International Rectifier

DESIGN TIP

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Estimating T_J of SO-8 Power MOSFETs

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Background

It is a fundamental industry need to accurately measure junction temperature (T_J) of power MOSFETs in an operating circuit. This need has led many designers to inquire how to accurately measure T_J for Power MOSFETs in SO-8 packages and question the R_{2JC} for these devices.[1] Several means to measure T_J for these power MOSFETs have been created throughout the industry. A common method used is the placement of a thermocouple on the top of the device. Another method is measuring the lead temperature and adding 10ºC to 15ºC to the measured temperature and assuming that was the T_J. An additional method would be the use of an infrared camera to measure case temperature.

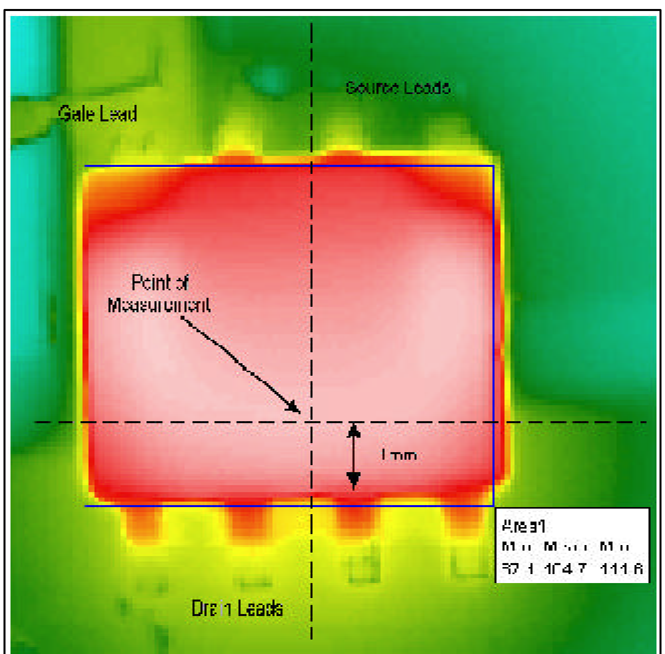


Figure 1. A critical issue in estimating junction temperature in an SO-8-packaged MOSFET is point of measurement. The hottest spot is near the drain leads on an SO-8 package.

Method

In practice, the actual junction temperature of a power MOSFET in a SO-8 package is within 5ºC of the measured case temperature of the device.[2] The case temperature (T_C) can be best measured with an infrared camera. An alternative would be to use a small thermocouple and suitable meter. The most critical issue is the point of measurement, refer to Figure 1.

The hottest spot on an SO-8-packaged MOSFET is near the drain leads. Measuring at this location gives a close indication of the junction temperature. Technical details in the following paragraphs validate the method for use in thermal design verification.

Validation

R_2 Measurements

To gain an intuitive understanding of why the ΔT_{JC} is so small, one must look at how R_{2JC} relates to R_{2CA}, R_{2JL}, and R_{2LA} for an SO-8 MOSFET.[1] Figure 2 depicts this relationship. Power dissipation (P_D) conduction is split in two ways in Figure 2. The first path is through the leads of the device. This is how most heat is removed from the device in a practical application. The second path is through the case. Using an Ohm's Law analogy[3], one can see that

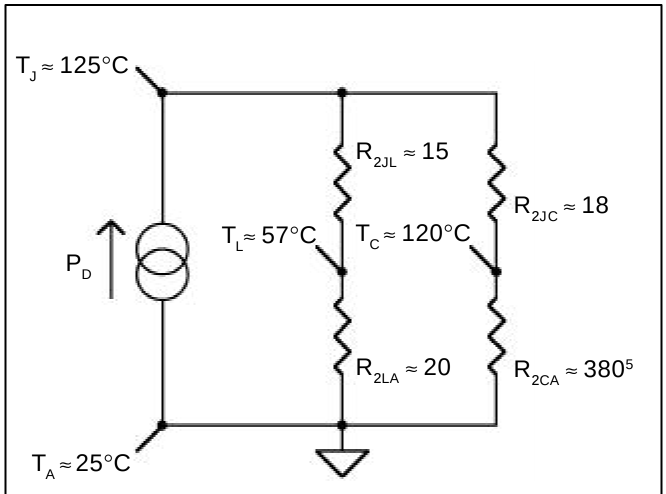
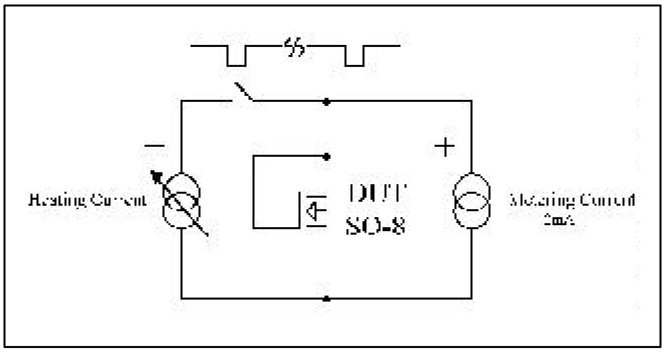


Figure 2. Typical R_2(ºC/W) for SO-8 MOSFETs

the power that is dissipated through the case of the device will create a small ΔT across R_{2JC}. In turn creating a very large ΔT across R_{2CA}.

T_J and ΔT_{JC} Measurements

The ΔT_{JC} of 5ºC has been validated through the use of gate threshold voltage (V_{GTH}) as a temperature sensitive electrical parameter (TSEP). The V_{GTH} of a MOSFET changes inversely with respect to its junction temperature. This is the foundation behind the circuit shown below.



The table below shows the results for some common International Rectifier SO-8 MOSFETs tested under similar conditions.

ΔT_{JC} Results

Device	T_J	T_C	ΔT_{JC}	P_D[4]
IRF7805	125ºC	124ºC	1ºC	3.6W
IRF7807	124ºC	121ºC	3ºC	3.5W
IRF7809	126ºC	125ºC	1ºC	3.6W
IRF7811	126ºC	124ºC	2ºC	3.9W

The variances in ΔT_{JC} are due to instrumentation errors. These measurement errors account for the +/-1ºC variation. For example:

- Infrared camera measurement error
- Metering current distribution over surface of die
- Voltage meter error
- Current meter error

Conclusion

R_{2JC}creates a difference in temperature that is typically less than 5ºC without a heat sink, in still air. Therefore, adding 5ºC to the measured case temperature of an SO-8 MOSFET is an effective means to get a close indication of the junction temperature.

Footnotes

[1]R_{2JC} - Thermal resistance junction-to-case (ºC/W)
R_{2CA} - Thermal resistance case-to-ambient (ºC/W)
R_{2JL} - Thermal resistance junction-to-lead (ºC/W)
R_{2LA} - Thermal resistance lead-to-ambient (ºC/W)

[2] No heat sink on device. Still air conditions.

[3] Substitute temperature for voltage and P_D for current in Ohm's Law.

[4] $R_{2JC} \neq (\Delta T_{JC} \ / \ P_D)$ for the thermal environment of this measurement.

[5] An exact value for R_{2CA} is difficult to measure. In order for this measurement to be true, the device must be thermally isolated so the heat is only dissipated through the top of the package. The value used in Figure 2 for R_{2CA} was derived through a series of tests.

First, R_{2CA} testing on an SO-8 MOSFET was done in free air. The resulting value was 190ºC/W. Then, an imperfect form of isolation was used on the bottom of the case, leaving the leads exposed. The goal was to get an intuitive idea of how much of an increase in R_{2CA} would be created by isolating only the bottom of the device. The measured value for R_{2CA} was 310ºC/W, an increase of 63%. It is intuitive that if the device had been isolated (case sides, bottom and leads) by a perfect material, then the final measured R_{2CA} would be at least twice the value of the R_{2CA} measured in free air.

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