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DESIGN TIPS

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CURRENT CAPABILITY OF TO-220 PACKAGE

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1. Background

From the early days, the two reference points for power transistor ratings have been:

- 25°C case temperature
- continuous current waveform.

This was a break from established tradition since, at the time power transistors were first introduced, diodes and thyristors were rated at higher temperatures and complex waveforms, more representative of actual operating conditions.

Today the 25°C rating of power transistors is well established, in spite of the problems and confusion it causes to design engineers and to the semiconductor manufacturers.

The source of these problems is the fact that electronic equipment is invariably designed to operate at ambient temperatures that are higher than 25°C. As a result, the 25°C current rating specifies a capability that, on the one hand must be met by the manufacturer, on the other hand is much beyond what any designer can reasonably use.

Embedding a current rating in the part number gives additional emphasis to a rating that cannot be utilized in practical applications. For this reason some manufacturers are using a current rating in the part number for operation at a higher temperature than 25°C. However, the temperature associated to this rating is not indicated in the part number and this compounds the confusion even further.

In an effort to provide useful information to the designers, International Rectifier publishes ***two*** current ratings for its power MOSFETs (one at 25 and one at 100°C) and ***a curve*** of current rating at any temperature between 25 and 150 °C or 175°C. IR does not use a current rating in the part number.

2. The Current Rating of Low Voltage HEXFET Power MOSFETs

In an ideal world the limitations of the die and those of the package would converge to the same operating point. This means that, as the current increases to the device limits, the die temperature and the package temperature would be at their respective limits, less safety margins.

In the real world, for the large majority of devices, die limitations occur well before package limitations, with the exception of the new, very low on-resistance MOSFETs. Their voltage drops are so low that their current handling capabilities exceed that of most popular packages. This has stimulated new package designs, as well as improvements in the leadframe material and in the epoxy compounds.

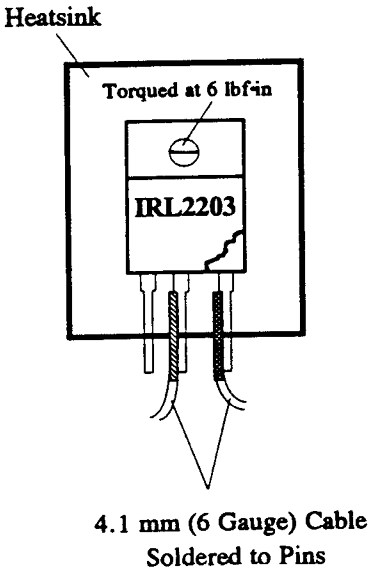

Figure 1 - The Set-Up Used for High Current Tests

3. *Package Limitations*

The limits to the current handling capability of a TO-220 package are much more difficult to establish than those of the die. The following experiment provides a better understanding of these limitations.

We have prepared IRL2203 (10mΩ, 30V) by partially removing the epoxy to expose the area where the wires are ultrasonically bonded to the source pin. This device has two 0.38 mm (15mils) source bonding wires. We have mounted this device on a large heatsink with thermal grease, torqueing the 6-32 screw to 0.6 N•m (6 lbf•in), as shown in Figure 1. Two 4.1 mm (6-gauge) cables were soldered to the leads 4 mm (0.15") from the package. The size of these wires is such that they do not contribute any power dissipation and the distance from the package is typical of TO-220 mounting techniques.

With a current of 75 A in the device, after reaching thermal equilibrium, the following temperatures were measured with a thermal imager:

- bonding wires: 220°C
- source pin: 180°C
- heatsink: 35°C

Knowing the resistance of the bonding wires (0.3mΩ) and the power dissipation (1.73W), the thermal resistance can be calculated to be 113°C/W. With this information and given that the glass transition point of this epoxy is over 190°C, the graph of Figure 2 can be generated.

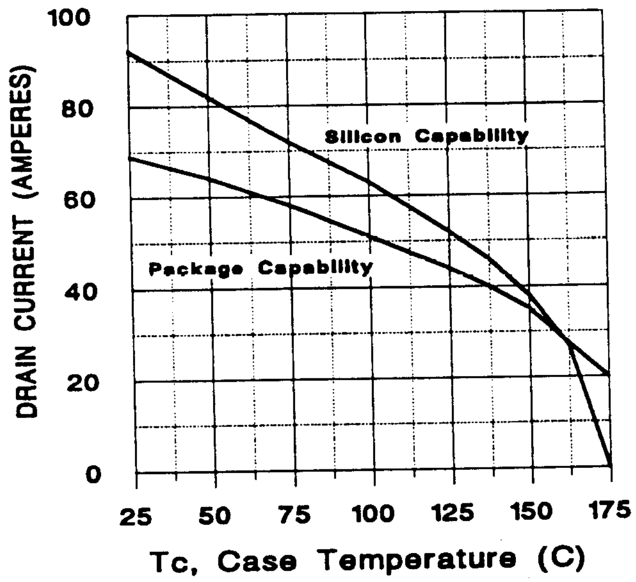

Figure 2 - Current Handling Capability of the TO-220 with a low voltage HEXFET (IRL2203)

Under these conditions the on-resistance of the IRL2203 is 17mΩ, the voltage drop is 1.28V and power dissipation is less than 100W. Hence, in the test described above, the temperature of the die itself is approximately 150°C.

This confirms what is shown in Figure 2, i.e. that over most of the temperature range the package limits the current capability of the device to a lower value what the die itself can handle. While it may appear that we are unduly limiting the device with the bond wires, this is not true for typical applications. The next section discusses this in more detail.

4. *Current Capability in a Typical Application*

The vast majority of low voltage MOSFETs are designed-in for their low on-resistance and low voltage drop, not for their current carrying capability. In spite of this, current rating is still used by many designers to compare devices from different manufacturers, hence the incentive to put as high a number as possible.

In order to achieve the rated current, cooling techniques are required that are not practical in reality. Thus, the wirebonds do not limit the maximum current capability, but rather the thermal design is the limiting factor.

Until all manufacturers agree to use a common rating technique, this confused state of affairs will continue. Meanwhile, the following paragraphs should provide helpful design guidelines.

1. ***International Rectifier has chosen to use the silicon capability as the limiting factor in establishing the current rating of its low voltage HEXFETs, while providing designers with information on package limitations.***

2. ***If the device must handle a significant amount of current for one second or more, its RMS value must be within the capability of the silicon and of the package, whichever is lower.***

   The package limitation is shown in Figure 2, the current limitation is normally shown in Figure 9 of the data sheet. The package limitation will be incorporated in the future revisions of the data sheet.