



Is Now Part of



**ON Semiconductor®**

To learn more about ON Semiconductor, please visit our website at  
[www.onsemi.com](http://www.onsemi.com)

ON Semiconductor and the ON Semiconductor logo are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.



# AN-9757

## Determination of Maximum Current Rating for Low RDS<sub>ON</sub> DPAK and D<sup>2</sup>PAK MOSFETs

### Introduction

A discrete transistor's current capability is limited by one of three factors; die temperature (RDS<sub>ON</sub>), 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<sub>ON</sub> DPAK and D<sup>2</sup>PAK MOSFET's. Equation (1) determines the RDS<sub>ON</sub> 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:

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

where T<sub>J</sub> is device maximum junction temperature; T<sub>C</sub> is case temperature; R<sub>θJC</sub> is the thermal resistance from junction to case; and RDS<sub>ON</sub> is the maximum device on-resistance at the maximum junction temperature.

The RDS<sub>ON</sub> 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<sup>2</sup>PAK with low RDS<sub>ON</sub> 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.

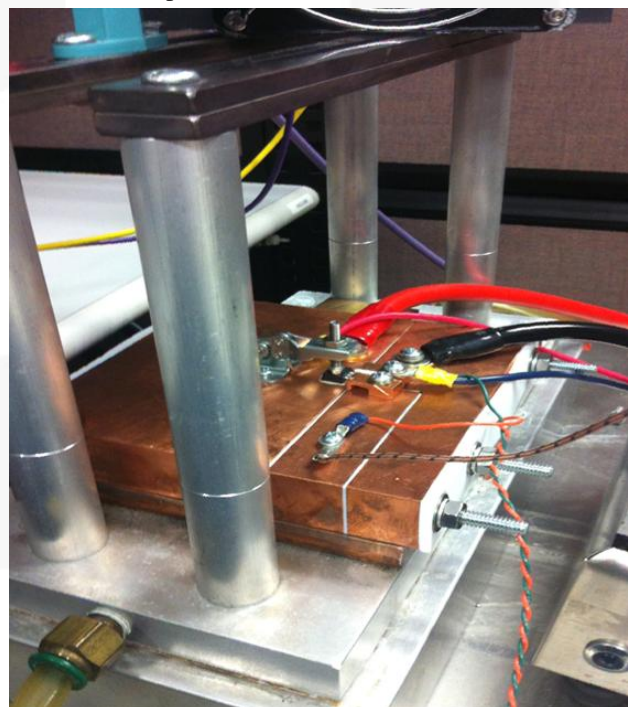


Figure 1. Test Setup

## 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  $T_J = 175^\circ\text{C}$ .  $R_{\theta JC}$  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  $T_J = 175^\circ\text{C}$ .  $R_{\theta JC}$  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<sup>2</sup>PAK package. The source lead of the DPAK is smaller and has less resistance, so the temperature versus current is similar to the D<sup>2</sup>PAK.

### 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<sup>2</sup> 2 oz. Copper Heat Sink (Calculated):

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

#### Note:

1. A heat sink of 1in<sup>2</sup> 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 ( $T_A = 25^\circ\text{C}$ )
- Source lead 180°C limit: 110 A\* ( $T_A = 85^\circ\text{C}$ )

\*Estimate from measured curves at  $T_A = 25^\circ\text{C}$ .

### 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<sup>2</sup> 2 oz. Copper Heat Sink (Calculated):

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

#### Note:

2. A heat sink of 1in<sup>2</sup> 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 ( $T_A = 25^\circ\text{C}$ )
- Source lead 180°C limit: 110 A\* ( $T_A = 85^\circ\text{C}$ )

\*Estimate from measured curves at  $T_A = 25^\circ\text{C}$ .

## Related Datasheet

[FDB9403\\_F085 N-Channel Power Trench® MOSFET 40 V, 110 A, 1.2 mΩ](#)

---

**DISCLAIMER**

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION, OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS.

**LIFE SUPPORT POLICY**

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF FAIRCHILD SEMICONDUCTOR CORPORATION.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

ON Semiconductor and  are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

## PUBLICATION ORDERING INFORMATION

### LITERATURE FULFILLMENT:

Literature Distribution Center for ON Semiconductor  
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA  
**Phone:** 303-675-2175 or 800-344-3860 Toll Free USA/Canada  
**Fax:** 303-675-2176 or 800-344-3867 Toll Free USA/Canada  
**Email:** [orderlit@onsemi.com](mailto:orderlit@onsemi.com)

**N. American Technical Support:** 800-282-9855 Toll Free  
USA/Canada  
**Europe, Middle East and Africa Technical Support:**  
Phone: 421 33 790 2910  
**Japan Customer Focus Center**  
Phone: 81-3-5817-1050

**ON Semiconductor Website:** [www.onsemi.com](http://www.onsemi.com)  
**Order Literature:** <http://www.onsemi.com/orderlit>  
For additional information, please contact your local  
Sales Representative