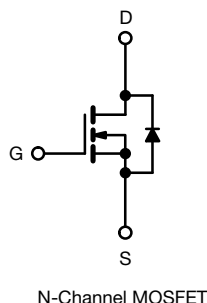
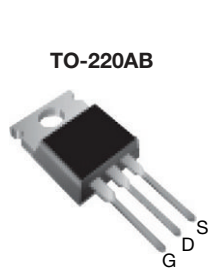


## EF Series Power MOSFET With Fast Body Diode



### FEATURES

- 4<sup>th</sup> generation E series technology
- Low figure-of-merit (FOM)  $R_{on} \times Q_g$
- Low effective capacitance ( $C_{o(er)}$ )
- Reduced switching and conduction losses
- Avalanche energy rated (UIS)
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



**RoHS**  
COMPLIANT  
HALOGEN  
**FREE**

### APPLICATIONS

- Server and telecom power supplies
- Switch mode power supplies (SMPS)
- Power factor correction power supplies (PFC)
- Lighting
  - High-intensity discharge (HID)
  - Fluorescent ballast lighting
- Industrial
  - Welding
  - Induction heating
  - Motor drives
  - Battery chargers
  - Solar (PV inverters)

### PRODUCT SUMMARY

|                                         |                 |       |
|-----------------------------------------|-----------------|-------|
| $V_{DS}$ (V) at $T_J$ max.              | 650             |       |
| $R_{DS(on)}$ typ. ( $\Omega$ ) at 25 °C | $V_{GS} = 10$ V | 0.168 |
| $Q_g$ max. (nC)                         | 32              |       |
| $Q_{gs}$ (nC)                           | 7               |       |
| $Q_{gd}$ (nC)                           | 7               |       |
| Configuration                           | Single          |       |

### ORDERING INFORMATION

|                                 |                  |
|---------------------------------|------------------|
| Package                         | TO-220AB         |
| Lead (Pb)-free and halogen-free | SiHP186N60EF-GE3 |

### ABSOLUTE MAXIMUM RATINGS ( $T_C = 25$ °C, unless otherwise noted)

| PARAMETER                                                 | SYMBOL           | LIMIT          | UNIT |
|-----------------------------------------------------------|------------------|----------------|------|
| Drain-source voltage                                      | $V_{DS}$         | 600            | V    |
| Gate-source voltage                                       | $V_{GS}$         | $\pm 30$       |      |
| Continuous drain current ( $T_J = 150$ °C)                | $V_{GS}$ at 10 V | $T_C = 25$ °C  | A    |
|                                                           |                  | $T_C = 100$ °C |      |
| Pulsed drain current <sup>a</sup>                         | $I_{DM}$         | 43             |      |
| Linear derating factor                                    |                  | 1.25           | W/°C |
| Single pulse avalanche energy <sup>b</sup>                | $E_{AS}$         | 24             | mJ   |
| Maximum power dissipation                                 | $P_D$            | 156            | W    |
| Operating junction and storage temperature range          | $T_J, T_{stg}$   | -55 to +150    | °C   |
| Drain-source voltage slope                                | $dv/dt$          | $T_J = 125$ °C | V/ns |
| Reverse diode $dv/dt$ <sup>d</sup>                        |                  |                |      |
| Soldering recommendations (peak temperature) <sup>c</sup> |                  | For 10 s       | °C   |

#### Notes

- Repetitive rating; pulse width limited by maximum junction temperature
- $V_{DD} = 120$  V, starting  $T_J = 25$  °C,  $L = 28.2$  mH,  $R_g = 25$   $\Omega$ ,  $I_{AS} = 1.3$  A
- 1.6 mm from case
- $I_{SD} \leq I_D$ ,  $di/dt = 700$  A/ $\mu$ s, starting  $T_J = 25$  °C

**THERMAL RESISTANCE RATINGS**

| PARAMETER                        | SYMBOL     | TYP. | MAX. | UNIT |
|----------------------------------|------------|------|------|------|
| Maximum junction-to-ambient      | $R_{thJA}$ | -    | 62   | °C/W |
| Maximum junction-to-case (drain) | $R_{thJC}$ | -    | 0.8  |      |

**SPECIFICATIONS** ( $T_J = 25\text{ }^{\circ}\text{C}$ , unless otherwise noted)

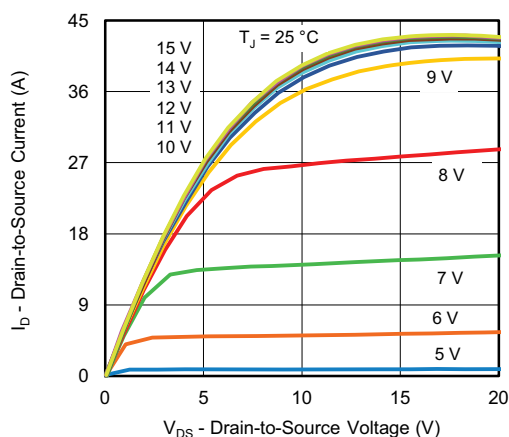
| PARAMETER                                                 | SYMBOL              | TEST CONDITIONS                                                                                                                                          |                                                | MIN. | TYP.  | MAX.      | UNIT                  |
|-----------------------------------------------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|------|-------|-----------|-----------------------|
| Static                                                    |                     |                                                                                                                                                          |                                                |      |       |           |                       |
| Drain-source breakdown voltage                            | $V_{DS}$            | $V_{GS} = 0\text{ V}$ , $I_D = 250\text{ }\mu\text{A}$                                                                                                   |                                                | 600  | -     | -         | V                     |
| $V_{DS}$ temperature coefficient                          | $\Delta V_{DS}/T_J$ | Reference to $25\text{ }^{\circ}\text{C}$ , $I_D = 1\text{ mA}$                                                                                          |                                                | -    | 0.69  | -         | V/ $^{\circ}\text{C}$ |
| Gate-source threshold voltage (N)                         | $V_{GS(th)}$        | $V_{DS} = V_{GS}$ , $I_D = 250\text{ }\mu\text{A}$                                                                                                       |                                                | 3.0  | -     | 5.0       | V                     |
| Gate-source leakage                                       | $I_{GSS}$           | $V_{GS} = \pm 20\text{ V}$                                                                                                                               |                                                | -    | -     | $\pm 100$ | nA                    |
|                                                           |                     | $V_{GS} = \pm 30\text{ V}$                                                                                                                               |                                                | -    | -     | $\pm 1$   | $\mu\text{A}$         |
| Zero gate voltage drain current                           | $I_{DSS}$           | $V_{DS} = 480\text{ V}$ , $V_{GS} = 0\text{ V}$                                                                                                          |                                                | -    | -     | 1         | $\mu\text{A}$         |
|                                                           |                     | $V_{DS} = 480\text{ V}$ , $V_{GS} = 0\text{ V}$ , $T_J = 125\text{ }^{\circ}\text{C}$                                                                    |                                                | -    | -     | 2         | mA                    |
| Drain-source on-state resistance                          | $R_{DS(on)}$        | $V_{GS} = 10\text{ V}$                                                                                                                                   | $I_D = 9.5\text{ A}$                           | -    | 0.168 | 0.193     | $\Omega$              |
| Forward transconductance <sup>a</sup>                     | $g_{fs}$            | $V_{DS} = 20\text{ V}$ , $I_D = 9.5\text{ A}$                                                                                                            |                                                | -    | 5.4   | -         | S                     |
| Dynamic                                                   |                     |                                                                                                                                                          |                                                |      |       |           |                       |
| Input capacitance                                         | $C_{iss}$           | $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 100\text{ V}$ ,<br>$f = 1\text{ MHz}$                                                                               |                                                | -    | 1081  | -         | pF                    |
| Output capacitance                                        | $C_{oss}$           |                                                                                                                                                          |                                                | -    | 52    | -         |                       |
| Reverse transfer capacitance                              | $C_{rss}$           |                                                                                                                                                          |                                                | -    | 5     | -         |                       |
| Effective output capacitance, energy related <sup>a</sup> | $C_{o(er)}$         | $V_{DS} = 0\text{ V to } 480\text{ V}$ , $V_{GS} = 0\text{ V}$                                                                                           |                                                | -    | 40    | -         |                       |
| Effective output capacitance, time related <sup>b</sup>   | $C_{o(tr)}$         |                                                                                                                                                          |                                                | -    | 247   | -         |                       |
| Total gate charge                                         | $Q_g$               | $V_{GS} = 10\text{ V}$                                                                                                                                   | $I_D = 9.5\text{ A}$ , $V_{DS} = 480\text{ V}$ | -    | 21    | 32        | nC                    |
| Gate-source charge                                        | $Q_{gs}$            |                                                                                                                                                          |                                                | -    | 7     | -         |                       |
| Gate-drain charge                                         | $Q_{gd}$            |                                                                                                                                                          |                                                | -    | 7     | -         |                       |
| Turn-on delay time                                        | $t_{d(on)}$         | $V_{DD} = 480\text{ V}$ , $I_D = 9.5\text{ A}$ ,<br>$V_{GS} = 10\text{ V}$ , $R_g = 9.1\text{ }\Omega$                                                   |                                                | -    | 14    | 28        | ns                    |
| Rise time                                                 | $t_r$               |                                                                                                                                                          |                                                | -    | 23    | 46        |                       |
| Turn-off delay time                                       | $t_{d(off)}$        |                                                                                                                                                          |                                                | -    | 25    | 50        |                       |
| Fall time                                                 | $t_f$               |                                                                                                                                                          |                                                | -    | 16    | 32        |                       |
| Gate input resistance                                     | $R_g$               | $f = 1\text{ MHz}$ , open drain                                                                                                                          |                                                | 0.3  | 0.7   | 1.4       | $\Omega$              |
| Drain-Source Body Diode Characteristics                   |                     |                                                                                                                                                          |                                                |      |       |           |                       |
| Continuous source-drain diode current                     | $I_S$               | MOSFET symbol showing the integral reverse p - n junction diode<br> |                                                | -    | -     | 18        | A                     |
| Pulsed diode forward current                              | $I_{SM}$            |                                                                                                                                                          |                                                | -    | -     | 43        |                       |
| Diode forward voltage                                     | $V_{SD}$            | $T_J = 25\text{ }^{\circ}\text{C}$ , $I_S = 9.5\text{ A}$ , $V_{GS} = 0\text{ V}$                                                                        |                                                | -    | -     | 1.2       | V                     |
| Reverse recovery time                                     | $t_{rr}$            | $T_J = 25\text{ }^{\circ}\text{C}$ , $I_F = I_S = 9.5\text{ A}$ ,<br>$di/dt = 100\text{ A}/\mu\text{s}$ , $V_R = 400\text{ V}$                           |                                                | -    | 111   | 222       | ns                    |
| Reverse recovery charge                                   | $Q_{rr}$            |                                                                                                                                                          |                                                | -    | 0.6   | 1.2       | $\mu\text{C}$         |
| Reverse recovery current                                  | $I_{RRM}$           |                                                                                                                                                          |                                                | -    | 10    | -         | A                     |

**Notes**

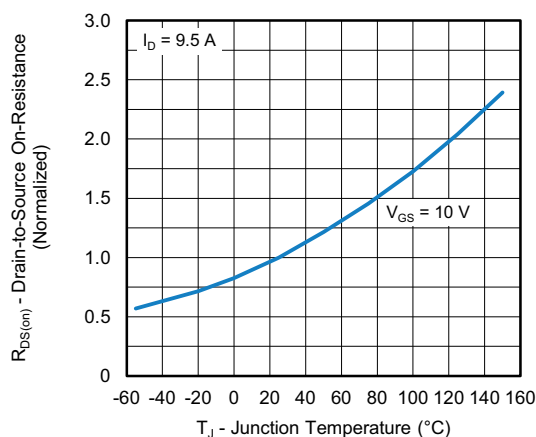
- a.  $C_{oss(er)}$  is a fixed capacitance that gives the same energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 % to 80 %  $V_{DSS}$   
b.  $C_{oss(tr)}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 % to 80 %  $V_{DSS}$



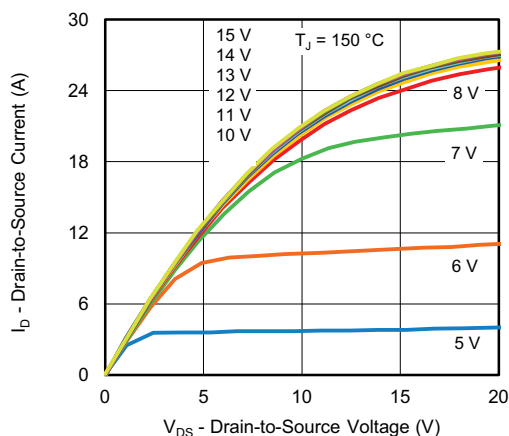
**TYPICAL CHARACTERISTICS** (25 °C, unless otherwise noted)



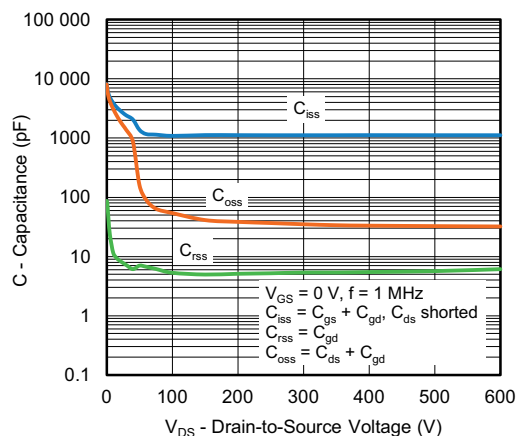
**Fig. 1 - Typical Output Characteristics**



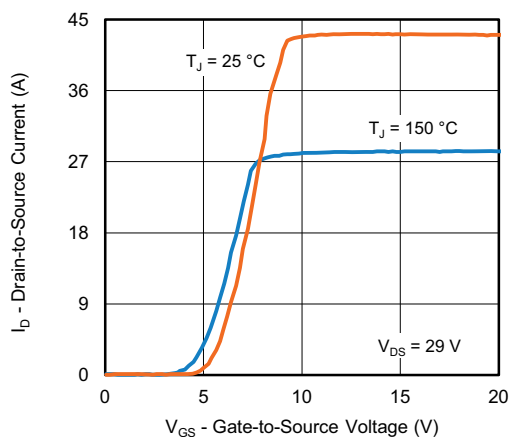
**Fig. 4 - Normalized On-Resistance vs. Temperature**



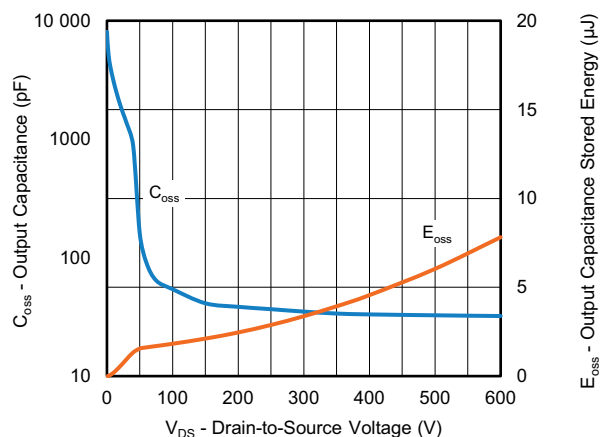
**Fig. 2 - Typical Output Characteristics**



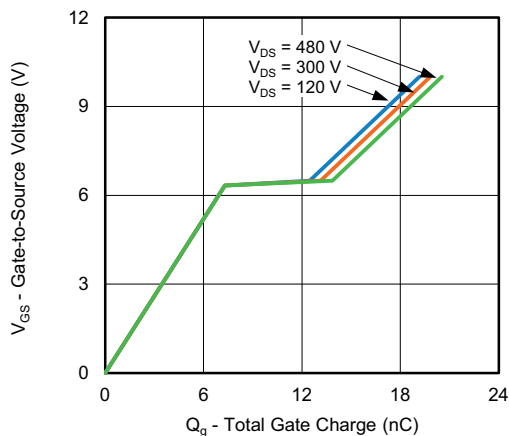
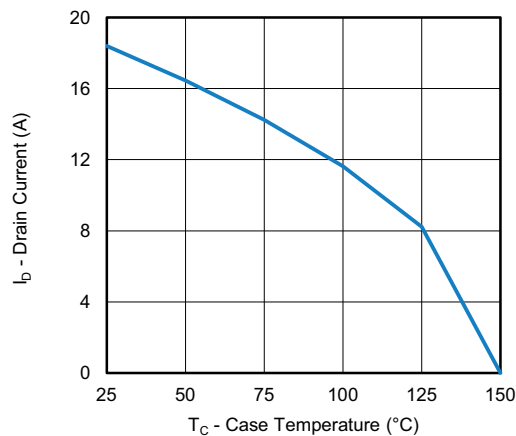
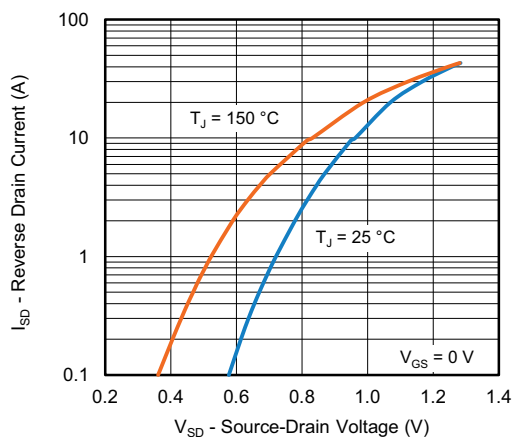
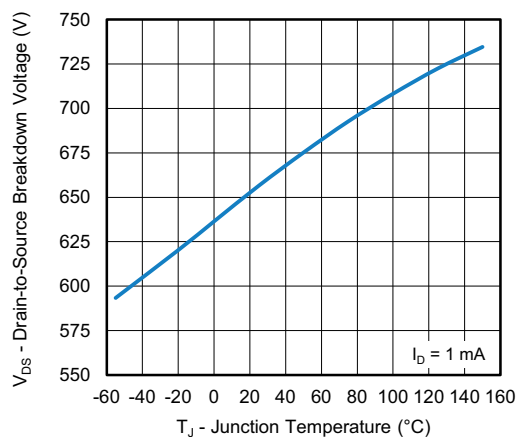
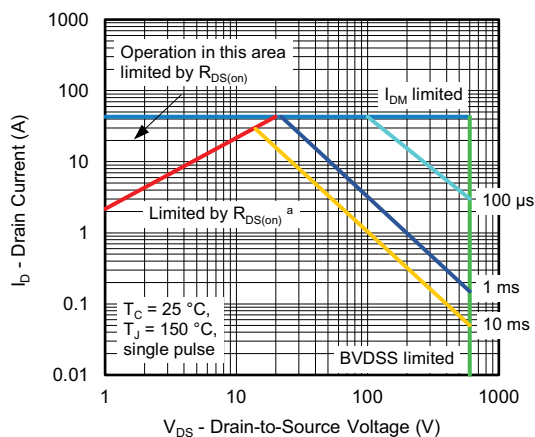
**Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage**



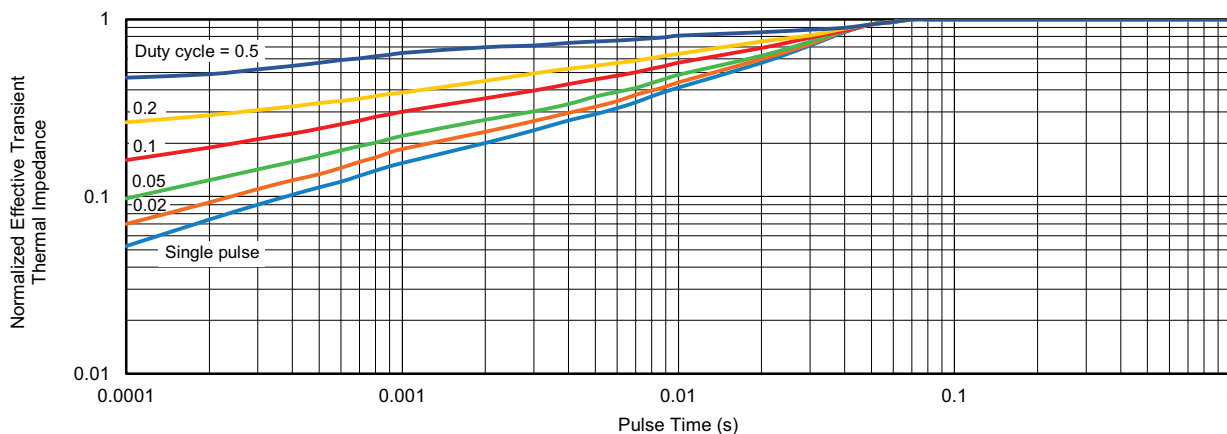
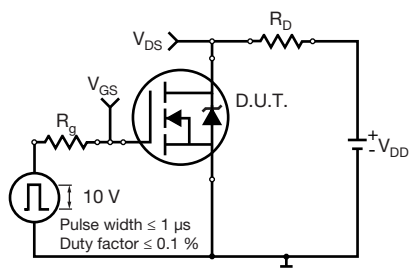
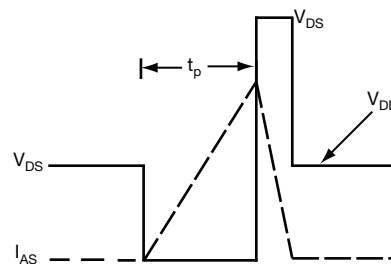
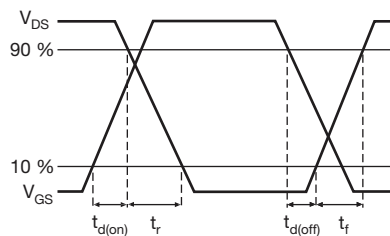
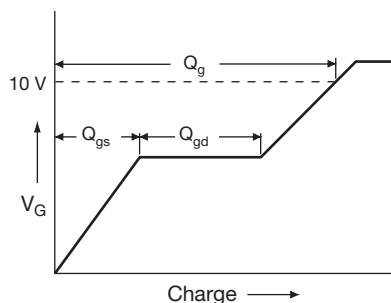
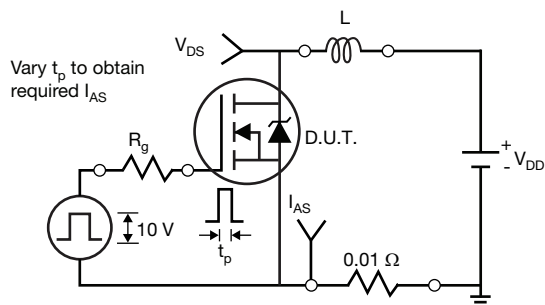
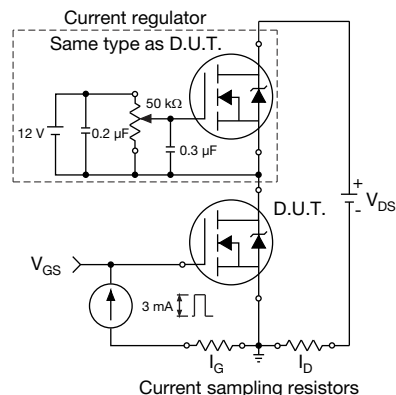
**Fig. 3 - Typical Transfer Characteristics**

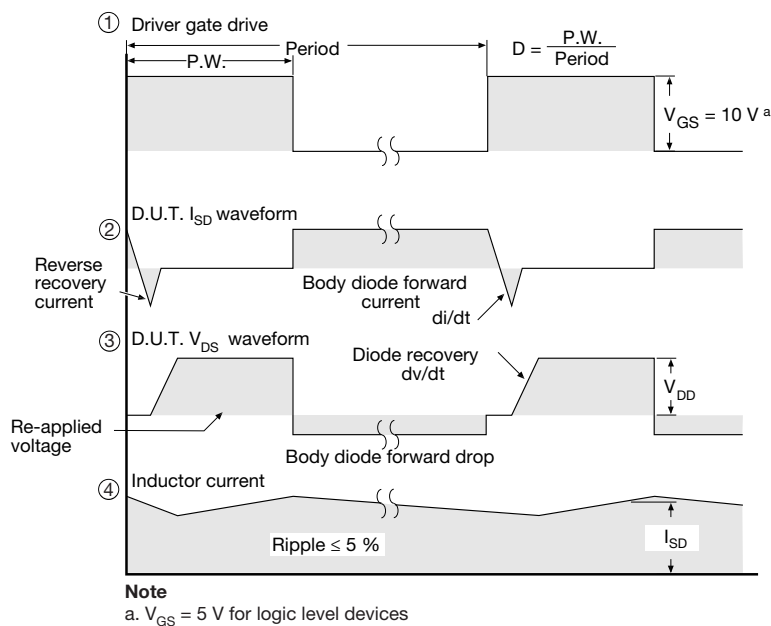
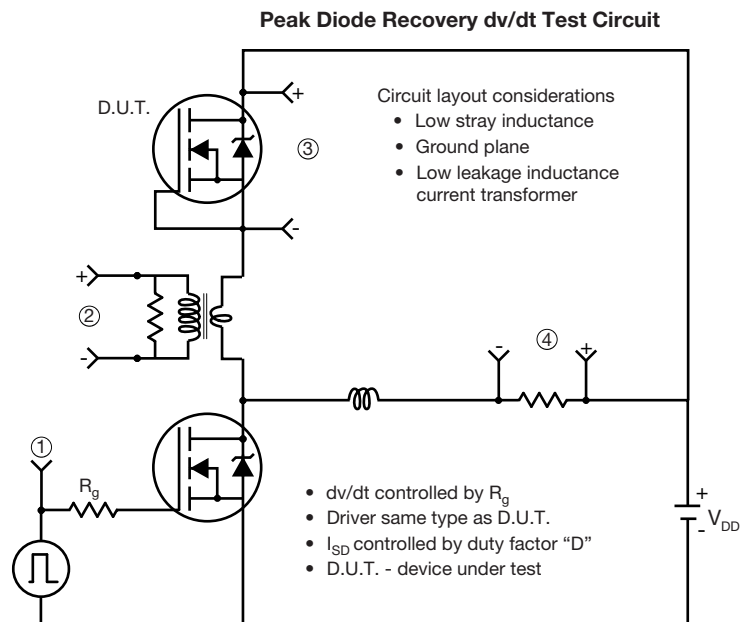


**Fig. 6 -  $C_{oss}$  and  $E_{oss}$  vs.  $V_{DS}$**


**Fig. 7 - Typical Gate Charge vs. Gate-to-Source Voltage**

**Fig. 10 - Maximum Drain Current vs. Case Temperature**

**Fig. 8 - Typical Source-Drain Diode Forward Voltage**

**Fig. 11 - Temperature vs. Drain-to-Source Voltage**

**Fig. 9 - Maximum Safe Operating Area**
**Note**

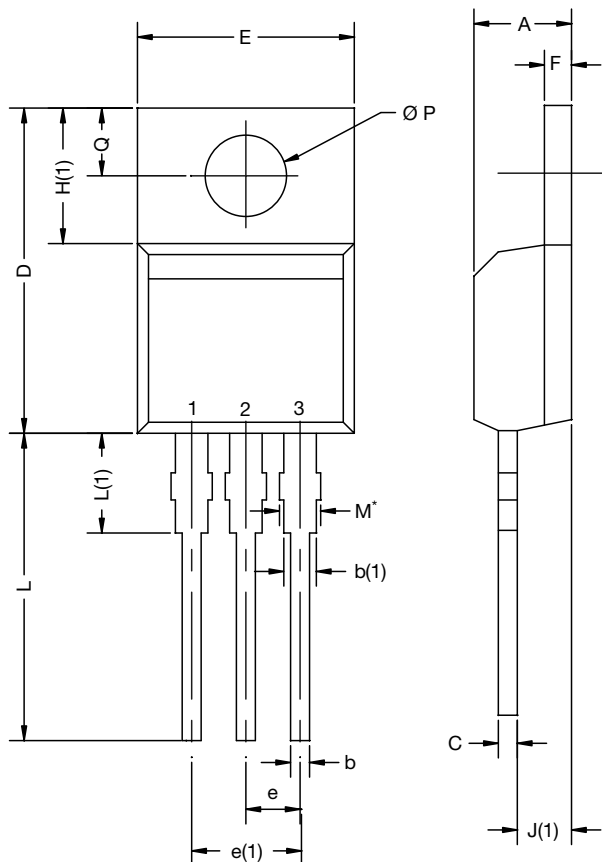
a.  $V_{GS} >$  minimum  $V_{GS}$  at which  $R_{DS(on)}$  is specified


**Fig. 12 - Normalized Transient Thermal Impedance, Junction-to-Case**

**Fig. 13 - Switching Time Test Circuit**

**Fig. 16 - Unclamped Inductive Waveforms**

**Fig. 14 - Switching Time Waveforms**

**Fig. 17 - Basic Gate Charge Waveform**

**Fig. 15 - Unclamped Inductive Test Circuit**

**Fig. 18 - Gate Charge Test Circuit**


**Fig. 19 - For N-Channel**

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## TO-220-1



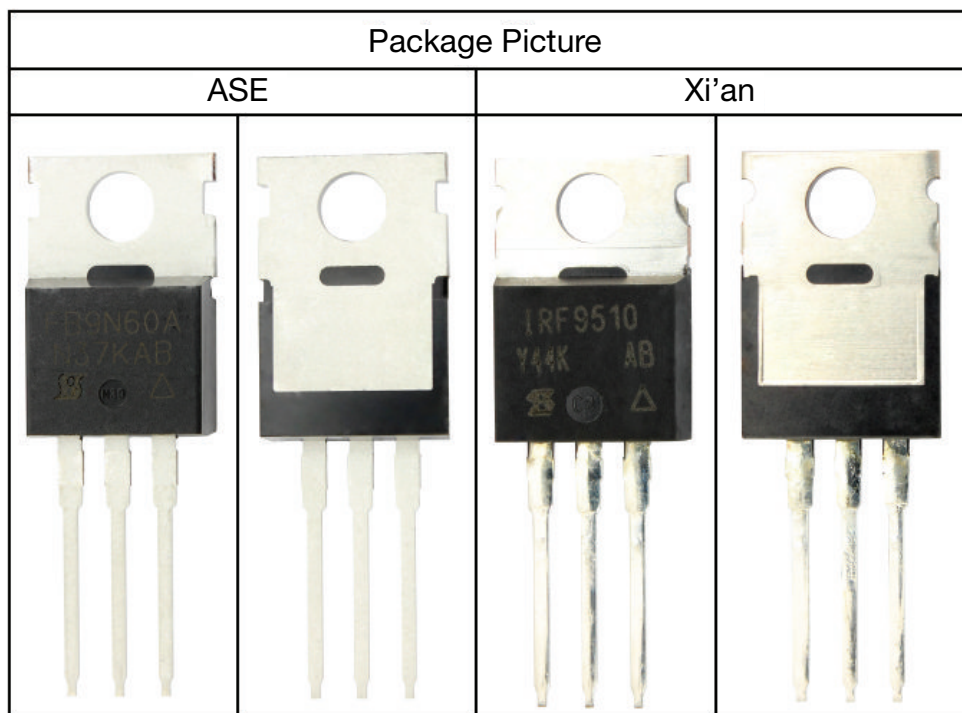
| DIM.            | MILLIMETERS |       | INCHES |       |
|-----------------|-------------|-------|--------|-------|
|                 | MIN.        | MAX.  | MIN.   | MAX.  |
| A               | 4.24        | 4.65  | 0.167  | 0.183 |
| b               | 0.69        | 1.02  | 0.027  | 0.040 |
| b(1)            | 1.14        | 1.78  | 0.045  | 0.070 |
| c               | 0.36        | 0.61  | 0.014  | 0.024 |
| D               | 14.33       | 15.85 | 0.564  | 0.624 |
| E               | 9.96        | 10.52 | 0.392  | 0.414 |
| e               | 2.41        | 2.67  | 0.095  | 0.105 |
| e(1)            | 4.88        | 5.28  | 0.192  | 0.208 |
| F               | 1.14        | 1.40  | 0.045  | 0.055 |
| H(1)            | 6.10        | 6.71  | 0.240  | 0.264 |
| J(1)            | 2.41        | 2.92  | 0.095  | 0.115 |
| L               | 13.36       | 14.40 | 0.526  | 0.567 |
| L(1)            | 3.33        | 4.04  | 0.131  | 0.159 |
| $\varnothing P$ | 3.53        | 3.94  | 0.139  | 0.155 |
| Q               | 2.54        | 3.00  | 0.100  | 0.118 |

ECN: X15-0364-Rev. C, 14-Dec-15  
DWG: 6031

### Note

- M\* = 0.052 inches to 0.064 inches (dimension including protrusion), heatsink hole for HVM

## Package Picture





## Disclaimer

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