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AN-9757

Determination of Maximum Current Rating for Low RDS_{ON} DPAK and D^2PAK MOSFETs

Introduction

A discrete transistor’s current capability is limited by one of three factors; die temperature (RDS_{ON}), wire-bond temperature, or source lead temperature. As silicon resistance declines, the maximum current limit is moving from the die to the package. This application note discusses a measurement technique used to determine a maximum current rating for low-RDS_{ON} DPAK and D^2PAK MOSFET’s. Equation (1) determines the RDS_{ON} limited maximum drain current for a MOSFET. The current limit is wire-bond or lead limited if this current is greater than the current that produces a bond-wire or lead temperature greater than the decomposition temperature of the mold compound. This temperature is around 200-220°C for most mold compounds. Note that this is the limit where immediate package damage occurs. A guard band needs to be added to ensure reliable operation.

Equation (1) determines the theoretical maximum current based on die temperature with an infinite heat sink:

$$I_D(\max) = \sqrt{\frac{T_J - T_C}{RDS_{ON} * R_{\theta JC}}} \quad (1)$$

where T_J is device maximum junction temperature; T_C is case temperature; $R_{\theta JC}$ is the thermal resistance from junction to case; and RDS_{ON} is the maximum device on-resistance at the maximum junction temperature.

The RDS_{ON} limit is defined by the total thermal resistance from junction to ambient. Wire-bond limit is determined by the wire-bond thickness and quantity, while source-lead limit is defined by the dimensions of the source lead and the heat sink capability of the source-lead contact.

Objective

Package current limitations for DPAK and D^2PAK with low RDS_{ON} is source-lead or wire-bond temperature. This measurement technique establishes a practical upper limit for drain current based on the temperature of the source lead as the limiting factor.

Setup

The basic setup in Figure 1 uses a copper block 6 x 6 x 1 inches. The block was machined into three pieces, as shown in Figure 1. Teflon was used to electrically isolate the block sections from each other. Custom copper pieces clamp the gate and source leads to the copper block *(see Figure 1)*. A commercial clamp was used to clamp the body of the device for drain contact. Mylar was used to isolate the copper from the hot or cold plate.

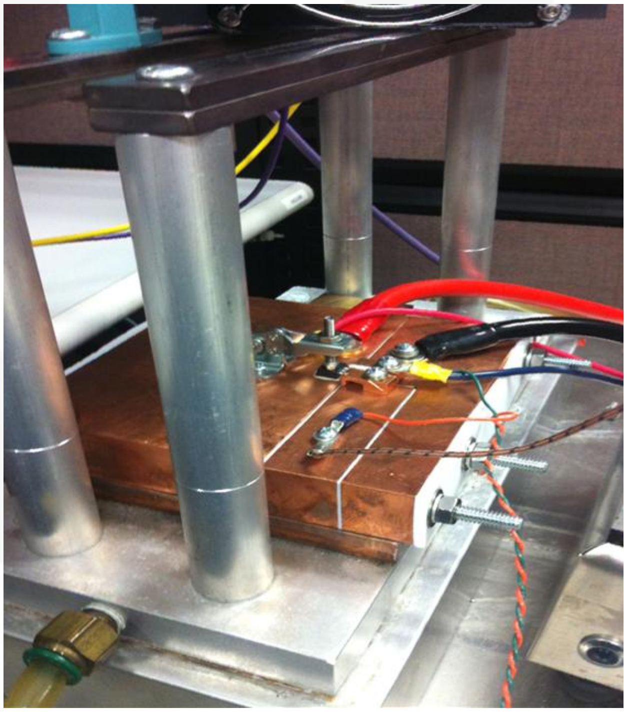

Figure 1. Test Setup

Summary

The clamped source-lead thermal resistance variation is dependent on the clamping location and pressure. Conductive thermal grease was used on the drain and source to produce consistent device temperatures. Clamping the source lead to the large copper block allows the maximum current to be obtained because the source-lead temperature is the limiting factor. The thermal characteristics of the source lead connection determine the maximum current limit if the drain heat sink is adequate. Measuring source-lead temperature versus drain current in the application provides a method for determining the maximum current. Maximum source-lead temperature is limited by the mold compound or PCB decomposition temperature.

A thermocouple was used to measure source-lead temperature and produced consistent results. Thermocouple placement was on the top of the source lead against the package with a small amount of thermal grease. This point was the highest source lead temperature that could be measured as it was as far as possible from the copper block heat sink.

A thermocouple was not placed below the drain, so block temperature was estimated using a thermocouple to measure temperature of block adjacent to drain, approximately at the midpoint of body of device on source side.

Example 1 — TO-263 (D2PAK)

The FDB9403_F085 is a package-limited device, as shown by the following calculations. Maximum on resistance is specified at 1.96 mΩ at T_J = 175°C. $R_{\theta JC}$ is specified as 0.43°C/W. Using these numbers in Equation (1), the theoretical die-limited maximum drain currents for an infinite heat sink are 465 A and 360 A, respectively, for ambient temperatures of 25°C and 85°C. Clearly, with an infinite heat sink, this part would be limited by the bond wires or the lead frame. Mold compound decomposition temperature for this part is 200°C, with a maximum mold compound safe operating temperature of 180°C.

Example 2 TO-252 (DPAK)

The FDB9407_F085 is a package-limited device, as shown by the following calculations. Maximum on resistance is specified at 3.22 mΩ at T_J = 175°C. $R_{\theta JC}$ is specified as 0.66°C/W. Using these numbers in Equation (1), the theoretical die-limited maximum drain currents for an infinite heat sink are 307 A and 206 A, respectively, for ambient temperatures of 25°C and 85°C. Clearly, with an infinite heat sink, this part would be limited by the bond wires or the lead frame. Mold compound decomposition temperature for this part is 200°C with a maximum mold compound safe operating temperature of 180°C. Note that the maximum ratings are the same as the D^2PAK package. The source lead of the DPAK is smaller and has less resistance, so the temperature versus current is similar to the D^2PAK.

FDB9403_F085 Current-Limit Summary

$R_{\theta JC}$ Limit with Infinite Heat Sink (Calculated):

- To 25°C infinite heat sink: 465 A
- To 85°C infinite heat sink: 360 A

$R_{\theta JC}$ Limit with 1in^2 2 oz. Copper Heat Sink (Calculated):

- To 25°C w/1in^2 2 oz. Copper heat sink: 40.8 A
- To 85°C w/1in^2 2 oz. Copper heat sink: 31.6 A

Note:

1. A heat sink of 1in^2 of 2 oz copper limits maximum current of this device to less than wire-bond or source-lead limits.

- Wire-bond limit: (3) x 20 mil: 132 A

Source Lead Temperature Limit (Measured):

- Source lead 180°C limit: 170 A (T_A = 25°C)
- Source lead 180°C limit: 110 A* (T_A = 85°C)

**Estimate from measured curves at T_A = 25°C.*

FDD9407_F085 Current Limit Summary

$R_{\theta JC}$ Limit with Infinite Heat Sink (Calculated):

- To 25°C infinite heat sink: 307 A
- To 85°C infinite heat sink: 206 A

$R_{\theta JC}$ Limit with 1in^2 2 oz. Copper Heat Sink (Calculated):

- To 25°C w/1in^2 2oz. Copper Heat Sink: 29.9 A
- To 85°C w/1in^2 2oz. Copper Heat Sink: 23.2 A

Note:

2. A heat sink of 1in^2 of 2 oz copper limits maximum current of this device to less than wire-bond or source-lead limits.

- Wire-bond limit: (2) x 20 mil: 88 A

Source Lead Temperature Limit (Measured):

- Source lead 180°C limit: 170 A (T_A = 25°C)
- Source lead 180°C limit: 110 A* (T_A = 85°C)

**Estimate from measured curves at T_A = 25°C.*

Related Datasheet

FDB9403_F085 N-Channel Power Trench® MOSFET 40 V, 110 A, 1.2 mΩ

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