

DirectFET® N-Channel Power MOSFET

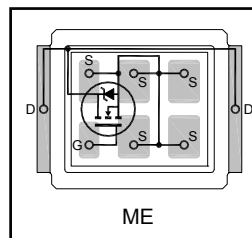
### Application

- Brushed motor drive applications
- BLDC motor drive applications
- Battery powered circuits
- Half-bridge and full-bridge topologies
- Synchronous rectifier applications
- Resonant mode power supplies
- OR-ing and redundant power switches
- DC/DC and AC/DC converters
- DC/AC inverters

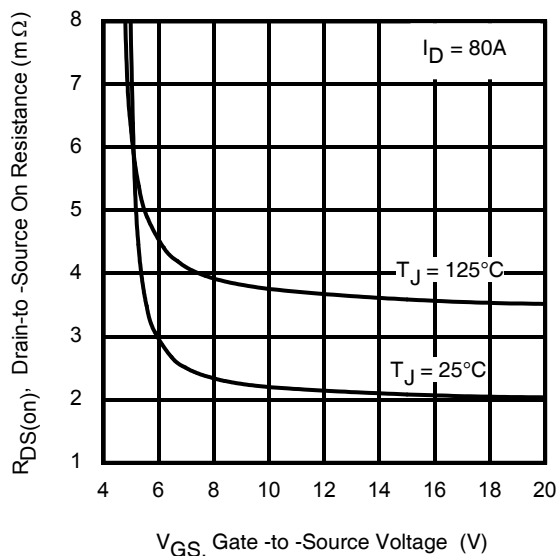
### Benefits

- Improved gate, avalanche and dynamic dv/dt ruggedness
- Fully characterized capacitance and avalanche SOA
- Enhanced body diode dv/dt and di/dt capability
- Lead-free, RoHS compliant

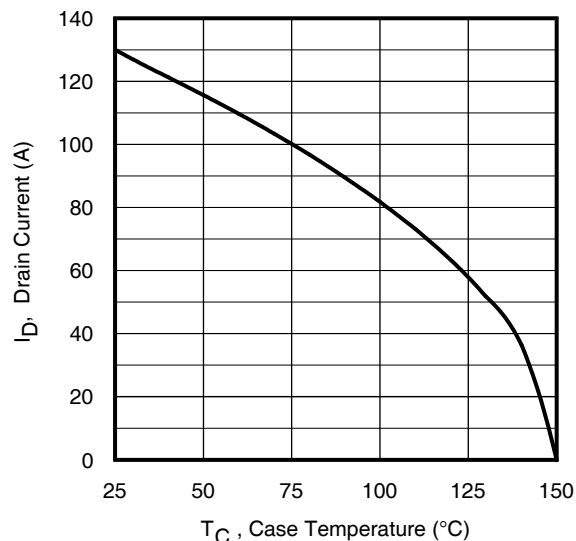
|                                |              |
|--------------------------------|--------------|
| <b>V<sub>DSS</sub></b>         | <b>60V</b>   |
| <b>R<sub>DS(on)</sub> typ.</b> | <b>2.2mΩ</b> |
|                                | <b>max</b>   |
| <b>I<sub>D</sub></b>           | <b>130A</b>  |



| Base part number | Package Type  | Standard Pack |          | Orderable Part Number |
|------------------|---------------|---------------|----------|-----------------------|
|                  |               | Form          | Quantity |                       |
| IRF60DM206       | DirectFET® ME | Tape and Reel | 4800     | IRF60DM206            |



**Fig 1.** Typical On-Resistance vs. Gate Voltage



**Fig 2.** Maximum Drain Current vs. Case Temperature

**Absolute Maximum Ratings**

| Symbol                          | Parameter                                           | Max.         | Units |
|---------------------------------|-----------------------------------------------------|--------------|-------|
| $I_D @ T_C = 25^\circ\text{C}$  | Continuous Drain Current, $V_{GS} @ 10\text{V}$     | 130          | A     |
| $I_D @ T_C = 100^\circ\text{C}$ | Continuous Drain Current, $V_{GS} @ 10\text{V}$     | 82           |       |
| $I_{DM}$                        | Pulsed Drain Current ①                              | 530          |       |
| $P_D @ T_C = 25^\circ\text{C}$  | Maximum Power Dissipation                           | 96           | W     |
|                                 | Linear Derating Factor                              | 0.78         | W/°C  |
| $V_{GS}$                        | Gate-to-Source Voltage                              | $\pm 20$     | V     |
| $T_J$<br>$T_{STG}$              | Operating Junction and<br>Storage Temperature Range | -55 to + 150 | °C    |

**Avalanche Characteristics**

|                              |                                 |                          |    |
|------------------------------|---------------------------------|--------------------------|----|
| $E_{AS}$ (Thermally limited) | Single Pulse Avalanche Energy ② | 81                       | mJ |
| $E_{AS}$ (Thermally limited) | Single Pulse Avalanche Energy ⑨ | 154                      |    |
| $I_{AR}$                     | Avalanche Current ①             | See Fig 15, 15, 23a, 23b | A  |
| $E_{AR}$                     | Repetitive Avalanche Energy ①   |                          | mJ |

**Thermal Resistance**

| Symbol             | Parameter               | Typ. | Max. | Units |
|--------------------|-------------------------|------|------|-------|
| $R_{\theta JA}$    | Junction-to-Ambient ① ⑦ | —    | 45   | °C/W  |
| $R_{\theta JA}$    | Junction-to-Ambient ③   | 12.5 | —    |       |
| $R_{\theta JA}$    | Junction-to-Ambient ②   | 20   | —    |       |
| $R_{\theta JC}$    | Junction-to-Case ④ ⑧    | —    | 1.3  |       |
| $R_{\theta J-PCB}$ | Junction-to-PCB Mounted | 0.75 | —    |       |

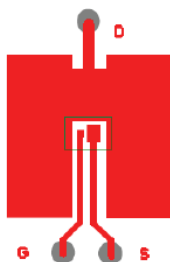
**Static @  $T_J = 25^\circ\text{C}$  (unless otherwise specified)**

| Symbol                          | Parameter                            | Min. | Typ. | Max. | Units | Conditions                                                               |
|---------------------------------|--------------------------------------|------|------|------|-------|--------------------------------------------------------------------------|
| $V_{(BR)DSS}$                   | Drain-to-Source Breakdown Voltage    | 60   | —    | —    | V     | $V_{GS} = 0\text{V}$ , $I_D = 250\mu\text{A}$                            |
| $\Delta V_{(BR)DSS}/\Delta T_J$ | Breakdown Voltage Temp. Coefficient  | —    | 38   | —    | mV/°C | Reference to $25^\circ\text{C}$ , $I_D = 1.0\text{mA}$                   |
| $R_{DS(on)}$                    | Static Drain-to-Source On-Resistance | —    | 2.2  | 2.9  | mΩ    | $V_{GS} = 10\text{V}$ , $I_D = 80\text{A}$ ④                             |
|                                 |                                      | —    | 2.7  | —    | mΩ    | $V_{GS} = 6.0\text{V}$ , $I_D = 40\text{A}$ ④                            |
| $V_{GS(th)}$                    | Gate Threshold Voltage               | 2.1  | 3.0  | 3.7  | V     | $V_{DS} = V_{GS}$ , $I_D = 150\mu\text{A}$                               |
| $I_{DSS}$                       | Drain-to-Source Leakage Current      | —    | —    | 1.0  | μA    | $V_{DS} = 60\text{V}$ , $V_{GS} = 0\text{V}$                             |
|                                 |                                      | —    | —    | 150  | μA    | $V_{DS} = 60\text{V}$ , $V_{GS} = 0\text{V}$ , $T_J = 125^\circ\text{C}$ |
| $I_{GSS}$                       | Gate-to-Source Forward Leakage       | —    | —    | 100  | nA    | $V_{GS} = 20\text{V}$                                                    |
|                                 | Gate-to-Source Reverse Leakage       | —    | —    | -100 | nA    | $V_{GS} = -20\text{V}$                                                   |
| $R_G$                           | Internal Gate Resistance             | —    | 0.8  | —    | Ω     |                                                                          |

**Notes:**

- ② Mounted on minimum footprint full size board with metalized back and with small clip heatsink.
- ③ Used double sided cooling , mounting pad with large heatsink.

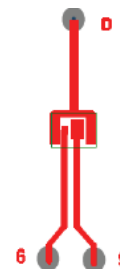
- ④ TC measured with thermocouple mounted to top (Drain) of part.



- ① Surface mounted on 1 in. square Cu board (still air).



- ② Mounted to a PCB with small clip heatsink (still air)

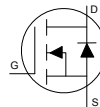


- ③ Mounted on minimum footprint full size board with metalized back and with small clip heatsink (still air)

**Dynamic @  $T_J = 25^\circ\text{C}$  (unless otherwise specified)**

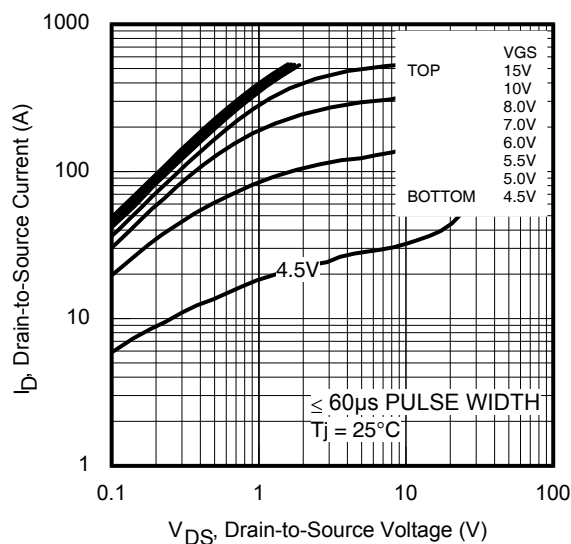
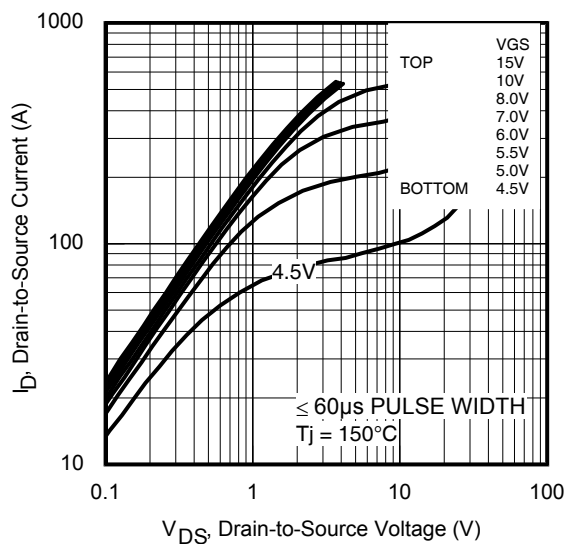
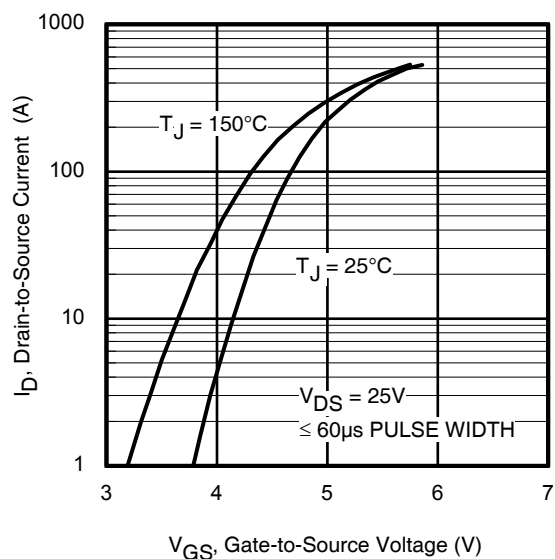
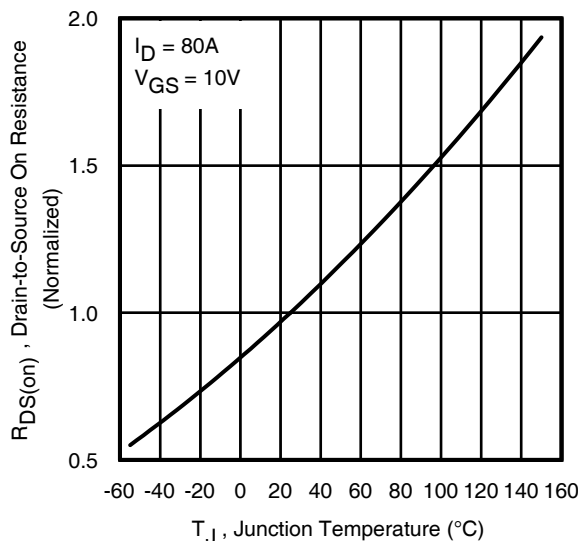
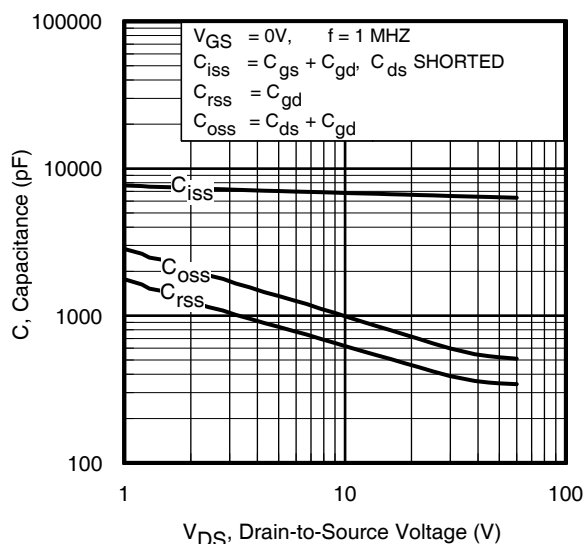
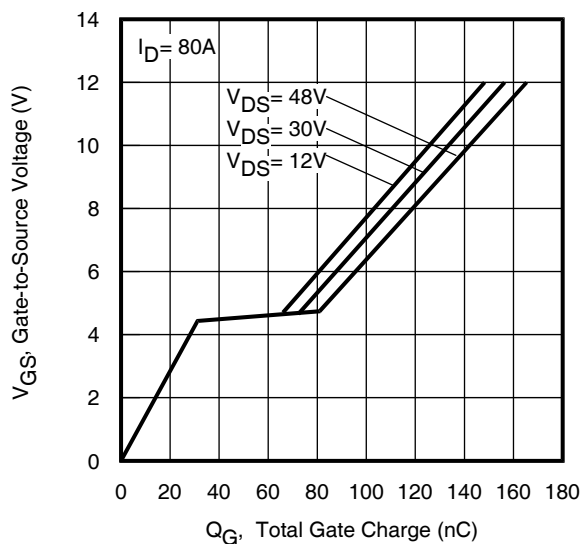
| Symbol                      | Parameter                                     | Min. | Typ. | Max. | Units | Conditions                                                                                  |
|-----------------------------|-----------------------------------------------|------|------|------|-------|---------------------------------------------------------------------------------------------|
| $g_{fs}$                    | Forward Transconductance                      | 148  | —    | —    | S     | $V_{DS} = 10\text{V}$ , $I_D = 80\text{A}$                                                  |
| $Q_g$                       | Total Gate Charge                             | —    | 133  | 200  | nC    | $I_D = 80\text{A}$<br>$V_{DS} = 30\text{V}$<br>$V_{GS} = 10\text{V}$ ④                      |
| $Q_{gs}$                    | Gate-to-Source Charge                         | —    | 33   | —    |       |                                                                                             |
| $Q_{gd}$                    | Gate-to-Drain ("Miller") Charge               | —    | 40   | —    |       |                                                                                             |
| $Q_{sync}$                  | Total Gate Charge Sync. ( $Q_g - Q_{gd}$ )    | —    | 93   | —    |       |                                                                                             |
| $t_{d(on)}$                 | Turn-On Delay Time                            | —    | 17   | —    | ns    | $V_{DD} = 30\text{V}$<br>$I_D = 30\text{A}$<br>$R_G = 2.7\Omega$<br>$V_{GS} = 10\text{V}$ ④ |
| $t_r$                       | Rise Time                                     | —    | 32   | —    |       |                                                                                             |
| $t_{d(off)}$                | Turn-Off Delay Time                           | —    | 60   | —    |       |                                                                                             |
| $t_f$                       | Fall Time                                     | —    | 30   | —    |       |                                                                                             |
| $C_{iss}$                   | Input Capacitance                             | —    | 6530 | —    | pF    | $V_{GS} = 0\text{V}$                                                                        |
| $C_{oss}$                   | Output Capacitance                            | —    | 650  | —    |       | $V_{DS} = 25\text{V}$                                                                       |
| $C_{rss}$                   | Reverse Transfer Capacitance                  | —    | 420  | —    |       | $f = 1.0\text{MHz}$                                                                         |
| $C_{oss \text{ eff. (ER)}}$ | Effective Output Capacitance (Energy Related) | —    | 670  | —    |       | $V_{GS} = 0\text{V}$ , $V_{DS} = 0\text{V}$ to $48\text{V}$ ⑥                               |
| $C_{oss \text{ eff. (TR)}}$ | Effective Output Capacitance (Time Related)   | —    | 840  | —    |       | $V_{GS} = 0\text{V}$ , $V_{DS} = 0\text{V}$ to $48\text{V}$ ⑤                               |

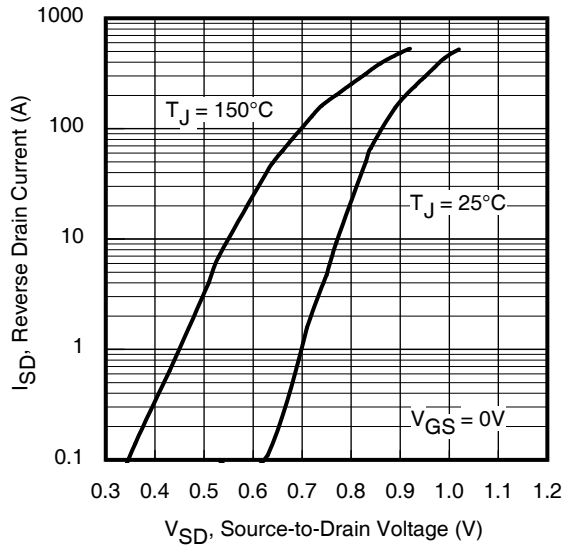
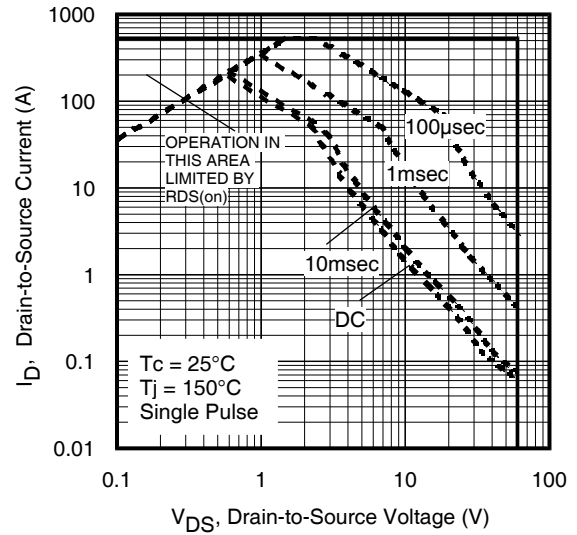
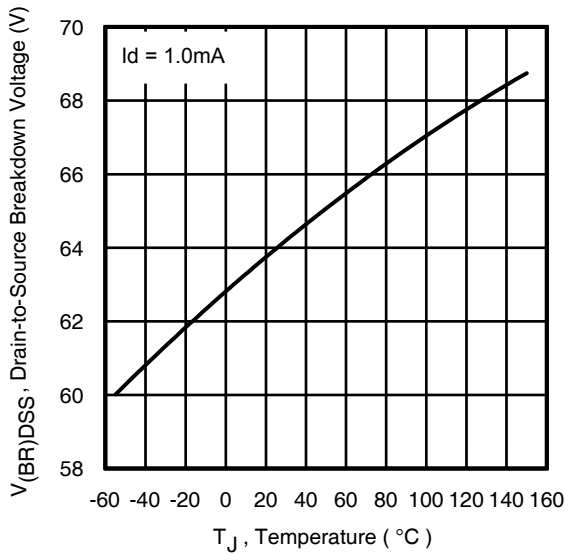
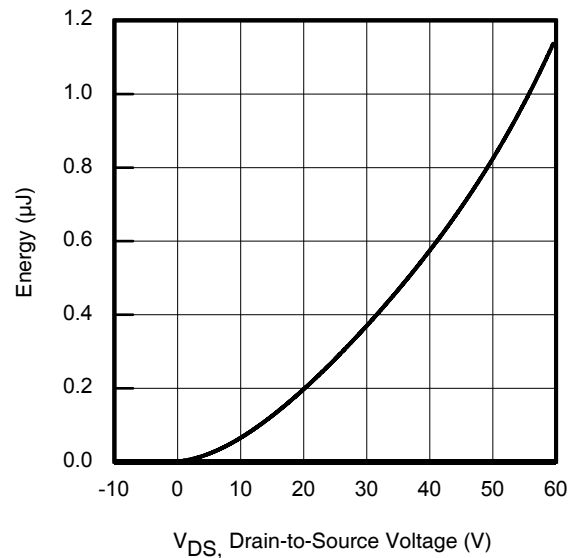
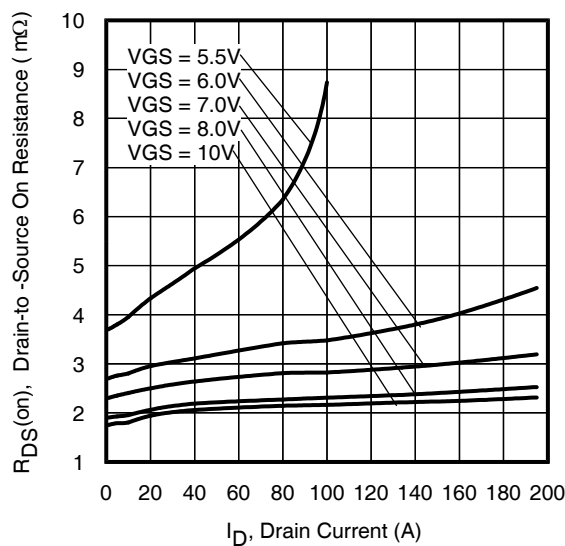
**Diode Characteristics**

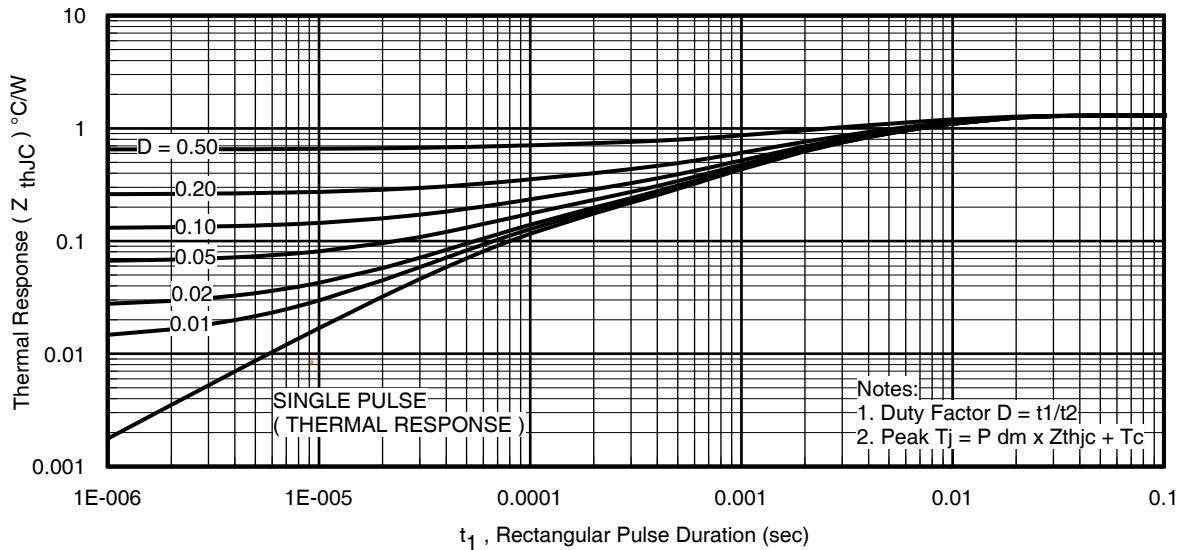
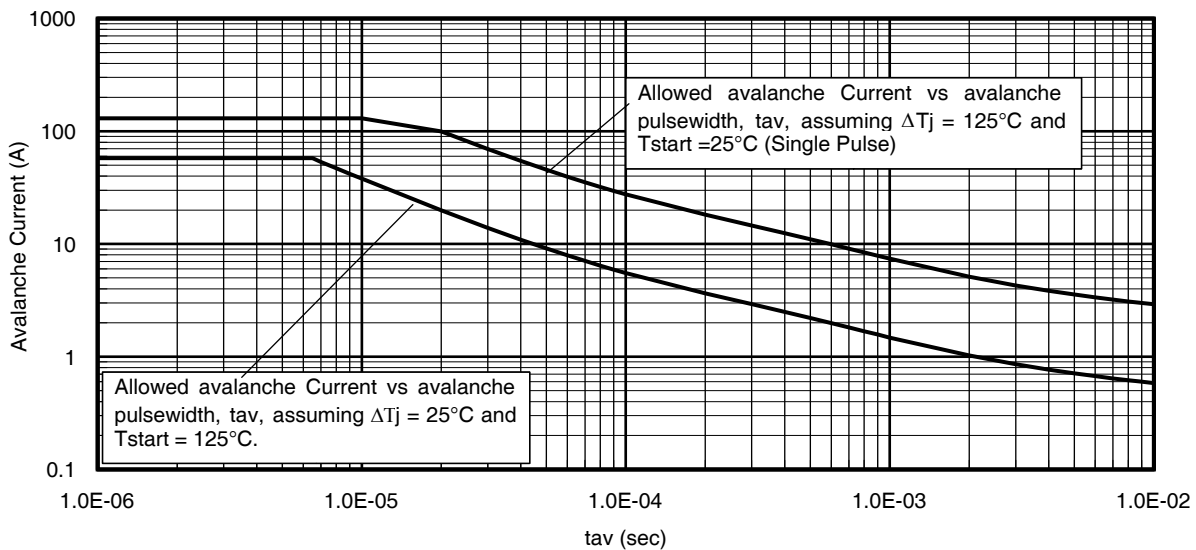
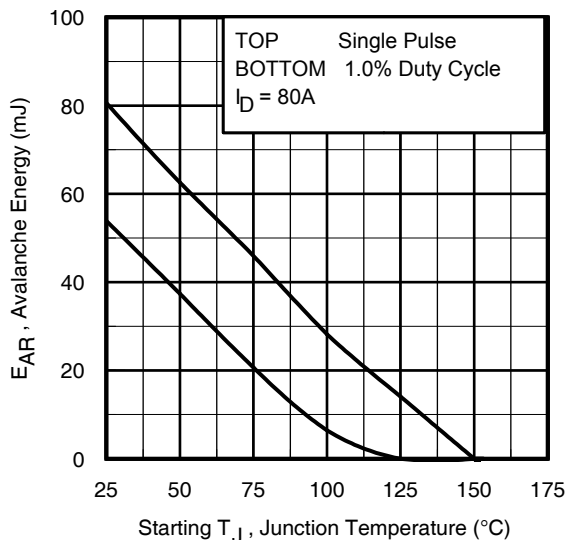
| Symbol    | Parameter                              | Min. | Typ.       | Max. | Units | Conditions                                                                                                                                         |
|-----------|----------------------------------------|------|------------|------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| $I_S$     | Continuous Source Current (Body Diode) | —    | —          | 130  | A     | MOSFET symbol showing the integral reverse p-n junction diode.  |
| $I_{SM}$  | Pulsed Source Current (Body Diode) ①   | —    | —          | 530  | A     |                                                                                                                                                    |
| $V_{SD}$  | Diode Forward Voltage                  | —    | —          | 1.2  | V     | $T_J = 25^\circ\text{C}$ , $I_S = 80\text{A}$ , $V_{GS} = 0\text{V}$ ④                                                                             |
| $dv/dt$   | Peak Diode Recovery ③                  | —    | 8.5        | —    | V/ns  | $T_J = 150^\circ\text{C}$ , $I_S = 80\text{A}$ , $V_{DS} = 60\text{V}$                                                                             |
| $t_{rr}$  | Reverse Recovery Time                  | —    | 47.5<br>48 | —    | ns    | $T_J = 25^\circ\text{C}$ $V_R = 51\text{V}$ ,<br>$T_J = 125^\circ\text{C}$ $I_F = 80\text{A}$                                                      |
| $Q_{rr}$  | Reverse Recovery Charge                | —    | 79<br>84   | —    | nC    | $T_J = 25^\circ\text{C}$ $di/dt = 100\text{A}/\mu\text{s}$ ④<br>$T_J = 125^\circ\text{C}$                                                          |
| $I_{RRM}$ | Reverse Recovery Current               | —    | 2.9        | —    | A     | $T_J = 25^\circ\text{C}$                                                                                                                           |

**Notes:**

- ① Repetitive rating; pulse width limited by max. junction temperature.
- ② Limited by  $T_J$  max, starting  $T_J = 25^\circ\text{C}$ ,  $L = 25\mu\text{H}$   
 $R_G = 50\Omega$ ,  $I_{AS} = 80\text{A}$ ,  $V_{GS} = 10\text{V}$ .
- ③  $I_{SD} \leq 80\text{A}$ ,  $di/dt \leq 1410\text{A}/\mu\text{s}$ ,  $V_{DD} \leq V_{(BR)DSS}$ ,  $T_J \leq 150^\circ\text{C}$ .
- ④ Pulse width  $\leq 400\mu\text{s}$ ; duty cycle  $\leq 2\%$ .
- ⑤  $C_{oss \text{ eff. (TR)}}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to  $80\% V_{DSS}$ .
- ⑥  $C_{oss \text{ eff. (ER)}}$  is a fixed capacitance that gives the same energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to  $80\% V_{DSS}$ .
- ⑦ When mounted on 1" square PCB (FR-4 or G-10 Material). For recommended footprint and soldering techniques refer to application note #AN-994.
- ⑧  $R_\theta$  is measured at  $T_J$  approximately  $90^\circ\text{C}$ .
- ⑨ Limited by  $T_J$  max, starting  $T_J = 25^\circ\text{C}$ ,  $L = 1\text{mH}$ ,  $R_G = 50\Omega$ ,  $I_{AS} = 17.5\text{A}$ ,  $V_{GS} = 10\text{V}$ .

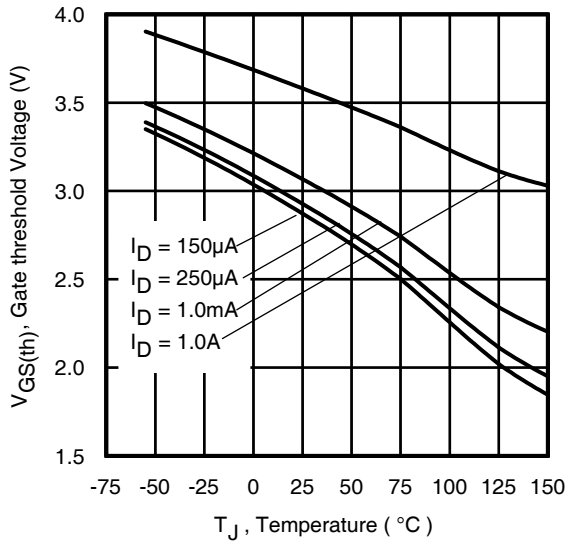
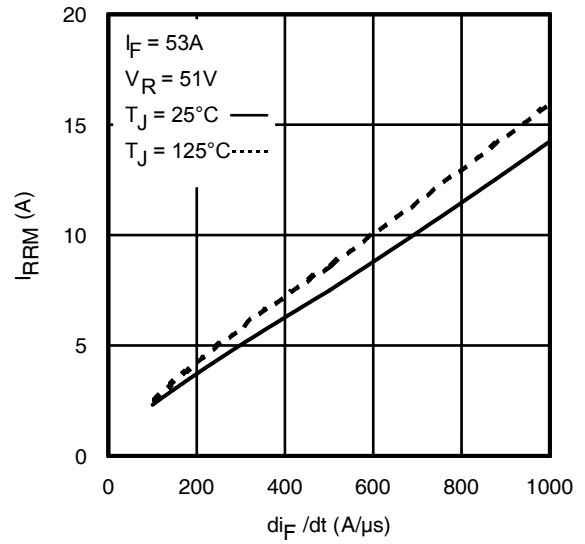
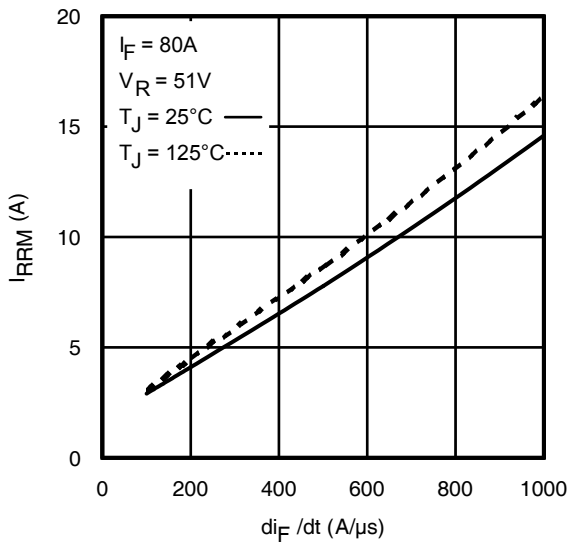
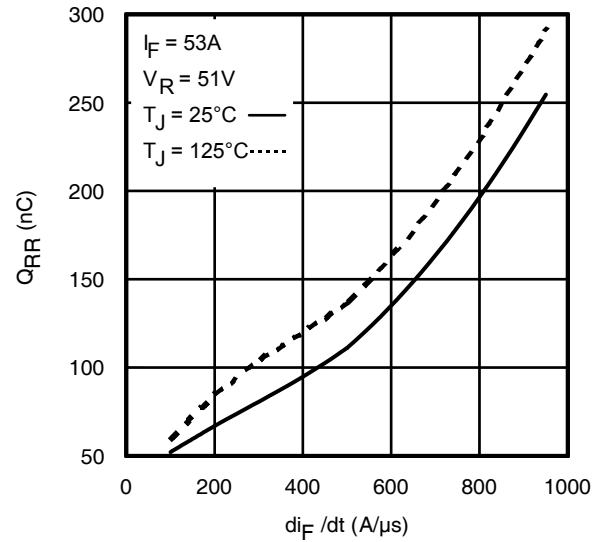
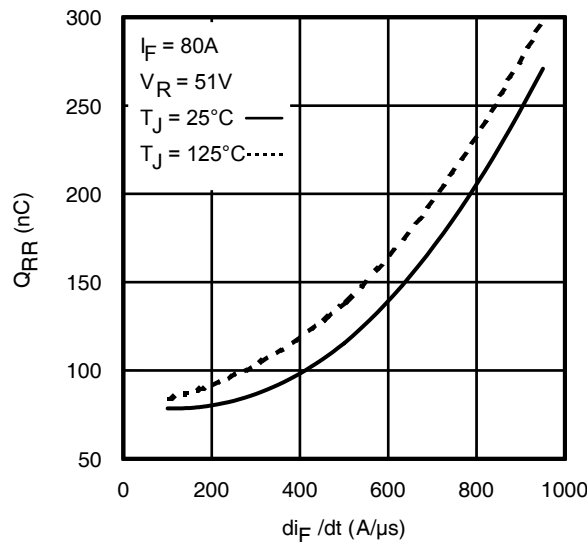

**Fig 3. Typical Output Characteristics**

**Fig 4. Typical Output Characteristics**

**Fig 5. Typical Transfer Characteristics**

**Fig 6. Normalized On-Resistance vs. Temperature**

**Fig 7. Typical Capacitance vs. Drain-to-Source Voltage**

**Fig 8. Typical Gate Charge vs. Gate-to-Source Voltage**

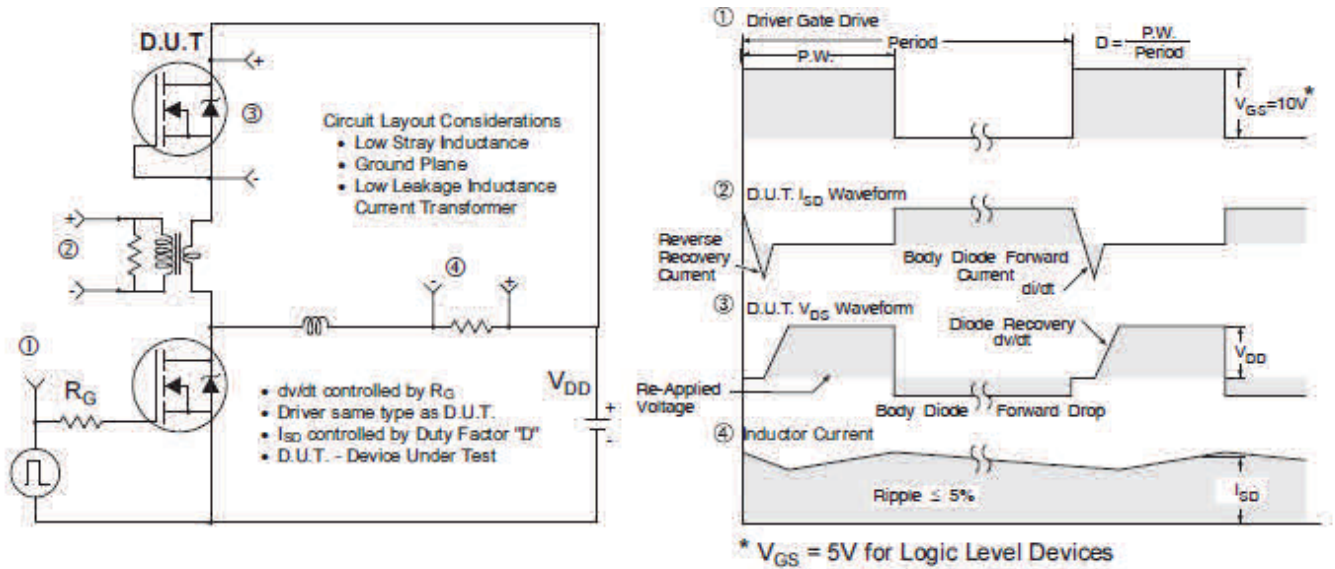

**Fig 9.** Typical Source-Drain Diode Forward Voltage

**Fig 10.** Maximum Safe Operating Area

**Fig 11.** Drain-to-Source Breakdown Voltage

**Fig 12.** Typical  $C_{oss}$  Stored Energy

**Fig 13.** Typical On-Resistance vs. Drain Current


**Fig 14.** Maximum Effective Transient Thermal Impedance, Junction-to-Case

**Fig 15.** Avalanche Current vs. Pulse Width

**Fig 16.** Maximum Avalanche Energy vs. Temperature

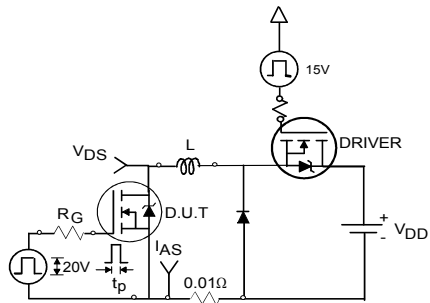
**Notes on Repetitive Avalanche Curves , Figures 15, 16:  
(For further info, see AN-1005 at [www.irf.com](http://www.irf.com))**

1. Avalanche failures assumption:  
Purely a thermal phenomenon and failure occurs at a temperature far in excess of  $T_{jmax}$ . This is validated for every part type.
2. Safe operation in Avalanche is allowed as long as  $T_{jmax}$  is not exceeded.
3. Equation below based on circuit and waveforms shown in Figures 23a, 23b.
4.  $P_{D(ave)}$  = Average power dissipation per single avalanche pulse.
5. BV = Rated breakdown voltage (1.3 factor accounts for voltage increase during avalanche).
6.  $I_{av}$  = Allowable avalanche current.
7.  $\Delta T$  = Allowable rise in junction temperature, not to exceed  $T_{jmax}$  (assumed as 25°C in Figure 14, 15).  
 $t_{av}$  = Average time in avalanche.  
 $D$  = Duty cycle in avalanche =  $t_{av} \cdot f$   
 $Z_{thJC}(D, t_{av})$  = Transient thermal resistance, see Figure 14)  
 $P_{D(ave)} = 1/2 (1.3 \cdot BV \cdot I_{av}) = \Delta T / Z_{thJC}$   
 $I_{av} = 2\Delta T / [1.3 \cdot BV \cdot Z_{th}]$   
 $E_{AS(AR)} = P_{D(ave)} \cdot t_{av}$

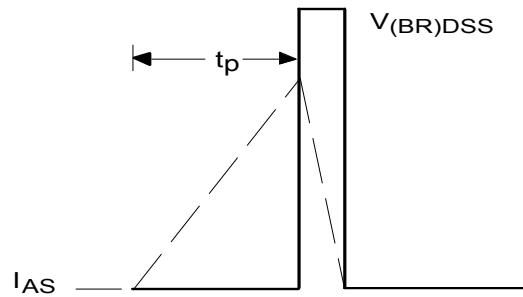

**Fig 17.** Threshold Voltage vs. Temperature

**Fig 18.** Typical Recovery Current vs.  $di/dt$ 

**Fig 19.** Typical Recovery Current vs.  $di/dt$ 

**Fig 20.** Typical Stored Charge vs.  $di/dt$ 

**Fig 21.** Typical Stored Charge vs.  $di/dt$



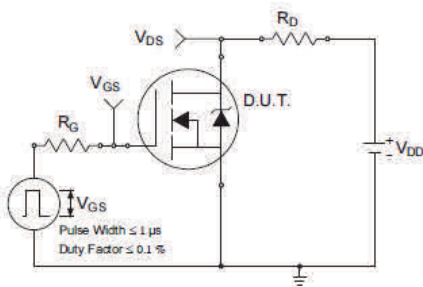
**Fig 22.** Peak Diode Recovery  $dv/dt$  Test Circuit for N-Channel HEXFET® Power MOSFETs



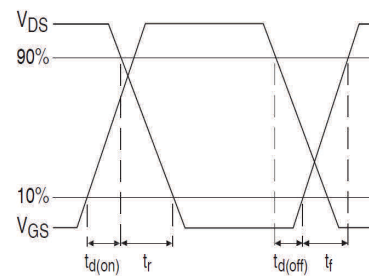
**Fig 23a.** Unclamped Inductive Test Circuit



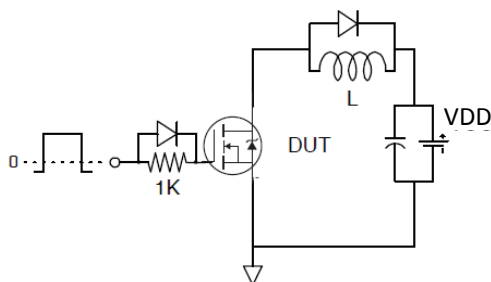
**Fig 23b.** Unclamped Inductive Waveforms



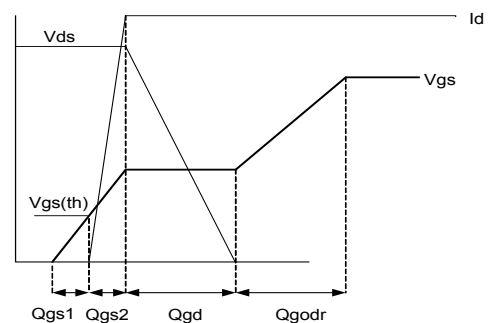
**Fig 24a.** Switching Time Test Circuit



**Fig 24b.** Switching Time Waveforms



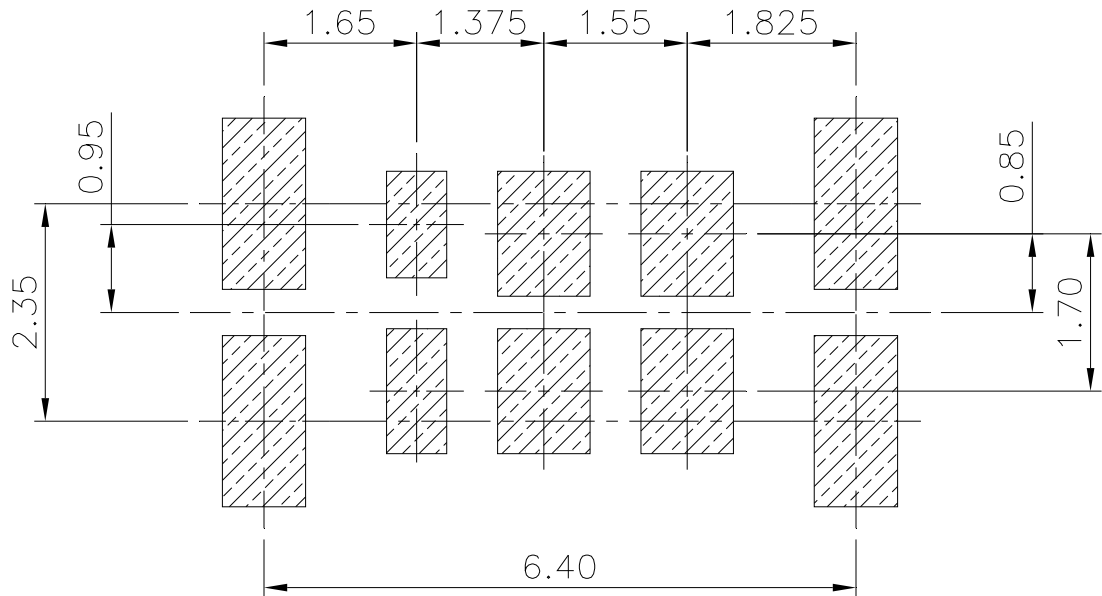
**Fig 25a.** Gate Charge Test Circuit



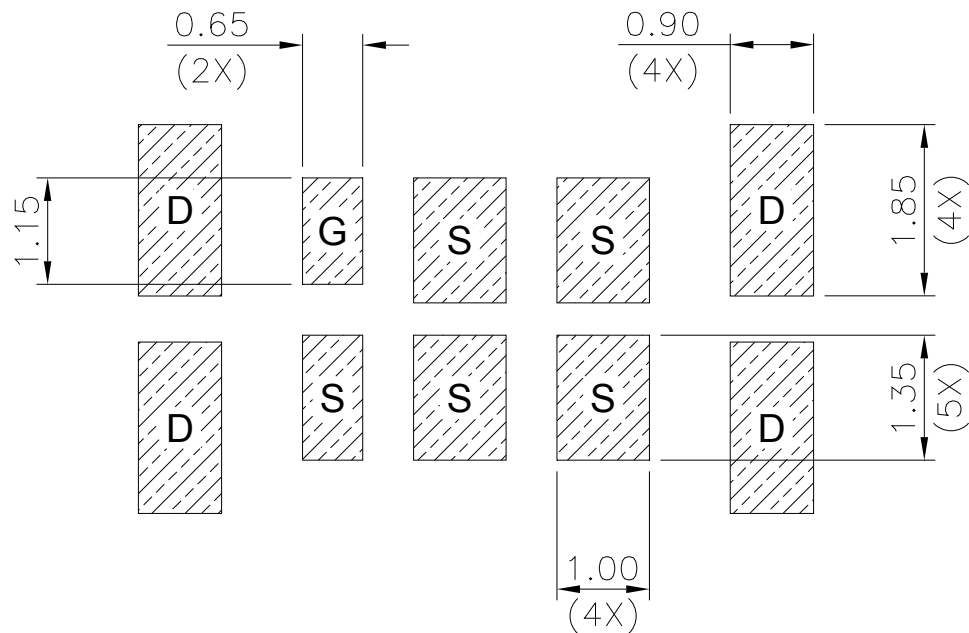
**Fig 25b.** Gate Charge Waveform

**DirectFET® Board Footprint, ME Outline  
(Medium Size Can, E-Designation)**

Please see DirectFET® application note AN-1035 for all details regarding the assembly of DirectFET®  
This includes all recommendations for stencil and substrate designs.



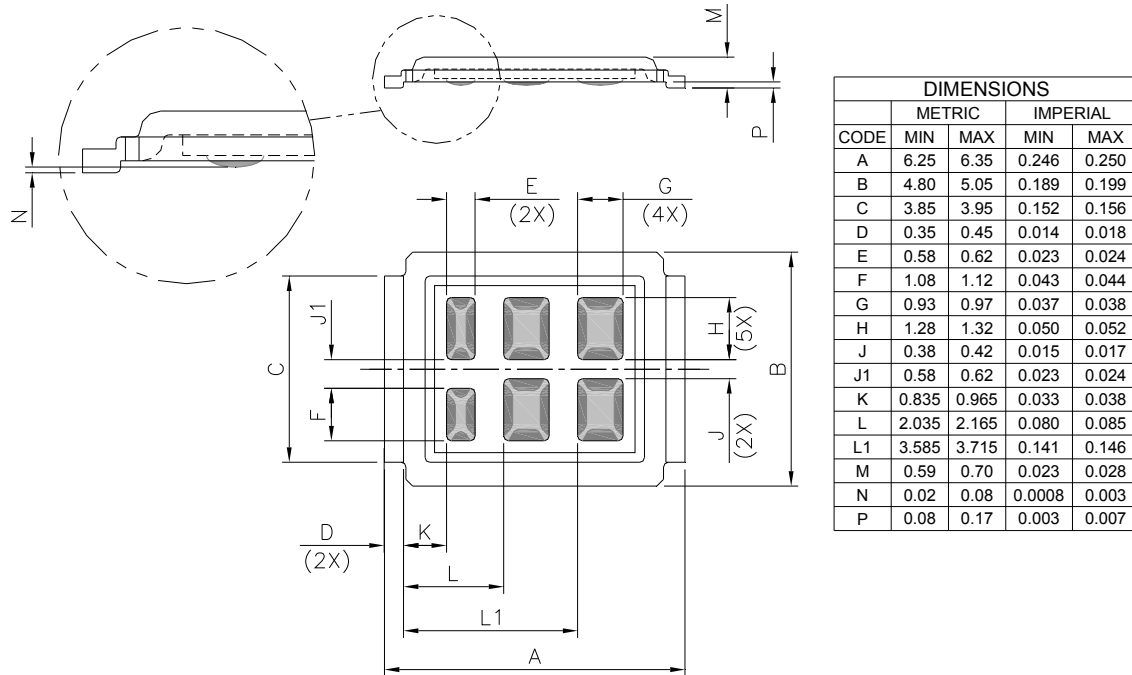
G = GATE  
D = DRAIN  
S = SOURCE



Note: For the most current drawing please refer to IR website at <http://www.irf.com/package/>

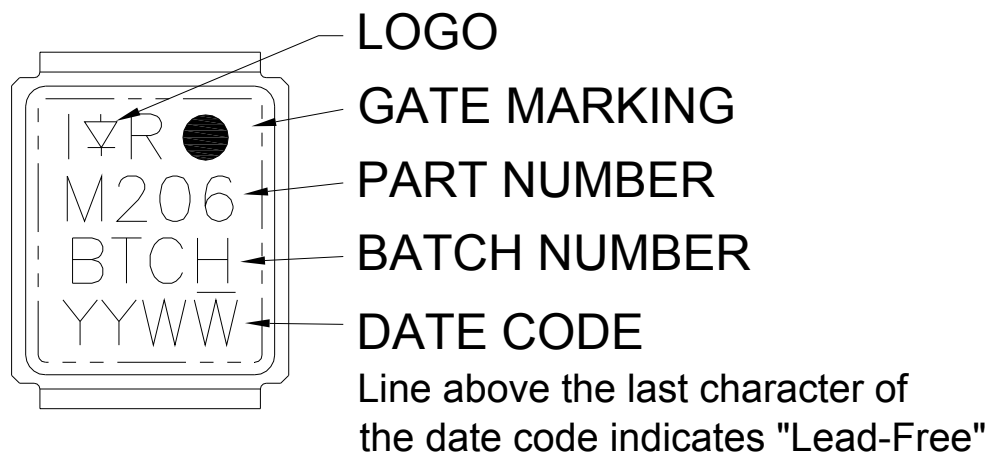
# DirectFET® Outline Dimension, ME Outline (Medium Size Can, E-Designation)

Please see DirectFET® application note AN-1035 for all details regarding the assembly of DirectFET®. This includes all recommendations for stencil and substrate designs.

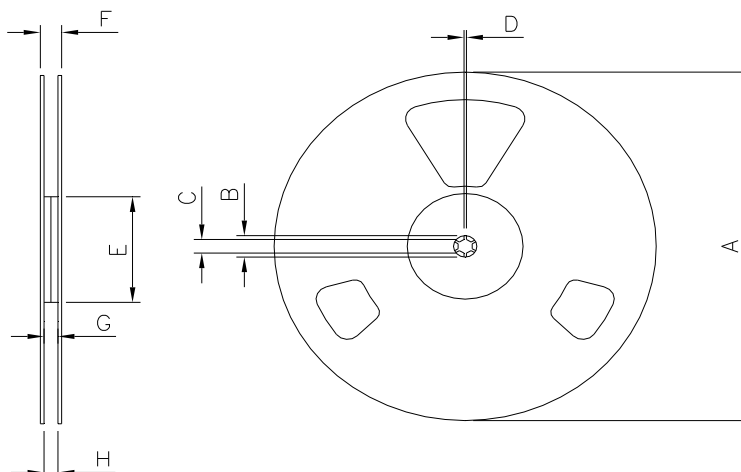


Dimensions are shown in  
millimeters (inches)

## DirectFET® Part Marking



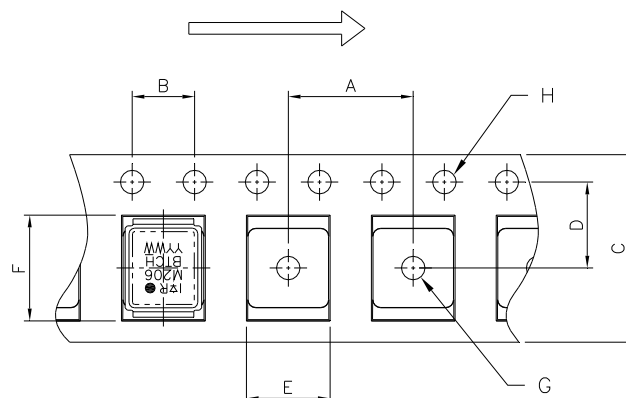
Note: For the most current drawing please refer to IR website at <http://www.irf.com/package/>

**DirectFET® Tape & Reel Dimension (Showing component orientation).**


NOTE: Controlling dimensions in mm  
Std reel quantity is 4800 parts, ordered as IRF60DM206

| REEL DIMENSIONS |        |      |          |       |
|-----------------|--------|------|----------|-------|
|                 | METRIC |      | IMPERIAL |       |
| CODE            | MIN    | MAX  | MIN      | MAX   |
| A               | 330.0  | N.C  | 12.992   | N.C   |
| B               | 20.2   | N.C  | 0.795    | N.C   |
| C               | 12.8   | 13.2 | 0.504    | 0.520 |
| D               | 1.5    | N.C  | 0.059    | N.C   |
| E               | 100.0  | N.C  | 3.937    | N.C   |
| F               | N.C    | 18.4 | N.C      | 0.724 |
| G               | 12.4   | 14.4 | 0.488    | 0.567 |
| H               | 11.9   | 15.4 | 0.469    | 0.606 |

LOADED TAPE FEED DIRECTION



NOTE: CONTROLLING  
DIMENSIONS IN MM

| DIMENSIONS |        |       |          |       |
|------------|--------|-------|----------|-------|
|            | METRIC |       | IMPERIAL |       |
| CODE       | MIN    | MAX   | MIN      | MAX   |
| A          | 7.90   | 8.10  | 0.311    | 0.319 |
| B          | 3.90   | 4.10  | 0.154    | 0.161 |
| C          | 11.90  | 12.30 | 0.469    | 0.484 |
| D          | 5.45   | 5.55  | 0.215    | 0.219 |
| E          | 5.10   | 5.30  | 0.201    | 0.209 |
| F          | 6.50   | 6.70  | 0.256    | 0.264 |
| G          | 1.50   | N.C   | 0.059    | N.C   |
| H          | 1.50   | 1.60  | 0.059    | 0.063 |

Note: For the most current drawing please refer to IR website at <http://www.irf.com/package/>

**Qualification Information<sup>†</sup>**

| Qualification Level        | Industrial<br>(per JEDEC JESD47F <sup>††</sup> guidelines) |                                               |
|----------------------------|------------------------------------------------------------|-----------------------------------------------|
| Moisture Sensitivity Level | DFET 1.5                                                   | MSL1<br>(per JEDEC J-STD-020D <sup>††</sup> ) |
| RoHS Compliant             | Yes                                                        |                                               |

† Qualification standards can be found at International Rectifier's web site  
<http://www.irf.com/product-info/reliability>

†† Applicable version of JEDEC standard at the time of product release.

\* Industrial qualification standards except autoclave test conditions.

International  
 Rectifier

**IR WORLD HEADQUARTERS:** 101 N. Sepulveda Blvd., El Segundo, California 90245, USA  
 To contact International Rectifier, please visit <http://www.irf.com/whoto-call/>

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