µ$R_{DS(on)}$ FET™ Series

PI5101-01-LGIZ

PICOR

*Semiconductor Power Solutions*

# 360µΩ, 5 V/60 A N-Channel MOSFET

## Product Description

The PI5101µ$R_{DS}$(on) FET™ solution combines a high-performance 5 V, 360 µΩ lateral N-Channel MOSFET with a thermally enhanced high density 4.1mm x 8mm x 2mm land-grid-array (LGA) package to enable world class performance in the footprint area of an industry standard SO-8 package. The PI5101 offers unprecedented figure-of-merits for DC & switching applications. The PI5101 will replace up to 6 conventional "SO-8 form factor" devices for the same on-state resistance, reducing board space by ~80%. The PI5101 offers unprecedented figure-of-merit for $R_{DS(on)}$ x $Q_G$, gate resistance ($R_G$) and package inductance ($L_{DS}$) outperforming conventional Trench MOSFETs and enabling very low loss operation.

The PI5101 LGA package is fully compatible with industry standard SMT assembly processes.

## Features

- Ultra Low "micro-Ohm" $R_{DS(on)}$
- Extremely Low Gate Charge
- Very Low Gate Resistance
- High Density, Low Profile
- Very Low Package Inductance
- Low Thermal Resistance

## Applications

- Power Path Management Solutions
- Active ORing & Load Switches
- High Current DC-DC Converters

## Product Summary

| Symbol | Condition | Value | |
|---|---|---|---|
| $I_D$ | $T_A$ = 25°C | 60 $A_{DC}$ | Max |
| $V_{(BR)DSS}$ | $I_D$ = 5 mA | 5 V | Min |
| $R_{DS(ON)}$ | $V_{GS}$ = 4.5 V | 360 µΩ | Typ |
| | $V_{GS}$ = 3.5 V | 380 µΩ | Typ |
| $Q_G$ | $V_{GS}$ = 4.5 V | 65 nC | Typ |
| $R_G$ | | 0.1 Ω | Typ |
| $L_{DS}$ | | 0.1 nH | Typ |

## Package Information

- 4.1mm x 8mm x 2mm Thermally Enhanced LGA

## Order Information

| Part Number | Package | Transport Media |
|---|---|---|
| PI5101-01-LGIZ | 4.1mm x 8mm x 2mm 3-Lead LGA | T&R |

## Maximum Rating and Thermal Characteristics

$T_A$ = 25°C unless otherwise specified.

| Parameter | | Symbol | Limit | Unit |
|---|---|---|---|---|
| Drain-to-Source Voltage | | $V_{DS}$ | 5 | V |
| Gate-to-Source Voltage | | $V_{GS}$ | ±5 | V |
| Drain Current | Continuous | $I_D$ | 60 | A |
| | Pulsed | $I_{DM}$ | 150 | A |
| Single Pulse Avalanche Current | $T_{AV}$ <100 µs | $I_{AS}$ | 100 | A |
| Maximum Power Dissipation | $T_A$ = 25°C | $P_D$ | 3.1 | W |
| | $T_A$ = 70°C | | 2 | W |
| Operating Junction and Storage Temperature Range | | $T_J$, $T_{STG}$ | -55 to 150 | °C |
| Thermal Resistance [1] | Junction-to-Ambient | $R_{\theta J\text{-}A}$ | 40 | °C/W |
| | Junction-to-PCB | $R_{\theta J\text{-}PCB}$ | 6 | °C/W |
| Lead Temperature (Soldering, 20 sec) | | | 260 | °C |

[1] The thermal resistance is measured when the device is mounted on 1 inch square 4-layer 2-oz copper FR-4 PCB at 0LFM and 40A drain current

## Electrical Characteristics

$T_A$ = 25°C unless otherwise specified.

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Input Specifications** | | | | | | |
| Drain-to-Source Breakdown Voltage | $V_{(BR)DSS}$ | $V_{GS}$ = 0 V, $I_D$ = 5 mA | 5.0 | | | V |
| Breakdown Voltage Temperature Coefficient | $\frac{\Delta V_{(BR)DSS}}{\Delta T_J}$ | Reference to 25°C, $V_{GS}$ = 0 V, $I_D$ = 5 mA | | 3.1 | | mV/℃ |
| Drain-to-Source Leakage Current | $I_{DSS}$ | $V_{DS}$ = 4.8 V, $V_{GS}$ = 0 V | | 0.2 | 2 | µA |
| Gate-to-Source Leakage | $I_{GSS}$ | $V_{GS}$ = 5 V, $V_{DS}$ = 0 V | | 10 | 200 | nA |
| Gate Threshold Voltage | $V_{GS(th)}$ | $V_{DS}$ = $V_{GS}$, $I_D$ = 1 mA | 0.4 | | 0.8 | V |
| Drain-to-Source On-State Resistance | $R_{DS(on)}$ | $V_{GS}$ = 4.5 V, $I_D$ = 60 A | | 360 | 450 | µΩ |
| | | $V_{GS}$ = 3.5 V, $I_D$ = 60 A | | 380 | 475 | µΩ |
| Turn-On Delay Time | $t_{d(on)}$ | $V_{GS}$ = 4.5 V, $I_D$ = 60 A, $R_G$ = 0.1Ω | | 14 | | ns |
| Rise Time | $t_r$ | $V_{GS}$ = 4.5 V, $I_D$ = 60 A, $R_G$ = 0.1Ω | | 4.5 | | ns |
| Turn-Off Delay Time | $t_{d(off)}$ | $V_{GS}$ = 4.5 V, $I_D$ = 60 A, $R_G$ = 0.1Ω | | 23 | | ns |
| Fall Time | $t_f$ | $V_{GS}$ = 4.5 V, $I_D$ = 60 A, $R_G$ = 0.1Ω | | 3.5 | | ns |
| Forward Transconductance | gfs | $I_D$ = 60 A, $V_{DS}$ = 4 V | | 620 | | S |
| **Gate Capacitance** | | | | | | |
| Input Capacitance | $C_{iss}$ | $V_{DS}$ = 5 V, $V_{GS}$ = 0 V, f = 1MHz; See Figure 6 | | 7600 | | pF |
| Output Capacitance | $C_{oss}$ | $V_{DS}$ = 5 V, $V_{GS}$ = 0 V, f = 1MHz; See Figure 6 | | 5200 | | pF |
| Reverse Transfer Capacitance | $C_{rss}$ | $V_{DS}$ = 5 V, $V_{GS}$ = 0 V, f = 1MHz | | 1100 | | pF |
| **Gate Charge** | | | | | | |
| Total Gate Charge | $Q_g$ | $V_{GS}$ = 4.5 V, $V_{DD}$ = 4.4 V, $I_D$ = 60 A; See Figure 3 | | 65 | | nC |
| Gate-to-Source Charge | $Q_{gs}$ | $V_{GS}$ = 4.5 V, $V_{DD}$ = 4.4 V, $I_D$ = 60 A | | 7.7 | | nC |
| Gate-to-Drain Charge | $Q_{gd}$ | $V_{GS}$ = 4.5 V, $V_{DD}$ = 4.4 V, $I_D$ = 60 A | | 9.0 | | nC |
| Gate Resistance | $R_G$ | | | 0.1 | | Ω |
| **Reverse Diode** | | | | | | |
| Source-to-Drain Reverse Recovery Time | $t_{rr}$ | $I_S$ = 16 A, di/dt = 33 A/µs | | 300 | | ns |
| Diode Forward Voltage | $V_{SD}$ | $I_S$ = 16 A, $V_{GS}$ = 0 V (Pulse Test) | | 0.63 | 1.0 | V |
| Package Inductance | $L_{DS}$ | | | 0.1 | | nH |

## Typical Characteristics

$T_A$ = 25°C unless otherwise specified.

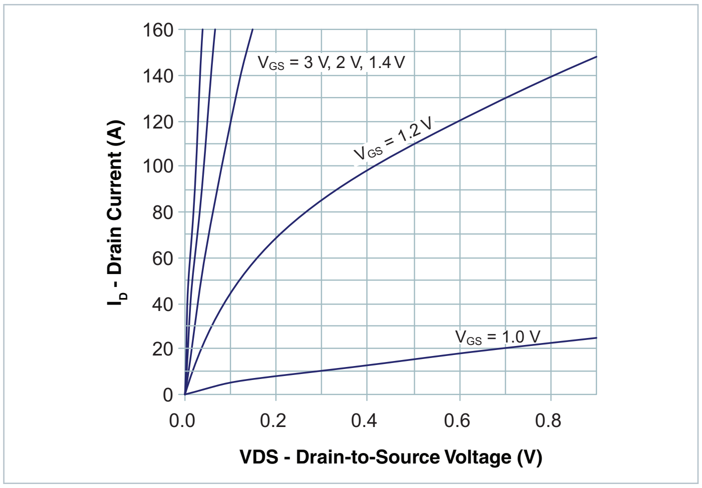



***Figure 1*** *— Output Characteristics (Pulsed $V_{GS}$)*

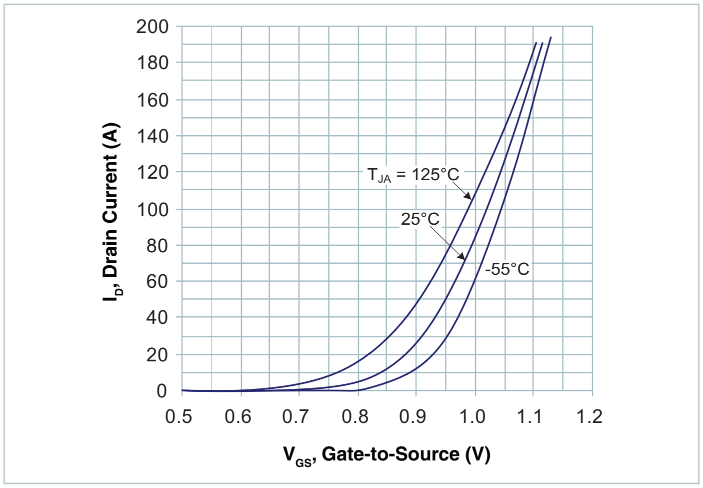



***Figure 4*** *— Transfer Characteristics (Pulsed $V_{GS}$)*

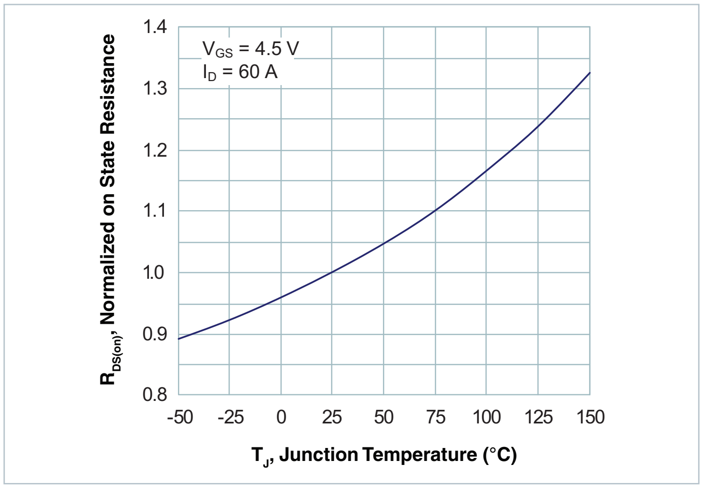



***Figure 2*** *— On-Resistance vs. Junction Temperature*

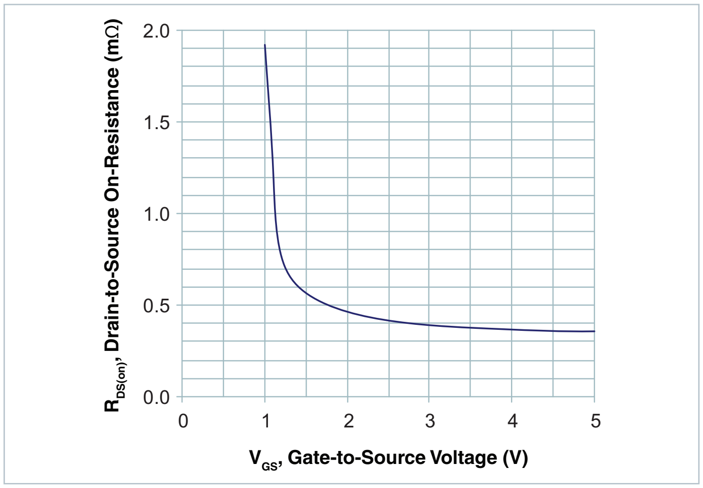



***Figure 5*** *— On-Resistance vs. Gate Voltage*

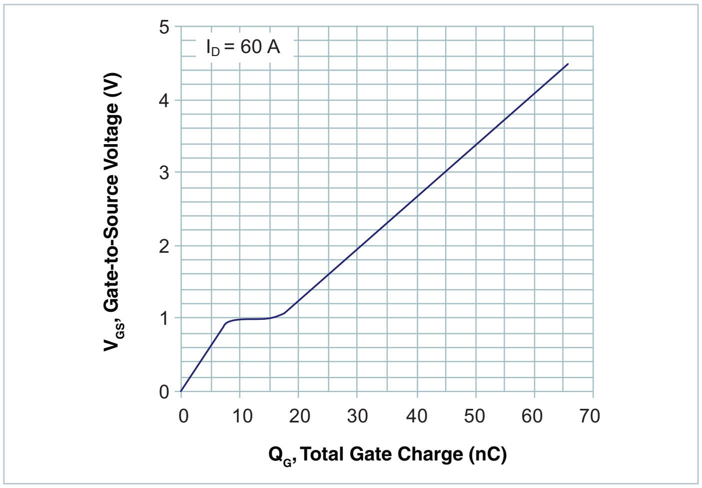



***Figure 3*** *— Gate Charge*

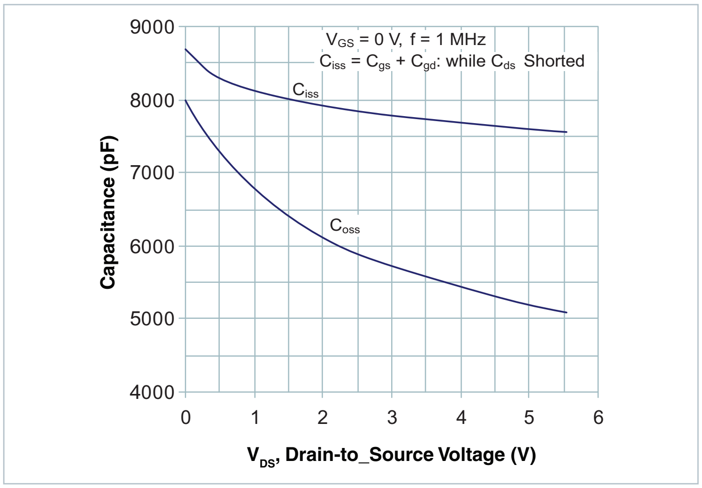



***Figure 6*** *— Gate Capacitance vs. Drain-to Source Voltage*

## Typical Characteristics

$T_A$ = 25°C unless otherwise specified.

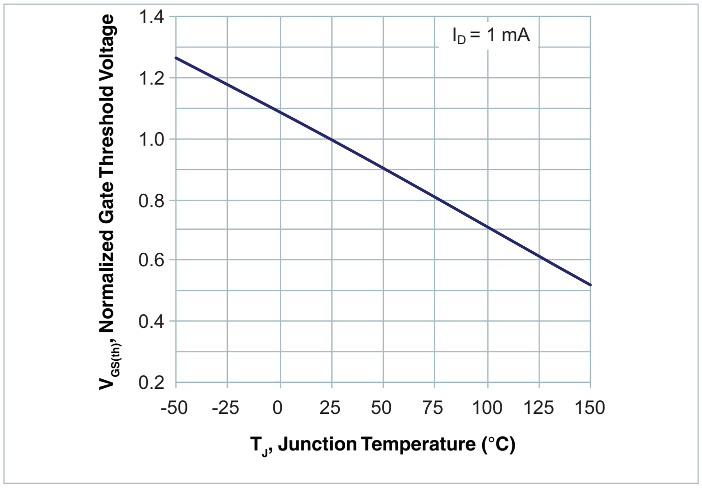



*Figure 7* — *Gate Threshold Voltage vs. Temperature*

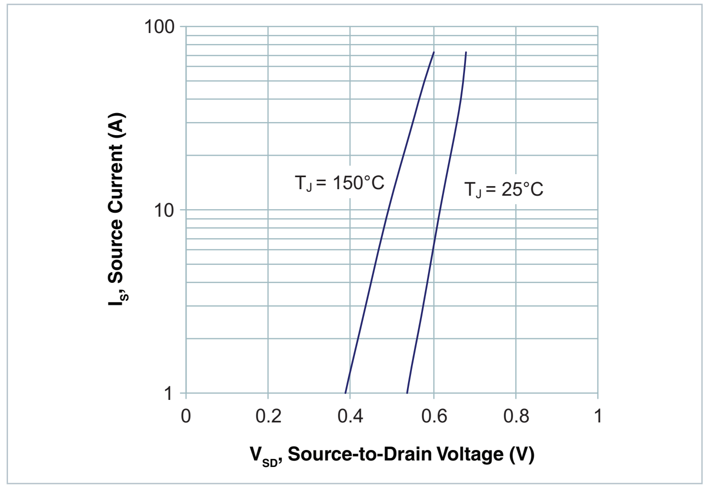



*Figure 10* — *Reverse Diode Forward Voltage (Pulsed Test)*

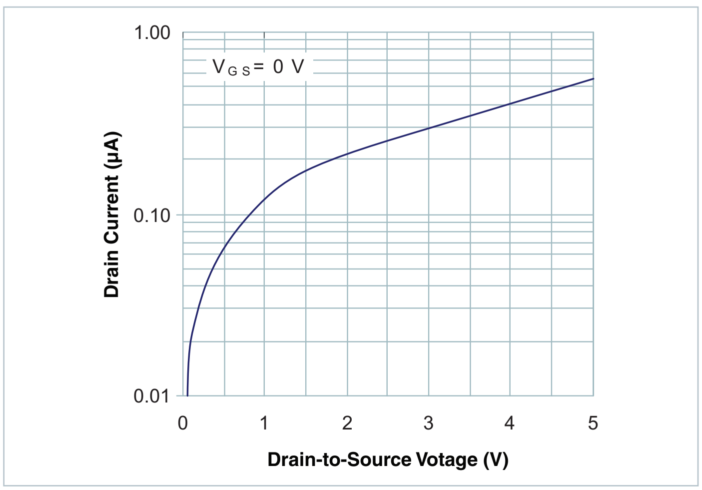



*Figure 8* — *Drain-to-Source Leakage Current*

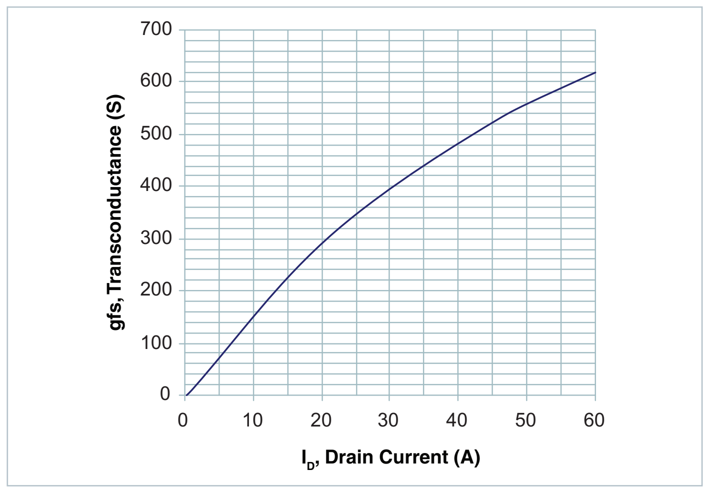



*Figure 11* — *Forward Transconductance*

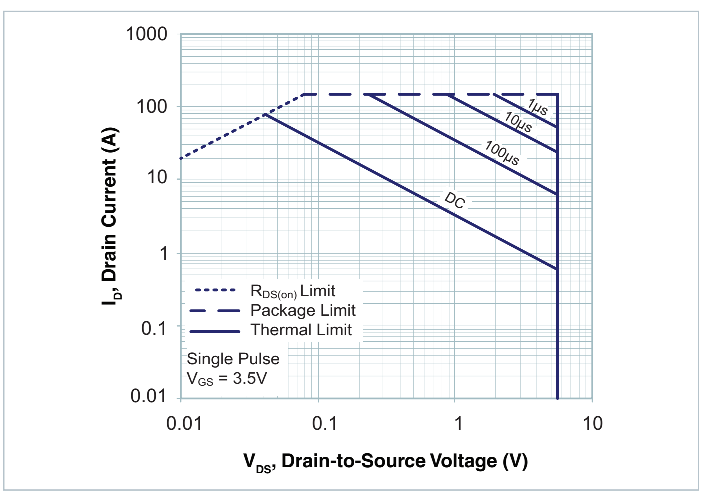



*Figure 9* — *Maximum Safe Operation Area*

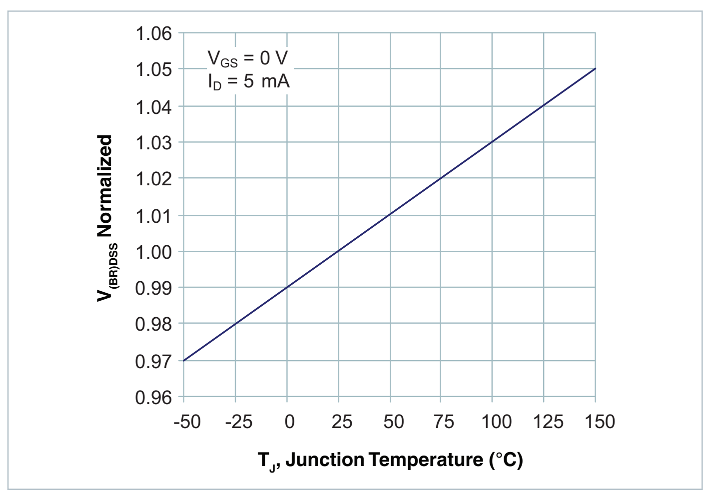



*Figure 12* — *Drain-to-Source Breakdown Voltage vs. temperature*

## Typical Characteristics

$T_A = 25°C$ unless otherwise specified.

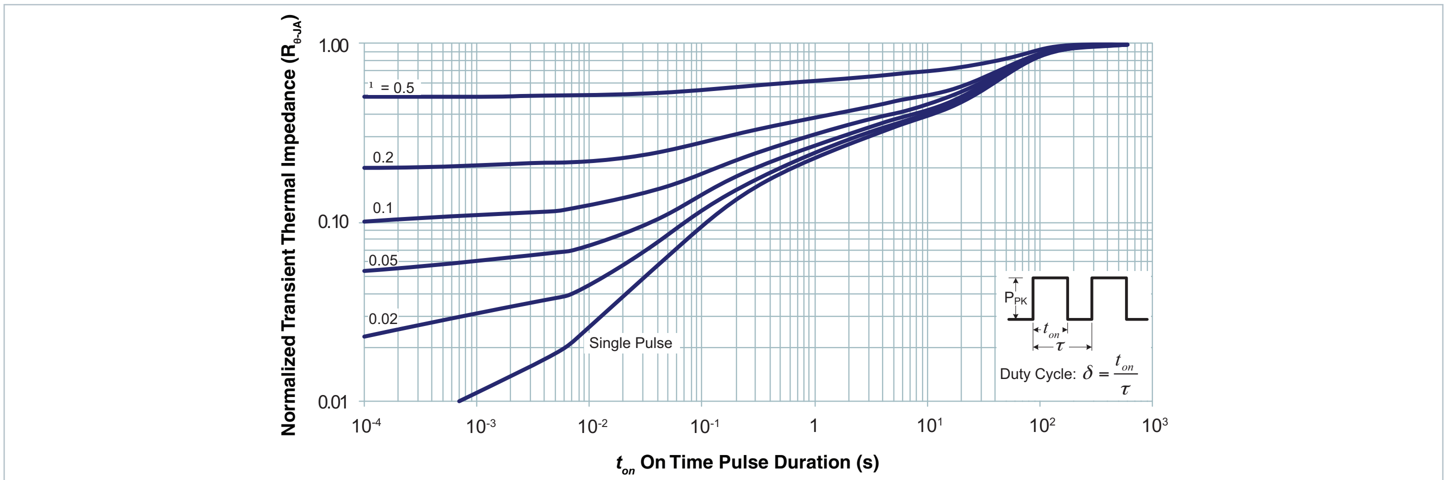



***Figure 13*** *— Normalized Transient Thermal Impedance, Junction-to-Ambient*

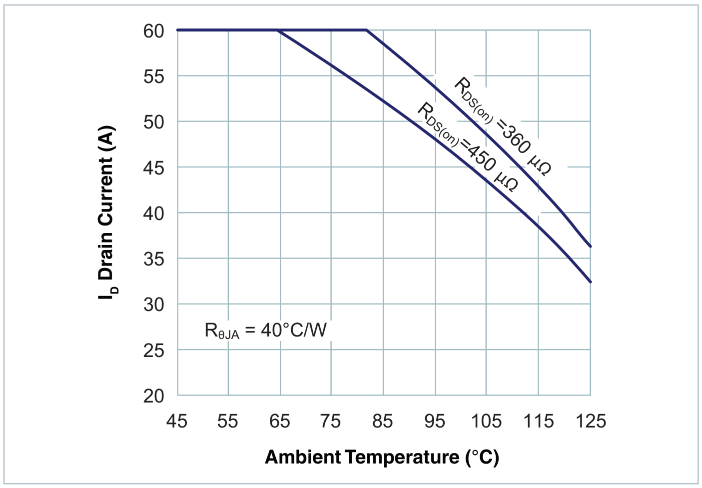



***Figure 14*** *— PI5101 Drain current de-rating based on the maximum TJ = 150°C vs. ambient temperature*

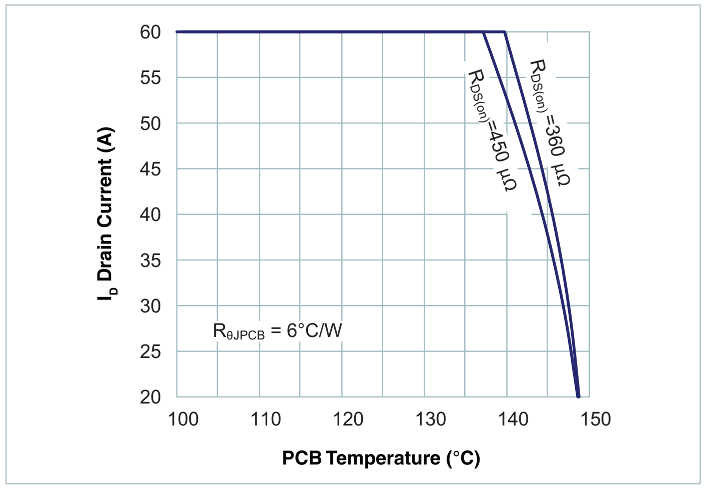



***Figure 15*** *— PI5101 Drain current de-rating vs. PCB temperature, for maximum TJ at 150°C*

## MOSFET Power Dissipation vs. Junction Temperature

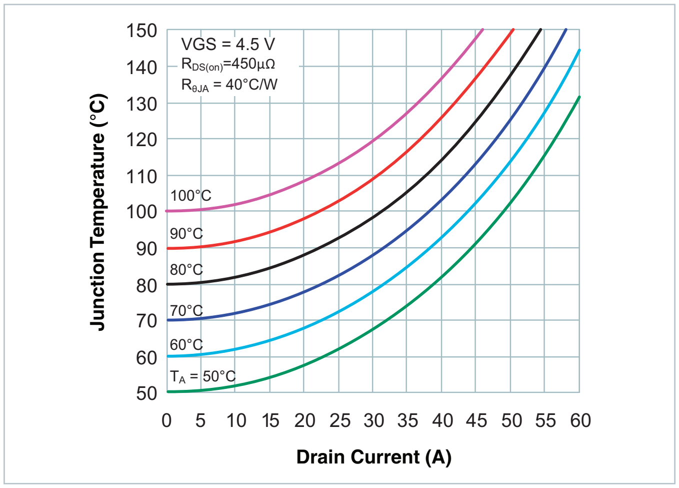



***Figure 16*** *— Junction Temperature vs. Drain Current for a given ambient temperature (0LFM)*

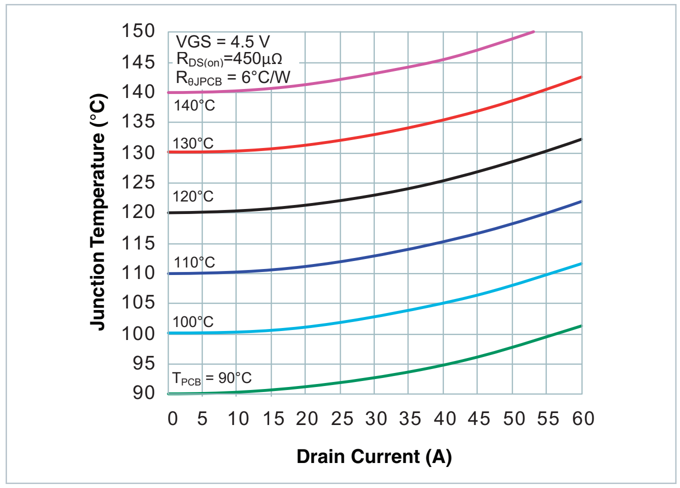



***Figure 17*** *— Junction Temperature vs. Drain Current for a given PCB temperature*

In applications such as low loss ORing Diodes or circuit breakers where the MOSFET is normally on during steady state operation, the MOSFET power dissipation is derived from the total Drain current and the on-state resistance of the MOSFET.

The PI5101 power dissipation can be calculated with the following equation:

$$P_D = I_D^2 \bullet R_{DS(on)}$$

Where:

**$P_D$:** MOSFET power dissipation
**$I_D$ :** Drain Current
**$R_{DS(on)}$:** MOSFET on-state resistance

***Note:*** *For the worst case condition, calculate with maximum rated $R_{DS(on)}$ at the MOSFET maximum operating junction temperature because $R_{DS(on)}$ is temperature dependent. Refer to figure 2 for normalized $R_{DS(on)}$ values over temperature. The PI5101 maximum $R_{DS(on)}$ at 25°C is 450 µΩ and will increase by 24% at 125°C junction temperature.*

The junction temperature rise is a function of power dissipation and thermal resistance.

$$T_{rise} = R_{\theta JA} \bullet P_D = R_{\ JA} \bullet I_D^2 \bullet R_{DS(on)}$$

Where:

**$R_{\theta JA}$ :** Junction-to-Ambient thermal resistance (40°C/W)

This may require iteration to get to the final junction temperature. figure 16 and figure 17 are added to aid the user to find the final junction temperature without the iterative calculations.

Figure 16 shows the MOSFETs final junction temperature curves versus conducted current at maximum $R_{DS(on)}$, and at given ambient temperatures at 0 LFM air flow. Figure 17 shows the MOSFETs final junction temperature curves versus conducted current at maximum $R_{DS(on)}$ at given PCB temperatures.

To find the final junction temperature for a given drain continuous DC or RMS current and a given ambient or PCB temperature; draw a vertical line from the drain current at the X-axis to intersect the ambient or PCB temperature line. At the intersection draw a horizontal line towards the Y-axis (Junction Temperature).

Example:

Assume that the MOSFET maximum drain current is 50 A and maximum operating ambient temperature is 70°C.

First use figure 16 to find the final junction temperature for 50 A drain current at 70°C ambient temperature. In figure 16 (illustrated in figure 18) draw a vertical line from 50 A to intersect the 70°C ambient temperature line (dark blue). At the intersection draw a horizontal line towards the Y-axis (Junction Temperature). The typical junction temperature with maximum $R_{DS(on)}$, at load current of 50 A and 70°C ambient is 126°C.

As a check, recalculate the junction temperature to confirm the plot results. Start from the final junction temperature, 126°C, and use the following steps:

RDS(on) is 450µΩ maximum at 25°C and will increase as the Junction temperature increases. From figure 2, at 126°C RDS(on) will increase by 24%, then RDS(on) maximum at 126°C is:

$$R_{DS(on)} = 450\ \mu\Omega \bullet 1.24 = 558\ \mu\Omega$$

Maximum power dissipation is:

$$P_{Dmax} = I_D^2 \bullet R_{DS(on)} = 50\ A \bullet 558\ \mu\Omega = 1.39\ W$$

Maximum junction temperature is:

$$T_{Jmax} = 70°C + \frac{40°C}{W}\ 50\ A^2 \bullet 558\ \mu\Omega = 125.8°C$$

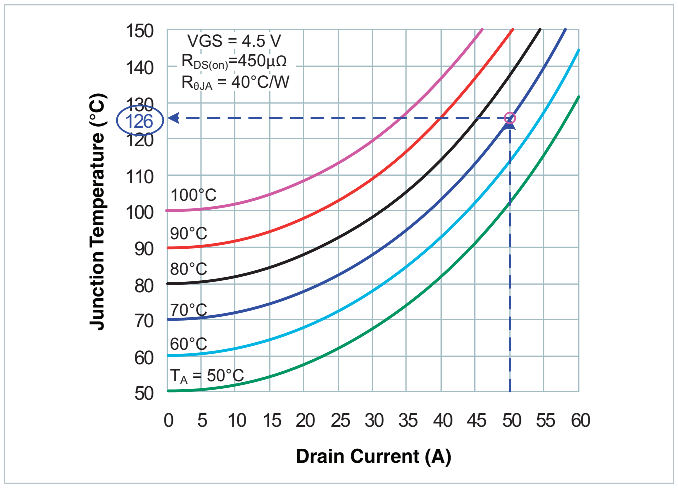
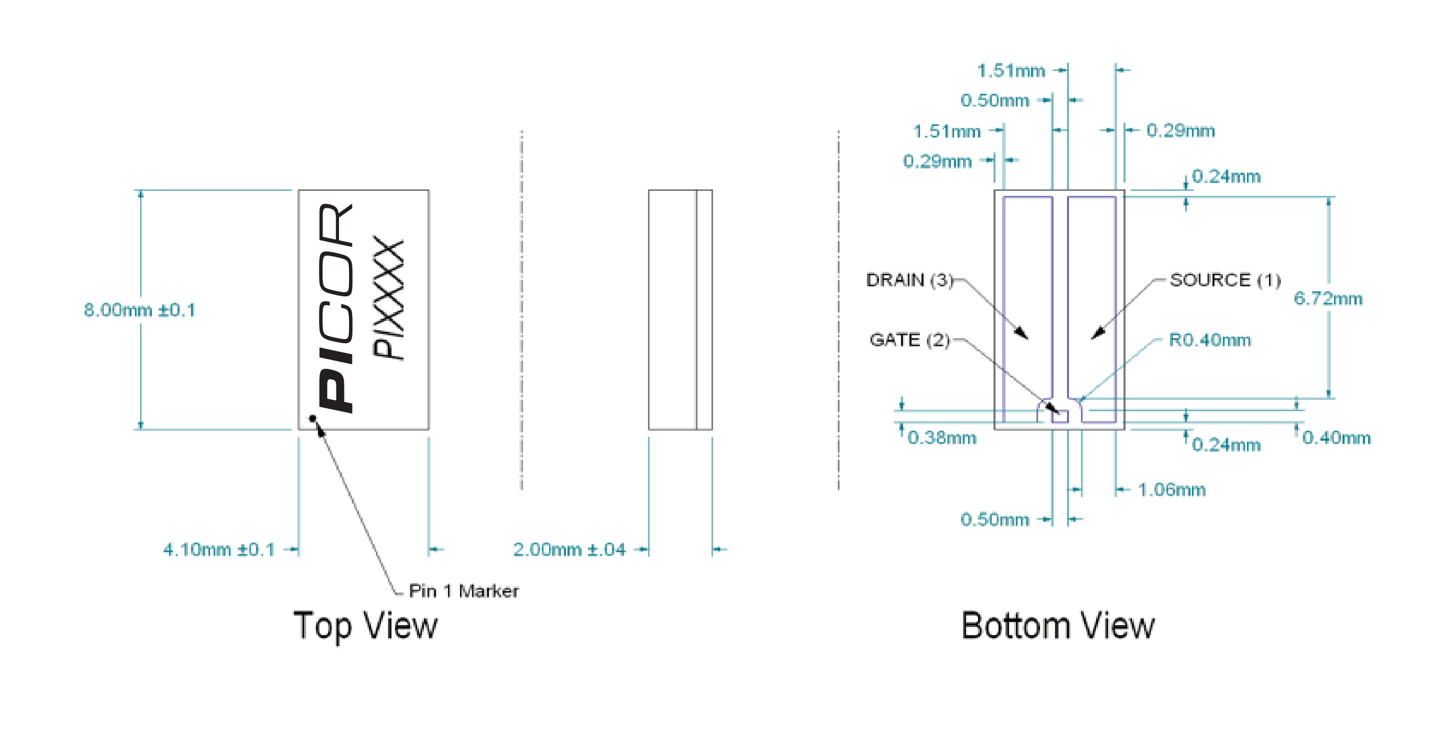
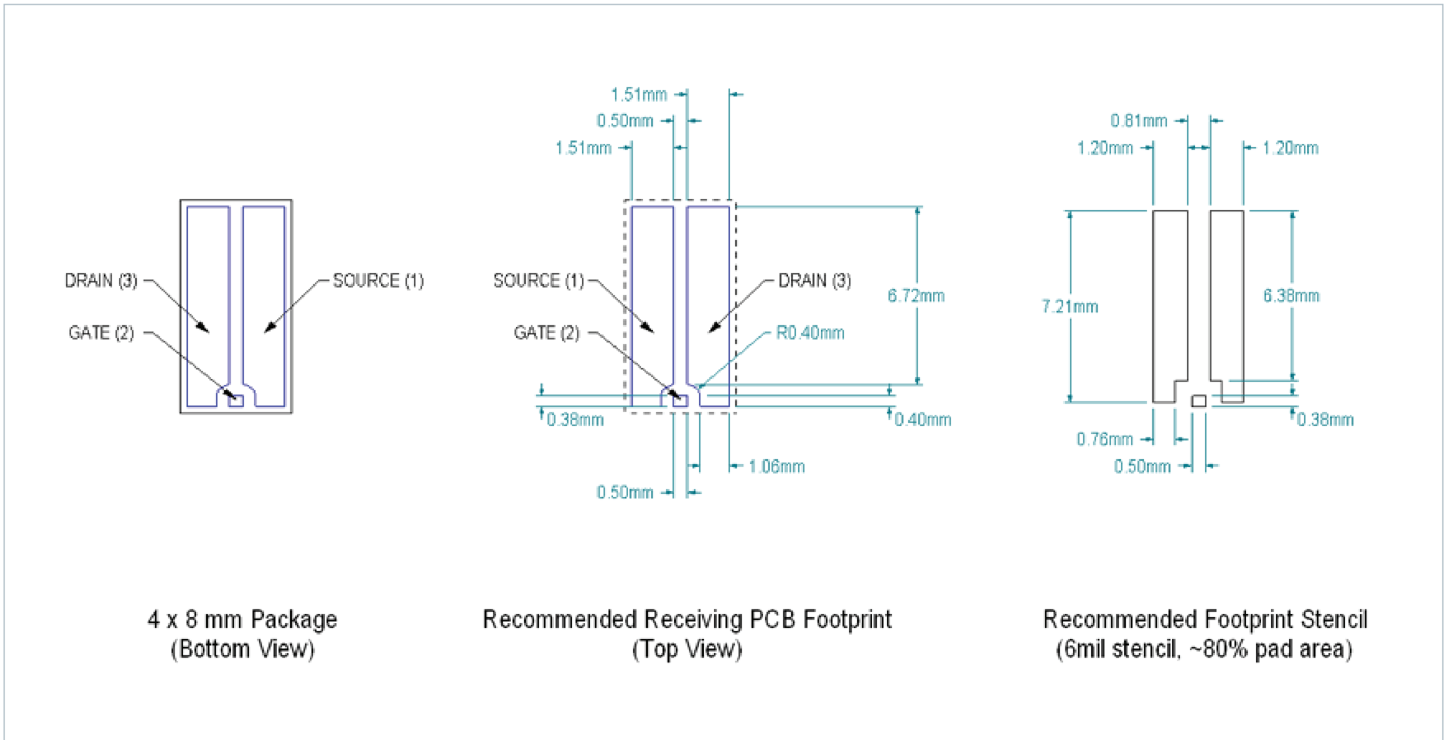



***Figure 18*** *— Example graphing of MOSFET junction temperature at $I_D$ = 50 A and $T_A$ = 70°C*

## Package Drawing




## Layout Recommendation



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