Application Brief

Power MOSFET Body Diode Continuous Current Carrying Capability

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Abstract

Silicon power MOSFETs include an intrinsic body diode between the drain and source terminals. With the MOSFET in the off state, the body diode blocks current flow in the reverse direction and conducts current when the diode is forward biased.

MOSFET Drain-to-source Voltage Limitations

The MOSFET breakdown voltage, BV_{DSS}, is the maximum voltage that can safely be applied from drain-to-source without driving the device into avalanche and is also the maximum body diode reverse bias voltage. The body diode forward voltage, V_{SD}, specified in the data sheet is the drop from source-to-drain at the defined current and is typically on the order of 0.8 V to 1.0 V.

Body Diode Current Capability

Often, engineers ask if the body diode can support the same maximum drain current specified in the MOSFET data sheet. In theory, the body diode can be expected to since the body diode is the same current path through the device. However, the limiting factor becomes the power dissipation. When the MOSFET is on, the conduction loss is $I_D{}^2$ x $R_{DS(on)}$. When the FET is off and the body diode conducts, the conduction loss is I_{SD} x V_{SD}. As explained in the *Understanding MOSFET data sheets, Part 3 - Continuous current ratings* blog, the maximum power dissipation specified in the FET data sheet is calculated as follows:

$$\text{Max } P_{DISS} = \frac{\text{Max } T_J - T_X}{R_{\theta JX}} = I_D^2 \times R_{DS(on)} \tag{1}$$

Where $R_{\theta JX}$ is either the thermal resistance from junction-to-case, $R_{\theta JC}$, or from junction-to-ambient, $R_{\theta JA}$ and T_X is either the case temperature, T_C, or the ambient temperature, T_A. Solving for I_D, the maximum drain current specified in the data sheet at T_X = 25°C when the FET is on:

$$\text{Max } I_D(T_X{=}25°C) = \sqrt{\frac{\left(\frac{\text{Max } T_J - 25°C}{R_{\theta JX}}\right)}{R_{DS(on)}\text{at Max } T_J}} \tag{2}$$

This equation can be extended to calculate the maximum continuous at 25°C current for the body diode:

$$\text{Max } P_{DISS} = \frac{\text{Max } T_J - 25°C}{R_{\theta JX}} = I_{SD} \times V_{SD} \tag{3}$$

Solving for I_{SD}, the maximum body diode current when the FET is off:

$$\text{Max } I_{SD}(T_X = 25°C) = \frac{\left(\frac{\text{Max } T_J - 25°C}{R_{\theta JX}}\right)}{V_{SD}} \tag{4}$$

Maximum Continuous Current Calculation Examples

The CSD19532Q5B, 100-V N-channel MOSFET is used as an example. First, a quick review of the maximum ratings from the first page of the data sheet. Note that the maximum body diode current is not specified in the FET data sheet. Also, there are multiple specifications for maximum drain current as explained in the previously referenced blog. For this example, the maximum body diode current is calculated for an ambient temperature, T_A = 25°C, using the typical $R_{\theta JA}$ = 40°C/W as follows:

$$\text{Max } P_{DISS}(T_A{=}25°C) = \frac{\text{Max } T_J - 25°C}{R_{\theta JA}} = \frac{150°C - 25°C}{40°C/W} = 3.1 \text{ W} \tag{5}$$

The CSD19532Q5B maximum continuous drain current:

$$\text{Max } I_D(T_A{=}25°C) = \sqrt{\frac{\text{Max } P_{DISS}}{R_{DS(on)} \text{ at Max } T_J}} \tag{6}$$

Maximum $R_{DS(on)}$ at T_J = 150°C can be calculated using the maximum specified $R_{DS(on)}$ = 4.9 mΩ at V_{GS} = 10 V and multiplying it by the normalizing factor shown in Figure 8 of the device data sheet:

$$\text{Max } R_{DS(on)} \text{ at Max } T_J = 4.9 \text{ m}\Omega \times 2.1 \ = 10.3 \text{ m}\Omega \tag{7}$$

$$\text{Max } I_D(T_A{=}25°C) = \sqrt{\frac{3.1 \text{ W}}{10.3 \text{ m}\Omega}} = 17 \text{ A} \tag{8}$$

To calculate the maximum diode current, use the maximum forward voltage specified in the data sheet as follows:

$$\text{Max } I_{SD}(T_A{=}25°C) = \frac{\text{Max } P_{DISS}}{V_{SD}} = \frac{3.1 \text{ W}}{1.0 \text{ V}} = 3.1 \text{ A} \tag{9}$$

Similarly, the silicon limited maximum continuous body diode current at T_C = 25°C can be calculated using the junction-to-case thermal impedance, $R_{\theta JC}$ = 0.8°C/W, as shown in the following equations.

$$\text{Max } P_{DISS}(T_C{=}25°C) = \frac{\text{Max } T_J - 25°C}{R_{\theta JC}} = \frac{150°C - 25°C}{0.8°C/W} = 156 \text{ W} \tag{10}$$

$$\text{Max } I_{SD}(T_C{=}25°C) = \frac{\text{Max } P_{DISS}}{V_{SD}} = \frac{156 \text{ W}}{1.0 \text{ V}} = 156 \text{ A} \tag{11}$$

Note that this calculation assumes an ideal heat sink is used to hold the case temperature at 25°C. This case is impossible in a real application with an actual heat sink and 156 W of power dissipation in a 5x6mm package.

Temperature Derating

At elevated temperatures, these calculations yield lower currents. For example, substituting T_A = 75°C in the previous calculation results in lower power dissipation and reduced body current capability, provides the following calculation results:

$$\text{Max } P_{DISS}(T_A{=}75°C) = \frac{\text{Max } T_J - 75°C}{R_{\theta JA}} = \frac{150°C - 75°C}{40°C/W} = 1.9 \text{ W} \tag{12}$$

$$\text{Max } I_{SD}(T_A{=}75°C) = \frac{\text{Max } P_{DISS}}{V_{SD}} = \frac{1.9 \text{ W}}{1.0 \text{ V}} = 1.9 \text{ A} \tag{13}$$

Summary

MOSFET data sheets specify the maximum drain current. A common question is, can the intrinsic body diode carry the same amount of current? As this application brief demonstrates, the current carrying capability of the body diode can be calculated, is limited by power dissipation, and is typically less than the maximum drain current specified in the data sheet.

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