# Understand Power MOSFET

# Data Sheet

# Understand MOSFET Data Sheet

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  - Power Dissipation and Current Rating
  - Eas Rating & Safe Operation Area (SOA)
  - Off-State Characteristics
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  - Resistive Switching Characteristics
  - Body Diode Characteristics

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# The Title Page

- Device type
- Features
- Vdss
- Rdson (max.)
- Id
- Package type
- Maximum ratings
- Thermal data
- Revision data

FTP18N20

N-Channel MOSFET

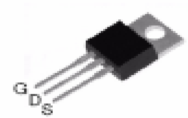
**Applications:**

- CRT, TV/Monitor
- Other Applications

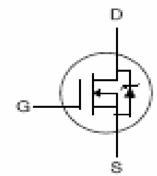
| $V_{DSS}$ | $R_{DS(ON)}$ (Max.) | $I_D$ |
|---|---|---|
| 200V | 0.18 Ω | 18A |

**Features:**

- Lead Free
- Low ON Resistance
- Low Gate Charge
- Peak Current vs Pulse Width Curve
- Inductive Switching Curves
- Improved UIS Ruggedness




TO-220
Not to Scale




Ordering Information

| PART NUMBER | PACKAGE | BRAND |
|---|---|---|
| FTP18N20 | TO-220 | FTP18N20 |

Absolute Maximum Ratings $T_C$=25 °C unless otherwise specified

| Symbol | Parameter | Maximum | Units |
|---|---|---|---|
| $V_{DSS}$ | Drain-to-Source Voltage (NOTE *1) | 200 | V |
| $I_D$ | Continuous Drain Current | 18 | A |
| $I_D$@ 100 °C | Continuous Drain Current | Figure 3 | |
| $I_{DM}$ | Pulsed Drain Current, $V_{GS}$@ 10V (NOTE *2) | Figure 6 | |
| $P_D$ | Power Dissipation | 156 | W |
| | Derating Factor above 25 °C | 1.25 | W/°C |
| $V_{GS}$ | Gate-to-Source Voltage | ± 30 | V |
| $E_{AS}$ | Single Pulse Avalanche Engergy L=500 μH, $I_D$=28.3 Amps | 200 | mJ |
| $I_{AS}$ | Pulsed Avalanche Rating | Figure 8 | |
| dv/dt | Peak Diode Recovery dv/dt (NOTE *3) | 3.0 | V/ns |
| $T_L$ $T_{PKG}$ | Maximum Temperature for Soldering Leads at 0.063in (1.6mm) from Case for 10 seconds Package Body for 10 seconds | 300 260 | °C |
| $T_J$ and $T_{STG}$ | Operating Junction and Storage Temperature Range | -55 to 150 | |

*Caution: Stresses greater than those listed in the "Absolute Maximum Ratings" Table may cause permanent damage to the device.*

Thermal Resistance

| Symbol | Parameter | Min. | Typ. | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| $R_{\theta JC}$ | Junction-to-Case | -- | -- | 0.8 | °C/W | Water cooled heatsink, $P_D$ adjusted for a peak junction temperature of +150 °C. |
| $R_{\theta JA}$ | Junction-to-Ambient | -- | -- | 62 | | 1 cubic foot chamber, free air. |



FTP18N20 REV. A April. 2006

# Maximum Ratings

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Absolute Maximum Ratings $T_C$=25 °C unless otherwise specified

| Symbol | Parameter | Maximum | Units |
|---|---|---|---|
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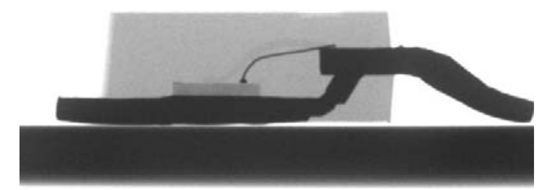
| $T_J$ and $T_{STG}$ | Operating Junction and Storage Temperature Range | -55 to 150 | |

***Caution:** Stresses greater than those listed in the "Absolute Maximum Ratings" Table may cause permanent damage to the device.*

# MOSFET Thermal Data

- **Thermal Resistances**
  - ➢ Rthjc: Proportional to Rdson, or inverse proportional to die size and current rating
  - ➢ Rthja: Function of packaging type, molding compound, thickness of the lead frame, ...

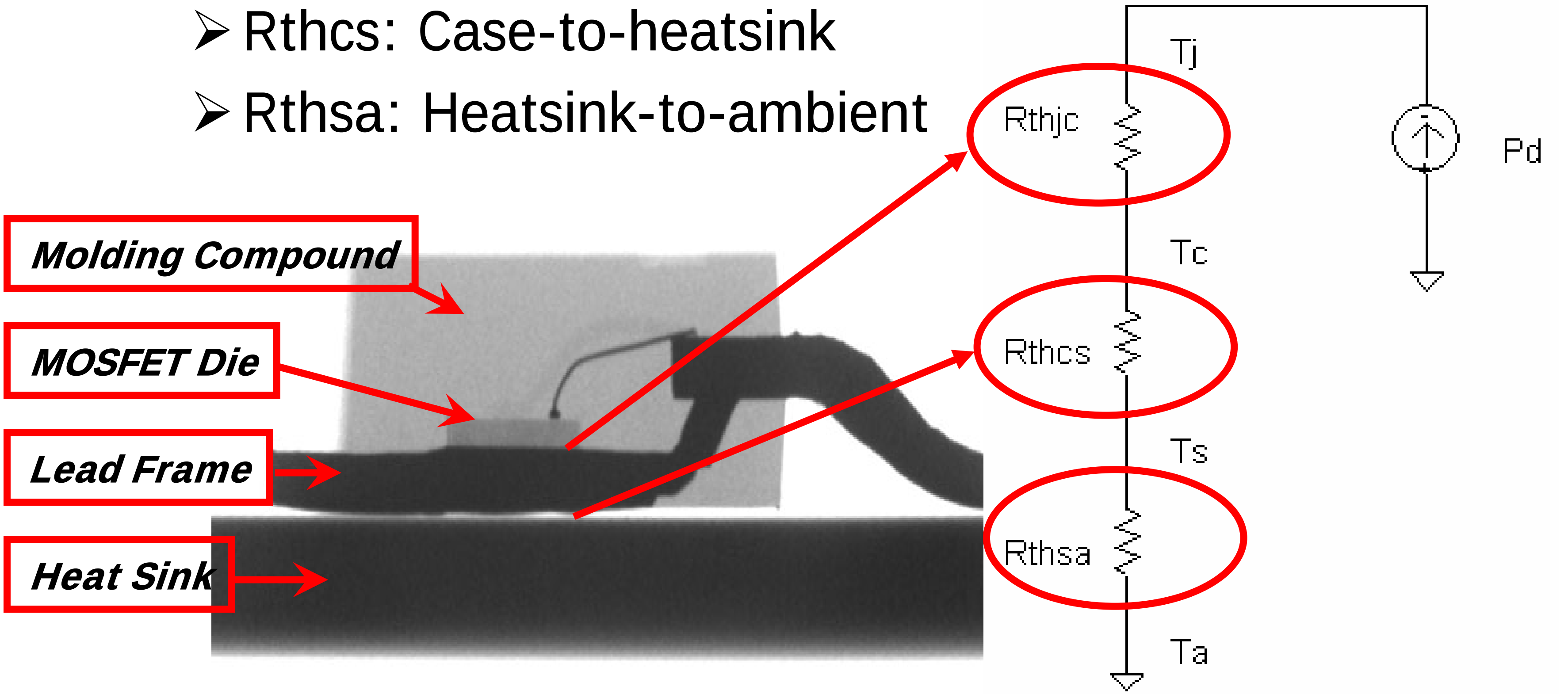


Thermal Resistance

| Symbol | Parameter | Min. | Typ. | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| $R_{\theta JC}$ | Junction-to-Case | -- | -- | 0.8 | °C/W | Water cooled heatsink, $P_D$ adjusted for a peak junction temperature of +150°C. |
| $R_{\theta JA}$ | Junction-to-Ambient | -- | -- | 62 | | 1 cubic foot chamber, free air. |

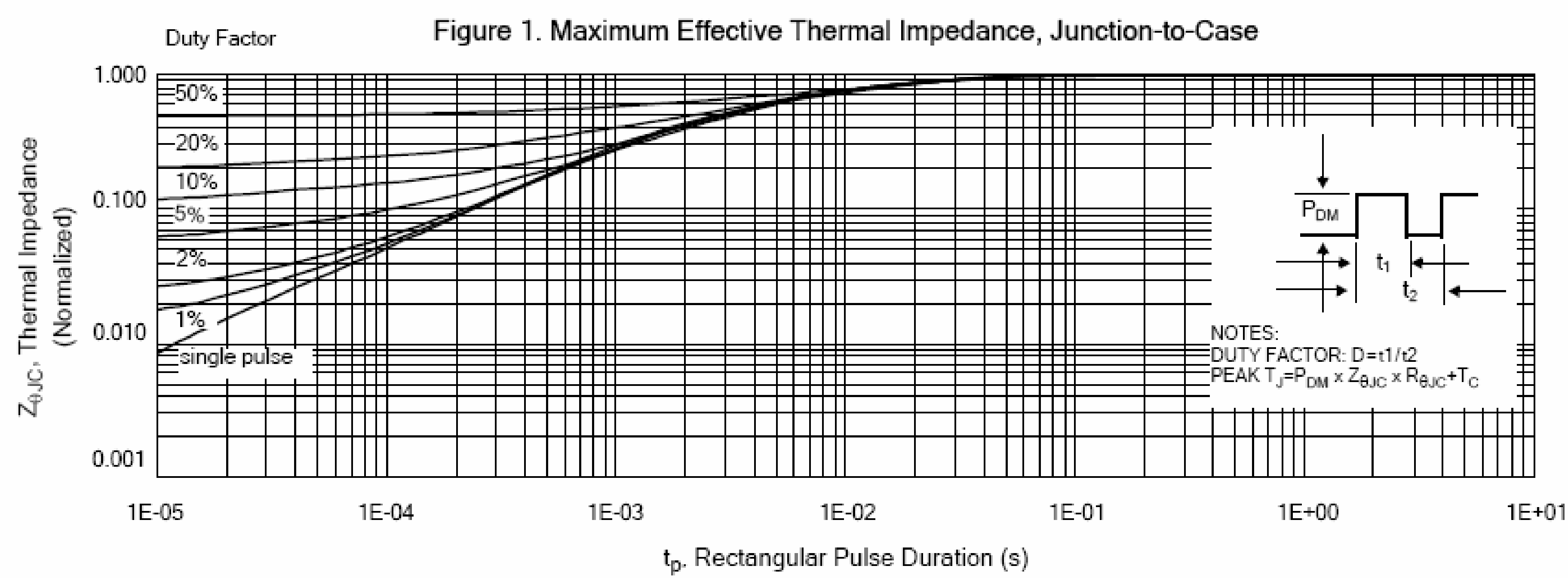
# Thermal Resistance

- **Equivalent Circuit**
  - Rthjc: Die-to-case
  - Rthcs: Case-to-heatsink
  - Rthsa: Heatsink-to-ambient



# Thermal Resistance

- **Maximum Transient Rthjc**
  - Function of duty cycle and period
  - Normalized value on data sheet



# Power Dissipation & Current Rating

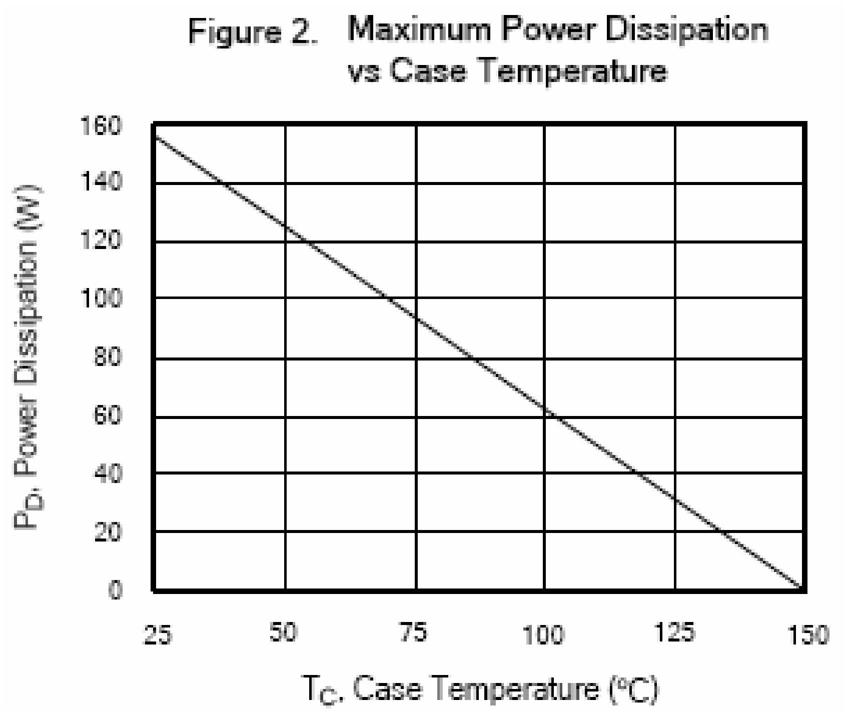
- **Calculating Pd**

$$Tj = Pd \times Rthjc + Tc$$

$$Pd_{\max} = (Tj_{\max} - Tc) / Rthjc$$

$$= (150°C - 25°C)/(0.8°C/W)$$

$$= 156W$$




- **De-rating Factor**
  - 1/Rthjc = 0.8 W/℃

# Maximum Current Rating Id

- **Calculating Id**

$$Pd_{\max} = Id_{\max}^2 \times Rdson$$

$$Id_{\max} = \sqrt{Pd_{\max} / Rdson}$$

$$= \sqrt{156W / (0.18\Omega \times 2.6)}$$

$$= 18.25\,A$$

$$Id_{100^\circ C} = \sqrt{Pd_{100^\circ C} / Rdson}$$

$$= \sqrt{\{(Tj - Tc) / Rthjc\} / Rdson}$$

$$= \sqrt{\{(150 - 100) / 0.8\} / (0.18\,\Omega \times 2.6)}$$

$$= 11.55\,A$$

Figure3. Maximum Continuous Drain Current vs Case Temperature

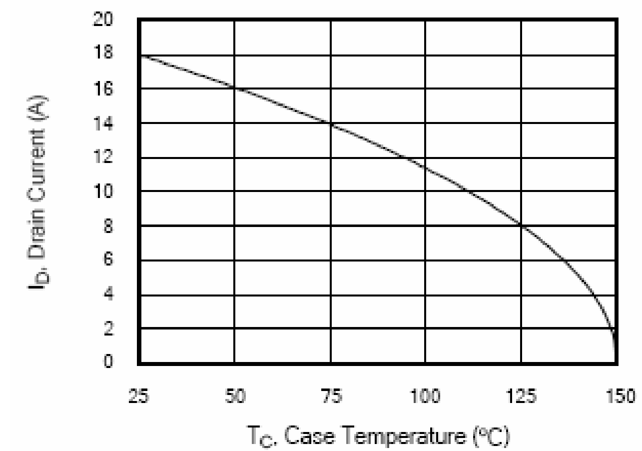
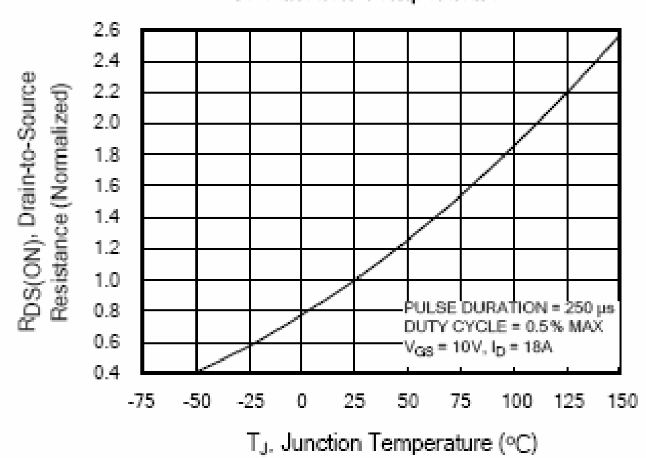


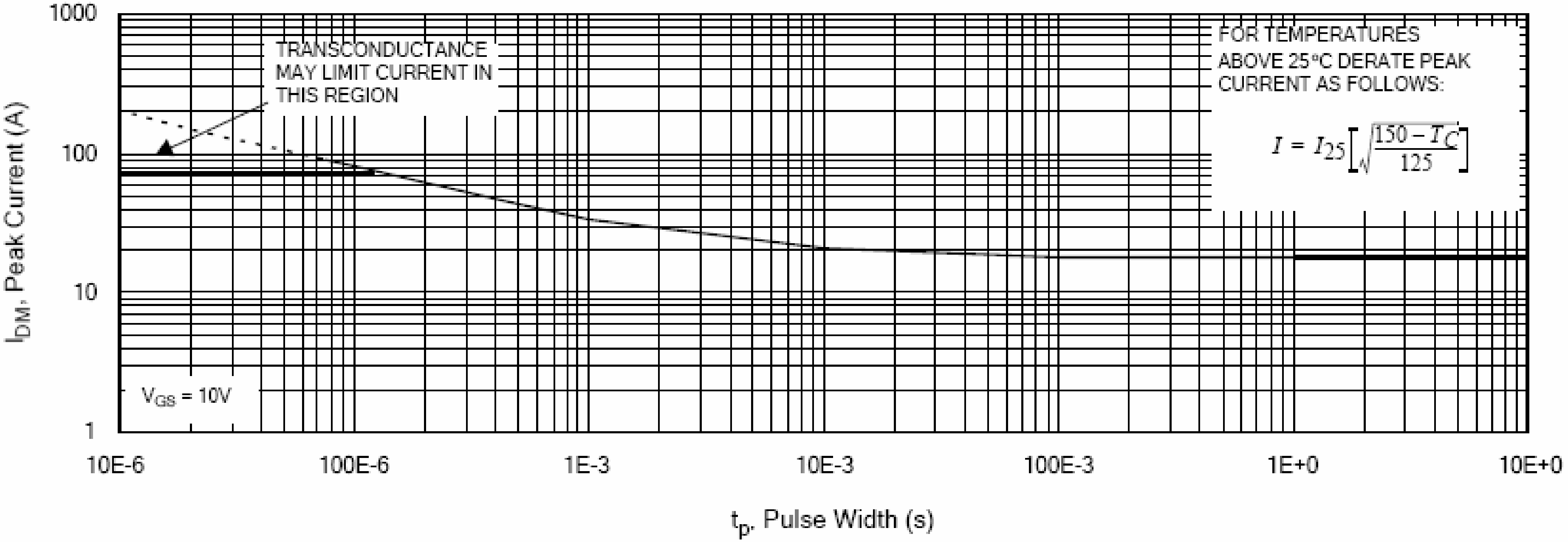

Figure 10. Typical Drain-to-Source ON Resistance vs Junction Temperature



# Maximum Pulsed Current

- **Maximum Pulsed Id**
  - Function of transient Rthjc, duty cycle, and period
  - Limited by Gfs or Vgs capability

Figure 6. Maximum Peak Current Capability



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# Single Pulsed Avalanche Rating

- **Eas Rating**

$$Eas = \frac{1}{2} \times L \times Ias^2$$

$$= \frac{1}{2} \times 500\mu H \times 28.3^2$$

$$= 200\,mJ$$

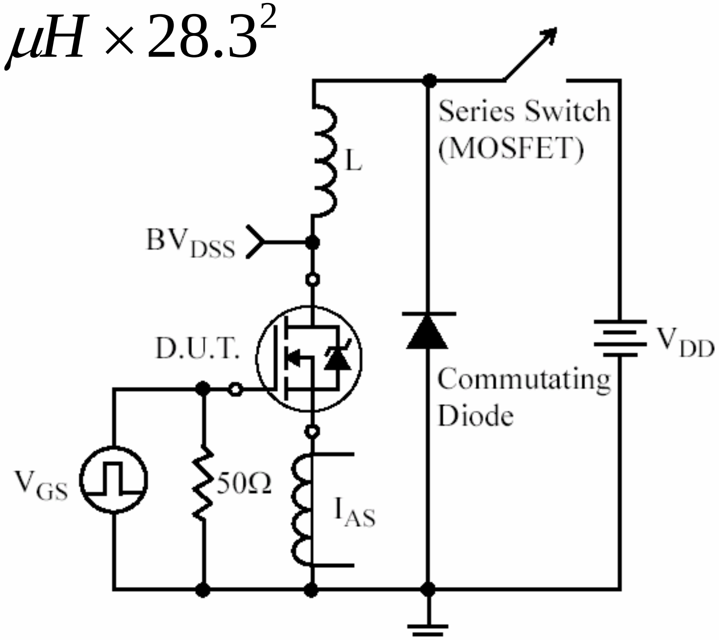

Figure 23. Unclamped Inductive Switching Test Circuit

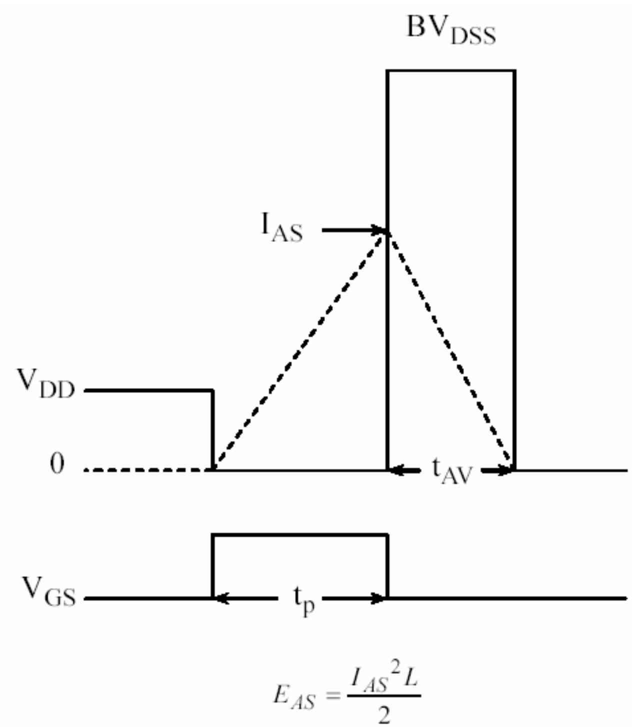

Figure 24. Unclamped Inductive Switching Waveforms

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# Off (Static) Characterization

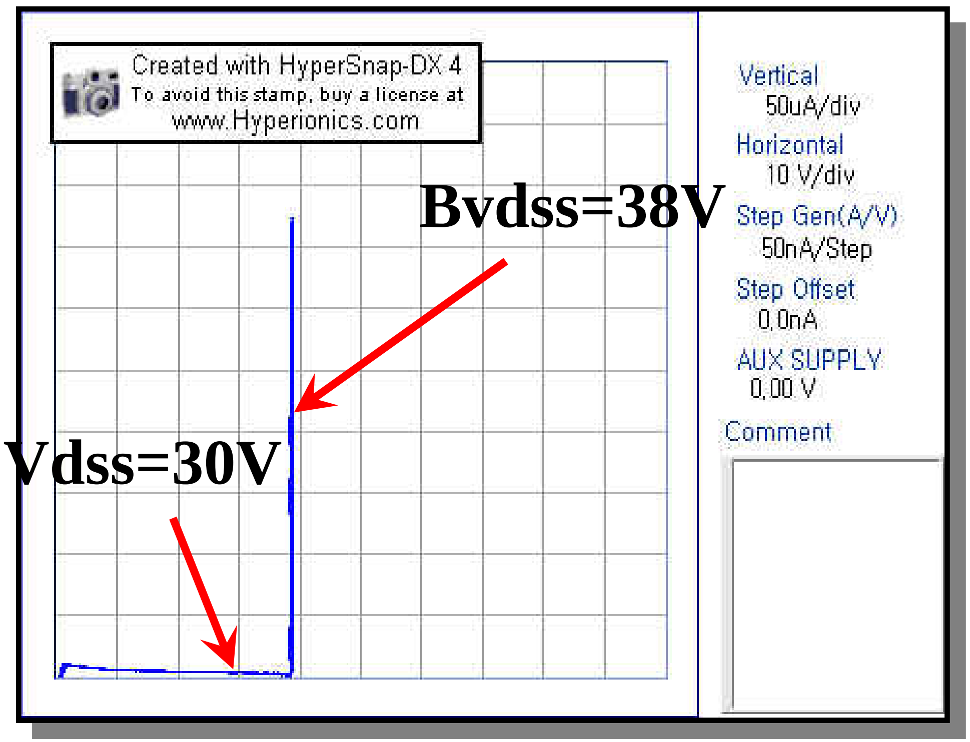
- **MOSFET at Off-State**
  - ➢ BVdss: Breakdown voltage
  - ➢ Idss: Drain leakage current
  - ➢ Igss: Gate leakage current

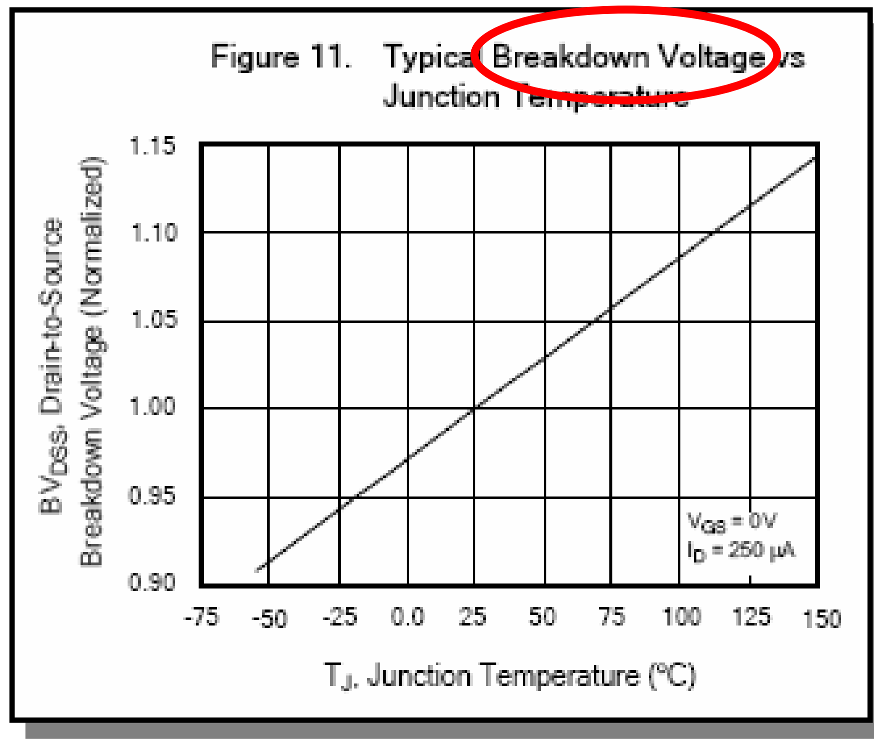
OFF Characteristics  $T_J$=25°C unless otherwise specified

| Symbol | Parameter | Min. | Typ. | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| $BV_{DSS}$ | Drain-to-Source Breakdown Voltage | 200 | -- | -- | V | $V_{GS}$=0V, $I_D$=250μA |
| $\Delta BV_{DSS}/\Delta T_J$ | BreakdownVoltage Temperature Coefficient, Figure 11. | -- | 0.25 | -- | V/°C | Reference to 25°C, $I_D$=250μA |
| $I_{DSS}$ | Drain-to-Source Leakage Current | -- | -- | 25 | μA | $V_{DS}$=200V, $V_{GS}$=0V |
| | | -- | -- | 250 | | $V_{DS}$=160V, $V_{GS}$=0V $T_J$=125°C |
| $I_{GSS}$ | Gate-to-Source Forward Leakage | -- | -- | 100 | nA | $V_{GS}$= +30V |
| | Gate-to-Source Reverse Leakage | -- | -- | -100 | | $V_{GS}$= -30V |

# Breakdown Voltage

- **Minimum Bvdss & Maximum Vdss**
  - Bvdss: Minimum breakdown voltage
  - Vdss: Maximum rated drain voltage



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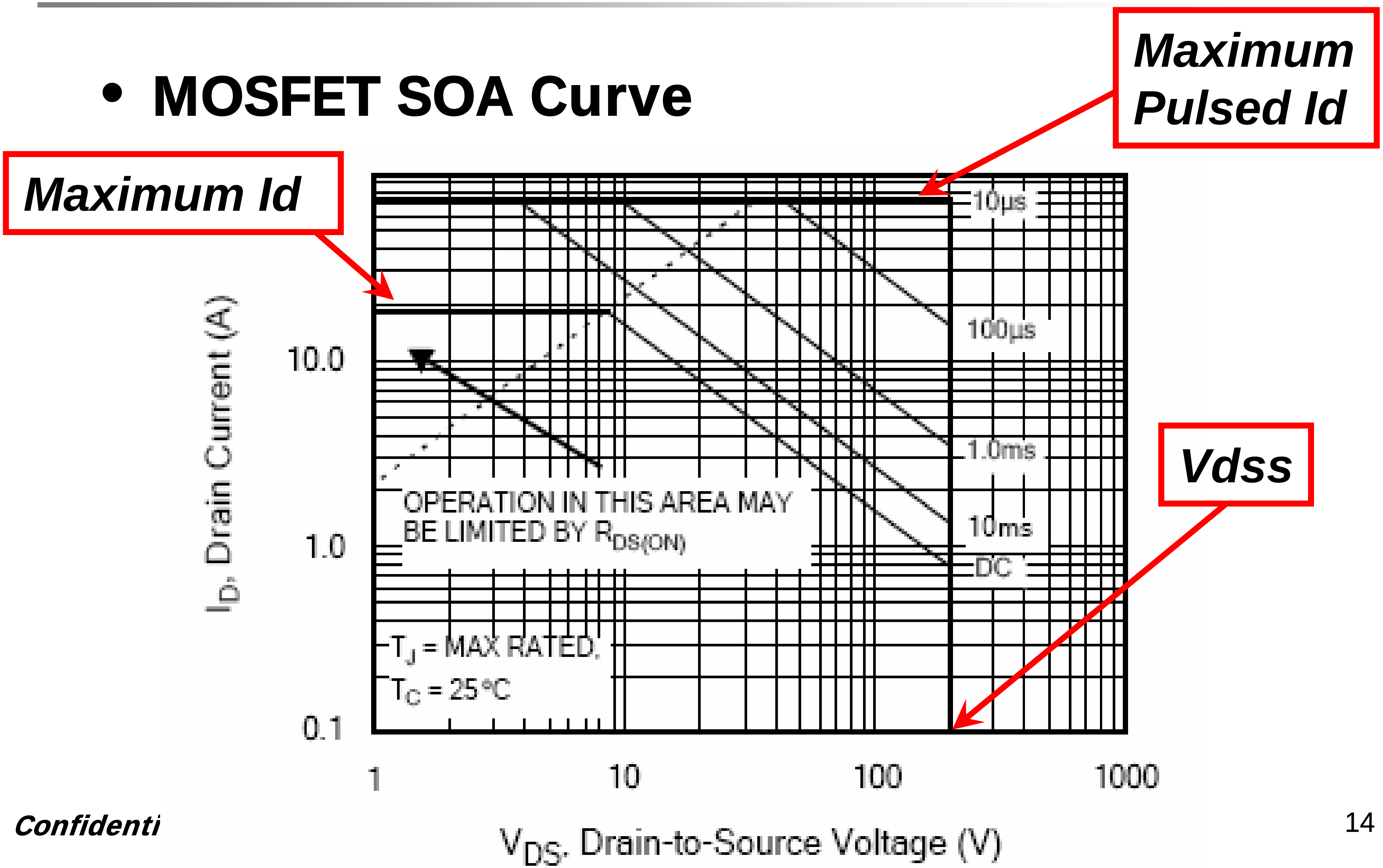
# Safe Operation Area (SOA)

- **MOSFET SOA Curve**



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# On (Static) Characteristics

- **MOSFET at On-State**
  - ➢ Rdson: On-state resistance
    - Function of Vgs and Id
    - **Watch for the test condition!**
  - ➢ Vth: Threshold voltage
  - ➢ Gfs: Trans-conductance, Gfs=△Id/△Vgs

**ON Characteristics** $T_J$=25°C unless otherwise specified

| Symbol | Parameter | Min. | Typ. | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| $R_{DS(ON)}$ | Static Drain-to-Source On-Resistance Figure 9 and 10. | -- | 0.14 | 0.18 | Ω | $V_{GS}$=10V, $I_D$=10.8A (NOTE *4) |
| $V_{GS(TH)}$ | Gate Threshold Voltage, Figure 12. | 2.0 | -- | 4.0 | V | $V_{DS}$=$V_{GS}$, $I_D$=250μA |
| gfs | Forward Transconductance | -- | 14.4 | -- | S | $V_{DS}$=15V, $I_D$=18A (NOTE *4) |

# Rdson Characteristic

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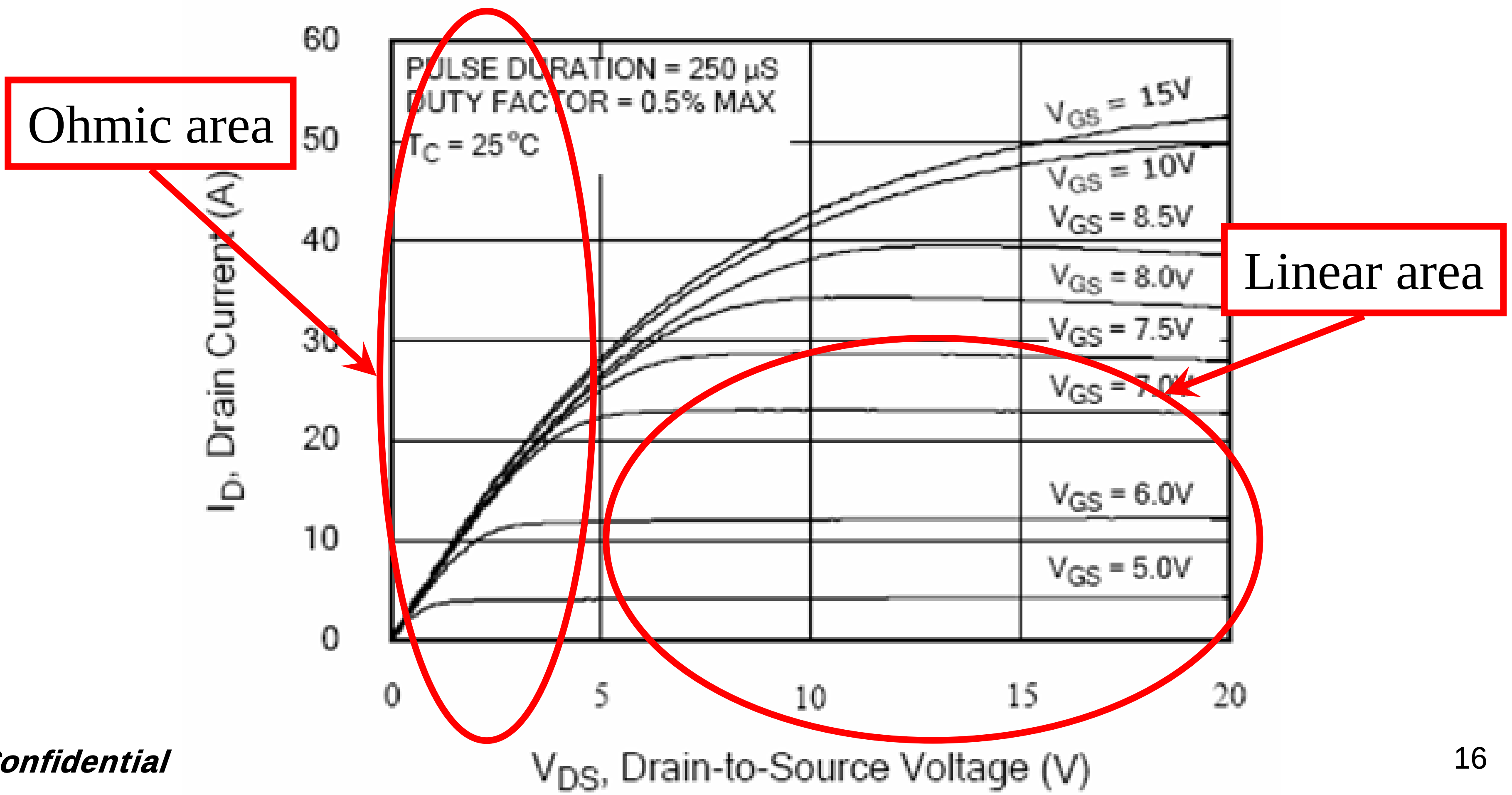
- **Rdson = △Vds / △Id**



# Transfer Function Gfs

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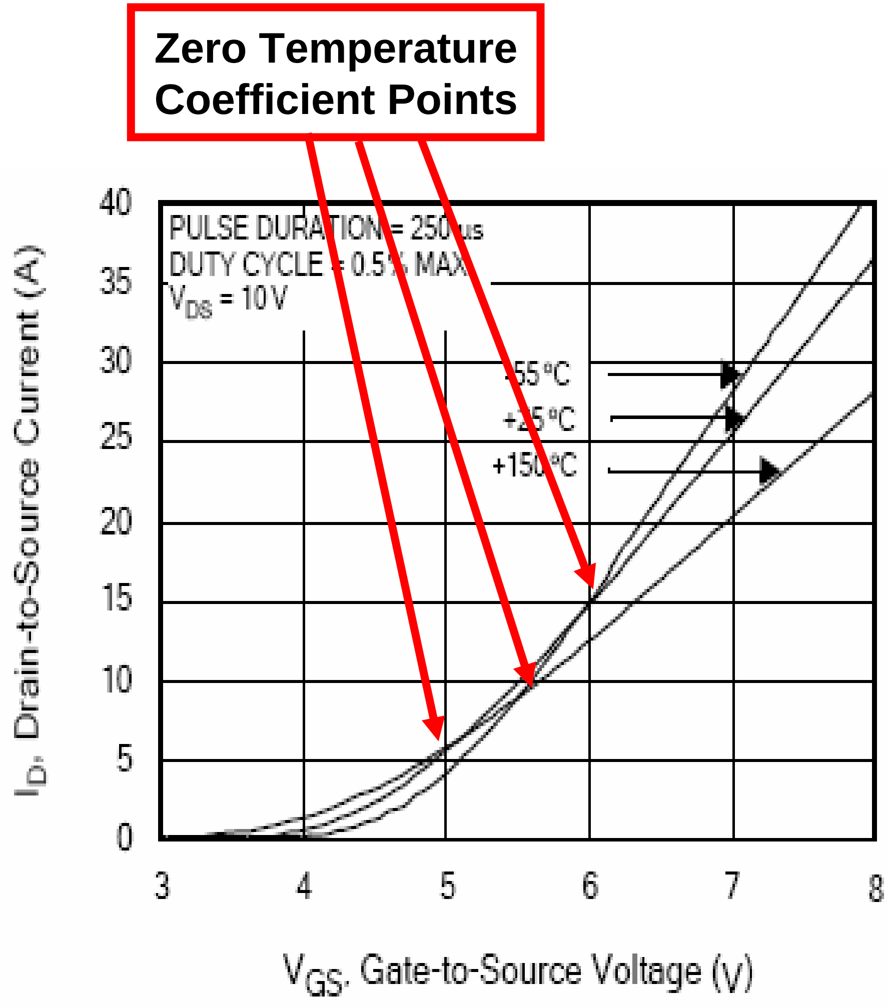
- **Zero Temperature Coefficient**
  - ➢ Important for paralleling MOSFETs
  - ➢ MOSFET is supposed to operate above the zero temperature coefficient
  - ➢ MOSFETs might be thermally running away if operates below this zero temperature coefficient point



# Dynamic Characteristics

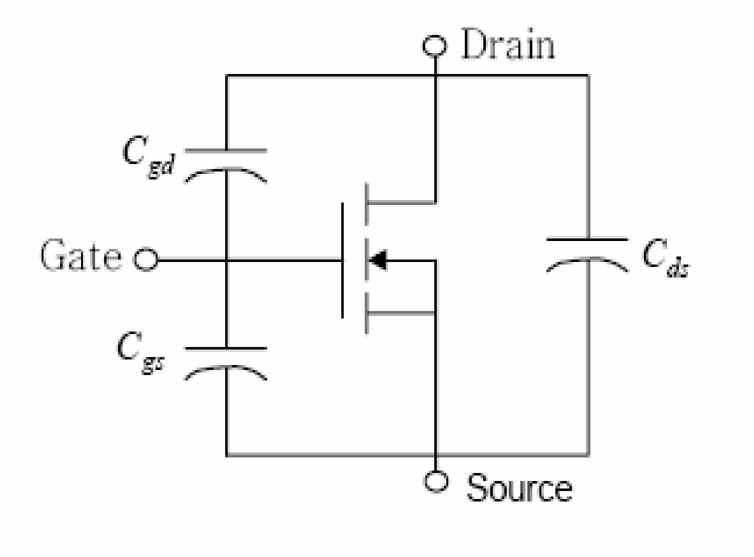
- **MOSFET at Dynamic (Switching) State**
  - Ciss, Coss, and Crss
  - Qg, Qgd, and Qgs
  - Guaranteed by design

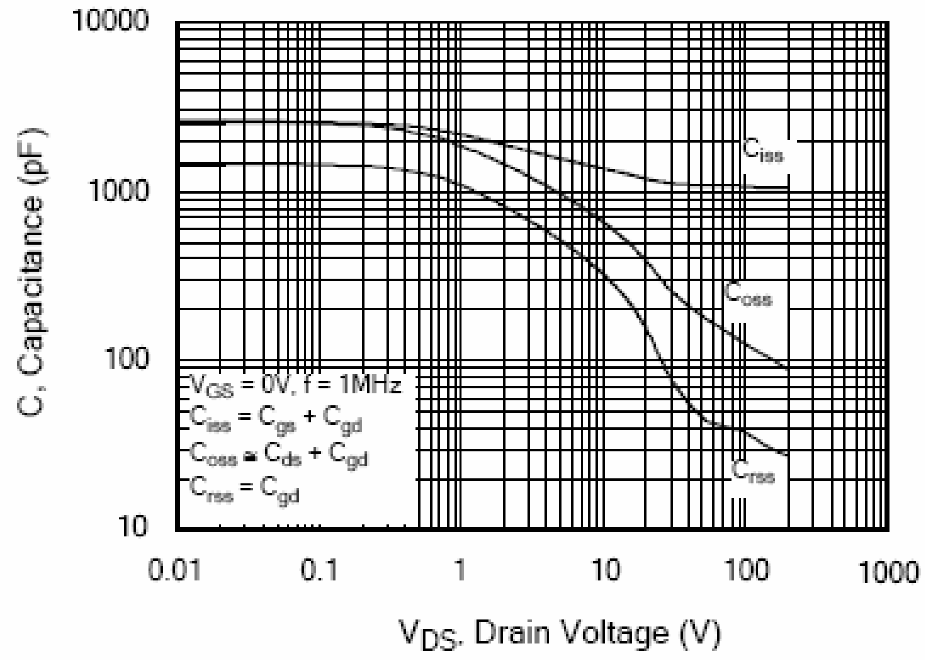
**Dynamic Characteristics** Essentially independent of operating temperature

| Symbol | Parameter | Min. | Typ. | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| $C_{iss}$ | Input Capacitance | -- | 1145 | -- | pF | $V_{GS}$=0V<br>$V_{DS}$=25V<br>f=1.0MHz<br>Figure 14 |
| $C_{oss}$ | Output Capacitance | -- | 105 | -- | | |
| $C_{rss}$ | Reverse Transfer Capacitance | -- | 310 | -- | | |
| $Q_g$ | Total Gate Charge | -- | 40 | -- | nC | $V_{DS}$=100V<br>$I_D$=18A<br>$V_{GS}$=10V<br>Figure 15 |
| $Q_{gs}$ | Gate-to-Source Charge | -- | 10.2 | -- | | |
| $Q_{gd}$ | Gate-to-Drain (“Miller”) Charge | -- | 20.3 | -- | | |

# Equivalent Capacitances

- **MOSFET Capacitances**
  - Input Capacitance: Ciss = Cgd + Cgs
  - Output Capacitance: Coss = Cgd + Cds
  - Miller Capacitance: Crss = Cgd



# Gate Charge and Capacitance

- **Physical Connections**

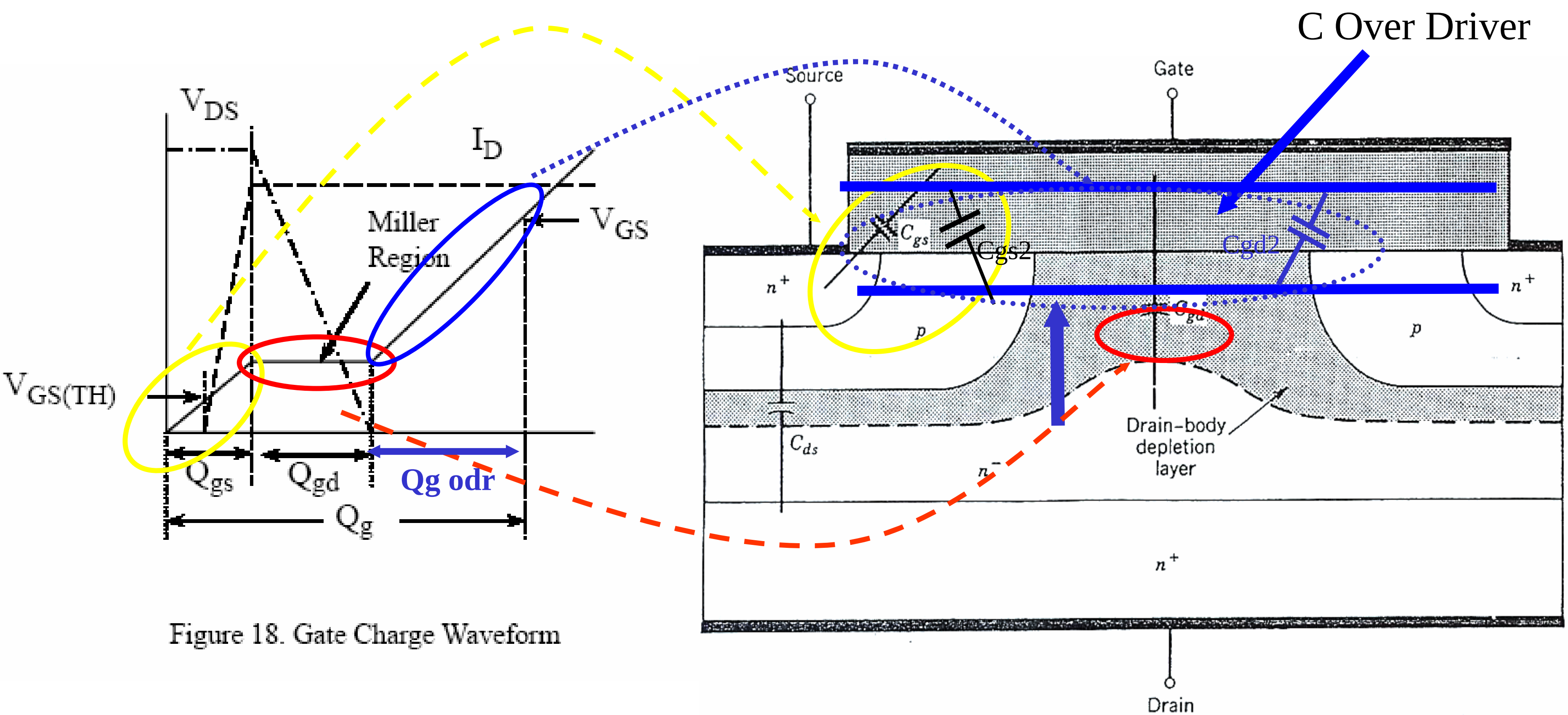
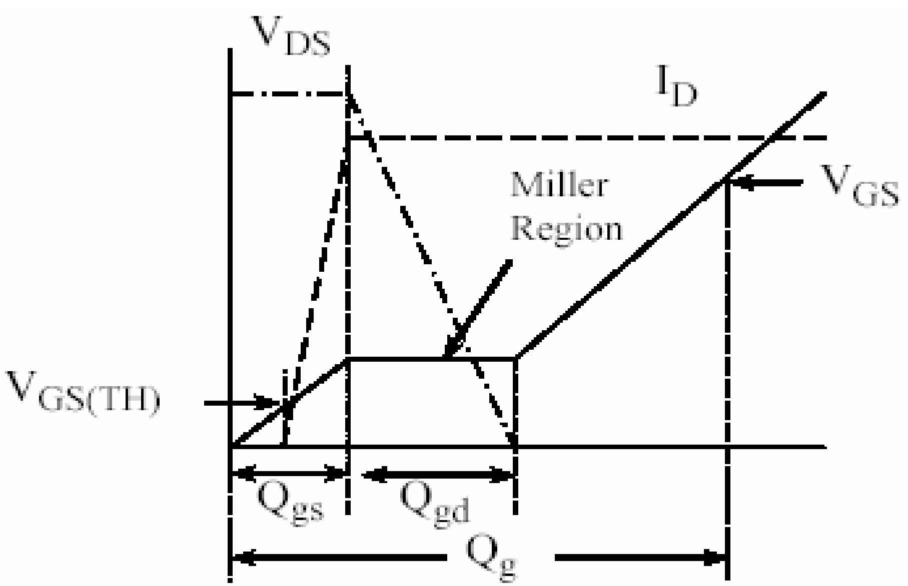


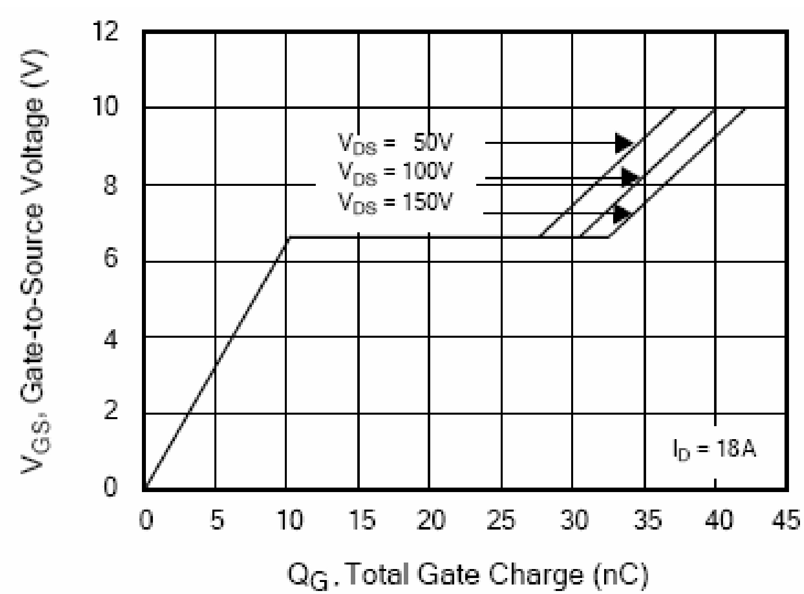

Figure 18. Gate Charge Waveform

MOSFET Structure

# Puzzle of Gate Charges

- **Smaller is better?**
  - ➢ Smaller Qg, less switching time → Less power losses
  - ➢ Smaller Qgd, fast dv/dt → Worse the EMC problem



# Resistive Switching Characteristic

- **Resistive Switching Delays**

**Resistive Switching Characteristics** Essentially independent of operating temperature

| Symbol | Parameter | Min. | Typ. | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| $t_{d(ON)}$ | Turn-on Delay Time | -- | 18 | -- | ns | $V_{DD}$=100 V |
| $t_{rise}$ | Rise Time | -- | 40 | -- | | $I_D$=18A |
| $t_{d(OFF)}$ | Turn-Off Delay Time | -- | 40 | -- | | $V_{GS}$=10V |
| $t_{fall}$ | Fall Time | -- | 20 | -- | | $R_G$=2.4Ω |

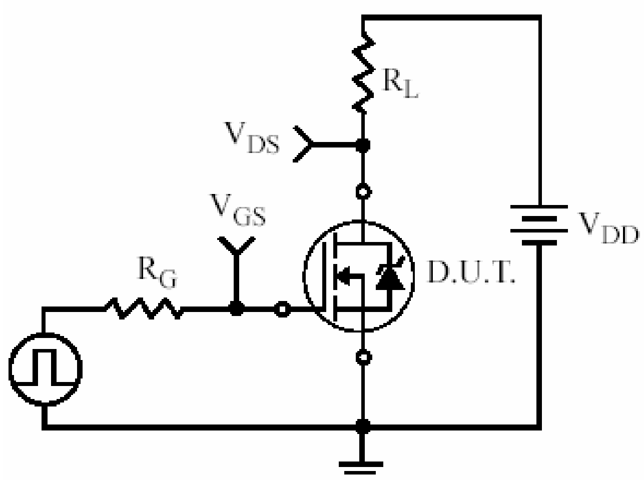



Figure 19. Resistive Switching Test Circuit

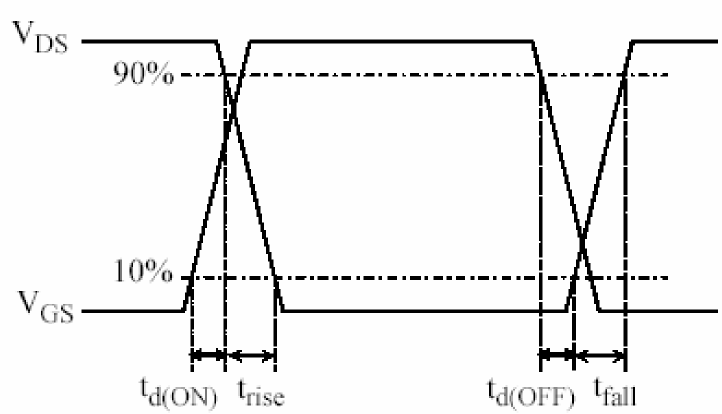



Figure 20. Resistive Switching Waveforms

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# Body Diode Characteristics

- **MOSFET Body Diode Operation**
  - Vsd: Forward drop voltage
  - Trr: Reverse recovery time
  - Qrr: Reverse recovery charges

**Source-Drain Diode Characteristics** $T_C$=25 °C unless otherwise specified

| Symbol | Parameter | Min. | Typ. | Max. | Units | Test Conditions |
|---|---|---|---|---|---|---|
| $I_S$ | Continuous Source Current (Body Diode) | -- | -- | 18 | A | Integral pn-diode in MOSFET |
| $I_{SM}$ | Maximum Pulsed Current (Body Diode) | -- | -- | 72 | A | |
| $V_{SD}$ | Diode Forward Voltage | -- | -- | 1.5 | V | $I_S$=18A, $V_{GS}$=0V |
| $t_{rr}$ | Reverse Recovery Time | -- | 225 | 337 | ns | $V_{GS}$=0V $I_F$=18A, di/dt=100 A/µs |
| $Q_{rr}$ | Reverse Recovery Charge | -- | 1300 | 1950 | nC | |

# Body Diode Characteristics

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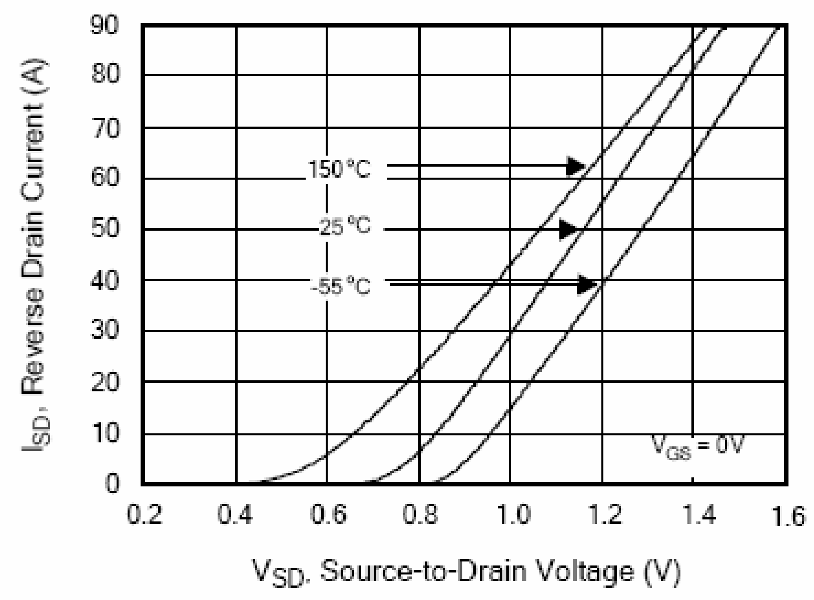
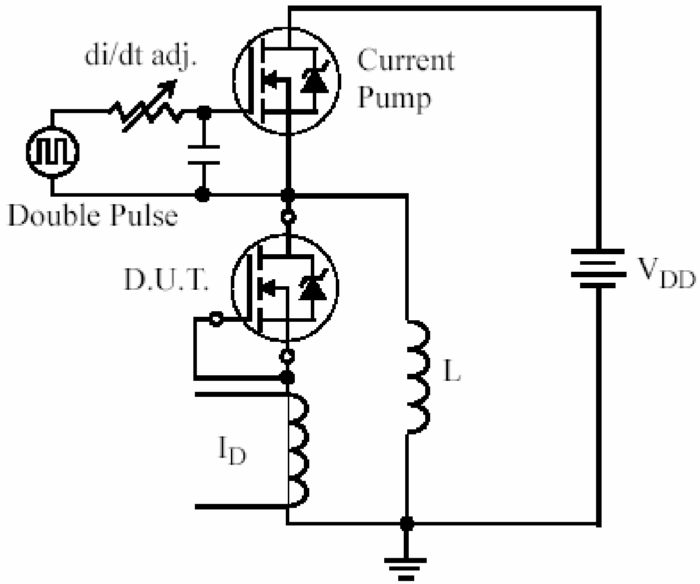
- It is a Parasitic Diode
- **Watch for dv/dt Failure!**
  - ➢ Resonant mode
  - ➢ Dead time operation



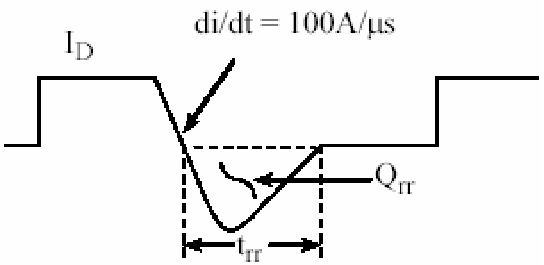




Figure 22. Diode Reverse Recovery Waveform

# End of Presentation

# Thank You!