Current Ratings for Vishay Siliconix MOSFETs

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SUMMARY

Vishay uses three approaches in providing the continuous drain current (I_D) rating for its MOSFETs. The values are printed in the "Absolute Maximum Ratings" table on the first page of the datasheet, and are intended to provide designers with sample conditions to determine if the part is being used properly in their applications. A general approach is taken to the calculation of this value. Yet every PCB layout and design is different, and every MOSFET is constructed differently. So no general process can be provided to calculate the maximum allowable current for every application. Instead, the values provided are numbers that Vishay guarantees under given conditions, and it is left to designers to model the performance of the MOSFET in their specific applications based on these values.

Please note that the methods below are for calculating the maximum allowable continuous DC current. This value cannot be used for dc-to-dc converters that utilize pulsed current with high peak currents. For this type of application, the Root Mean Squared current (I_{RMS}) must be calculated and then compared to the I_D rating on the data sheet with $I_{RMS} << I_D$ MAX. Formulas for calculating I_{RMS} can be found in most power electronics texts. In addition, high transient spike currents seen at turn on or turn off must be compared to the SOA curve to determine if they will damage the MOSFETs.

FORMULA METHOD FOR I_D RATINGS

The first approach is to calculate I_D with the standard current calculation, which is shown below. In this formula, T_{JMAX} is the maximum junction temperature specified on the datasheet (either 150 °C or 175 °C) and T_A is the maximum ambient temperature allowed when the MOSFET is in steady-state operation. $r_{DS(on)}$ is the maximum on-resistance rating at a specific temperature and a specific drive voltage (such as 4.5 V or 10 V), and R_{thJA} is the steady-state junction-to-ambient thermal resistance of the MOSFET as specified on the datasheet.

$$I_D = \sqrt{\frac{T_{JMAX} - T_A}{r_{DS(on)}\, R_{thJA}}}$$

The following example is based on the Si7884DP, which is a 40 V MOSFET in the PowerPAK® SO-8 package.

ABSOLUTE MAXIMUM RATINGS T_A = 25 °C, unless otherwise noted

Parameter		Symbol	10 sec	Steady State	Unit
Drain-Source Voltage		V_{DS}	40		V
Gate-Source Voltage		V_{GS}	± 20		
Continuous Drain Current (T_J = 150 °C)[a]	T_A = 25 °C	I_D	20	12	A
	T_A = 70 °C		16	10	
Pulsed Drain Current		I_{DM}	50		
Avalanche Current	L = 0.1 mH	I_{AS}	30		
Continuous Source Current (Diode Conduction)[a]		I_S	4.7	1.7	
Maximum Power Dissipation[a]	T_A = 25 °C	P_D	5.2	1.9	W
	T_A = 70 °C		3.3	1.2	
Operating Junction and Storage Temperature Range		T_J, T_{stg}	- 55 to 150		°C
Soldering Recommendations (Peak Temperature)[b,c]			260		

THERMAL RESISTANCE RATINGS

Parameter		Symbol	Typical	Maximum	Unit
Maximum Junction-to-Ambient[a]	t ≤ 10 sec	R_{thJA}	19	24	°C/W
	Steady State		52	65	
Maximum Junction-to-Case (Drain)	Steady State	R_{thJC}	1.2	1.8	

From the "Absolute Maximum Ratings" table we get the following values:

Parameter	Value	Comments
T_{JMAX}	150 °C	Maximum junction temperature; note that some devices are rated at 175 °C
T_A	25 °C	Ambient temperature; used with R_{thJ-A}
$R_{thJA\ MAX}$	65 °C/W	Maximum value at steady state
$r_{DS(on)}$ MAX at 10 V (at Temp)	0.0126 Ω	From 0.007 Ω x 1.8; 0.007 Ω is from the "Electrical Characteristics" section of the data sheet; 1.8 is a typical factor used to rate $r_{DS(on)}$ at higher temperatures; an actual curve can be found in the "Typical Performance Curves" section of the data sheet

I_D = SQR ROOT OF (150-25)/(0.007x1.8)x65 = 12 A

The I_D of 12 A is specified in the "Absolute Maximum Ratings" table for the steady-state value at a T_A of 25 °C.

The formula can also use R_{thJC} in the denominator instead of R_{thJA}. The R_{thJC} value provided on datasheets is a best-case thermal resistance value, while the R_{thJA} value is usually more representative of actual board layout conditions. Therefore, the designer can calculate a range to determine the boundaries of a device's operation. Vishay usually specifies the R_{thJA} since it gives the worst-case condition using a 1-in-by-1-in. PCB area on an FR4 board, with 2 oz of copper or more as a pad. In most board designs today, even smaller guidelines are used for the PCB layout. Since it is impractical to calculate values for every possible design, Vishay uses the standard 1-in-by-1-in condition for the R_{thJA} rating.

The formula can also be stated as $T_J = T_A + I_D^2 \times r_{DS(on)} \times R_{thJA}$. There is no difference in the result; however, this method can be easier for understanding the dynamics at work.

$I_D^2 \times r_{DS(on)}$ is the standard calculation for power loss in Watts (W). R_{thJA} is specified in °C/W and the product of power and thermal resistance results is measured in °C, since the Watts cancel out. Adding this value to T_A, which is also measured in °C, results in the temperature rise of the junction (T_J). As long as this value is below the maximum rating (such as 150 °C), the design is thermally within the boundaries of the safe operating area for the MOSFET. Normally design engineers will place a de-rating value on the maximum junction temperature, such as 80 %, so that designs don't come near the maximum value. This is a good practice and is recommended by Vishay.

PACKAGE LIMITATION METHOD FOR I_D RATINGS

The second method for determining the I_D rating for a MOSFET is to determine how much current the package can handle. This is the next step before stating a value in the "Absolute Maximum Ratings" table. After using the standard current calculation to determine a value, engineering will determine if the package can handle that amount of current. For MOSFETs with higher $r_{DS(on)}$ ratings, the formula calculation is usually good enough. However, for ultra-low $r_{DS(on)}$ ratings, the calculated value usually exceeds the current-handling capability of the MOSFET package.

The weakest part of the MOSFET's package is the wires used to bond the silicon die to the lead frame. Based on the material of the wires and the number of wires used, a certain current-carrying value can be determined. If the current exceeds this value, the wires can melt, resulting in catastrophic destruction of the device. To strengthen this part of the package, a clip is used instead of wires. Clips usually have greater current-carrying capability since there is more metallic mass. However, different clips are used based on the size of the silicon die, which means that the current capability also varies. No specific guideline can be provided other than to rely on the maximum I_D ratings on the data sheet. If the ratings are lower than values designers calculate, then the capability of the package has been factored into the rating.

MEASUREMENT METHOD FOR I_D RATINGS

The third method for determining the maximum I_D rating of a MOSFET is to drive the device to destruction by applying current methodically until breakdown. This method is usually used to determine the pulsed drain current value (I_{DM}), but it can also be used for the continuous current ratings.

When this method is applied, the MOSFET is driven into saturation and no more current can pass through the device. After measuring this value on a typical sample size of parts, the rating will be provided on the datasheet with a guard band. This guard band can be as much as 50 %.

CONCLUSION

Three methods are used to arrive at the I_D rating for Vishay's MOSFET products - formula, package limitations, and actual measurements. The number on the data sheet is the limiting value based on the three approaches. The conditions used may not replicate every application in the field, but are a departure point for designers to understand the limitations of the device. Followed carefully, they will help designers ensure that they are using MOSFETs well within the operating conditions required for robust and reliable operation.

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