APPLICATION NOTE 972A

Thermal and Mechanical Considerations For FullPak Applications

(HEXFET is a trademark of International Rectifier)

by Peter Wood

Plastic Packages

Plastic molded semiconductors have been available for more than 30 years and have become the preferred packages for all commercial and industrial equipment. The most popular power package by far is the TO-220AB, but recently, as higher power requirements have emerged, the TO-247AC has gained popularity.

While both of these packages have excellent thermal characteristics, they are non-isolated and in most instances need isolating from the grounded framework of the equipment that uses them.

Two methods for providing electrical isolation are frequently used:

1. Isolated heatsink inside the grounded enclosure.

2. Insulating mica or plastic film mounting to grounded heatsink.

Both methods raise the system cost and additionally cause EMI/RFI problems due to the capacitance to ground of the isolation scheme.

Whenever an additional component such as a mounting insulator is used, there is a consequent reduction in system reliability, especially if there is a high voltage across the insulator.

A need for self isolated TO-220 and TO-247 packages is clearly indicated. The requirements for such packages are listed below:

1. Same physical outline as the TO-247 or TO-220.

2. Same pin spacing and pinout as the TO-247 or TO-220.

3. Same mounting hole dimensions as the TO-247 or TO-220.

4. Similar thermal characteristics to non-isolated version with insulating washer.

5. Minimum capacitance to mounting surface.

6. Adequate creepage distances pin-to-pin and pin-to-heatsink to meet current safety codes (UL, CSA, VDE, etc.).

7. Maximum corona-free isolation voltage.

International Rectifier FullPaks

Careful consideration of the aforementioned requirements for both the TO-220 and TO-247 fully isolated plastic packages led to the International Rectifier FullPak case styles manufactured to the outline diagrams shown in Figures 2 and 4.

Thermal Characteristics

As with non-isolated devices, thermal resistance from the semiconductor die to the surface of the package is inversely proportional to the area of the die and directly proportional to the sum of the components of thermal resistance within the package. The picture is further complicated by the amount of heat spreading that takes place within the header on which the die is mounted.

Thus, a thin header will cause only minimal heat spreading and, therefore, the effective area of thermal injection to the heatsink will be limited to approximately the actual die area. With a thicker header the effective injection area becomes significantly larger than the die area even though the actual thermal resistance per unit area is larger due to the increased thickness.

Within the package, junction temperature becomes a function of power and thermal resistance:

$$T_j \alpha P_D \cdot R_{\theta(JC)}$$

For a thermally efficient package it is therefore necessary to design with the following objectives to minimize $R_{\theta(JC)}$:

1. Maximum copper header thickness.

2. Maximum copper header area.

3. Minimum insulation thickness consistent with isolation voltage and capacitance requirements.

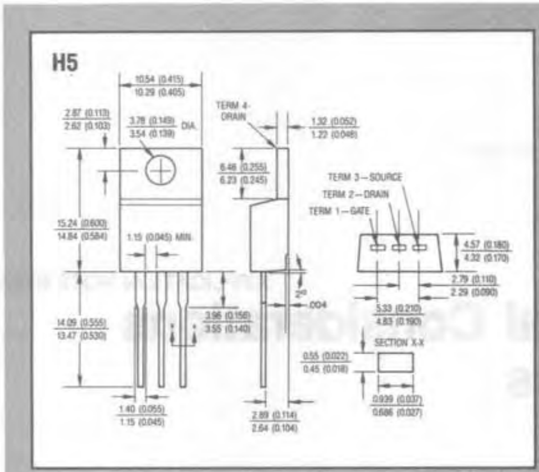

Figure 1. Standard TO-220AB plastic package.

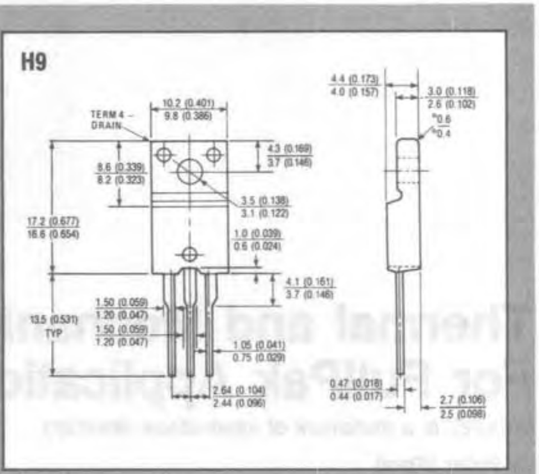

Figure 2. The fully isolated FullPak plastic case style of the TO-220.

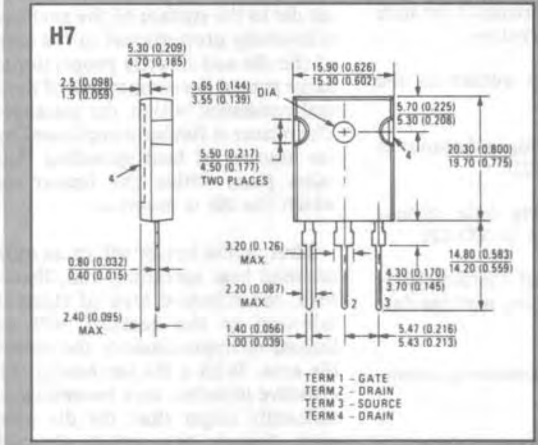

Figure 3. Standard TO-247AC plastic package.

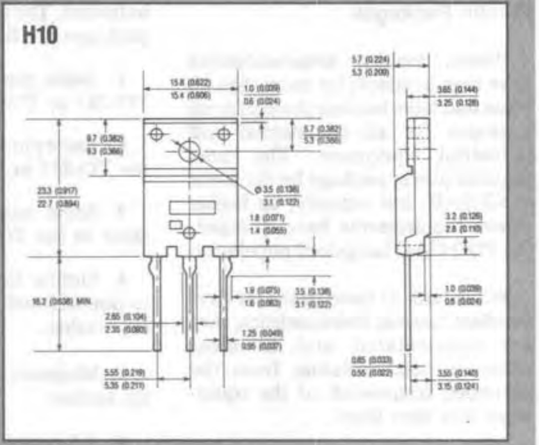

Figure 4. The fully isolated FullPak plastic case style of the TO-247.

All dimensions in millimeters and (inches)

4. Maximum thermal conductivity of package material.

5. Surface flatness for best heat transfer to heatsink.

Thermal measurements on both the TO-220 and TO-247 FullPaks have resulted in some interesting data for thermal resistance.

It is apparent from Table 1 that the thermal resistance of the TO-220 FullPak is higher than a standard TO-220 with mica washer while the TO-247 FullPak is only slightly higher than the non-isolated TO-247 with mica washer.

In the standard TO-220 package the header has about thirty percent more area than in the FullPak. Both types of TO-247 packages, however, have similar header areas and, thus, exhibit similar thermal resistances.

The typical impact on junction temperature rise of the higher thermal resistance values of International Rectifier FullPak packages is summarized in Table 2. This table shows typical design values of full load power dissipation in the various HEXFET power MOSFET sizes, and the corresponding *additional* temperature rise of the HEXFET junction in the FullPak fully isolated case style, versus standard packages with mica mounting washers.

Electrical Performance

Two of the most important properties of the FullPak are its ability to provide electrical isolation while still maintaining adequate thermal conductivity.

Unfortunately these two requirements are in direct conflict with each other since the thicker insulation required for high voltage isolation and lower capacitance also has greater thermal resistance.

Table 1. Average values thermal resistance junction to case of samples measured, with thermal compound

6-32 STEEL MOUNTING SCREW				DIE SIZE
8-INCH LB TORQUE		12-INCH LB TORQUE		
TO-220 + MICA	TO-220 FullPak	TO-247 + MICA	TO-247 FullPak	
2.759° C/W	3.651° C/W	—	—	HEX 2
2.322	3.151	—	—	HEX 3
2.013	2.901	1.289	1.405	HEX 4
—	—	1.190	1.236	HEX 5

Table 2. Typical additional junction temperature rise in FullPak case style vs non-isolated package

HEXFET Die Size	FullPak Package	Typical Full-Load Power	Approx Additional Junction Temp Rise in FullPak
HEX 2	TO-220	5W	5°C
HEX 3	TO-220	8W	7.5°C
HEX 4	TO-220	12W	12°C
HEX 4	TO-247	15W	2°C
HEX 5	TO-247	22W	1.5°C

Note: This table compares the FullPak with the non-isolated package with external mica insulation, and same external heatsink. Note that the additional junction temperature rise in the FullPak is generally not too significant.

As a compromise the isolation voltage is specified at 1.5 kV RMS for both the TO-220 and TO-247 FullPaks. As stated earlier the thermal resistances of the FullPaks are somewhat comparable to the non-isolated cases mounted with insulating films.

Capacitance

A standard TO-220 mounted to a heatsink with a mica insulator of 0.002" (.05mm) thickness has a capacitance (tab to heatsink) of approximately 40 pF. A TO-247 mounted the same way is approximately 60 pF.

Comparable values for the FullPaks are 20 pF and 30 pF maximum for the two outlines.

In practical terms the reduced capacitance of FullPaks versus standard types means that capacitively-coupled switching currents are greatly reduced and hence the EMI/RFI problems associated with standards such as VDE, UL, CSA, etc., are minimized.

Creepage Distances

International Rectifier FullPak devices are designed to present sufficient creepage distances from pin-to-pin and from pin-to-mounting surface to meet the requirements of UL 1012 and similar safety specifications.

Figure 6 shows actual package dimensions used to calculate crepage distances shown in Table 3. The lower half of Table 3 shows actual voltage capability based on the UL formula of 0.5mm per 100V +0.58mm.

The voltage stress levels (Table 3) indicate that the requirements of UL 1012 can be met by International Rectifier's TO-220 FullPak up to a voltage of 350 VDC and for the TO-247 FullPak, up to 1100 VDC.

Mounting and Mechanical Considerations

International Rectifier FullPak devices are intended to be mounted by screws as shown in Figure 7, spring clips or even pop-rivets (Figure 8). Because of their unique construction, non-insulated hardware can be used with the certainty that when mounted, FullPaks can withstand at least 1500V RMS impressed from device to heatsink. Recommended mounting torques are shown in Figure 7.

In many low cost applications FullPak HEXFETs can be attached to sheet metal by means of pop rivets. Some words of caution should be heeded. Most ordinary pop-rivets are aluminum *with a steel break stem mandrel. These should not be used* as they exert too much force on the FullPak body.

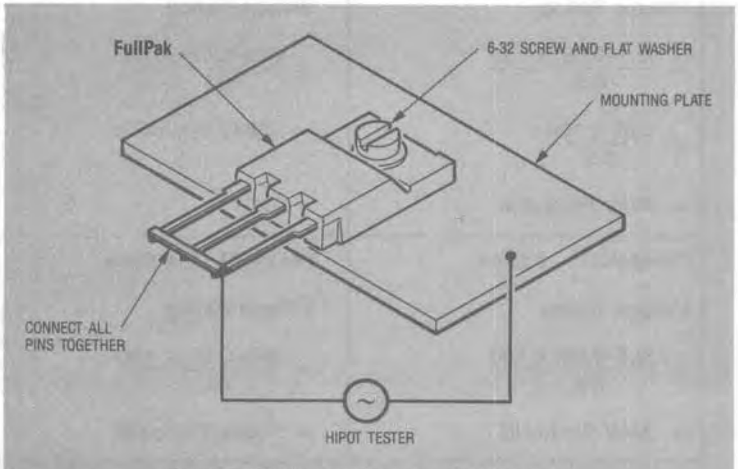

Figure 5. FullPak mounting set-up for Hipot tester.

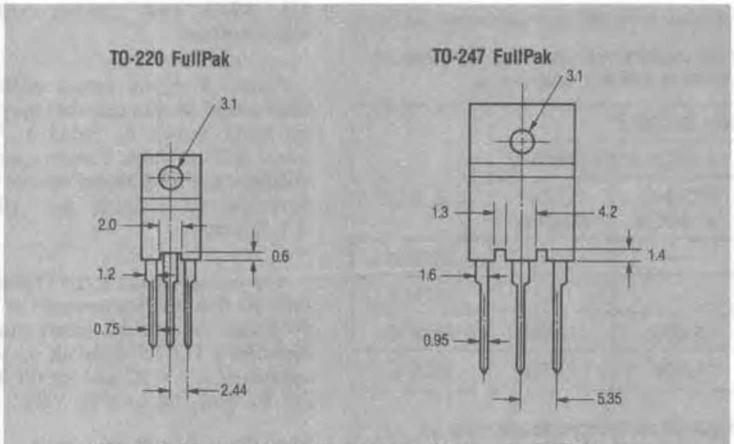

Figure 6. Minimum pin-to-pin creepage distances for FullPaks (mm).

Table 3. Creepage comparisons for TO-220 and TO-247 FullPaks

<table>
<tr><th>TO-220
FullPak</th><th>TO-247
FullPak</th></tr>
<tr><td>Minimum Creepage Pin-to-Pin
$= 2.44 - 0.75 + 0.23 + 0.6$
$= 2.1\text{mm}$</td><td>Minimum Creepage Pin-to-Pin
$= 5.35 - 0.7 + 2.8 = 7.5\text{mm}$</td></tr>
<tr><td>Minimum Creepage Pin-to-HS
$= 2.3\text{mm}$</td><td>Minimum Creepage Pin-to-HS
$= 3.15 + 2.8 = 6.1\text{mm}$</td></tr>
<tr><td colspan="2">Calculations using the UL formula of 0.58mm + 0.5mm/100V per UL 1012 Table 26.5 yield actual minimum voltage ratings as follows:</td></tr>
<tr><td>Pin-to-Pin = 2.1mm
Voltage Rating
$= \frac{(2.1-0.58) \times 100}{0.5}$
$= \frac{1.52 \times 100}{0.5}$
= 304V Pin-to-Pin</td><td>Pin-to-Pin = 7.5mm
Voltage Rating
$= \frac{(7.5-0.58) \times 100}{0.5}$
= 1384V Pin-to-Pin</td></tr>
<tr><td>Pin-to-HS = 2.3mm
Voltage Rating
$= \frac{(2.3-0.58) \times 100}{0.5}$
= 344V Pin-to-HS</td><td>Pin-to-HS = 6.0mm
Voltage Rating
$= \frac{(6.0-0.58) \times 100}{0.5}$
= 1084V Pin-to-HS</td></tr>
</table>

Aluminum-soft set rivets with aluminum break stem mandrels are ideally suited to this application and provide about 100 lb force between the FullPak and the sheet metal heatsink.

The mounting hole in both the TO-220 and TO-247 FullPak is the same size (0.130 inches) which is just right for a 1/8-inch pop-rivet inserted from the device side only. The hole in the heatsink should be 0.129 to 0.133 inch (#30 drill).

When attaching an International Rectifier TO-220 or TO-247 FullPak to a heatsink with a pop-rivet it is important that the configuration shown in Figure 8 be used.

If the pop-rivet is expanded into the FullPak hole, i.e., inserted from the back of the heatsink, the FullPak will be damaged or the HEXFET die cracked.

Conclusion

The FullPak power MOSFET devices described in this application note are a superior package to any other isolated devices on the market today. The combination of International Rectifier HEXFET reliability and FullPak packaging technology make these power MOSFET devices the quality choice for virtually any industrial or commercial application. This is especially true when the equipment requirements of industrial safety specifications such as VDE, UL, CSA, etc., have to be met.

The electrical performance of International Rectifier FullPaks mirrors exactly the specifications of the familiar non-isolated TO-220 and TO-247 devices. Only the mechanical and thermal capabilities are different. Thus, it is easy to retrofit existing equipment circuits with the fully isolated FullPak devices since the type numbers correlate to the non-isolated HEXFETs. For example, the IRFP450 HEXFET becomes the IRFIP450 FullPak HEXFET, and the IRF830 becomes the IRFI830, etc.

For complete performance characteristics and specifications consult the FullPak data sheets which are available from International Rectifier. ☐

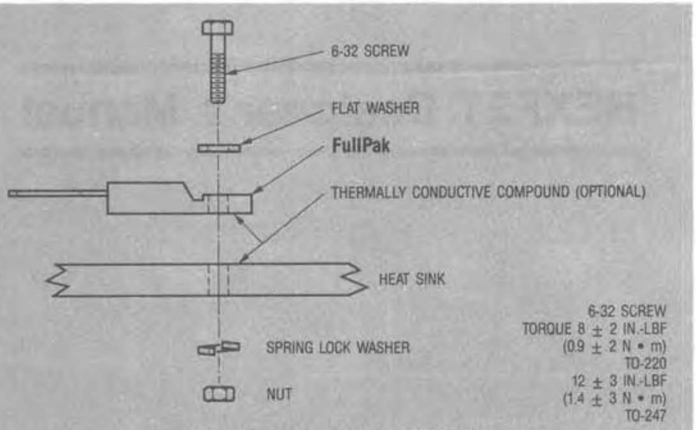

Figure 7. Screw mounting of FullPak

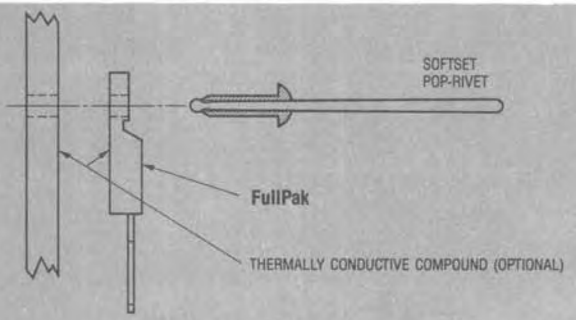

Figure 8. Pop Rivet Mounting of FullPak

Table 4. Recommended pop-rivet part numbers for FullPak applications

Heatsink Thickness	TO-220 FullPak	TO-247 FullPak
1/32 to 1/16	PAD43ABS	PAD43ABS
1/8	PAD44ABS	PAD46ABS
3/16	PAD46ABS	PAD46ABS
1/4	PAD46ABS	PAD48ABS

Note: The above rivets are available from

POP Fasteners Division
Emhart Fastening Systems Group
510 River Road
Shelton, Connecticut 06484

Phone: (203) 735-9341

See catalog # P265 (12/88) for additional pop-rivet applications information.