International Rectifier **DESIGN TIP** DT 94-17

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THERMAL RESISTANCE CHARACTERIZATION FOR NEW SURFACE MOUNT DEVICES

by Tyler Fure

Many new surface mounted power devices have no connection for a heat sink, so they rely on the drain's exposed metal leads and thermal connection to the traces to dissipate heat. Since the characterization for heat sink mountable devices assumes an infinite sink, a new method of thermal characterization is necessary that will accurately reflect the operation of these new devices. This Design Tip describes how International Rectifier characterizes thermal resistance for HEXFET® power MOSFETs in the new SO-8, Micro8, and Micro3 packages. General information on thermal design is available in AN-949B.

1. Thermal Resistance Characterization

Total thermal resistance ($R_{\theta JA}$) for semiconductor devices consists of the sum of all thermal resistances between the junction and the ambient environment. Thermal resistance ratings are continuous by definition and require the device to be in thermal equillibrium. Transient thermal impedence ($Z_{\theta JC}$), based on pulsed current, provides a method to calculate junction temperature rise due to current with any duty cycle (AN-949B). Measurement of junction to ambient thermal resistance requires a method to measure the ambient and junction temperatures (T_A and T_J respectively) as well as the power dissipation (P_D). The formula for junction to ambient thermal resistance follows:

$$R_{\theta JA} = \frac{(T_J - T_A)}{P_D}$$

Measurement of the junction temperature requires a temperature sensitive electrical parameter (TSEP). We use $R_{DS(ON)}$ as the TSEP because the test circuit is simple and requires no switching. This parameter changes approximately 1% / °C, providing adequate change for an accurate temperature measurement. The test circuit, shown in Figure 1, applies a constant voltage to the gate and allows an adjustable amount of current through the device, thereby heating the junction. Using $R_{DS(ON)}$ as the TSEP provides for a true steady-state measurement because it is monitored continuously.

In order to measure $R_{\theta JA}$ for these new devices, the following four main steps are performed: 1) Calibrate $R_{DS(ON)}$ at maximum junction temperature, 2) Mount the device on a PC board, 3) Apply power and stabilize the junction temperature at its calibrated value, 4) Measure P_D and T_A to calculate $R_{\theta JA}$.

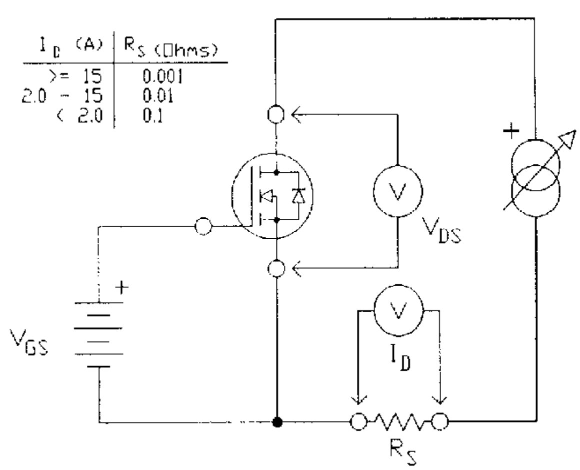

Figure 1
Test circuit for thermal characterization.

The first step is to calibrate $R_{DS(ON)}$ at the maximum rated junction temperature (T_{JMAX}) for each device. A thermostatic bath heats the devices to T_{JMAX} and ensures that the junction temperature is constant during calibration. When the devices are in thermal equillibrium, $R_{DS(ON)}$ is measured at five pulsed current levels, as shown in Figure 2. Known values of $R_{DS(ON)}$ are necessary for a range of current levels because it is not known beforehand the level of current that will heat the junction to T_{JMAX}.

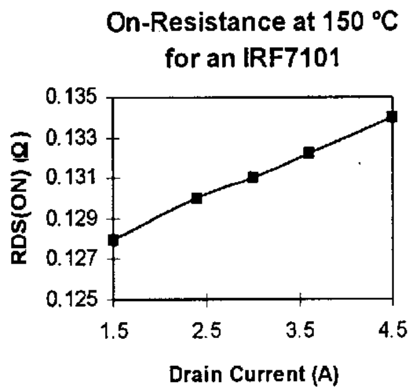

Figure 2
Calibration curve provides on-resistance values for 150 °C junction temperature.

The second step is to mount the individually calibrated devices for testing. SO-8 devices are mounted on a one inch square copper plated PCB (FR-4, 2 oz. copper), as shown in Figure 3.

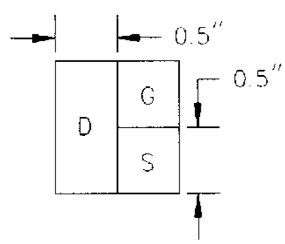

Figure 3
Test board for SO-8 thermal characterization (2 oz. copper on FR-4).

This is the industry standard test board. As packages continue to shrink though, the $R_{\theta JA}$ values produced with a board of this size become unrealistic. International Rectifier is now improving the standard by using test boards that more closely simulate real applications. The new Micro8 and Micro3 devices are tested on a PCB (GIN, 1 oz. copper) using the recommended footprint, shown in Figure 4. Therefore, designers can be confident that calculations based on the published values will accurately reflect the circuit in operation.

The third step is to apply power and heat the junction to T_{JMAX}. The drain current is slowly increased with the standard gate voltage applied (i.e. the V_{GS} at which I_D is rated). Power dissipation and $R_{DS(ON)}$ is calculated from drain voltage and current. The drain current continues to increase until $R_{DS(ON)}$ reaches a calibrated value, and the device is in thermal equilibrium (i.e. the junction remains at 150 °C for several minutes). At this point, a continuous power dissipation maintains the junction temperature at 150 °C as measured by the curve in Figure 2.

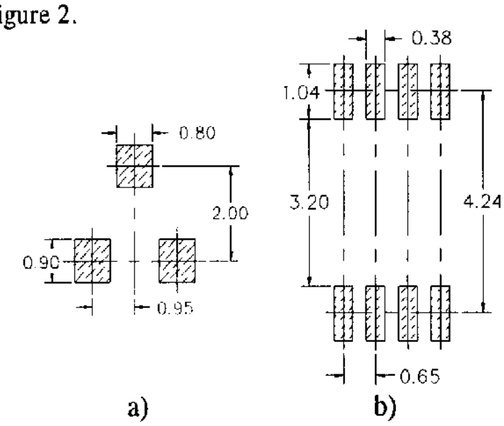

Figure 4
The recommended footprint for a) Micro3 and b) Micro8 closely approximates true applications (in mm).

The fourth step is to calculate $R_{\theta JA}$. Once the device reaches thermal equilibrium, the ambient temperature and power dissipation is measured. The junction is at its calibrated 150 °C value, so thermal resistance can be computed from the above equation.

2. Conclusion

Thermal resistance characterization must be done under steady-state conditions. It is a continuous, stable measurement with the devices in thermal equilibrium. Pulsed current characterization provides useful information as the transient thermal impedence, but should not be confused with $R_{\theta JA}$. The actual thermal resistance of a surface mounted device in a customer application depends heavily on the size of the drain pad. The values published by International Rectifier will accurately reflect actual operation because the recommended footprint is used for characterization.