International Rectifier
APPLICATION NOTES
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Thermal and Mechanical Considerations For FullPak Applications

(HEXFET is a trademark of International Rectifier)

by Peter Wood, Donald A. Dapkus II

Plastic Packages

Plastic molded semiconductors have been available for decades 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 to be isolated from the grounded framework of the equipment that uses them.

Three 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, or

3. Elastomeric thermally conductive insulation material such as Sil-Pad® manufactured by The Bergquist Company.

All 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 hardware.

5. Minimum capacitance to mounting surface.

6. Adequate creepage distance 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 1 through 4.

International Rectifier FullPak HEXFET power MOSFET devices are identified by the letter "I" which is added to the standard part number immediately following the "IRF" portion of the part number. For example, the standard TO-220 device, IRFZ44, becomes IRFIZ44G in the FullPak package; the standard TO-247 device, IRFP054, becomes IRFIP054. As shown above, the TO-220 FullPak part numbers end in the letter "G". This is a manufacturing code; it designates that the device was packaged at IR Great Britain. Figures 5 and 6 describe the various marking on both FullPak devices.

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.

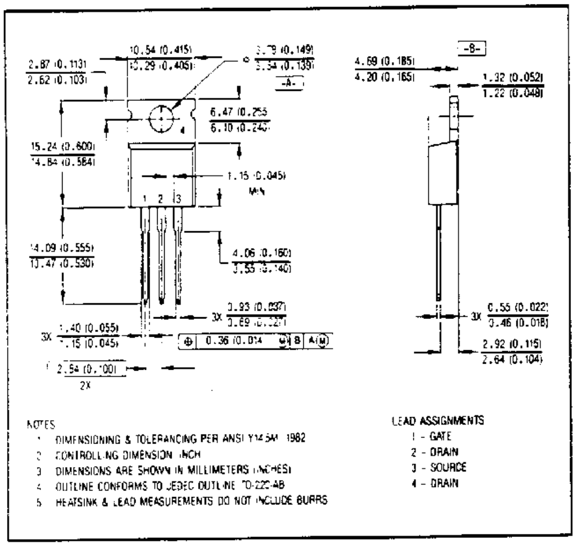

Figure 1. Standard TO-220AB plastic package

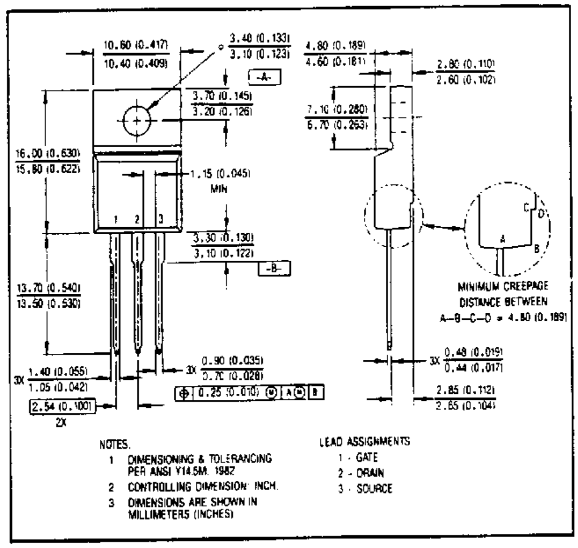

Figure 2. The fully isolated FullPak plastic case style of the TO-220

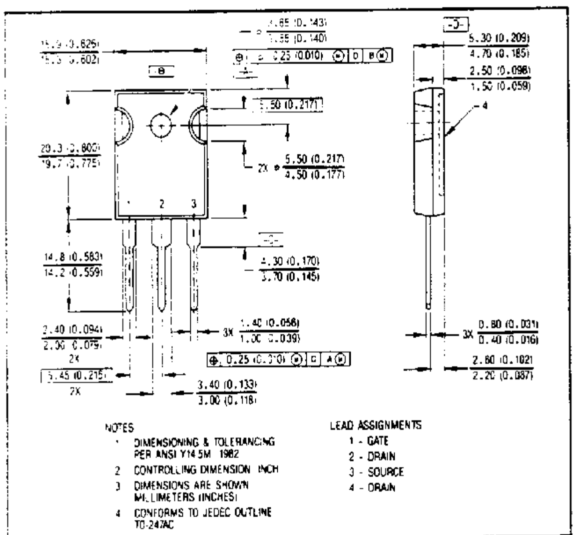

Figure 3. Standard TO-247AC plastic package

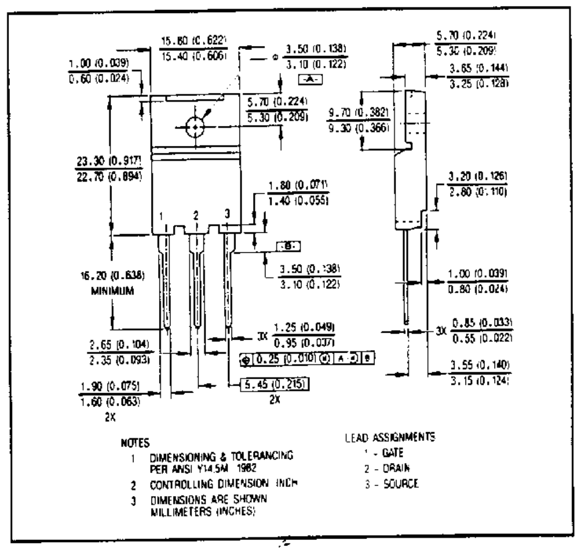

Figure 4. The fully isolated FullPak plastic case style of the TO-247

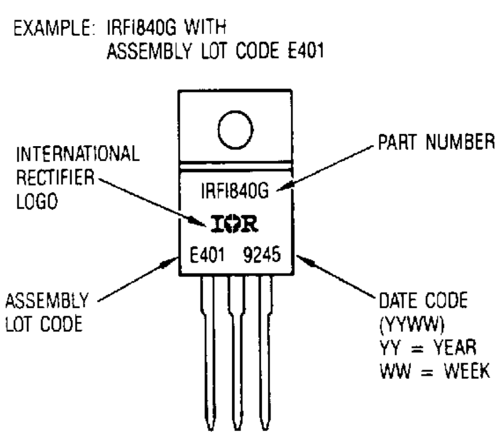

Figure 5. TO-220 FullPak package marking

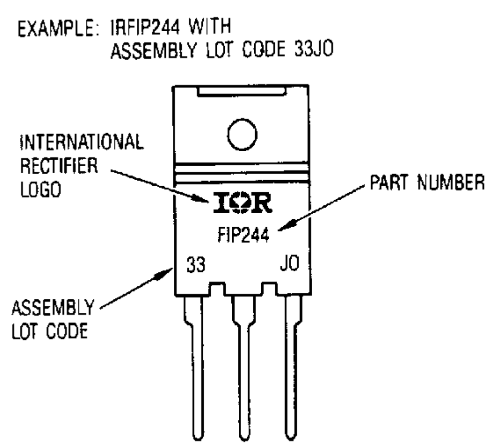

Figure 6. TO-247 FullPak package marking

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 of the header is larger due to the increased thickness.

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

$$T_J \propto P_D \cdot R_{\theta JC}$$

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.

4. Maximum thermal conductivity of package material.

5. Surface flatness for best heat transfer to heatsink.

Table 1 lists thermal resistances junction-to-sink ($R_{\theta JS}$) for both the TO-220 and TO-247 standard devices mounted with Sil-Pad K-6® which is a Kapton-based thermally conductive insulator pad manufactured by The Berquist Company. The TO-220 also requires an insulating shoulder washer as the screw hole is not isolated as is the TO-247. Table 1 also lists the thermal resistances for both International Rectifier FullPaks (TO-220 and TO-247) when mounted using thermal grease.

The mounting method requires mentioning. In order to obtain more uniformly distributed and consistent mounting pressure, we use a metal bar across the plastic body instead of using a screw. Five pounds-force • inch of torque is applied to both ends of the bar. Thermal resistance measurements using this mounting method are more consistent than mounting using the intended screw hole.

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 junction in the FullPak fully isolated case style, versus standard packages with Sil-Pad® insulating material.

Table 1. Average values of samples measured

MOUNTED WITH BAR ACROSS BODY 5LBF • IN. TORQUE				DIE SIZE
TO-220 + Sil-Pad	TO-220 FullPak	TO-247 + Sil-Pad	TO-247 FullPak	
3.7°C/W	4.2°C/W	—	—	HEX-1
3.1	3.6	—	—	HEX-2
2.5	2.8	—	—	HEX-3
2.1	2.7	1.4	1.7	HEX-4
—	—	0.9	1.3	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-1	TO-220	2W	1.0°C
HEX-2	TO-220	5	2.5
HEX-3	TO-220	8	2.4
HEX-4	TO-220	12	7.2
HEX-4	TO-247	15	4.5
HEX-5	TO-247	22	8.8

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

As the size of the heatsink decreases, the junction's operating temperature increases due to the increase in $R_{\theta SA}$. As a result, the *percentage* increase of the junction temperature decreases when comparing the FullPak to a Sil-Pad® -insulated standard TO-220. In other words, smaller heatsinks with larger $R_{\theta SA}$'s tend to mask the additional temperature rise caused by the FullPak. In designs with these conditions, there is usually less than 5% degradation in current capability due to the FullPak.

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.

As a compromise the isolation voltage is specified at 2.5 kV RMS for the TO-220 and 2.0 kV RMS for the TO-247 FullPaks. As stated earlier the thermal resistances of the FullPaks are somewhat comparable to the non-isolated cases mounted with insulating films. Figure 7 details the test configuration for Hipot testing of the FullPak.

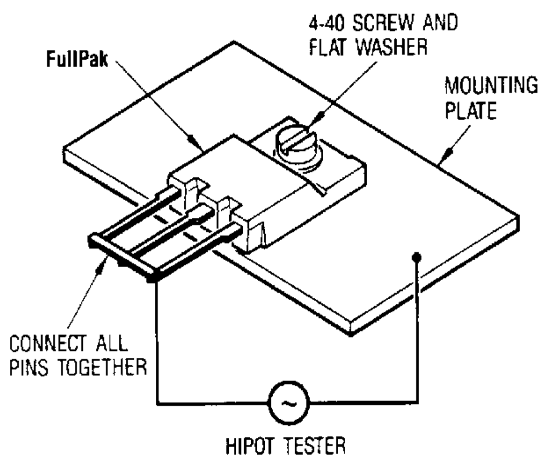

Figure 7. FullPak mounting set-up for Hipot tester

Capacitance

A standard TO-220 mounted to a heatsink with a mica insulator of 0.002" (0.05mm) thickness has a capacitance (tab to heatsink) of approximately 40 pF. A TO-247 mounted the same way is approximately 60 pF. Similar values were measured using Sil-Pad K-6® as the insulator.

Comparable values for the FullPaks are 12 pF and 26 pF typical 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 Distance

International Rectifier FullPak devices are designed to present sufficient creepage distance from pin-to-mounting surface to meet the requirements of the various safety standards. The lower half of Table 3 shows actual voltage capability pin-to-mounting surface based on the UL formula of 0.5mm per 100V +0.58mm.

Mounting and Mechanical Considerations

International Rectifier FullPak devices are intended to be mounted by screws as shown in Figure 8, spring clips or even POP® brand blind rivets (Figure 9). Because of their unique construction, non-insulated hardware can be used with the certainty that when mounted, FullPaks can withstand at least 2.0kV RMS impressed from device to heatsink. Recommended mounting torques are shown in Figure 8.

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

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 blind 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 blind rivet it is important that the configuration shown in Figure 9 be used, otherwise, if the blind 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

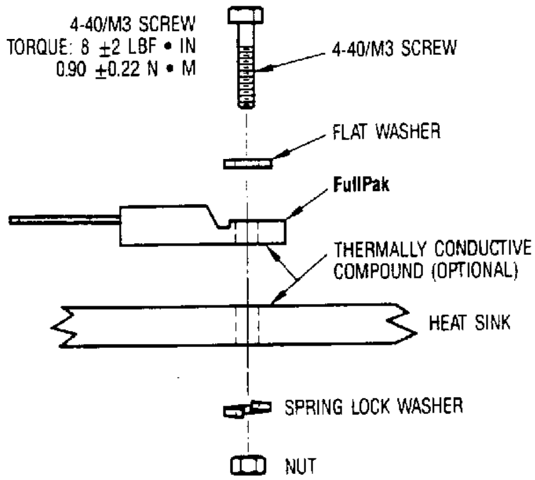

Figure 8. Screw mounting of FullPak

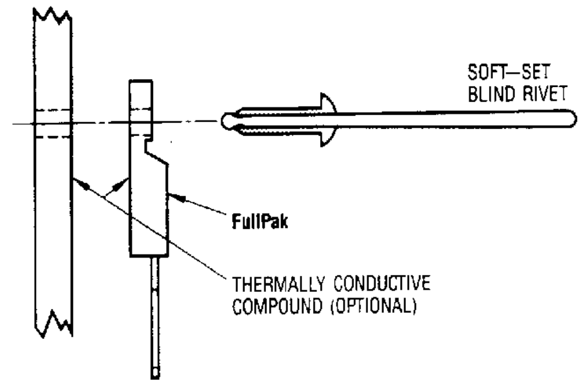

Figure 9. Blind rivet mounting of FullPak

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 HEXFET device. For example, the IRFP450 becomes the IRFIP450 FullPak, and the IRF830 becomes the IRFI830G, etc.

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

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

TO-220 FullPak	TO-247 FullPak
Minimum Creepage Pin-to-HS = 4.8mm	Minimum Creepage Pin-to-HS = 3.15 + 2.8 = 6.0mm
Calculations using the UL formula of 0.58mm + 0.5mm/100V per UL 1012 Table 26.5 yield actual minimum voltage ratings as follows:	
Pin-to-HS = 4.8mm Voltage Rating $= \frac{(4.8-0.58) \times 100}{0.5}$ = 844V Pin-to-HS	Pin-to-HS = 6.0mm Voltage Rating $= \frac{(6.0-0.58) \times 100}{0.5}$ = 1084V Pin-to-HS

Table 4. Recommended POP® brand blind 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) 924-9341
FAX: (203) 924-8741

See Emhart catalog # P265 (2/92) for additional POP® rivet applications information.

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