

## Silicon Carbide Power MOSFET N-Channel Enhancement Mode

### Features

- ★ 3<sup>rd</sup> Generation SIC MOSFET technology
- ★ High blocking voltage with low on-resistance
- ★ High speed switching with low capacitances
- ★ Fast intrinsic diode with low reverse recovery (Qrr)
- ★ Halogen free, Rohs compliant

### Benefits

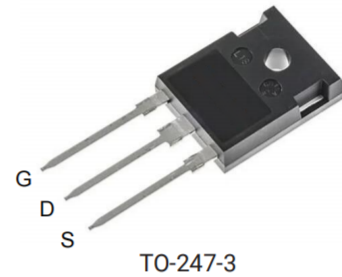
- ★ Higher system efficiency
- ★ Reduced Cooling requirements
- ★ Increased power density
- ★ Increased system switching frequency
- ★ Easy to parallel and simple to drive
- ★ Enable new hard switching PFC topologies(Totem-Pole)

### Applications

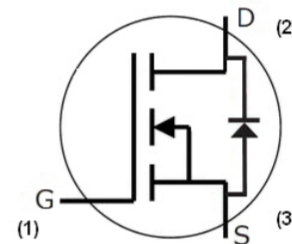
- ★ EV charging
- ★ Server power supplies
- ★ Solar PV inverters
- ★ UPS
- ★ DC/DC converters

### Product Summary

| $V_{DS}$ | $R_{DS(on)}$ | $I_D @ 25^\circ$ |
|----------|--------------|------------------|
| 650V     | 60m $\Omega$ | 29 A             |



Package



### Maximum Ratings

| Symbol         | Parameter                                                                    | Value       | Unit             | Note              |
|----------------|------------------------------------------------------------------------------|-------------|------------------|-------------------|
| $V_{DSS}$      | Drain - Source Voltage, $T_c = 25^\circ\text{C}$                             | 650         | V                |                   |
| $V_{GS}$       | Gate - Source voltage (Under transient events < 100 ns)                      | -8/+19      | V                | Fig. 29           |
| $I_D$          | Continuous Drain Current, $V_{GS} = 15\text{ V}$ , $T_c = 25^\circ\text{C}$  | 29          | A                | Fig. 19<br>Note 1 |
|                | Continuous Drain Current, $V_{GS} = 15\text{ V}$ , $T_c = 100^\circ\text{C}$ | 20          |                  |                   |
| $I_{D(pulse)}$ | Pulsed Drain Current, Pulse width $t_p$ limited by $T_{jmax}$                | 99          | A                |                   |
| $P_D$          | Power Dissipation, $T_c=25^\circ\text{C}$ , $T_j = 175^\circ\text{C}$        | 150         | W                | Fig. 20           |
| $T_j, T_{stg}$ | Operating Junction and Storage Temperature                                   | -40 to +175 | $^\circ\text{C}$ |                   |
| $T_L$          | Solder Temperature, 1.6mm (0.063") from case for 10s                         | 260         | $^\circ\text{C}$ |                   |
| $M_d$          | Mounting Torque, (M3 or 6-32 screw)                                          | 1<br>8.8    | Nm<br>lbf-in     |                   |

Note (1): Die limits are 37A (25°C) and 27A (100°C)

**Electrical Characteristics** ( $T_C = 25^\circ\text{C}$  unless otherwise specified)

| Symbol        | Parameter                                      | Min. | Typ. | Max. | Unit          | Test Conditions                                                                                                                                                                                                 | Note         |
|---------------|------------------------------------------------|------|------|------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| $V_{(BR)DSS}$ | Drain-Source Breakdown Voltage                 | 650  |      |      | V             | $V_{GS} = 0\text{ V}, I_D = 100\text{ }\mu\text{A}$                                                                                                                                                             |              |
| $V_{GSon}$    | Gate-Source Recommended Turn-On Voltage        |      | 15   |      | V             | Static                                                                                                                                                                                                          | Fig. 29      |
| $V_{GSoff}$   | Gate-Source Recommended Turn-Off Voltage       |      | -4   |      | V             |                                                                                                                                                                                                                 |              |
| $V_{GS(th)}$  | Gate Threshold Voltage                         | 1.8  | 2.3  | 3.6  | V             | $V_{DS} = V_{GS}, I_D = 5\text{ mA}$                                                                                                                                                                            | Fig. 11      |
|               |                                                |      | 1.9  |      | V             | $V_{DS} = V_{GS}, I_D = 5\text{ mA}, T_J = 175^\circ\text{C}$                                                                                                                                                   |              |
| $I_{DSS}$     | Zero Gate Voltage Drain Current                |      | 1    | 50   | $\mu\text{A}$ | $V_{DS} = 650\text{ V}, V_{GS} = 0\text{ V}$                                                                                                                                                                    |              |
| $I_{GSS}$     | Gate-Source Leakage Current                    |      | 10   | 250  | nA            | $V_{GS} = 15\text{ V}, V_{DS} = 0\text{ V}$                                                                                                                                                                     |              |
| $R_{DS(on)}$  | Drain-Source On-State Resistance               | 42   | 60   | 79   | m $\Omega$    | $V_{GS} = 15\text{ V}, I_D = 13.2\text{ A}$                                                                                                                                                                     | Fig. 4, 5, 6 |
|               |                                                |      | 80   |      |               | $V_{GS} = 15\text{ V}, I_D = 13.2\text{ A}, T_J = 175^\circ\text{C}$                                                                                                                                            |              |
| $g_{fs}$      | Transconductance                               |      | 10   |      | S             | $V_{DS} = 20\text{ V}, I_{DS} = 13.2\text{ A}$                                                                                                                                                                  | Fig. 7       |
|               |                                                |      | 9    |      |               | $V_{DS} = 20\text{ V}, I_{DS} = 13.2\text{ A}, T_J = 175^\circ\text{C}$                                                                                                                                         |              |
| $C_{iss}$     | Input Capacitance                              |      | 1020 |      | pF            | $V_{GS} = 0\text{ V}, V_{DS} = 600\text{ V}$<br>$f = 1\text{ MHz}$<br>$V_{AC} = 25\text{ mV}$                                                                                                                   | Fig. 17, 18  |
| $C_{oss}$     | Output Capacitance                             |      | 80   |      |               |                                                                                                                                                                                                                 |              |
| $C_{rss}$     | Reverse Transfer Capacitance                   |      | 9    |      |               |                                                                                                                                                                                                                 |              |
| $C_{o(er)}$   | Effective Output Capacitance (Energy Related)  |      | 95   |      | pF            | $V_{GS} = 0\text{ V}, V_{DS} = 0\text{ V to } 400\text{ V}$                                                                                                                                                     | Note 1       |
| $C_{o(tr)}$   | Effective Output Capacitance (Time Related)    |      | 132  |      |               |                                                                                                                                                                                                                 |              |
| $E_{oss}$     | $C_{oss}$ Stored Energy                        |      | 15   |      | $\mu\text{J}$ | $V_{DS} = 600\text{ V}, 1\text{ MHz}$                                                                                                                                                                           | Fig. 16      |
| $E_{ON}$      | Turn-On Switching Energy (Body Diode)          |      | 110  |      | $\mu\text{J}$ | $V_{DS} = 400\text{ V}, V_{GS} = -4\text{ V}/15\text{ V}, I_D = 13.2\text{ A},$<br>$R_{G(ext)} = 2.5\text{ }\Omega, L = 135\text{ }\mu\text{H}, T_J = 175^\circ\text{C}$<br>FWD = Internal Body Diode of MOSFET | Fig. 25      |
| $E_{OFF}$     | Turn Off Switching Energy (Body Diode)         |      | 22   |      |               |                                                                                                                                                                                                                 |              |
| $E_{ON}$      | Turn-On Switching Energy (External SiC Diode)  |      | 63   |      | $\mu\text{J}$ | $V_{DS} = 400\text{ V}, V_{GS} = -4\text{ V}/15\text{ V}, I_D = 13.2\text{ A},$<br>$R_{G(ext)} = 2.5\text{ }\Omega, L = 135\text{ }\mu\text{H}, T_J = 175^\circ\text{C}$<br>FWD = External SiC Diode            | Fig. 25      |
| $E_{OFF}$     | Turn Off Switching Energy (External SiC Diode) |      | 28   |      |               |                                                                                                                                                                                                                 |              |
| $t_{d(on)}$   | Turn-On Delay Time                             |      | 9    |      | ns            | $V_{DD} = 400\text{ V}, V_{GS} = -4\text{ V}/15\text{ V}$<br>$I_D = 13.2\text{ A}, R_{G(ext)} = 2.5\text{ }\Omega, L = 135\text{ }\mu\text{H}$<br>Timing relative to $V_{DS}$<br>Inductive load                 | Fig. 26      |
| $t_r$         | Rise Time                                      |      | 20   |      |               |                                                                                                                                                                                                                 |              |
| $t_{d(off)}$  | Turn-Off Delay Time                            |      | 17   |      |               |                                                                                                                                                                                                                 |              |
| $t_f$         | Fall Time                                      |      | 8    |      |               |                                                                                                                                                                                                                 |              |
| $R_{G(int)}$  | Internal Gate Resistance                       |      | 3    |      | $\Omega$      | $f = 1\text{ MHz}, V_{AC} = 25\text{ mV}$                                                                                                                                                                       |              |
| $Q_{gs}$      | Gate to Source Charge                          |      | 14   |      | nC            | $V_{DS} = 400\text{ V}, V_{GS} = -4\text{ V}/15\text{ V}$<br>$I_D = 13.2\text{ A}$<br>Per IEC60747-8-4 pg 21                                                                                                    | Fig. 12      |
| $Q_{gd}$      | Gate to Drain Charge                           |      | 14   |      |               |                                                                                                                                                                                                                 |              |
| $Q_g$         | Total Gate Charge                              |      | 46   |      |               |                                                                                                                                                                                                                 |              |

Note (1):  $C_{o(er)}$ , a lumped capacitance that gives same stored energy as  $C_{oss}$  while  $V_{ds}$  is rising from 0 to 400V

$C_{o(tr)}$ , a lumped capacitance that gives same charging time as  $C_{oss}$  while  $V_{ds}$  is rising from 0 to 400V

## Reverse Diode Characteristics ( $T_C = 25^\circ\text{C}$ unless otherwise specified)

| Symbol                | Parameter                        | Typ. | Max. | Unit | Test Conditions                                                                                                                                   | Note          |
|-----------------------|----------------------------------|------|------|------|---------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| $V_{SD}$              | Diode Forward Voltage            | 5.1  |      | V    | $V_{GS} = -4\text{ V}, I_{SD} = 6.6\text{ A}, T_J = 25^\circ\text{C}$                                                                             | Fig. 8, 9, 10 |
|                       |                                  | 4.8  |      | V    | $V_{GS} = -4\text{ V}, I_{SD} = 6.6\text{ A}, T_J = 175^\circ\text{C}$                                                                            |               |
| $I_S$                 | Continuous Diode Forward Current |      | 23   | A    | $V_{GS} = -4\text{ V}, T_C = 25^\circ\text{C}$                                                                                                    |               |
| $I_{S, \text{pulse}}$ | Diode pulse Current              |      | 99   | A    | $V_{GS} = -4\text{ V}$ , pulse width $t_p$ limited by $T_{J\text{max}}$                                                                           |               |
| $t_{rr}$              | Reverse Recover time             | 20   |      | ns   | $V_{GS} = -4\text{ V}, I_{SD} = 13.2\text{ A}, V_R = 400\text{ V}$<br>$\text{dif}/\text{dt} = 1200\text{ A}/\mu\text{s}, T_J = 175^\circ\text{C}$ |               |
| $Q_{rr}$              | Reverse Recovery Charge          | 190  |      | nC   |                                                                                                                                                   |               |
| $I_{rm}$              | Peak Reverse Recovery Current    | 16   |      | A    |                                                                                                                                                   |               |
| $t_{rr}$              | Reverse Recover time             | 29   |      | ns   | $V_{GS} = -4\text{ V}, I_{SD} = 13.2\text{ A}, V_R = 400\text{ V}$<br>$\text{dif}/\text{dt} = 750\text{ A}/\mu\text{s}, T_J = 175^\circ\text{C}$  |               |
| $Q_{rr}$              | Reverse Recovery Charge          | 181  |      | nC   |                                                                                                                                                   |               |
| $I_{rm}$              | Peak Reverse Recovery Current    | 9    |      | A    |                                                                                                                                                   |               |

## Thermal Characteristics

| Symbol          | Parameter                                   | Typ. | Unit                      | Test Conditions | Note    |
|-----------------|---------------------------------------------|------|---------------------------|-----------------|---------|
| $R_{\theta JC}$ | Thermal Resistance from Junction to Case    | 0.99 | $^\circ\text{C}/\text{W}$ |                 | Fig. 21 |
| $R_{\theta JA}$ | Thermal Resistance From Junction to Ambient | 40   |                           |                 |         |

## Typical Performance

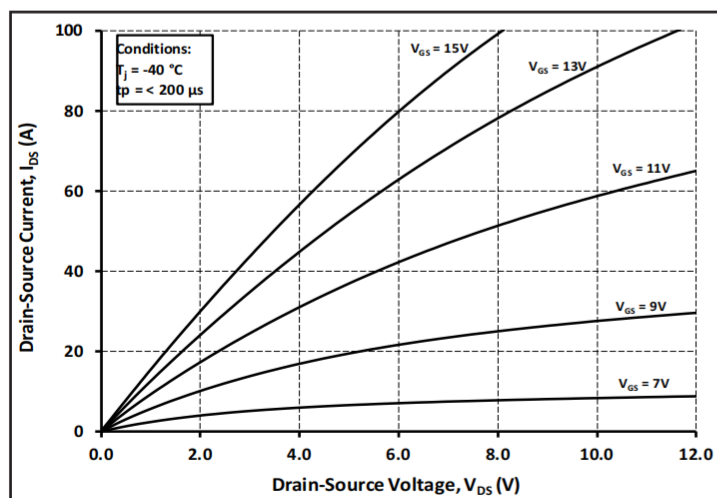


Figure 1. Output Characteristics  $T_J = -40^\circ\text{C}$

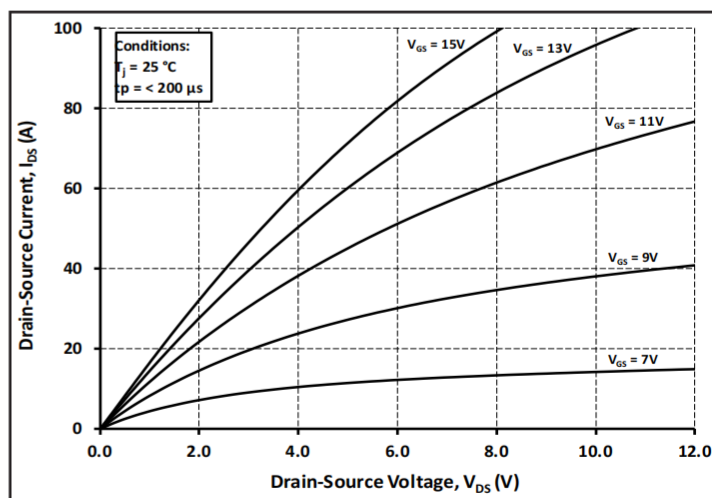


Figure 2. Output Characteristics  $T_J = 25^\circ\text{C}$

## Typical Performance

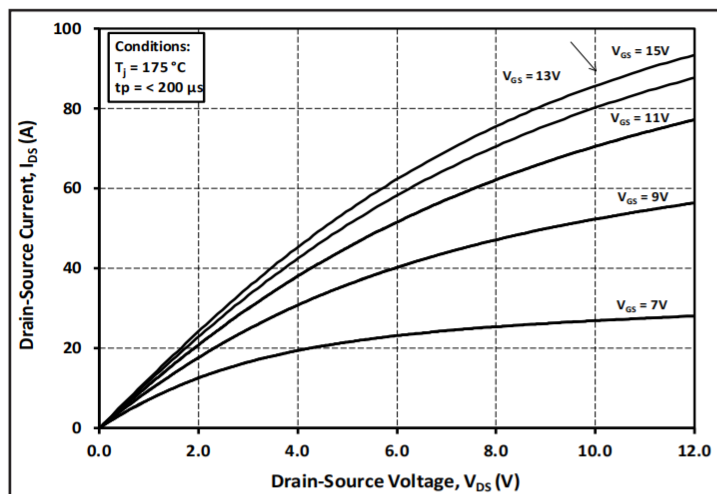


Figure 3. Output Characteristics  $T_J = 175\text{ }^{\circ}\text{C}$

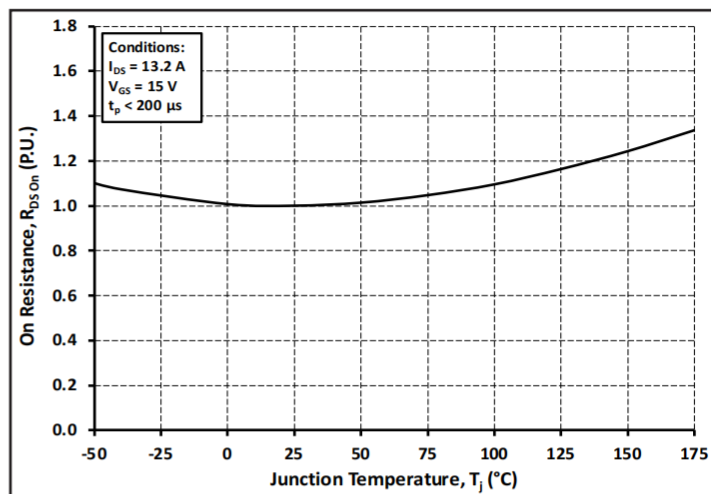


Figure 4. Normalized On-Resistance vs. Temperature

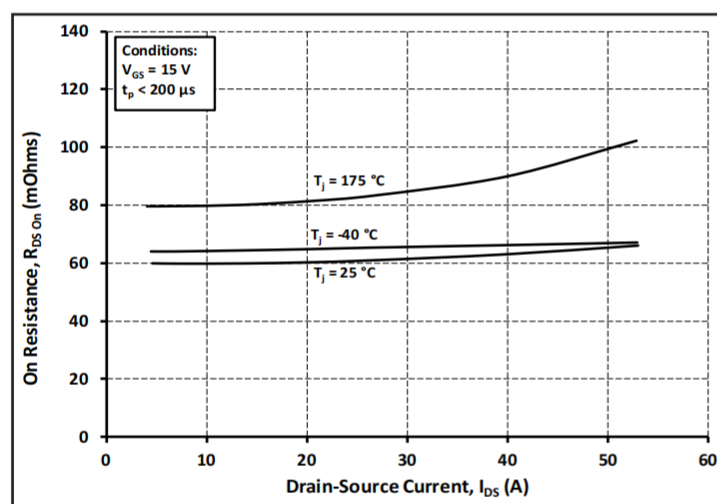


Figure 5. On-Resistance vs. Drain Current For Various Temperatures

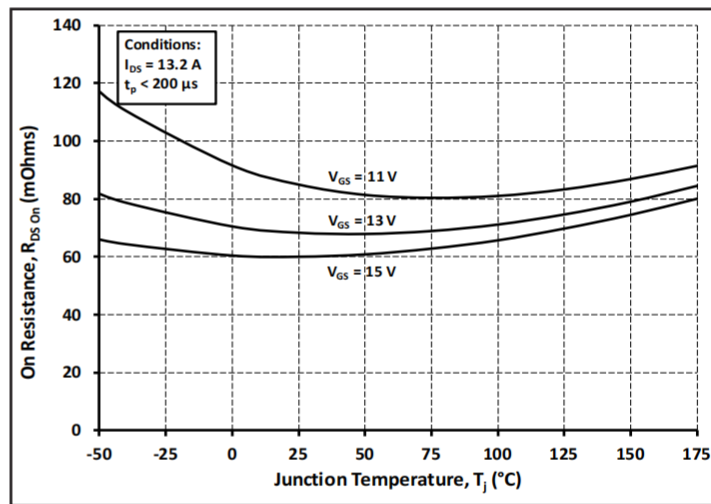


Figure 6. On-Resistance vs. Temperature For Various Gate Voltage

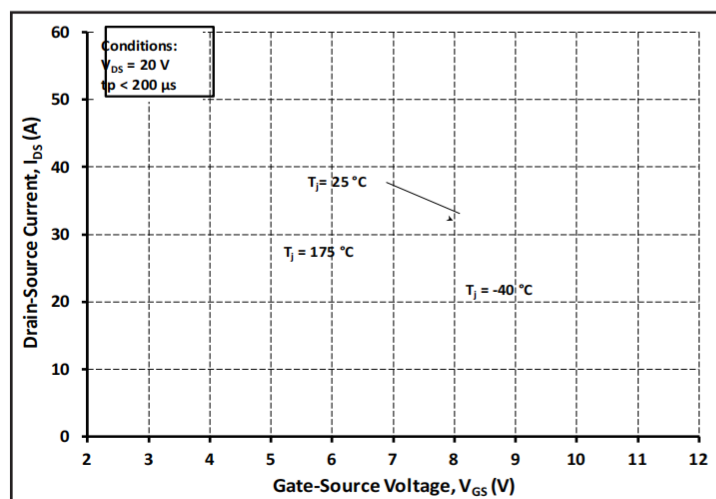


Figure 7. Transfer Characteristic for Various Junction Temperatures

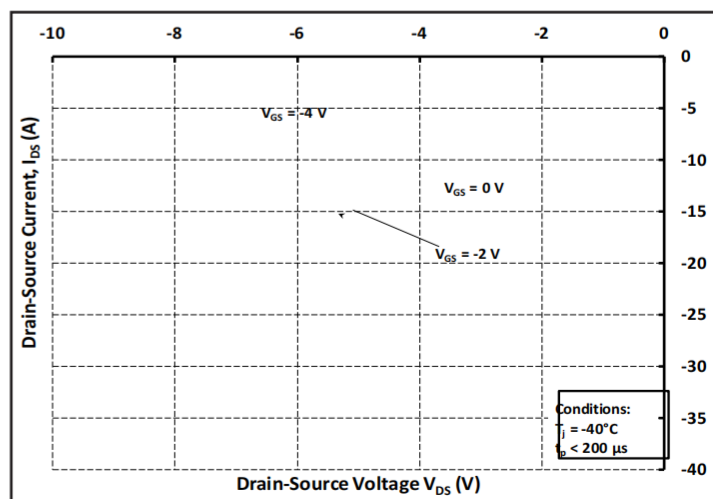


Figure 8. Body Diode Characteristic at  $-40\text{ }^{\circ}\text{C}$

## Typical Performance

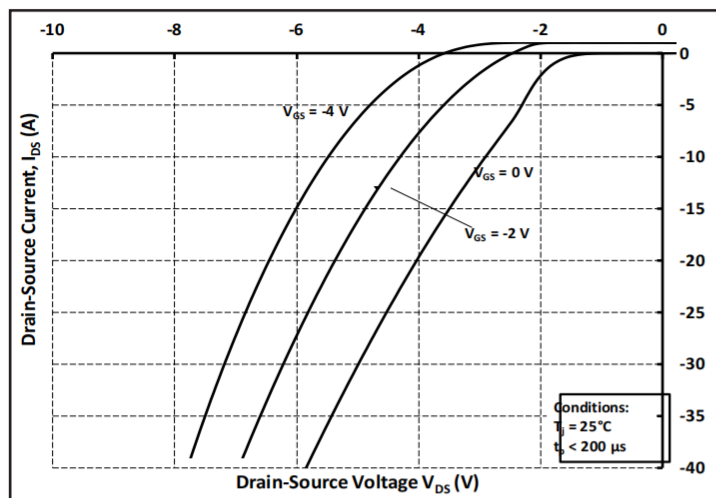


Figure 9. Body Diode Characteristic at 25 °C

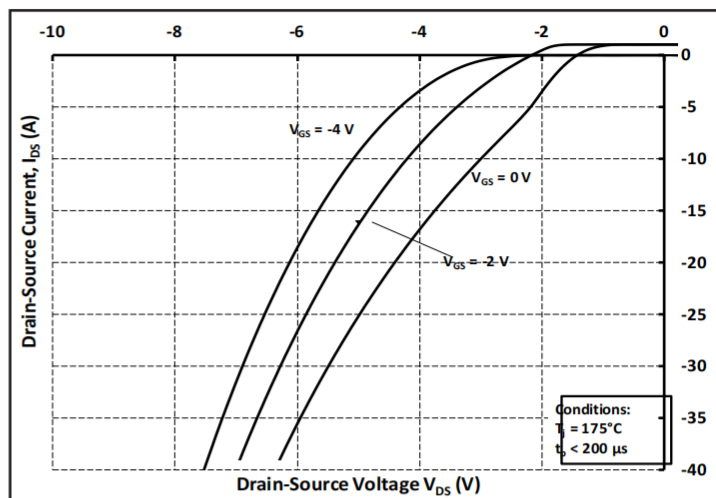


Figure 10. Body Diode Characteristic at 175 °C

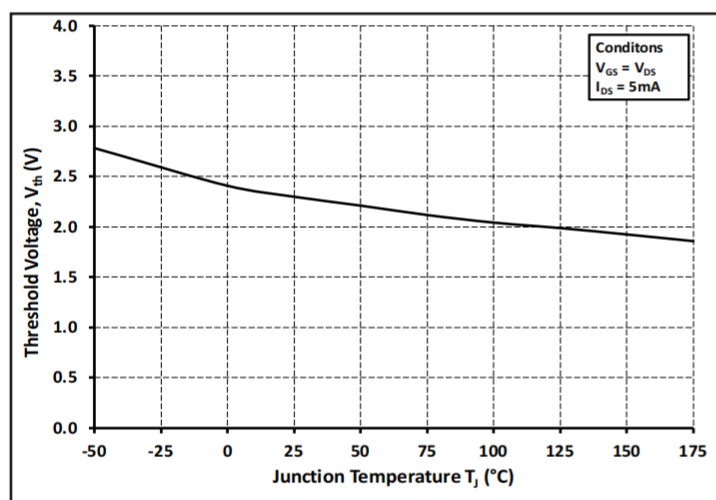


Figure 11. Threshold Voltage vs. Temperature

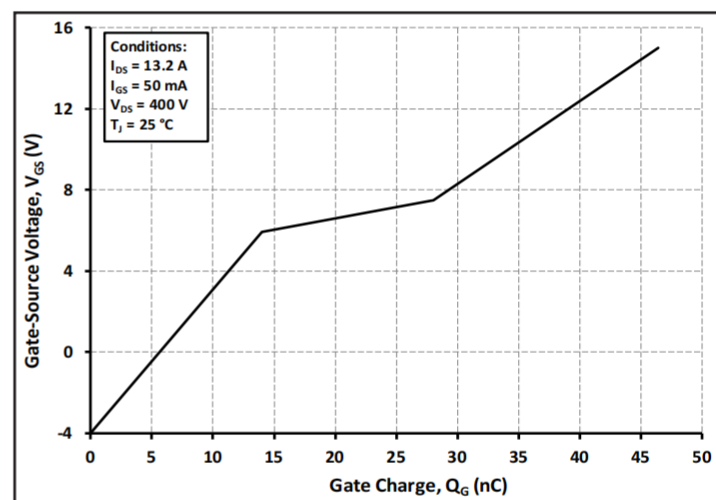


Figure 12. Gate Charge Characteristics

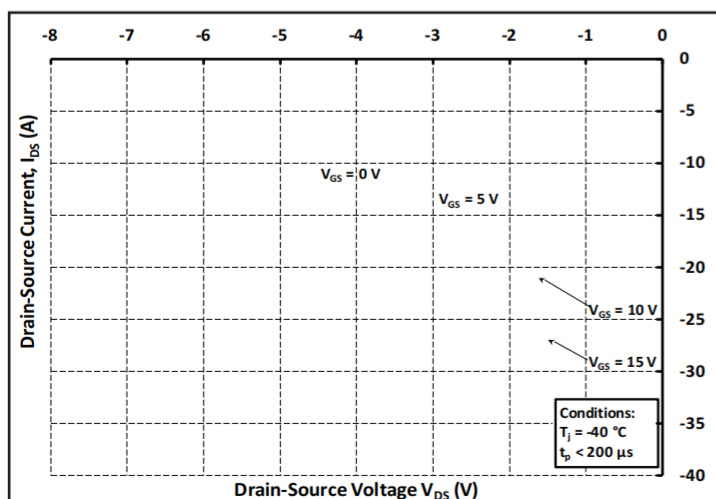


Figure 13. 3rd Quadrant Characteristic at -40 °C

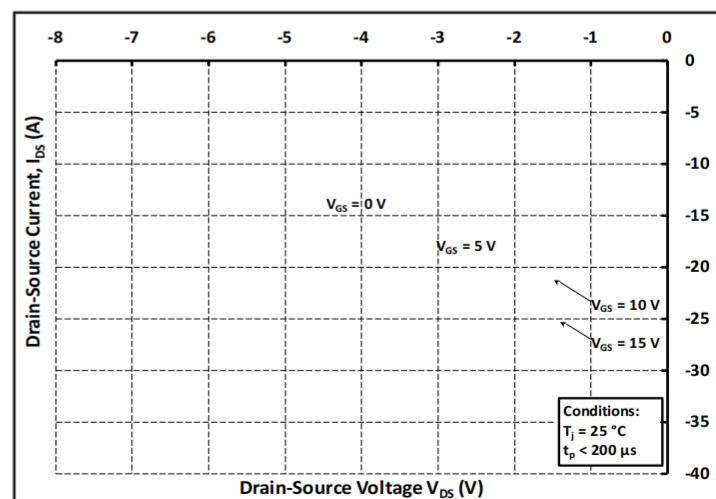


Figure 14. 3rd Quadrant Characteristic at 25 °C



## Typical Performance

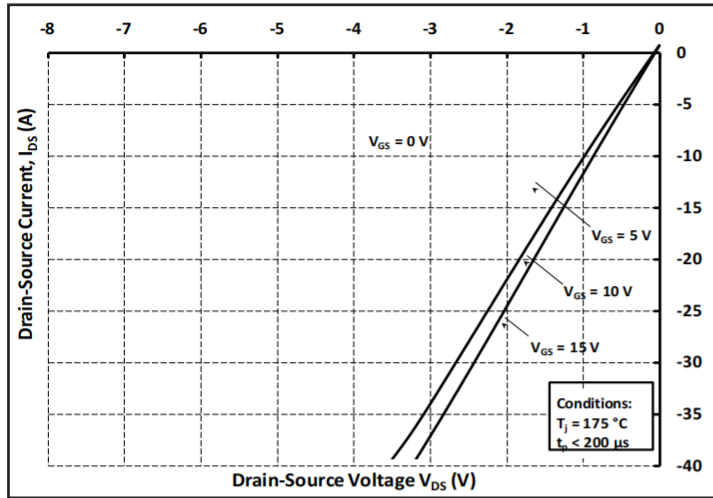


Figure 15. 3rd Quadrant Characteristic at 175 °C

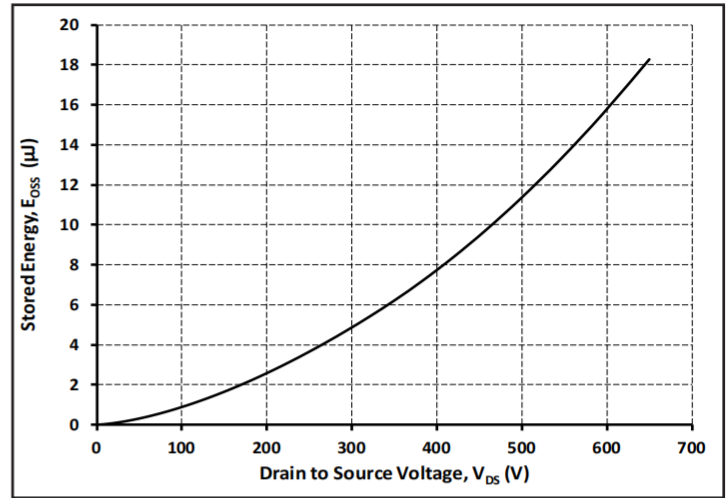


Figure 16. Output Capacitor Stored Energy

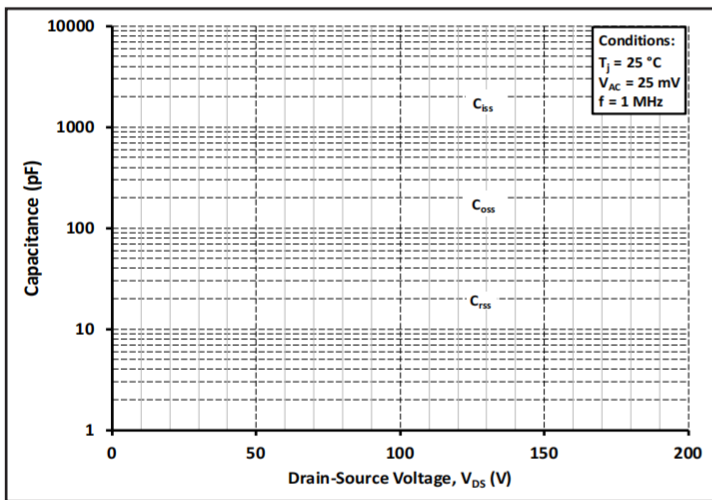


Figure 17. Capacitances vs. Drain-Source Voltage (0 - 200V)

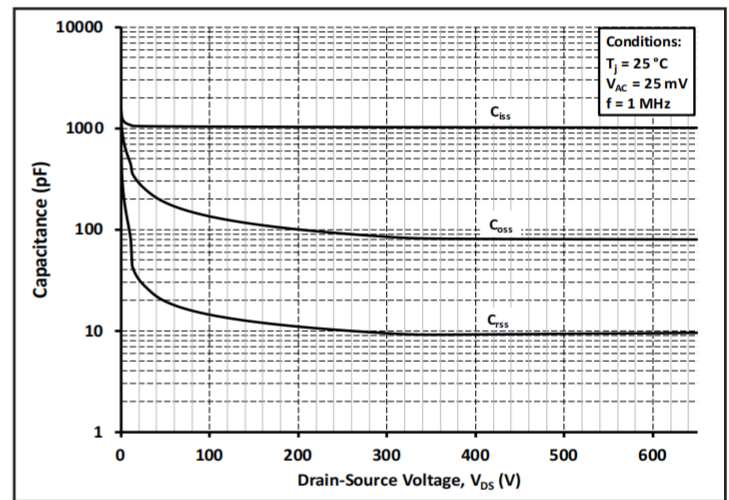


Figure 18. Capacitances vs. Drain-Source Voltage (0 - 650V)

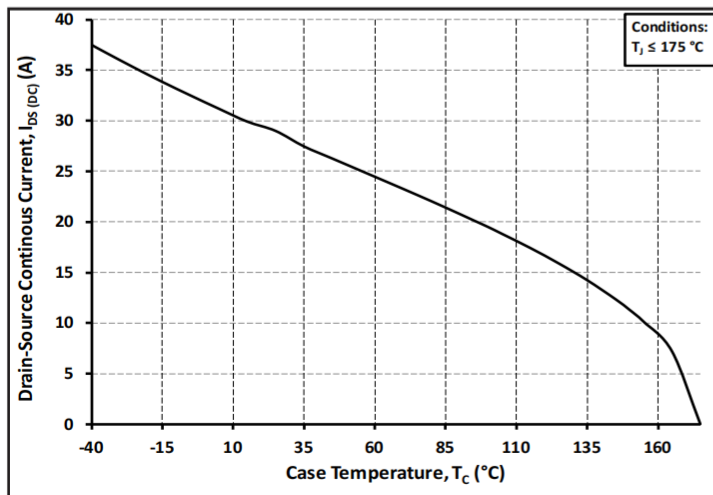


Figure 19. Continuous Drain Current Derating vs. Case Temperature

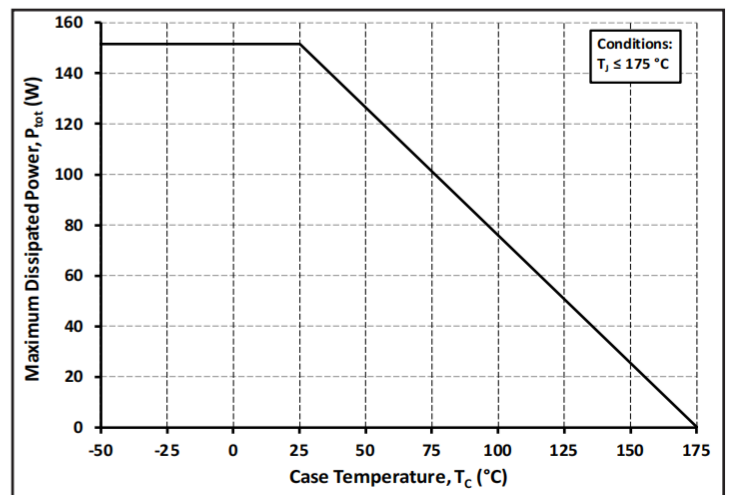


Figure 20. Maximum Power Dissipation Derating Vs Case Temperature

## Typical Performance

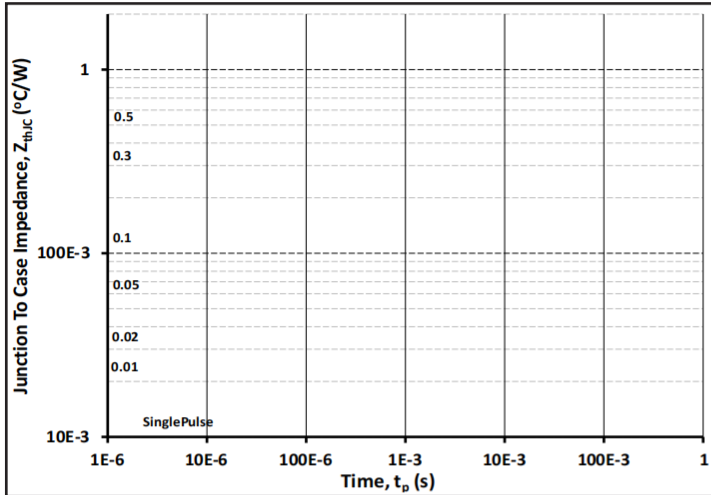


Figure 21. Transient Thermal Impedance (Junction - Case)

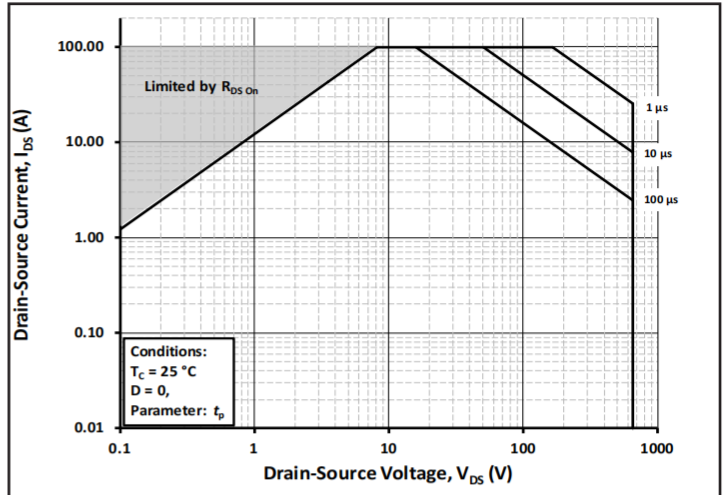


Figure 22. Safe Operating Area

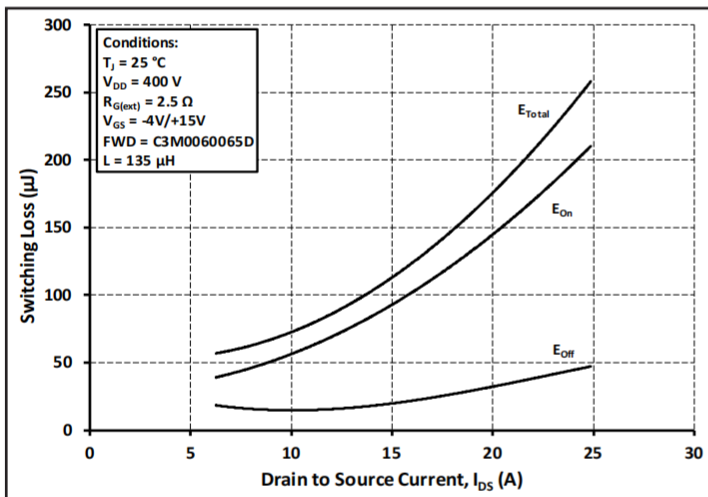


Figure 23. Clamped Inductive Switching Energy vs. Drain Current ( $V_{DS} = 400V$ )

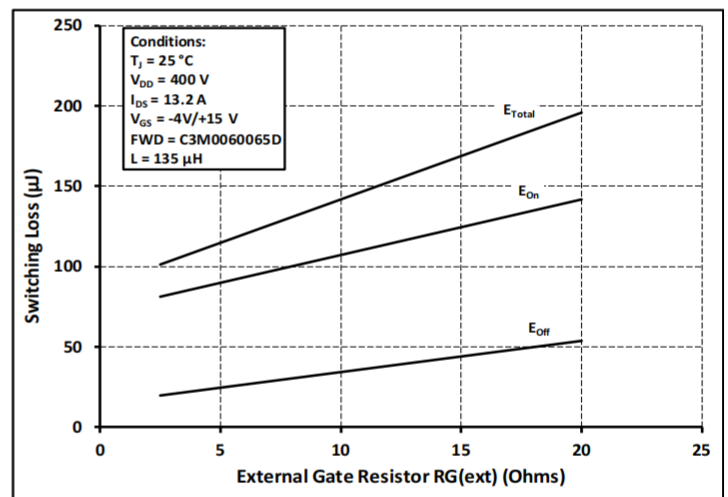


Figure 24. Clamped Inductive Switching Energy vs.  $R_{G(ext)}$

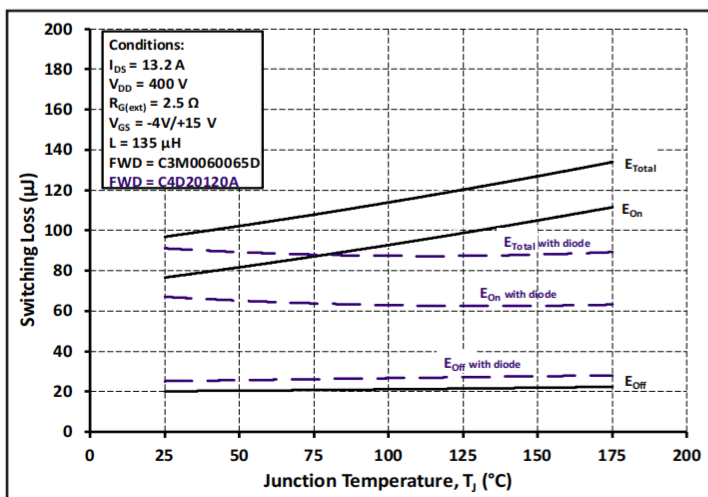


Figure 25. Clamped Inductive Switching Energy vs. Temperature

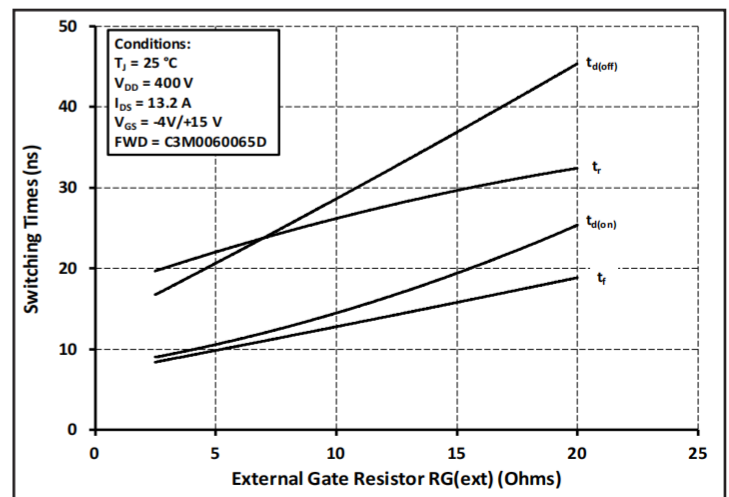


Figure 26. Switching Times vs.  $R_{G(ext)}$

## Test Circuit Schematic

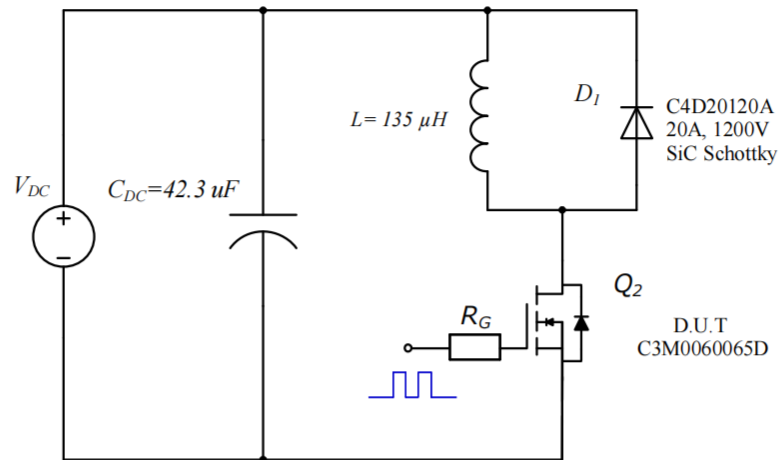


Figure 27. Clamped Inductive Switching Waveform Test Circuit

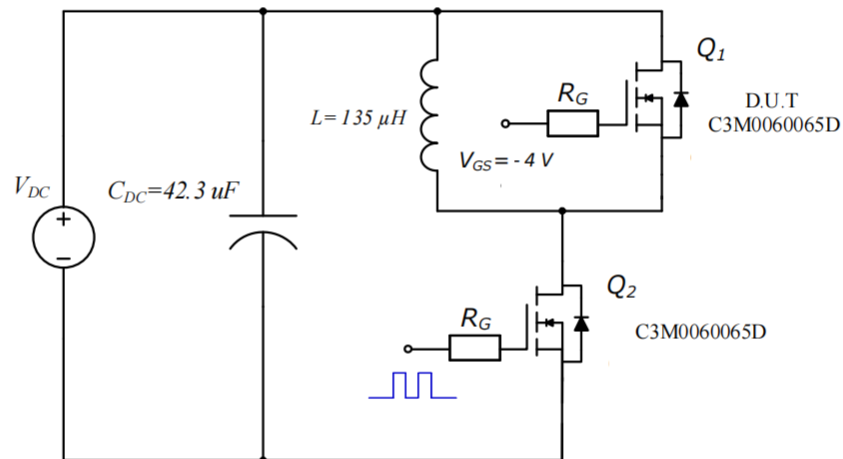


Figure 28. Body Diode Recovery Test Circuit

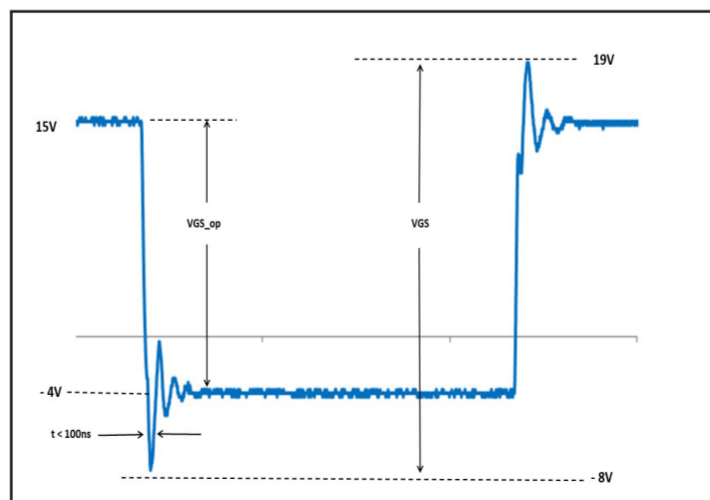
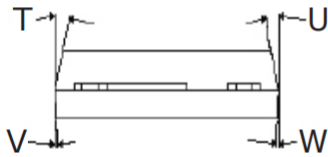
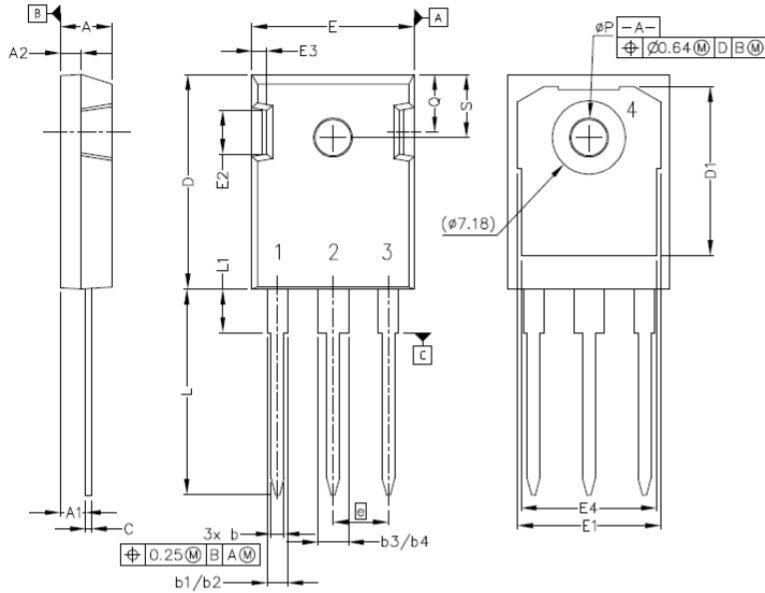


Figure 29.  $V_{GS}$  Waveform Example



## Package Dimensions

### Package TO-247-3

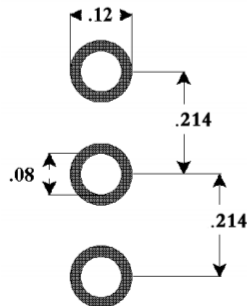


#### Pinout Information:

- Pin 1 = Gate
- Pin 2, 4 = Drain
- Pin 3 = Source

| POS | Inches   |      | Millimeters |       |
|-----|----------|------|-------------|-------|
|     | Min      | Max  | Min         | Max   |
| A   | .190     | .205 | 4.83        | 5.21  |
| A1  | .090     | .100 | 2.29        | 2.54  |
| A2  | .075     | .085 | 1.91        | 2.16  |
| b   | .042     | .052 | 1.07        | 1.33  |
| b1  | .075     | .095 | 1.91        | 2.41  |
| b2  | .075     | .085 | 1.91        | 2.16  |
| b3  | .113     | .133 | 2.87        | 3.38  |
| b4  | .113     | .123 | 2.87        | 3.13  |
| c   | .022     | .027 | 0.55        | 0.68  |
| D   | .819     | .831 | 20.80       | 21.10 |
| D1  | .640     | .695 | 16.25       | 17.65 |
| D2  | .037     | .049 | 0.95        | 1.25  |
| E   | .620     | .635 | 15.75       | 16.13 |
| E1  | .516     | .557 | 13.10       | 14.15 |
| E2  | .145     | .201 | 3.68        | 5.10  |
| E3  | .039     | .075 | 1.00        | 1.90  |
| E4  | .487     | .529 | 12.38       | 13.43 |
| e   | .214 BSC |      | 5.44 BSC    |       |
| N   | 3        |      | 3           |       |
| L   | .780     | .800 | 19.81       | 20.32 |
| L1  | .161     | .173 | 4.10        | 4.40  |
| ØP  | .138     | .144 | 3.51        | 3.65  |
| Q   | .216     | .236 | 5.49        | 6.00  |
| S   | .238     | .248 | 6.04        | 6.30  |
| T   | 9°       | 11°  | 9°          | 11°   |
| U   | 9°       | 11°  | 9°          | 11°   |
| V   | 2°       | 8°   | 2°          | 8°    |
| W   | 2°       | 8°   | 2°          | 8°    |

## Recommended Solder Pad Layout



TO-247-3