1)	110
TO-220AB with lead form	(Note 3)	1	(Note 1)	80
D-64	—	—	(Note 1)	160

Thermal resistance values are in K/W

Notes:
1. Depends on board material and area of board; see text.
2. 5 for HEX-1 die, 3 for HEX-2 die, 5 to 8 for diodes.
3. Between 1 and 3.5, depending on die size.

Table 3. Thermal Conductivity of Commonly Used Printed Circuit Board Material and Ceramic Substrate

Material	Thermal Conductivity (Watt-in./in.^{2}-°C)	% Increase Over FR-4/G-10
Glass Epoxy: FR-4/G-10	0.0072	—
Alumina Ceramic	0.45	52.5%
Aluminum Nitride	3.3	458%
Beryllia Ceramic*	5.2	722%

***Caution:** The dust from sawing or breaking Beryllia is highly toxic if inhaled.

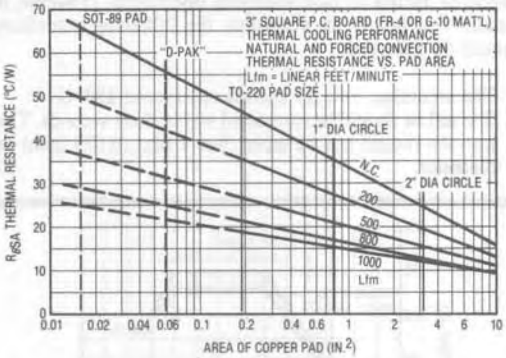

Figure 3. Thermal Resistance of 3-inch Square Printed Circuit Board

Handling

The SOT-89, D-Pak, and D-64 devices are all available for automated assembly using the tape and reel method of packaging. The tapes are available with devices in several different orientations, which affects the quantity on the reel. SOT-89 reels holds 1,000 pieces, independent of the device orientation. D-Pak reels hold either 2,000 or 3,000 pieces, depending on the device orientation. D-64 reels hold 1,800 pieces each.

The devices are held in the pockets in the tape with an adhesive-coated, polyester retainer film. The force required to peel this film from the tape increases with storage time as shown in Figure 4.

More information about tape and reel is available on each data sheet, in HDM-1, Volume II, or from the factory.

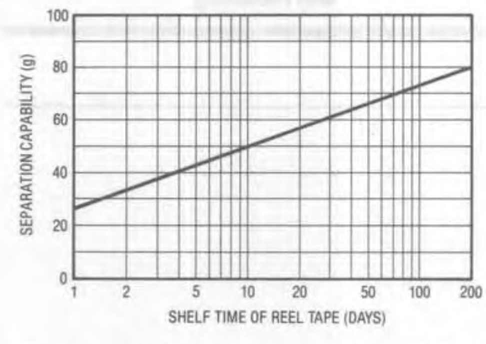

Figure 4. Separation Capability vs. Shelf Time of Reel Tape

Handling HEXFETs

The following measures should be taken to prevent damage to the HEXFETs from electrostatic discharge (ESD):

- Always store and transport HEXFETs in closed conductive containers.
- Remove HEXFETs from containers only after the operator and the container are grounded at a static-controlled work station.
- Personnel who handle HEXFETs should wear a static dissipative outer garment and should be grounded at all times.
- Floors should have a grounded static dissipative covering or be treated with a static dissipative compound.
- Tables should have a grounded static dissipative covering.
- Avoid insulating materials of any kind while handling HEXFETs, since these materials may acquire a static charge, which, if discharged through the HEXFET, could destroy it.
- Always use a grounded soldering iron to install or remove HEXFETs.
- Test HEXFETs only at a static-controlled work station.
- Use all of these protective measures simultaneously and in conjunction with trained personnel.

More detailed information on protection against ESD is available in Application Note AN-955.

Mounting and Soldering

All package types have pre-tinned leads to facilitate soldering. After placement on the board, the device is held in place either by a previously dispensed adhesive or by solder paste. Generally used methods of soldering are listed below.

- Wave soldering
- Vapor phase reflow
- Infra-red reflow
- Pulse-heat soldering tool
- Hand soldering

In all cases, good preparation of the board is essential to obtain the quality of solder joint necessary for good themal contact as well as good electrical contact. Oxide should be removed by a method appropriate to the degree of oxidation that has taken place, such as trichloroethane for light oxidation, an organic acid flux for medium oxidation, or ferric cholride solution for heavy oxidation.

Wave soldering. In its simplest form, wave soldering requires the following steps:

- Accurate dispensing of adhesive where the device is to be mounted.
- Accurate placement of the device on the solder pads and the adhesive (usually accomplished with a "pick-and-place" robot).
- Curing of the adhesive.
- Preheat, foam flux and wave solder.
- Cool and clean flux.

Vapor-phase reflow soldering. This process employs a solder paste to supply the flux and the solder to the solder pad. The paste also acts as an adhesive to hold the device in position while reflowing takes place.

The paste is typically 70% solder and 30% binder. The solder is typically 300 mesh size particles of 60-40 Pb-Sn alloy (occasionally 62-36-2 Pb-Sn-Ag). The binder contains activator (flux), solvent and thickener lubricator mix. The paste is placed on the pads by a silk screening process with a thickness of 8 to 10 mils.

The device is then placed on the prepared pad. Accurate placement is essential, although some alignment of the device with the pad will result when the solder melts due to the surface tension of the solder.

The solder paste is melted by passing the boards through a hot vapor. The solder is melted as the vapor condenses on the board and components. Two methods of vapor-phase reflow are popular. They include (1) the conveyor belt method, in which the boards are carried on a conveyor belt over boiling fluid; and (2) the dual vapor system, in which the boards travel vertically through zones of vapor of different temperatures.

Soldering is carried out in a furnace at a temperature of 230°C to 250°C, preferably in less than 20 seconds. Preheating time should be 120 seconds or longer. Whichever type of heating method is used, the object is to achieve the required time-temperature profile. Figure 5 shows the temperature profile required for belt furnace with tunnel heating. Figure 6 shows the temperature profile required for solder bath soldering with preheating.

Infra-red reflow. The preparatory steps to board heating are the same as those for the vapor-phase reflow method. In the infra-red process, the board is passed under infra-red radiators to achieve reflow of the solder. Care must be exercised not to overheat any large "black bodies" that may be mounted on the board.

Pulse-heat reflow. This method requires a special heat collet which directs the flow of a heated gas around the surface-mounted device and onto the terminals and the printed circuit board pads. The heating, reflowing and cooling cycles should be similar to those shown in Figure 5.

Hand soldering. Manual soldering should be avoided if possible, since the component can easily be dislocated and damaged during manual soldering operations. However, if repairs to a board are necessary, the following guidelines should be observed:

1. The soldering iron tip should not exceed 250°C
2. The reflow should be completed within three seconds. The iron tip should not be more than 1 mm (0.039 inch) in diameter. □

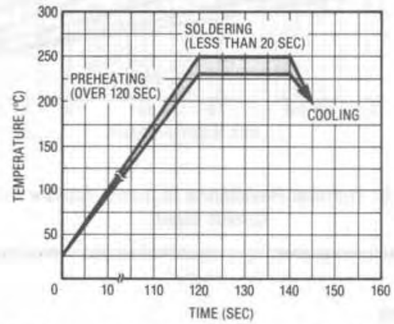

Figure 5. Temperature Time Profile for Two-Zone Reflow Soldering

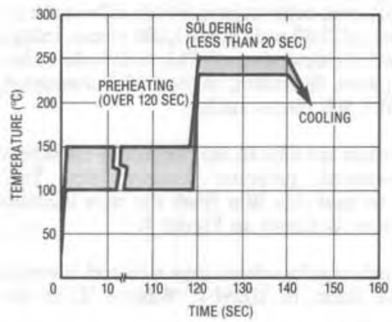

Figure 6. Temperature Time Profile for Solder Bath Soldering with Preheating