Application Brief

Estimating Leakage Currents of Power MOSFETs

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Abstract

Many electronic systems utilize power MOSFETs to turn off subsystems to reduce power consumption when not in use. Load switching is commonly employed in battery powered systems to maximize battery runtime. Estimating the leakage current of MOSFETs is key to reducing the overall discharge current of the battery in low-power or standby modes of operation.

Introduction

Leakage currents flow between the MOSFET terminals and are specified in the FET datasheet. Gate to source leakage current, I_{GSS}, flows between gate and source. Drain to source leakage current, I_{DSS}, flows between drain and source. As shown in Table 1, the datasheets for TI's FETs specify the maximum value of the I_{GSS} at the absolute maximum of V_{GS} and V_{DS} = 0V, and a maximum value of the I_{DSS} at 80% of the drain to source breakdown voltage, BV_{DSS} and VGS = 0V. Both parameters are specified at an ambient temperature of T_A = 25°C. Always check the datasheet of the MOSFET, as other FET vendors can specify leakage currents for conditions differently than TI.

Table 1. Leakage Specifications from the Electrical Characteristics Table in the Datasheet

(T_A = 25°C unless otherwise stated)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
STATIC CHARACTERISTICS						
BV_{DSS}	Drain to Source Voltage	V_{GS} = 0V, I_D = 250μA	30			V
I_{DSS}	Drain to Source Leakage Current	V_{GS} = 0V, V_{DS} = 24V			1	μA
I_{GSS}	Gate to Source Leakage Current	V_{DS} = 0V, V_{GS} = 20V			100	nA
$V_{GS(th)}$	Gate to Source Threshold Voltage	V_{DS} = V_{GS}, I_D = 250μA	1.1	1.4	1.8	V
$R_{DS(on)}$	Drain to Source On Resistance	V_{GS} = 4.5V, I_D = 25A		2.4	2.9	mΩ
		V_{GS} = 10V, I_D = 25A		1.7	2.0	mΩ
g_{fs}	Transconductance	V_{DS} = 3V, I_D = 25A		120		S

Voltage and Temperature Effects

Two earlier technical articles, *What's Not in the Power MOSFET Datasheet, Part 1: Temperature Dependency* and *What's Not in the Power MOSFET Datasheet Part 2: Voltage-dependent Leakage Currents*, detail how FET leakage currents vary with temperature and voltage. I_{GSS} and I_{DSS} have positive temperature and voltage coefficients. This document shows how to use the normalized graphs from the previous articles to estimate leakage at conditions not included in the datasheets. Figure 1 and Figure 2 are plots of normalized I_{DSS} and I_{GSS} versus the temperature for a 30V TI FET without gate ESD protection.

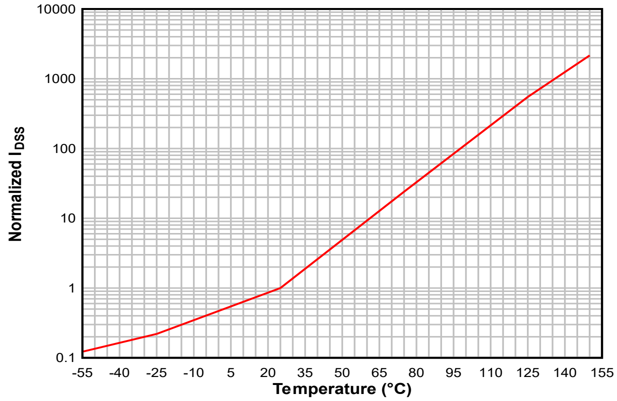

Figure 1. Normalized I_{DSS} Versus Temperature

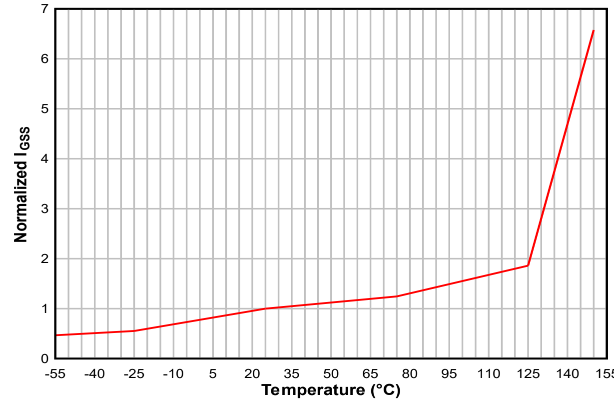

Figure 2. Normalized I_{GSS} Versus Temperature

Figure 3 and Figure 4 are plots of normalized I_{DSS} and I_{GSS} versus V_{DS} and V_{GS} for a 30V TI FET without gate ESD protection, respectively.

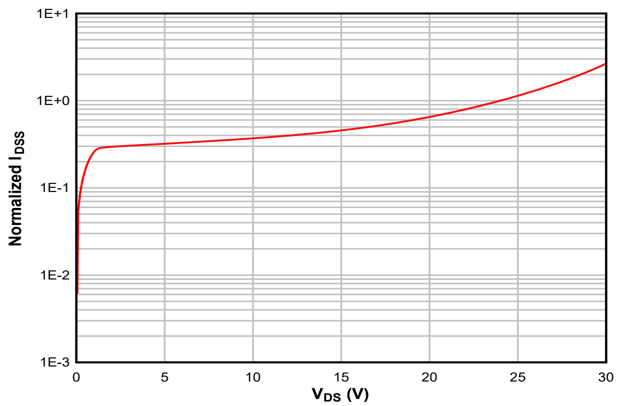

Figure 3. Normalized I_{DSS} Versus Voltage

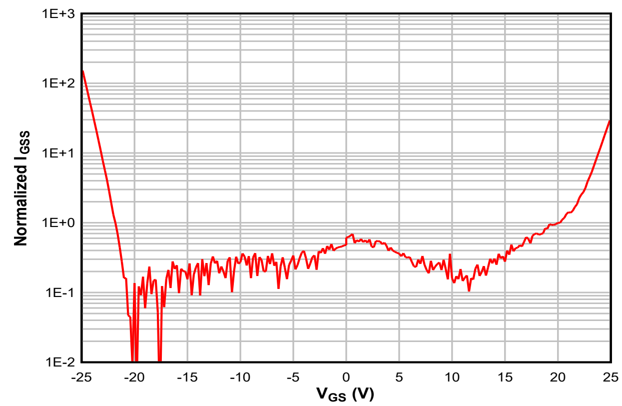

Figure 4. Normalized I_{GSS} Versus Voltage

Using Normalized Plots to Estimate I_{GSS}

The following example demonstrates how these plots can be used to estimate leakage currents for conditions not included in the datasheet.

Example 1 What is the maximum I_{GSS} for a 30V TI N-channel FET without gate ESD protection at V_{GS} = 5V and T = 75°C?

Estimation Instructions With the I_{GSS} versus temperature plot (Figure 5):

1. Draw a vertical line from 75°C on the X-axis to where the line intercepts the curve.
2. Draw a horizontal line from where the X-axis met the curve to the Y-axis intercept.

This is the normalized temperature factor, F_T = 1.25, for I_{GSS} at 75°C. Using the same methodology on the I_{GSS} versus V_{GS} graph, the normalized factor of I_{GSS} at V_{GS} = 5V is F_V = 0.35. This is shown in Figure 5 and Figure 6.

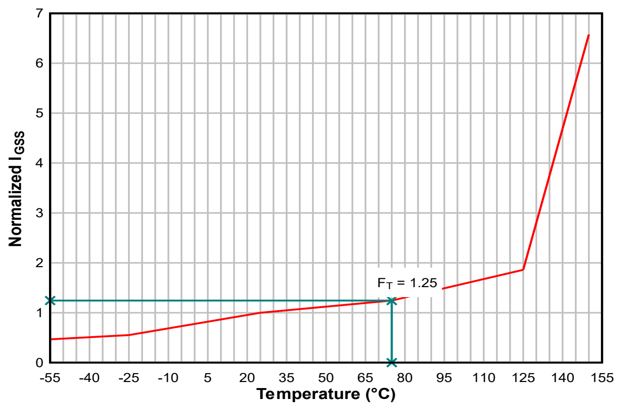

Figure 5. Normalized I_{GSS} Versus Temperature

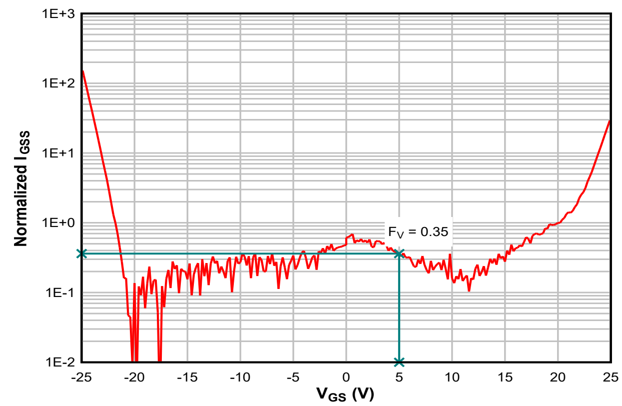

Figure 6. Normalized I_{GSS} Versus Voltage

The estimated max I_{GSS} is then calculated at V_{GS} = 5V and T = 75°C, as shown in Equation 1 and Equation 2:

$$\mathrm{MaxI_{GSS}(5V, 75°C) = I_{GSS(max)} \times F_V \times F_T} \tag{1}$$

$$\mathrm{MaxI_{GSS}(5V, 75°C) = 100nA \times 0.35 \times 1.25 = 44nA} \tag{2}$$

Using Normalized Plots to Estimate I_{DSS}

The following example demonstrates how these plots can be used to estimate leakage currents for conditions not included in the datasheet.

Example 2 What is I_{DSS} at V_{DS} = 12V and T = 125°C?

Estimation Instructions With the normalized I_{DSS} versus temperature plot (Figure 7):

1. Draw a vertical line from 125°C on the X-axis to where the line intercepts the curve.
2. Draw a horizontal line from where the X-axis met the curve to the Y-axis intercept.

The same methodology can be used to determine the temperature and voltage factors, as shown in Figure 7 and Figure 8.

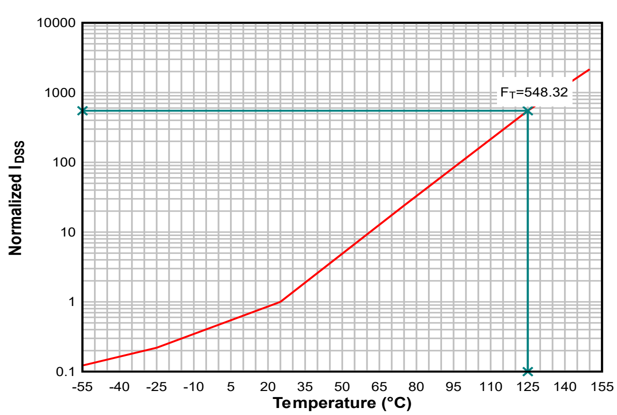

Figure 7. Normalized I_{DSS} Versus Temperature

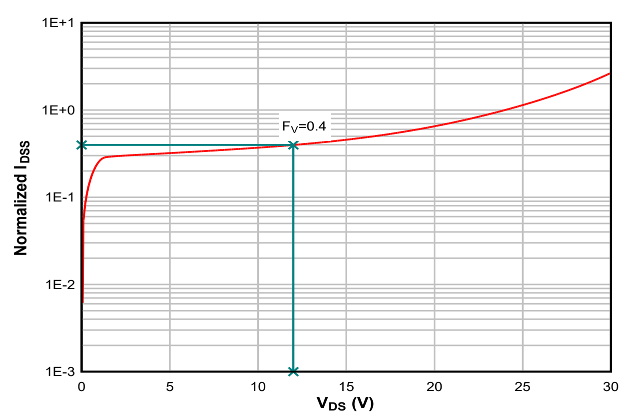

Figure 8. Normalized I_{DSS} Versus Voltage

From Figure 7, F_T = 548 and from Figure 8, F_V = 0.4. The estimated max I_{DSS} is then calculated as follows:

$$\mathrm{MaxI_{DSS}(12V, 125°C) = I_{DSS(max)} \times F_V \times F_T} \tag{3}$$

$$\mathrm{MaxI_{DSS}(12V, 125°C) = 1\mu A \times 0.4 \times 548 = 219\mu A} \tag{4}$$

Summary

Estimating leakage currents of power MOSFETs is useful when the FET is operating at conditions not included in the datasheet. A method for estimating these currents was demonstrated in this article by using normalized I_{GSS} and I_{DSS} graphs. Future work in this area includes the development and release of a new FET selection tool to make this process easier for the designer.

References

1. Texas Instruments, *MOSFET Support and Training Tools*, application note.
2. Texas Instruments, *What's Not in the Power MOSFET Datasheet, Part 1: Temperature Dependency*, technical article.
3. Texas Instruments, *What's Not in the Power MOSFET Datasheet Part 2: Voltage-dependent Leakage Currents*, technical article.

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