

# ISL9N316AD3ST

## N-Channel Logic Level PWM Optimized UltraFET® Trench Power MOSFETs

### General Description

This device employs a new advanced trench MOSFET technology and features low gate charge while maintaining low on-resistance.

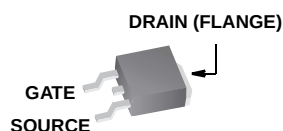
Optimized for switching applications, this device improves the overall efficiency of DC/DC converters and allows operation to higher switching frequencies.

### Applications

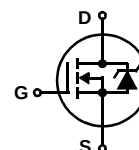
- DC/DC converters

### Features

- Fast switching
- $r_{DS(ON)} = 0.014\Omega$  (Typ),  $V_{GS} = 10V$
- $r_{DS(ON)} = 0.020\Omega$  (Typ),  $V_{GS} = 4.5V$
- $Q_g$  (Typ) = 13nC,  $V_{GS} = 5V$
- $Q_{gd}$  (Typ) = 4.5nC
- $C_{ISS}$  (Typ) = 1450pF



TO-252



### MOSFET Maximum Ratings $T_A = 25^\circ\text{C}$ unless otherwise noted

| Symbol         | Parameter                                                                                       | Ratings    | Units               |
|----------------|-------------------------------------------------------------------------------------------------|------------|---------------------|
| $V_{DSS}$      | Drain to Source Voltage                                                                         | 30         | V                   |
| $V_{GS}$       | Gate to Source Voltage                                                                          | $\pm 20$   | V                   |
| $I_D$          | Drain Current                                                                                   |            |                     |
|                | Continuous ( $T_C = 25^\circ\text{C}$ , $V_{GS} = 10V$ )                                        | 48         | A                   |
|                | Continuous ( $T_C = 100^\circ\text{C}$ , $V_{GS} = 4.5V$ )                                      | 28         | A                   |
|                | Continuous ( $T_C = 25^\circ\text{C}$ , $V_{GS} = 10V$ , $R_{\theta JA} = 52^\circ\text{C/W}$ ) | 10         | A                   |
|                | Pulsed                                                                                          | Figure 4   | A                   |
| $P_D$          | Power dissipation                                                                               | 65         | W                   |
|                | Derate above $25^\circ\text{C}$                                                                 | 0.43       | W/ $^\circ\text{C}$ |
| $T_J, T_{STG}$ | Operating and Storage Temperature                                                               | -55 to 175 | $^\circ\text{C}$    |

### Thermal Characteristics

|                 |                                                                                 |      |                    |
|-----------------|---------------------------------------------------------------------------------|------|--------------------|
| $R_{\theta JC}$ | Thermal Resistance Junction to Case TO-252                                      | 2.31 | $^\circ\text{C/W}$ |
| $R_{\theta JA}$ | Thermal Resistance Junction to Ambient TO-252                                   | 100  | $^\circ\text{C/W}$ |
| $R_{\theta JA}$ | Thermal Resistance Junction to Ambient TO-252, 1in <sup>2</sup> copper pad area | 52   | $^\circ\text{C/W}$ |

### Package Marking and Ordering Information

| Device Marking | Device        | Package  | Reel Size | Tape Width | Quantity   |
|----------------|---------------|----------|-----------|------------|------------|
| N316AD         | ISL9N316AD3ST | TO-252AA | 330mm     | 16mm       | 2500 units |

**Electrical Characteristics**  $T_A = 25^\circ\text{C}$  unless otherwise noted

| Symbol | Parameter | Test Conditions | Min | Typ | Max | Units |
|--------|-----------|-----------------|-----|-----|-----|-------|
|--------|-----------|-----------------|-----|-----|-----|-------|

**Off Characteristics**

|              |                                   |                                                                 |    |   |           |               |
|--------------|-----------------------------------|-----------------------------------------------------------------|----|---|-----------|---------------|
| $B_{V_{DS}}$ | Drain to Source Breakdown Voltage | $I_D = 250\mu\text{A}$ , $V_{GS} = 0\text{V}$                   | 30 | - | -         | V             |
| $I_{DSS}$    | Zero Gate Voltage Drain Current   | $V_{DS} = 25\text{V}$<br>$V_{GS} = 0\text{V}$ $T_C = 150^\circ$ | -  | - | 1         | $\mu\text{A}$ |
| $I_{GSS}$    | Gate to Source Leakage Current    | $V_{GS} = \pm 20\text{V}$                                       | -  | - | $\pm 100$ | nA            |

**On Characteristics**

|              |                                  |                                                                                           |   |                |                 |          |
|--------------|----------------------------------|-------------------------------------------------------------------------------------------|---|----------------|-----------------|----------|
| $V_{GS(TH)}$ | Gate to Source Threshold Voltage | $V_{GS} = V_{DS}$ , $I_D = 250\mu\text{A}$                                                | 1 | -              | 3               | V        |
| $r_{DS(ON)}$ | Drain to Source On Resistance    | $I_D = 48\text{A}$ , $V_{GS} = 10\text{V}$<br>$I_D = 28\text{A}$ , $V_{GS} = 4.5\text{V}$ | - | 0.014<br>0.020 | 0.0155<br>0.023 | $\Omega$ |

**Dynamic Characteristics**

|                     |                               |                                                          |                                                                         |   |      |     |    |
|---------------------|-------------------------------|----------------------------------------------------------|-------------------------------------------------------------------------|---|------|-----|----|
| C <sub>ISS</sub>    | Input Capacitance             | V <sub>DS</sub> = 15V, V <sub>GS</sub> = 0V,<br>f = 1MHz |                                                                         | - | 1450 | -   | pF |
| C <sub>OSS</sub>    | Output Capacitance            |                                                          |                                                                         | - | 300  | -   | pF |
| C <sub>RSS</sub>    | Reverse Transfer Capacitance  |                                                          |                                                                         | - | 120  | -   | pF |
| Q <sub>g(TOT)</sub> | Total Gate Charge at 10V      | V <sub>GS</sub> = 0V to 10V                              | V <sub>DD</sub> = 15V<br>I <sub>D</sub> = 28A<br>I <sub>g</sub> = 1.0mA | - | 25   | 38  | nC |
| Q <sub>g(5)</sub>   | Total Gate Charge at 5V       | V <sub>GS</sub> = 0V to 5V                               |                                                                         | - | 13   | 20  | nC |
| Q <sub>g(TH)</sub>  | Threshold Gate Charge         | V <sub>GS</sub> = 0V to 1V                               |                                                                         | - | 1.5  | 2.3 | nC |
| Q <sub>gs</sub>     | Gate to Source Gate Charge    |                                                          |                                                                         | - | 4.3  | -   | nC |
| Q <sub>gd</sub>     | Gate to Drain “Miller” Charge |                                                          |                                                                         | - | 4.5  | -   | nC |

**Switching Characteristics** ( $V_{GS} = 4.5\text{V}$ )

|              |                     |                                                                                            |   |    |     |    |
|--------------|---------------------|--------------------------------------------------------------------------------------------|---|----|-----|----|
| $t_{ON}$     | Turn-On Time        | $V_{DD} = 15\text{V}$ , $I_D = 10\text{A}$<br>$V_{GS} = 4.5\text{V}$ , $R_{GS} = 11\Omega$ | - | -  | 115 | ns |
| $t_{d(ON)}$  | Turn-On Delay Time  |                                                                                            | - | 15 | -   | ns |
| $t_r$        | Rise Time           |                                                                                            | - | 60 | -   | ns |
| $t_{d(OFF)}$ | Turn-Off Delay Time |                                                                                            | - | 25 | -   | ns |
| $t_f$        | Fall Time           |                                                                                            | - | 30 | -   | ns |
| $t_{OFF}$    | Turn-Off Time       |                                                                                            | - | -  | 83  | ns |

**Switching Characteristics** ( $V_{GS} = 10\text{V}$ )

|              |                     |                                                                                           |   |    |     |    |
|--------------|---------------------|-------------------------------------------------------------------------------------------|---|----|-----|----|
| $t_{ON}$     | Turn-On Time        | $V_{DD} = 15\text{V}$ , $I_D = 10\text{A}$<br>$V_{GS} = 10\text{V}$ , $R_{GS} = 11\Omega$ | - | -  | 57  | ns |
| $t_{d(ON)}$  | Turn-On Delay Time  |                                                                                           | - | 8  | -   | ns |
| $t_r$        | Rise Time           |                                                                                           | - | 30 | -   | ns |
| $t_{d(OFF)}$ | Turn-Off Delay Time |                                                                                           | - | 45 | -   | ns |
| $t_f$        | Fall Time           |                                                                                           | - | 30 | -   | ns |
| $t_{OFF}$    | Turn-Off Time       |                                                                                           | - | -  | 115 | ns |

**Unclamped Inductive Switching**

|          |                |                                          |     |   |   |               |
|----------|----------------|------------------------------------------|-----|---|---|---------------|
| $t_{AV}$ | Avalanche Time | $I_D = 2.9\text{A}$ , $L = 3.0\text{mH}$ | 195 | - | - | $\mu\text{s}$ |
|----------|----------------|------------------------------------------|-----|---|---|---------------|

**Drain-Source Diode Characteristics**

|          |                               |                                                                |   |   |      |    |
|----------|-------------------------------|----------------------------------------------------------------|---|---|------|----|
| $V_{SD}$ | Source to Drain Diode Voltage | $I_{SD} = 28\text{A}$                                          | - | - | 1.25 | V  |
|          |                               | $I_{SD} = 13\text{A}$                                          | - | - | 1.0  | V  |
| $t_{rr}$ | Reverse Recovery Time         | $I_{SD} = 28\text{A}$ , $dI_{SD}/dt = 100\text{A}/\mu\text{s}$ | - | - | 20   | ns |
| $Q_{RR}$ | Reverse Recovered Charge      | $I_{SD} = 28\text{A}$ , $dI_{SD}/dt = 100\text{A}/\mu\text{s}$ | - | - | 7    | nC |

## Typical Characteristic

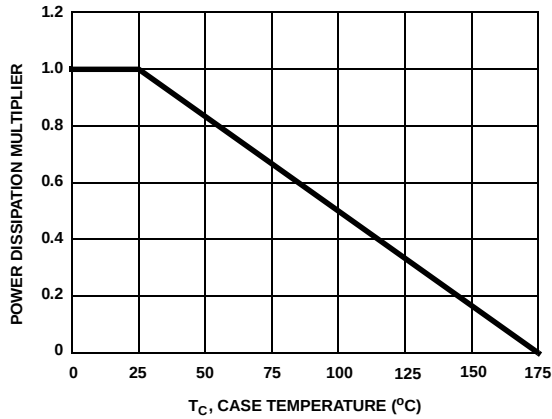


Figure 1. Normalized Power Dissipation vs Ambient Temperature

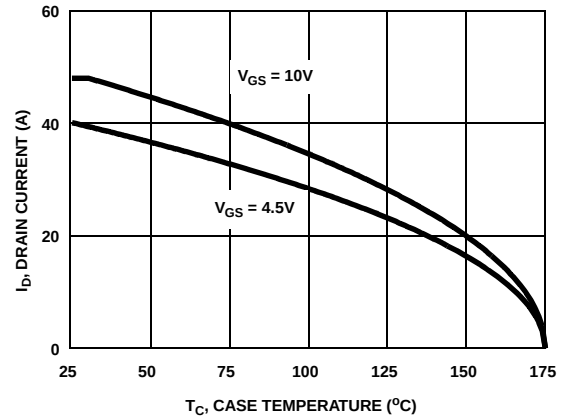


Figure 2. Maximum Continuous Drain Current vs Case Temperature

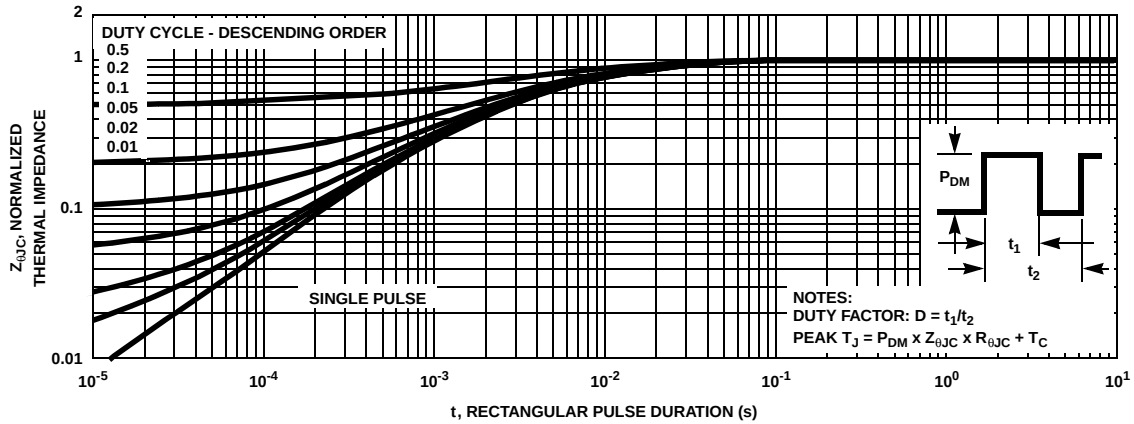


Figure 3. Normalized Maximum Transient Thermal Impedance

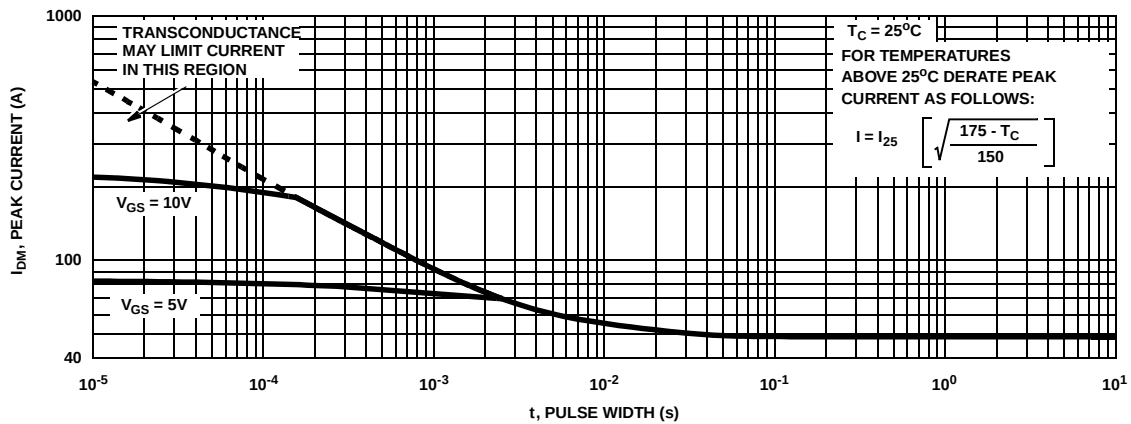


Figure 4. Peak Current Capability

# Typical Characteristic (Continued)

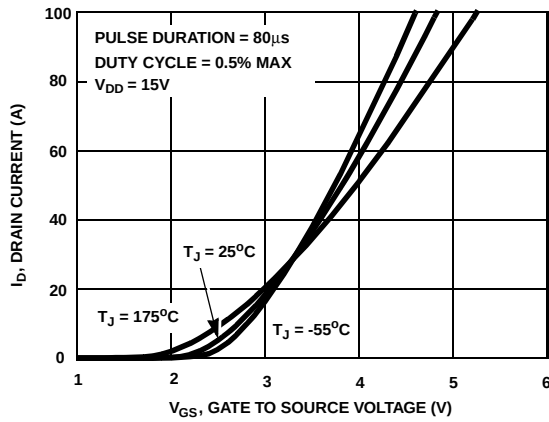


Figure 5. Transfer Characteristics

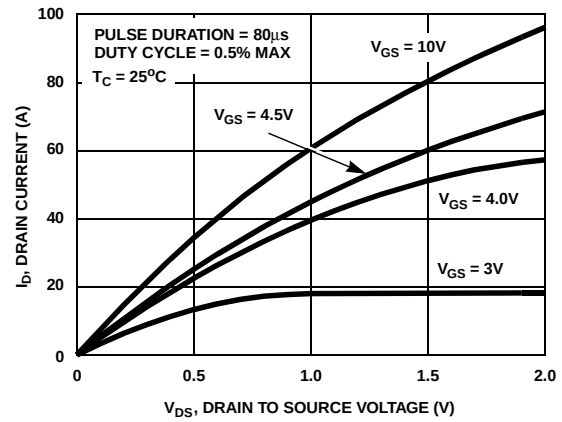


Figure 6. Saturation Characteristics

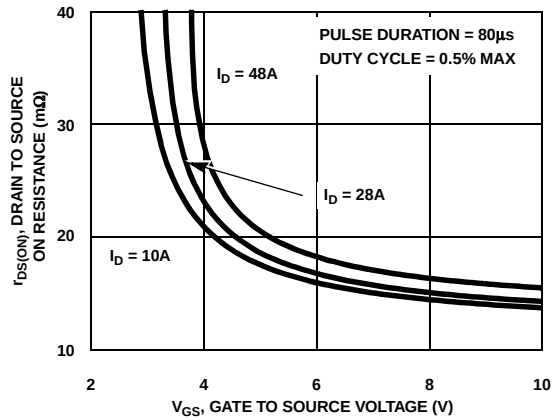


Figure 7. Drain to Source On Resistance vs Gate Voltage and Drain Current

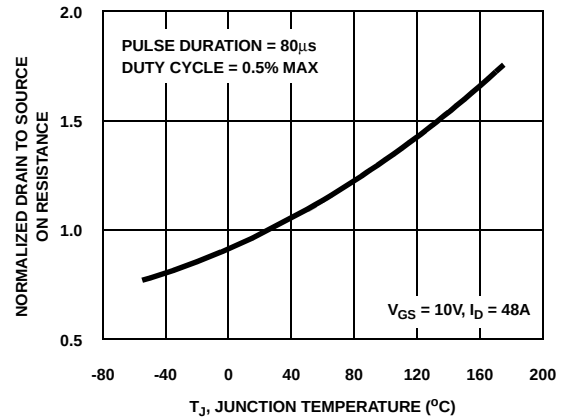


Figure 8. Normalized Drain to Source On Resistance vs Junction Temperature

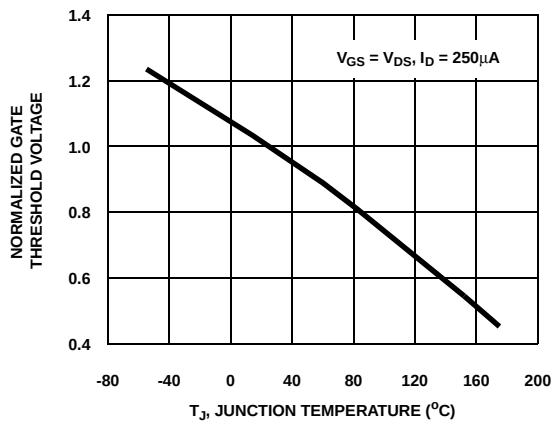


Figure 9. Normalized Gate Threshold Voltage vs Junction Temperature

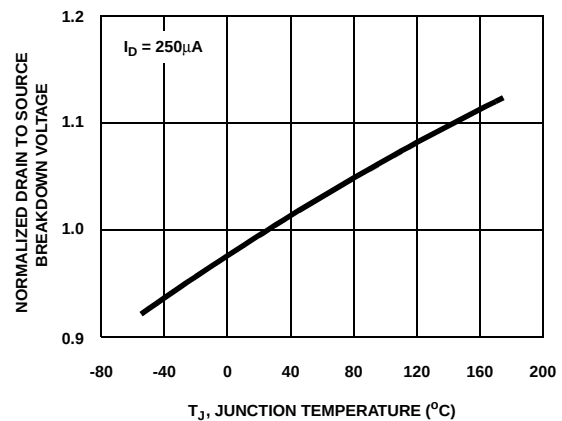


Figure 10. Normalized Drain to Source Breakdown Voltage vs Junction Temperature

## Typical Characteristic (Continued)

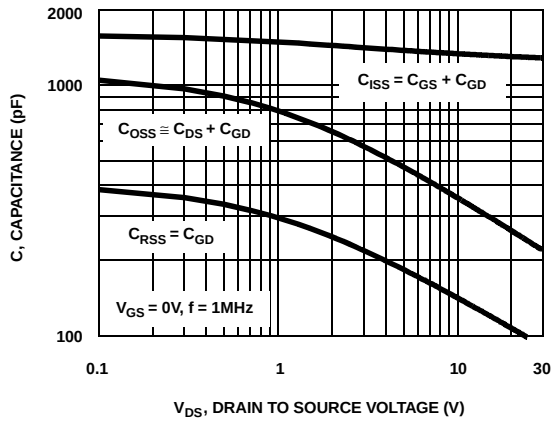


Figure 11. Capacitance vs Drain to Source Voltage

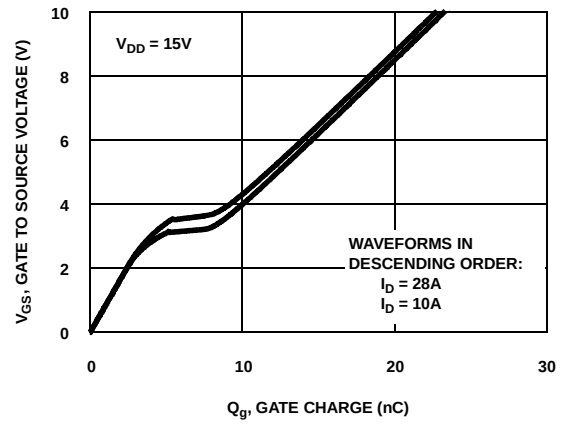


Figure 12. Gate Charge Waveforms for Constant Gate Currents

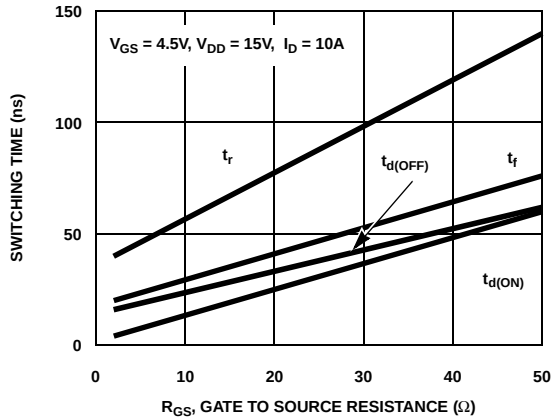


Figure 13. Switching Time vs Gate Resistance

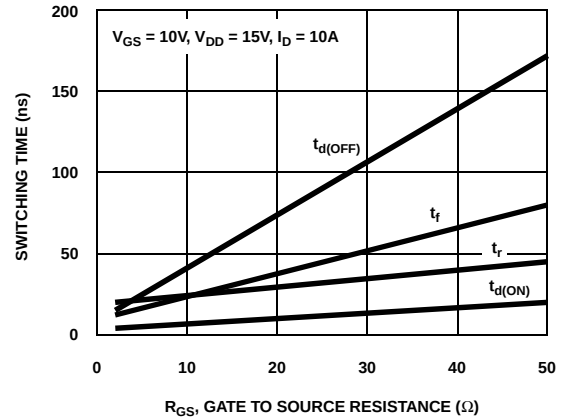


Figure 14. Switching Time vs Gate Resistance

## Test Circuits and Waveforms

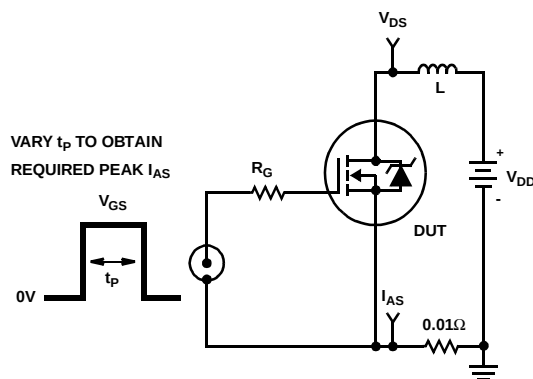


Figure 15. Unclamped Energy Test Circuit

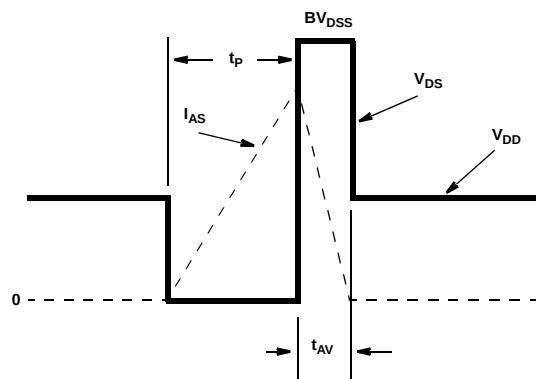


Figure 16. Unclamped Energy Waveforms

# Test Circuits and Waveforms (Continued)

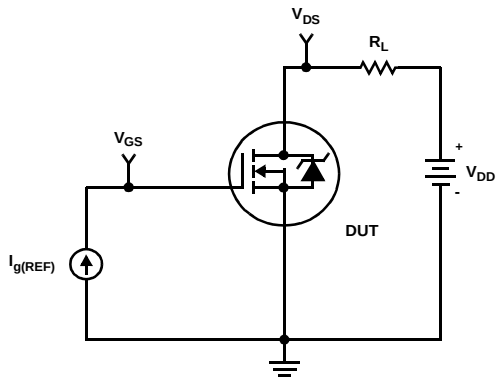


Figure 17. Gate Charge Test Circuit

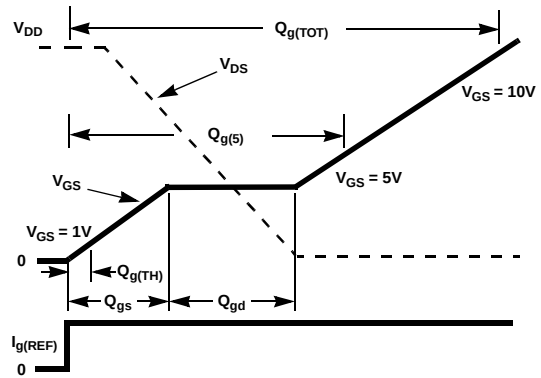


Figure 18. Gate Charge Waveforms

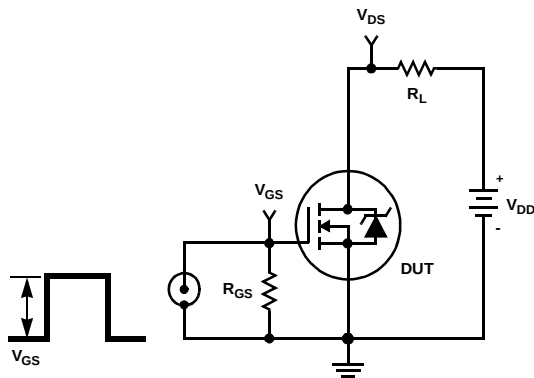


Figure 19. Switching Time Test Circuit

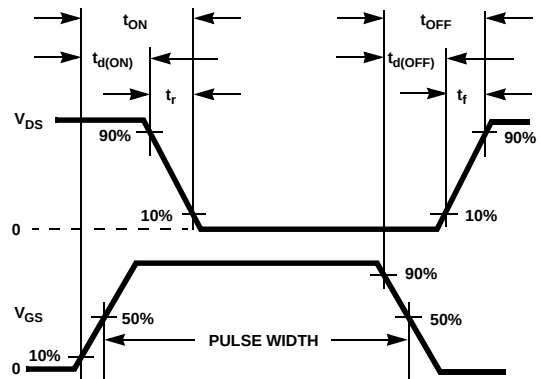


Figure 20. Switching Time Waveforms

## Thermal Resistance vs. Mounting Pad Area

The maximum rated junction temperature,  $T_{JM}$ , and the thermal resistance of the heat dissipating path determines the maximum allowable device power dissipation,  $P_{DM}$ , in an application. Therefore the application's ambient temperature,  $T_A$  ( $^{\circ}\text{C}$ ), and thermal resistance  $R_{\theta JA}$  ( $^{\circ}\text{C/W}$ ) must be reviewed to ensure that  $T_{JM}$  is never exceeded. Equation 1 mathematically represents the relationship and serves as the basis for establishing the rating of the part.

$$P_{DM} = \frac{(T_{JM} - T_A)}{Z_{\theta JA}} \quad (\text{EQ. 1})$$

In using surface mount devices such as the TO-252 package, the environment in which it is applied will have a significant influence on the part's current and maximum power dissipation ratings. Precise determination of  $P_{DM}$  is complex and influenced by many factors:

1. Mounting pad area onto which the device is attached and whether there is copper on one side or both sides of the board.
2. The number of copper layers and the thickness of the board.
3. The use of external heat sinks.
4. The use of thermal vias.
5. Air flow and board orientation.
6. For non steady state applications, the pulse width, the duty cycle and the transient thermal response of the part, the board and the environment they are in.

Fairchild provides thermal information to assist the designer's preliminary application evaluation. Figure 21 defines the  $R_{\theta JA}$  for the device as a function of the top copper (component side) area. This is for a horizontally positioned FR-4 board with 1oz copper after 1000 seconds of steady state power with no air flow. This graph provides the necessary information for calculation of the steady state junction temperature or power dissipation. Pulse applications can be evaluated using the Fairchild device Spice thermal model or manually utilizing the normalized maximum transient thermal impedance curve.

Displayed on the curve are  $R_{\theta JA}$  values listed in the Electrical Specifications table. The points were chosen to depict the compromise between the copper board area, the thermal resistance and ultimately the power dissipation,  $P_{DM}$ .

Thermal resistances corresponding to other copper areas can be obtained from Figure 21 or by calculation using Equation 2.  $R_{\theta JA}$  is defined as the natural log of the area times a coefficient added to a constant. The area, in square inches is the top copper area including the gate and source pads.

$$R_{\theta JA} = 33.32 + \frac{23.84}{(0.268 + \text{Area})} \quad (\text{EQ. 2})$$

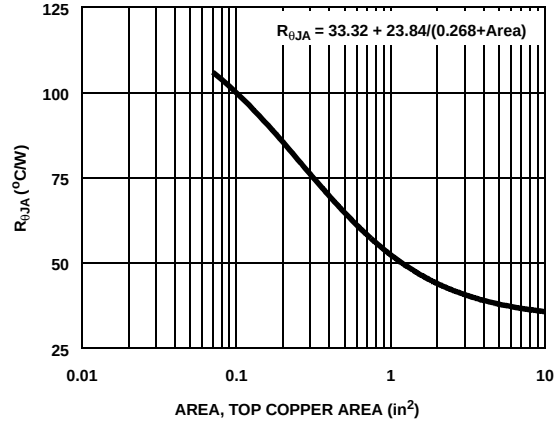


Figure 21. Thermal Resistance vs Mounting Pad Area

**PSPICE Electrical Model**

.SUBCKT ISL9N316AD3ST 2 1

3 ;rev May 2001

CA 12 8 9e-10  
 CB 15 14 9.5e-10  
 CIN 6 8 1.2e-9

DBODY 7 5 DBODYMOD  
 DBREAK 5 11 DBREAKMOD  
 DPLCAP 10 5 DPLCAPMOD

EBREAK 11 7 17 18 31.8  
 EDS 14 8 5 8 1  
 EGS 13 8 6 8 1  
 ESG 6 10 6 8 1  
 EVTHRES 6 21 19 8 1  
 EVTEMP 20 6 18 22 1

IT 8 17 1

LGATE 1 9 5.61e-9  
 LDRAIN 2 5 1.0e-9  
 LSOURCE 3 7 1.98e-9

MMED 16 6 8 8 MMEDMOD  
 MSTRO 16 6 8 8 MSTROMOD  
 MWEAK 16 21 8 8 MWEAKMOD

RBREAK 17 18 RBREAKMOD 1  
 RDRAIN 50 16 RDRAINMOD 2e-3  
 RGATE 9 20 1.98  
 RLDRAIN 2 5 10  
 RLGATE 1 9 56.1  
 RLSOURCE 3 7 19.8  
 RSLC1 5 51 RSLCMOD 1e-6  
 RSLC2 5 50 1e3  
 RSOURCE 8 7 RSOURCEMOD 9.5e-3  
 RVTHRES 22 8 RVTHRESMOD 1  
 RVTEMP 18 19 RVTEMPMOD 1

S1A 6 12 13 8 S1AMOD  
 S1B 13 12 13 8 S1BMOD  
 S2A 6 15 14 13 S2AMOD  
 S2B 13 15 14 13 S2BMOD

VBAT 22 19 DC 1

$$\text{ESLC } 51 \ 50 \ \text{VALUE} = \{ (V(5,51) / \text{ABS}(V(5,51))) * (\text{PWR}(V(5,51)) / (1e-6 * 110), 3) \}$$

.MODEL DBODYMOD D (IS = 2.4e-11 N = 1.09 RS = 9.2e-3 TRS1 = 9e-4 TRS2 = 1e-6 XTI = 2.2 CJO = 7e-10 M = 0.49 TT = 8e-11)

.MODEL DBREAKMOD D (RS = 0. 8 TRS1 = 1e- 3 TRS2 = -8.9e-6)

.MODEL DPLCAPMOD D (CJO = 4e-1 0IS = 1e-3 0N = 10 M = 0.43)

.MODEL MMEDMOD NMOS (VTO = 1.625 KP = 4 IS = 1e-30 N = 10 TOX = 1 L = 1u W = 1u RG = 1.98)

.MODEL MSTROMOD NMOS (VTO = 2.08 KP = 55 IS = 1e-30 N = 10 TOX = 1 L = 1u W = 1u)

.MODEL MWEAKMOD NMOS (VTO = 1.32 KP = 0.04 IS = 1e-30 N = 10 TOX = 1 L = 1u W = 1u RG = 19.8 RS = 0.1)

.MODEL RBREAKMOD RES (TC1 = 1e- 3 TC2 = -7e-7)

.MODEL RDRAINMOD RES (TC1 = 1.7e- 2 TC2 = 5e-5)

.MODEL RSLCMOD RES (TC1 = 3.5e-4 TC2 = 5e-6)

.MODEL RSOURCEMOD RES (TC1 = 1e-3 TC2 = 1e-6)

.MODEL RVTHRESMOD RES (TC1 = -2.1e-3 TC2 = -0.5e-5)

.MODEL RVTEMPMOD RES (TC1 = -1.8e- 3 TC2 = 1e-6)

.MODEL S1AMOD VSWITCH (RON = 1e-5 ROFF = 0.1 VON = -4.0 VOFF = -1.0)

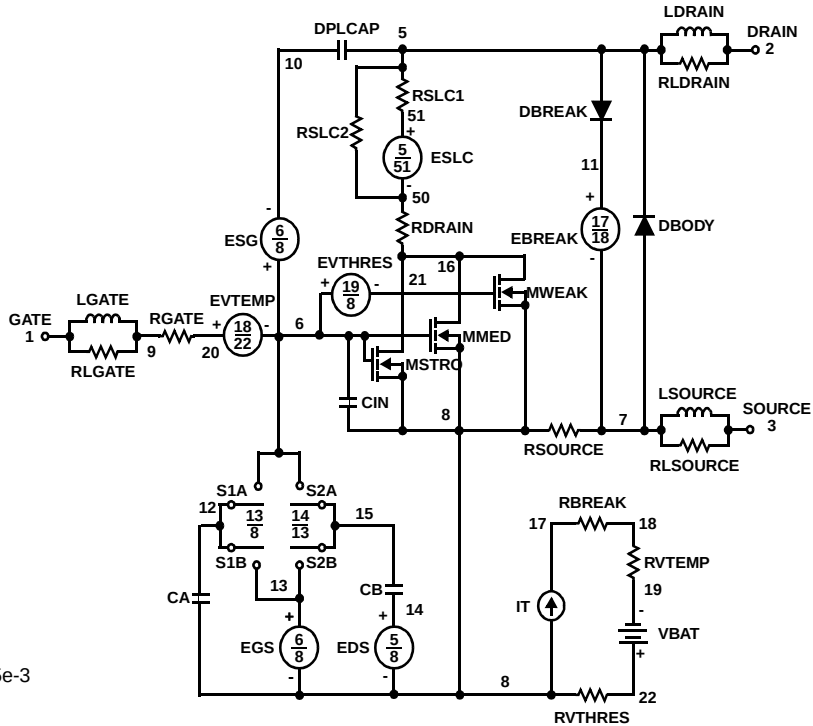
.MODEL S1BMOD VSWITCH (RON = 1e-5 ROFF = 0.1 VON = -1.0 VOFF = -4.0)

.MODEL S2AMOD VSWITCH (RON = 1e-5 ROFF = 0.1 VON = -0.3 VOFF = 0.2)

.MODEL S2BMOD VSWITCH (RON = 1e-5 ROFF = 0.1 VON = 0.2 VOFF = -0.3)

.ENDS

NOTE: For further discussion of the PSPICE model, consult **A New PSPICE Sub-Circuit for the Power MOSFET Featuring Global Temperature Options**; IEEE Power Electronics Specialist Conference Records, 1991, written by William J. Hepp and C. Frank Wheatley.







**SPICE Thermal Model**

REV 23 May 2001

TISL9N316AD3ST

CTHERM1 th 6 1.0e-3  
 CHERM2 6 5 1.5e-3  
 CHERM3 5 4 1.9e-3  
 CHERM4 4 3 3e-3  
 CHERM5 3 2 5.0e-3  
 CHERM6 2 tl 2.5e-2

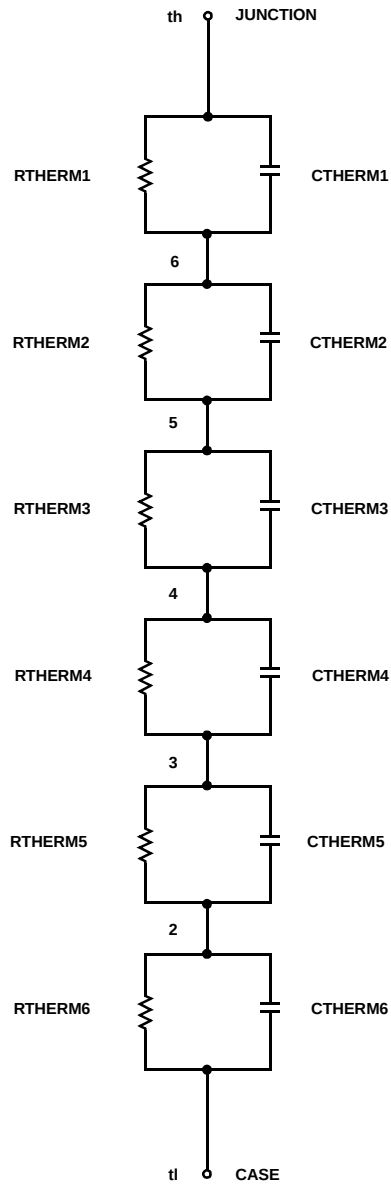
RHERM1 th 6 2.5e-3  
 RHERM2 6 5 3.5e-3  
 RHERM3 5 4 5.2e-2  
 RHERM4 4 3 5.0e-1  
 RHERM5 3 2 5.7e-1  
 RHERM6 2 tl 6.9e-1

**SABER Thermal Model**

SABER thermal model TISL9N316AD3ST

```
template thermal_model th tl
thermal_c th, tl
{
  ctherm.ctherm1 th 6 = 1.0e-3
  ctherm.ctherm2 6 5 = 1.5e-3
  ctherm.ctherm3 5 4 = 1.9e-3
  ctherm.ctherm4 4 3 = 3e-3
  ctherm.ctherm5 3 2 = 5e-3
  ctherm.ctherm6 2 tl = 2.5e-2
```

```
  rtherm.rtherm1 th 6 = 2.5e-3
  rtherm.rtherm2 6 5 = 3.5e-3
  rtherm.rtherm3 5 4 = 5.2e-2
  rtherm.rtherm4 4 3 = 5.0e-1
  rtherm.rtherm5 3 2 = 5.7e-1
  rtherm.rtherm6 2 tl = 6.9e-1
}
```



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|                                   |                                  |                                  |                              |                   |
|-----------------------------------|----------------------------------|----------------------------------|------------------------------|-------------------|
| ACE <sup>Ex</sup> <sup>TM</sup>   | FAST <sup>®</sup>                | OPTOLOGIC <sup>TM</sup>          | SMART START <sup>TM</sup>    | VCX <sup>TM</sup> |
| Bottomless <sup>TM</sup>          | FAST <sup>r</sup> <sup>TM</sup>  | OPTOPLANAR <sup>TM</sup>         | STAR*POWER <sup>TM</sup>     |                   |
| CoolFET <sup>TM</sup>             | FRFET <sup>TM</sup>              | PACMAN <sup>TM</sup>             | Stealth <sup>TM</sup>        |                   |
| CROSSVOLT <sup>TM</sup>           | GlobalOptoisolator <sup>TM</sup> | POP <sup>TM</sup>                | SuperSOT <sup>TM</sup> -3    |                   |
| DenseTrench <sup>TM</sup>         | GTO <sup>TM</sup>                | Power247 <sup>TM</sup>           | SuperSOT <sup>TM</sup> -6    |                   |
| DOME <sup>TM</sup>                | HiSeC <sup>TM</sup>              | PowerTrench <sup>®</sup>         | SuperSOT <sup>TM</sup> -8    |                   |
| EcoSPARK <sup>TM</sup>            | ISOPLANAR <sup>TM</sup>          | QFET <sup>TM</sup>               | SyncFET <sup>TM</sup>        |                   |
| E <sup>2</sup> CMOS <sup>TM</sup> | LittleFET <sup>TM</sup>          | QS <sup>TM</sup>                 | TinyLogic <sup>TM</sup>      |                   |
| EnSigna <sup>TM</sup>             | MicroFET <sup>TM</sup>           | QT Optoelectronics <sup>TM</sup> | TruTranslation <sup>TM</sup> |                   |
| FACT <sup>TM</sup>                | MicroPak <sup>TM</sup>           | Quiet Series <sup>TM</sup>       | UHC <sup>TM</sup>            |                   |
| FACT Quiet Series <sup>TM</sup>   | MICROWIRE <sup>TM</sup>          | SILENT SWITCHER <sup>®</sup>     | UltraFET <sup>®</sup>        |                   |

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## PRODUCT STATUS DEFINITIONS

### Definition of Terms

| Datasheet Identification | Product Status         | Definition                                                                                                                                                                                                            |
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