

**RADIATION HARDENED  
POWER MOSFET  
SURFACE MOUNT (LCC-28)**

**Product Summary**

Part Number	Radiation Level	RDS(on)	I <sub>D</sub>	Channel
IRHQ6110	100 kRads(Si)	0.6Ω	3.0A	N
IRHQ63110	300 kRads(Si)	0.6Ω	3.0A	N
IRHQ6110	100 kRads(Si)	1.1Ω	-2.3A	P
IRHQ63110	300 kRads(Si)	1.2Ω	-2.3A	P



**Description**

IR HiRel RAD-Hard™ HEXFET® MOSFET Technology provides high performance power MOSFETs for space applications. This technology has over a decade of proven performance and reliability in satellite applications. These devices have been characterized for both Total Dose and Single Event Effects (SEE). The combination of low RDS(on) and low gate charge reduces the power losses in switching applications such as DC to DC converters and motor control. These devices retain all of the well established advantages of MOSFETs such as voltage control, fast switching and temperature stability of electrical parameters.

**Features**

- Single Event Effect (SEE) Hardened
- Low RDS(on)
- Low Total Gate Charge
- Proton Tolerant
- Simple Drive Requirements
- Hermetically Sealed
- Ceramic Package
- Surface Mount
- Light Weight

**Absolute Maximum Ratings (Per Die)**

**Pre-Irradiation**

Symbol	Parameter	N-Channel	P-Channel	Units
I <sub>D1</sub> @ V <sub>GS</sub> = ±12V, T <sub>C</sub> = 25°C	Continuous Drain Current	3.0	-2.3	A
I <sub>D2</sub> @ V <sub>GS</sub> = ±12V, T <sub>C</sub> = 100°C	Continuous Drain Current	1.9	-1.5	
I <sub>DM</sub> @ T <sub>C</sub> = 25°C	Pulsed Drain Current ①	12	-9.2	
P <sub>D</sub> @ T <sub>C</sub> = 25°C	Maximum Power Dissipation	12	12	W
	Linear Derating Factor	0.1	0.1	W/°C
V <sub>GS</sub>	Gate-to-Source Voltage	± 20	± 20	V
E <sub>AS</sub>	Single Pulse Avalanche Energy ②	85②	75②	mJ
I <sub>AR</sub>	Avalanche Current ①	3.0	-2.3	A
E <sub>AR</sub>	Repetitive Avalanche Energy ①	1.2	1.2	mJ
dv/dt	Peak Diode Recovery dv/dt	3.0③	-9.0③	V/ns
T <sub>J</sub> T <sub>STG</sub>	Operating Junction and Storage Temperature Range	-55 to +150		°C
	Package Mounting Surface Temp.	300 ( for 5s)		
	Weight	0.89 (Typical)		g

For Footnotes, refer to the page 2 for N Channel and page 3 for P Channel

**Electrical Characteristics for Each N-Channel Device @ T<sub>J</sub> = 25°C (Unless Otherwise Specified)**

Symbol	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV <sub>DSS</sub>	Drain-to-Source Breakdown Voltage	100	—	—	V	V <sub>GS</sub> = 0V, I <sub>D</sub> = 1.0mA
ΔBV <sub>DSS</sub> /ΔT <sub>J</sub>	Breakdown Voltage Temp. Coefficient	—	0.11	—	V/°C	Reference to 25°C, I <sub>D</sub> = 1.0mA
R <sub>DS(on)</sub>	Static Drain-to-Source On-State Resistance	—	—	0.60	Ω	V <sub>GS</sub> = 12V, I <sub>D2</sub> = 1.9A ④
V <sub>GS(th)</sub>	Gate Threshold Voltage	2.0	—	4.0	V	V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = 1.0mA
G <sub>fs</sub>	Forward Transconductance	1.4	—	—	S	V <sub>DS</sub> = 15V, I <sub>D2</sub> = 1.9A ④
I <sub>DSS</sub>	Zero Gate Voltage Drain Current	—	—	25	μA	V <sub>DS</sub> = 80V, V <sub>GS</sub> = 0V
		—	—	250		V <sub>DS</sub> = 80V, V <sub>GS</sub> = 0V, T <sub>J</sub> = 125°C
I <sub>GSS</sub>	Gate-to-Source Leakage Forward	—	—	100	nA	V <sub>GS</sub> = 20V
	Gate-to-Source Leakage Reverse	—	—	-100		V <sub>GS</sub> = -20V
Q <sub>G</sub>	Total Gate Charge	—	—	17	nC	I <sub>D1</sub> = 3.0A
Q <sub>GS</sub>	Gate-to-Source Charge	—	—	4.0		V <sub>DS</sub> = 50V
Q <sub>GD</sub>	Gate-to-Drain ('Miller') Charge	—	—	5.5		V <sub>GS</sub> = 12V
t <sub>d(on)</sub>	Turn-On Delay Time	—	—	20	ns	V <sub>DD</sub> = 50V
t <sub>r</sub>	Rise Time	—	—	25		I <sub>D1</sub> = 3.0A
t <sub>d(off)</sub>	Turn-Off Delay Time	—	—	40		R <sub>G</sub> = 7.5Ω
t <sub>f</sub>	Fall Time	—	—	40		V <sub>GS</sub> = 12V
L <sub>S</sub> + L <sub>D</sub>	Total Inductance	—	6.1	—	nH	Measured from the center of drain pad to center of source pad
C <sub>iss</sub>	Input Capacitance	—	270	—	pF	V <sub>GS</sub> = 0V
C <sub>oss</sub>	Output Capacitance	—	110	—		V <sub>DS</sub> = 25V
C <sub>rss</sub>	Reverse Transfer Capacitance	—	23	—		f = 1.0MHz

**Source-Drain Diode Ratings and Characteristics for Each N-Channel Device**

Symbol	Parameter	Min.	Typ.	Max.	Units	Test Conditions
I <sub>S</sub>	Continuous Source Current (Body Diode)	—	—	3.0	A	
I <sub>SM</sub>	Pulsed Source Current (Body Diode) ①	—	—	12		
V <sub>SD</sub>	Diode Forward Voltage	—	—	1.2	V	T <sub>J</sub> = 25°C, I <sub>S</sub> = 3.0A, V <sub>GS</sub> = 0V ④
t <sub>rr</sub>	Reverse Recovery Time	—	—	173	ns	T <sub>J</sub> = 25°C, I <sub>F</sub> = 3.0A, V <sub>DD</sub> ≤ 25V
Q <sub>rr</sub>	Reverse Recovery Charge	—	—	863	nC	di/dt = 100A/μs ④
t <sub>on</sub>	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L <sub>S</sub> +L <sub>D</sub> )				

**Thermal Resistance for Each N-Channel Device**

Symbol	Parameter	Min.	Typ.	Max.	Units
R <sub>θJC</sub>	Junction-to-Case	—	—	10.4	°C/W

**Footnotes:**

- ① Repetitive Rating; Pulse width limited by maximum junction temperature.
- ② V<sub>DD</sub> = 25V, starting T<sub>J</sub> = 25°C, L = 18.7mH, Peak I<sub>L</sub> = 3.0A, V<sub>GS</sub> = 12V
- ③ I<sub>SD</sub> ≤ 3.0A, di/dt ≤ 165A/μs, V<sub>DD</sub> ≤ 100V, T<sub>J</sub> ≤ 150°C
- ④ Pulse width ≤ 300 μs; Duty Cycle ≤ 2%
- ⑤ Total Dose Irradiation with V<sub>GS</sub> Bias. 12 volt V<sub>GS</sub> applied and V<sub>DS</sub> = 0 during irradiation per MIL-STD-750, Method 1019, condition A.
- ⑥ Total Dose Irradiation with V<sub>DS</sub> Bias. 80volt V<sub>DS</sub> applied and V<sub>GS</sub> = 0 during irradiation per MIL-STD-750, Method 1019, condition A.

**Electrical Characteristics for Each P-Channel Device @ T<sub>j</sub> = 25°C (Unless Otherwise Specified)**

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV <sub>DSS</sub>	Drain-to-Source Breakdown Voltage	-100	—	—	V	V <sub>GS</sub> = 0V, I <sub>D</sub> = -1.0mA
ΔBV <sub>DSS</sub> /ΔT <sub>J</sub>	Breakdown Voltage Temp. Coefficient	—	-0.10	—	V/°C	Reference to 25°C, I <sub>D</sub> = -1.0mA
R <sub>DS(on)</sub>	Static Drain-to-Source On-State Resistance	—	—	1.1	Ω	V <sub>GS</sub> = -12V, I <sub>D1</sub> = -1.5A ④
V <sub>GS(th)</sub>	Gate Threshold Voltage	-2.0	—	-4.0	V	V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = -1.0mA
G <sub>fs</sub>	Forward Transconductance	1.1	—	—	S	V <sub>DS</sub> = -15V, I <sub>D2</sub> = -1.5A ④
I <sub>DSS</sub>	Zero Gate Voltage Drain Current	—	—	-25	μA	V <sub>DS</sub> = -80V, V <sub>GS</sub> = 0V
		—	—	-250		V <sub>DS</sub> = -80V, V <sub>GS</sub> = 0V, T <sub>J</sub> = 125°C
I <sub>GSS</sub>	Gate-to-Source Leakage Forward	—	—	-100	nA	V <sub>GS</sub> = -20V
	Gate-to-Source Leakage Reverse	—	—	100		V <sub>GS</sub> = 20V
Q <sub>G</sub>	Total Gate Charge	—	—	16	nC	I <sub>D1</sub> = -2.3A
Q <sub>GS</sub>	Gate-to-Source Charge	—	—	4.3		V <sub>DS</sub> = -50V
Q <sub>GD</sub>	Gate-to-Drain ('Miller') Charge	—	—	3.3		V <sub>GS</sub> = -12V
t <sub>d(on)</sub>	Turn-On Delay Time	—	—	21	ns	V <sub>DD</sub> = -50V
t <sub>r</sub>	Rise Time	—	—	17		I <sub>D1</sub> = -2.3A
t <sub>d(off)</sub>	Turn-Off Delay Time	—	—	32		R <sub>G</sub> = 7.5Ω
t <sub>f</sub>	Fall Time	—	—	32		V <sub>GS</sub> = -12V
L <sub>s</sub> + L <sub>D</sub>	Total Inductance	—	6.1	—	nH	Measured from the center of drain pad to center of source pad
C <sub>iss</sub>	Input Capacitance	—	285	—	pF	V <sub>GS</sub> = 0V
C <sub>oss</sub>	Output Capacitance	—	90	—		V <sub>DS</sub> = -25V
C <sub>rss</sub>	Reverse Transfer Capacitance	—	13	—		f = 1.0MHz

**Source-Drain Diode Ratings and Characteristics for Each P-Channel Device**

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
I <sub>S</sub>	Continuous Source Current (Body Diode)	—	—	-2.3	A	
I <sub>SM</sub>	Pulsed Source Current (Body Diode) ①	—	—	-9.2		
V <sub>SD</sub>	Diode Forward Voltage	—	—	-3.0	V	T <sub>J</sub> = 25°C, I <sub>S</sub> = -2.3A, V <sub>GS</sub> = 0V ④
t <sub>rr</sub>	Reverse Recovery Time	—	—	138	ns	T <sub>J</sub> = 25°C, I <sub>F</sub> = -2.3A, V <sub>DD</sub> ≤ -25V
Q <sub>rr</sub>	Reverse Recovery Charge	—	—	555	nC	di/dt = 100A/μs ④
t <sub>on</sub>	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L <sub>s</sub> +L <sub>D</sub> )				

**Thermal Resistance for Each P-Channel Device**

	Parameter	Min.	Typ.	Max.	Units
R <sub>θJC</sub>	Junction-to-Case	—	—	10.4	°C/W

**Footnotes:**

- ① Repetitive Rating; Pulse width limited by maximum junction temperature.
- ② V<sub>DD</sub> = -25V, starting T<sub>J</sub> = 25°C, L = 28.4mH, Peak I<sub>L</sub> = -2.3A, V<sub>GS</sub> = -12V
- ③ I<sub>SD</sub> ≤ -2.3A, di/dt ≤ -244A/μs, V<sub>DD</sub> ≤ -100V, T<sub>J</sub> ≤ 150°C
- ④ Pulse width ≤ 300 μs; Duty Cycle ≤ 2%
- ⑤ Total Dose Irradiation with V<sub>GS</sub> Bias. -12 volt V<sub>GS</sub> applied and V<sub>DS</sub> = 0 during irradiation per MIL-STD-750, Method 1019, condition A.
- ⑥ Total Dose Irradiation with V<sub>DS</sub> Bias. -80volt V<sub>DS</sub> applied and V<sub>GS</sub> = 0 during irradiation per MIL-STD-750, Method 1019, condition A.

## Radiation Characteristics

IR HiRel Radiation Hardened MOSFETs are tested to verify their radiation hardness capability. The hardness assurance program at IR HiRel is comprised of two radiation environments. Every manufacturing lot is tested for total ionizing dose (per notes 5 and 6) using the TO-3 package. Both pre- and post-irradiation performance are tested and specified using the same drive circuitry and test conditions in order to provide a direct comparison.

**Table 1. Electrical Characteristics for Each N-Ch. Dev. @ Tj = 25°C, Post Total Dose Irradiation ⑤⑥**

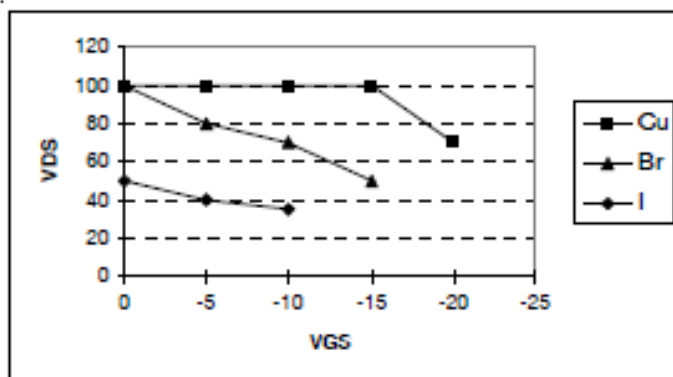
Symbol	Parameter	100 kRads (Si) <sup>1</sup>		300 kRads (Si) <sup>2</sup>		Units	Test Conditions
		Min.	Max.	Min.	Max.		
BV <sub>DSS</sub>	Drain-to-Source Breakdown Voltage	100	—	100	—	V	V <sub>GS</sub> = 0V, I <sub>D</sub> = 1.0mA
V <sub>GS(th)</sub>	Gate Threshold Voltage	2.0	4.0	1.25	4.5	V	V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = 1.0mA
I <sub>GSS</sub>	Gate-to-Source Leakage Forward	—	100	—	100	nA	V <sub>GS</sub> = 20V
I <sub>GSS</sub>	Gate-to-Source Leakage Reverse	—	-100	—	-100	nA	V <sub>GS</sub> = -20V
I <sub>DSS</sub>	Zero Gate Voltage Drain Current	—	25	—	25	μA	V <sub>DS</sub> = 80V, V <sub>GS</sub> = 0V
R <sub>DS(on)</sub>	Static Drain-to-Source <sup>④</sup> On-State Resistance (TO-3)	—	0.556	—	0.706	Ω	V <sub>GS</sub> = 12V, I <sub>D2</sub> = 1.9A
R <sub>DS(on)</sub>	Static Drain-to-Source <sup>④</sup> On-State Resistance (LCC-28)	—	0.60	—	0.75	Ω	V <sub>GS</sub> = 12V, I <sub>D2</sub> = 1.9A
V <sub>SD</sub>	Diode Forward Voltage <sup>④</sup>	—	1.2	—	1.2	V	V <sub>GS</sub> = 0V, I <sub>S</sub> = 3.0A

1. Part number IRHQ6110
2. Part number IRHQ63110

IR HiRel radiation hardened MOSFETs have been characterized in heavy ion environment for Single Event Effects (SEE). Single Event Effects characterization is illustrated in Fig. a and Table 2.

**Table 2. Typical Single Event Effect Safe Operating Area**

Ion	LET (MeV/(mg/cm <sup>2</sup> ))	Energy (MeV)	Range (μm)	VDS (V)				
				@ VGS = 0V	@ VGS = -5V	@ VGS = -10V	@ VGS = -15V	@ VGS = -20V
Cu	28.0	285	43.0	100	100	100	100	70
Br	36.8	305	39.0	100	80	70	50	—
I	59.8	343	32.6	50	40	35	—	—



**Fig a.** Typical Single Event Effect, Safe Operating Area

For Footnotes, refer to the page 2.

**Radiation Characteristics**

IR HiRel Radiation Hardened MOSFETs are tested to verify their radiation hardness capability. The hardness assurance program at IR HiRel is comprised of two radiation environments. Every manufacturing lot is tested for total ionizing dose (per notes 5 and 6) using the TO-3 package. Both pre- and post-irradiation performance are tested and specified using the same drive circuitry and test conditions in order to provide a direct comparison.

**Table1. Electrical Characteristics for Each P-Ch. Dev. @ Tj = 25°C, Post Total Dose Irradiation ⑤⑥**

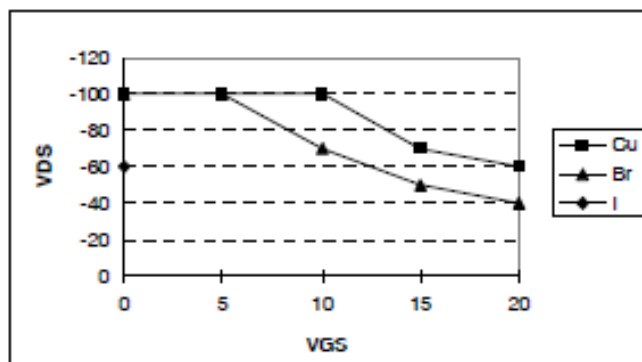
	Parameter	100 kRads (Si) <sup>1</sup>		300 kRads (Si) <sup>2</sup>		Units	Test Conditions
		Min.	Max.	Min.	Max.		
BV <sub>DSS</sub>	Drain-to-Source Breakdown Voltage	-100	—	-100	—	V	V <sub>GS</sub> = 0V, I <sub>D</sub> = -1.0mA
V <sub>GS(th)</sub>	Gate Threshold Voltage	-2.0	-4.0	-2.0	-5.0	V	V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = -1.0mA
I <sub>GSS</sub>	Gate-to-Source Leakage Forward	—	-100	—	-100	nA	V <sub>GS</sub> = -20V
I <sub>GSS</sub>	Gate-to-Source Leakage Reverse	—	100	—	100	nA	V <sub>GS</sub> = 20V
I <sub>DSS</sub>	Zero Gate Voltage Drain Current	—	-25	—	-25	μA	V <sub>DS</sub> = -80V, V <sub>GS</sub> = 0V
R <sub>DS(on)</sub>	Static Drain-to-Source ④ On-State Resistance (TO-3)	—	1.056	—	1.056	Ω	V <sub>GS</sub> = -12V, I <sub>D2</sub> = -1.5A
R <sub>DS(on)</sub>	Static Drain-to-Source ④ On-State Resistance (LCC-28)	—	1.1	—	1.1	Ω	V <sub>GS</sub> = -12V, I <sub>D2</sub> = -1.5A
V <sub>SD</sub>	Diode Forward Voltage ④	—	-3.0	—	-3.0	V	V <sub>GS</sub> = 0V, I <sub>D</sub> = -2.3A

1. Part number IRHQ6110
2. Part number IRHQ63110

IR HiRel radiation hardened MOSFETs have been characterized in heavy ion environment for Single Event Effects (SEE). Single Event Effects characterization is illustrated in Fig. a and Table 2.

**Table 2. Typical Single Event Effect Safe Operating Area**

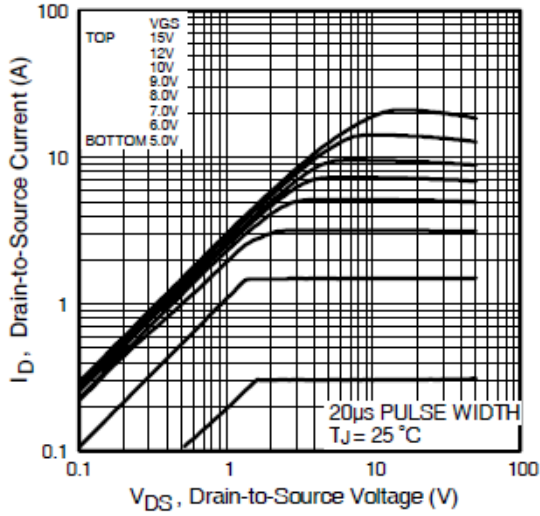
Ion	LET (MeV/(mg/cm <sup>2</sup> ))	Energy (MeV)	Range (μm)	VDS (V)				
				@ VGS = 0V	@ VGS = 5V	@ VGS = 10V	@ VGS = 15V	@ VGS = 20V
Cu	28.0	285	43.0	-100	-100	-100	-70	-60
Br	36.8	305	39.0	-100	-100	-70	-50	-40
I	59.8	343	32.6	-60	—	—	—	—



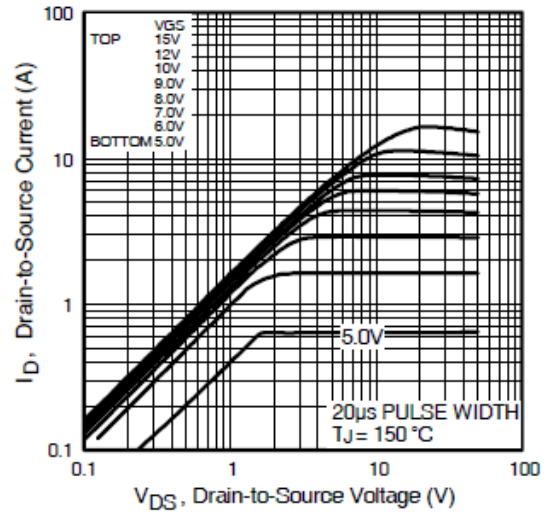
**Fig a.** Typical Single Event Effect, Safe Operating Area

For Footnotes, refer to the page 3.

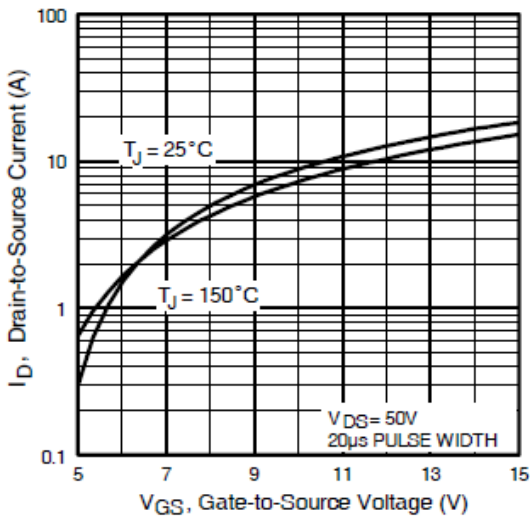
**N-Channel  
Q1, Q4**



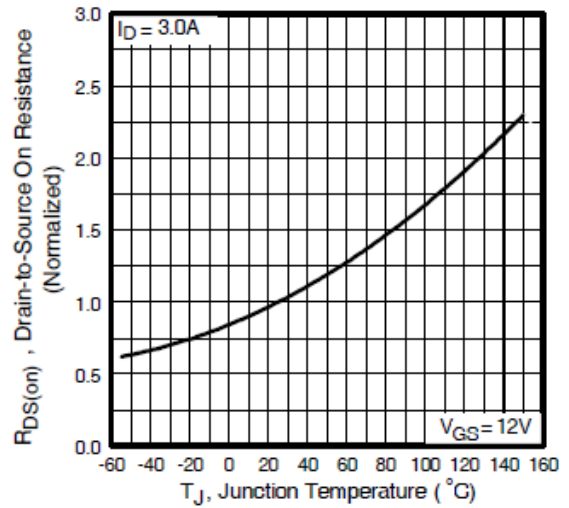
**Fig 1.** Typical Output Characteristics



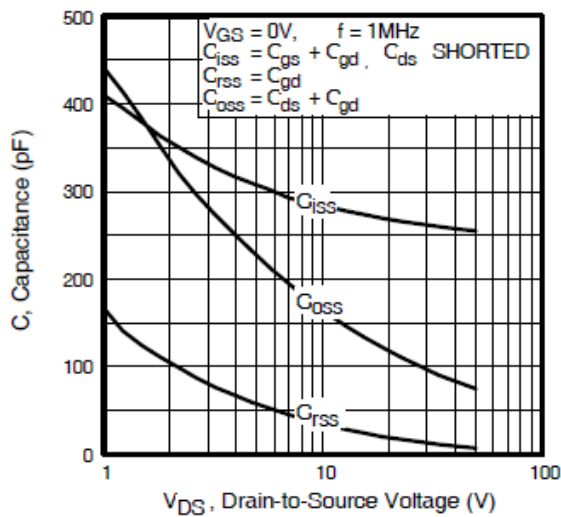
**Fig 2.** Typical Output Characteristics



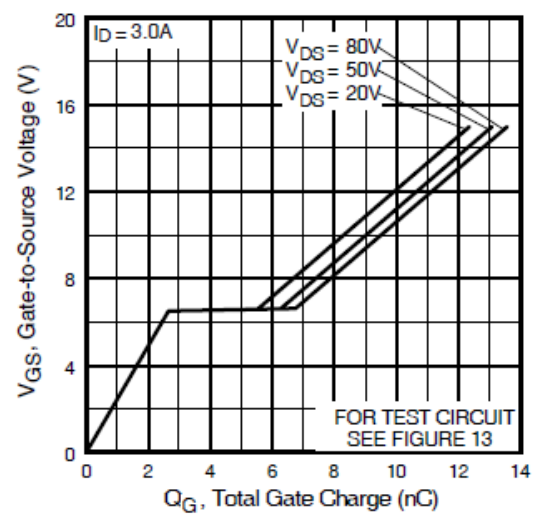
**Fig 3.** Typical Transfer Characteristics



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

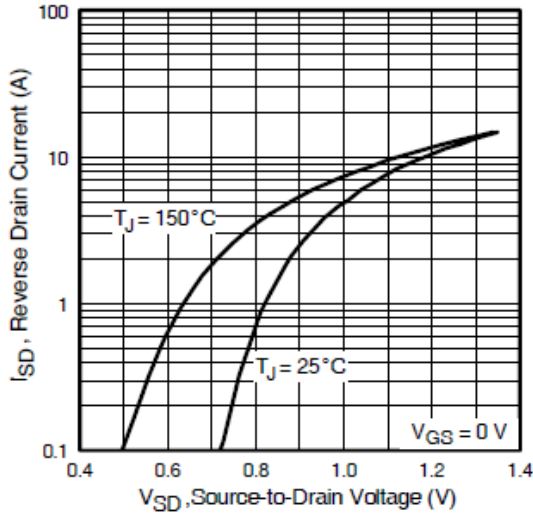


**Fig 5.** Typical Capacitance Vs. Drain-to-Source Voltage

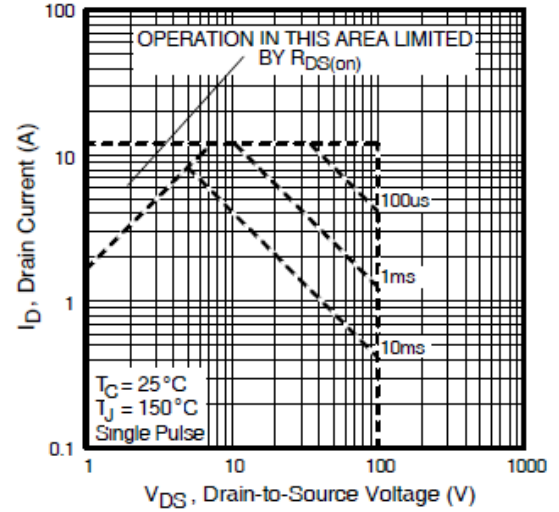


**Fig 6.** Typical Gate Charge Vs. Gate-to-Source Voltage

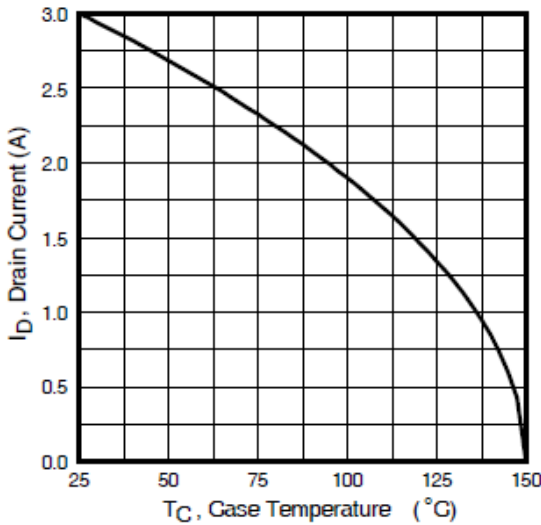
**N-Channel  
Q1, Q4**



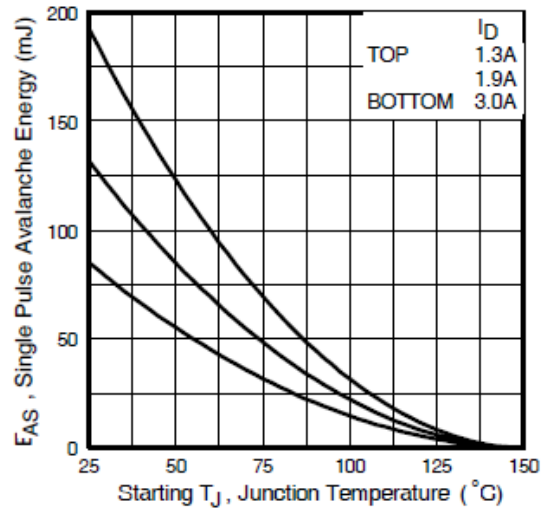
**Fig 7.** Typical Source-Drain Diode Forward Voltage



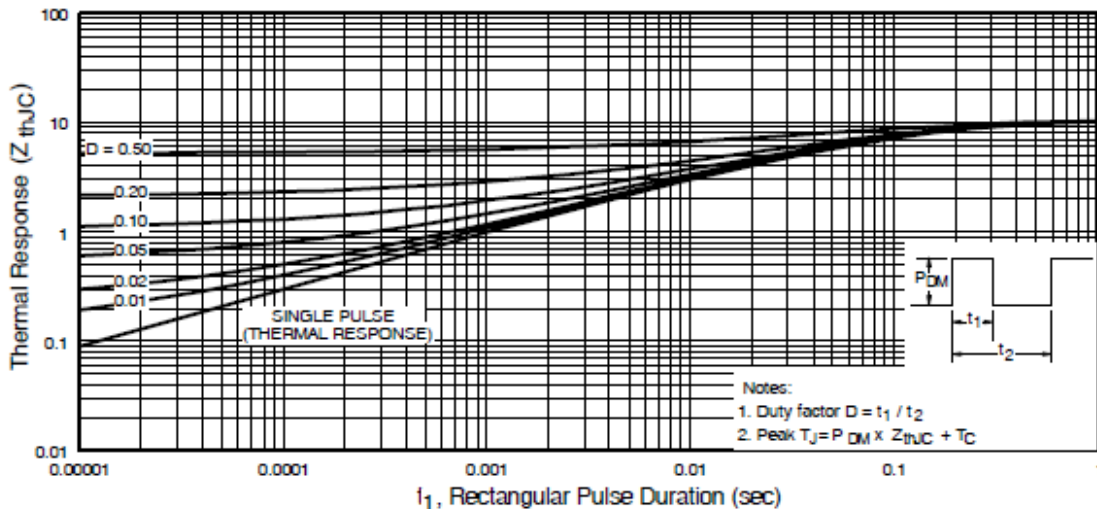
**Fig 8.** Maximum Safe Operating Area



**Fig 9.** Maximum Drain Current Vs. Case Temperature

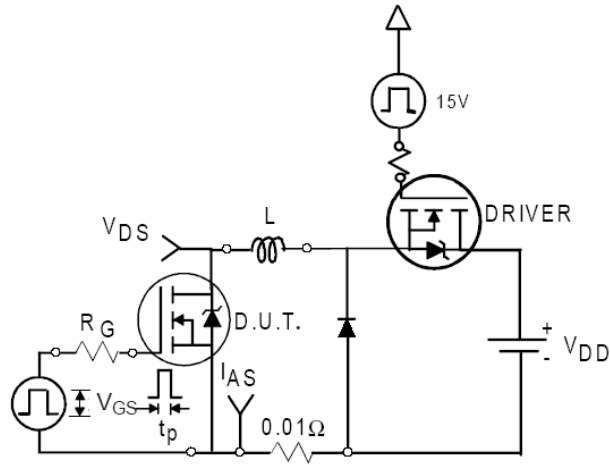


**Fig 10.** Maximum Avalanche Energy Vs. Drain Current

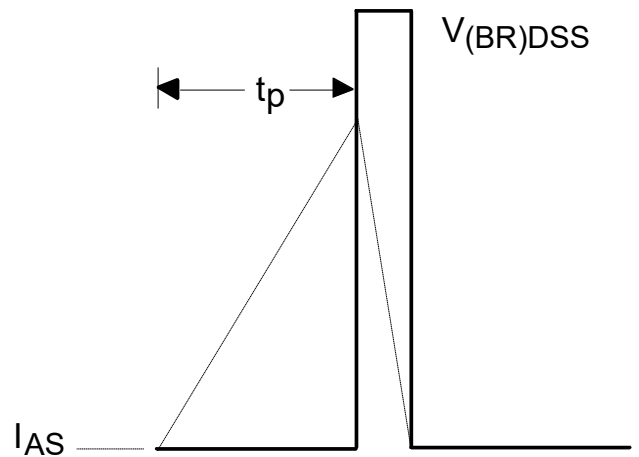


**Fig 11.** Maximum Effective Transient Thermal Impedance, Junction-to-Ambient

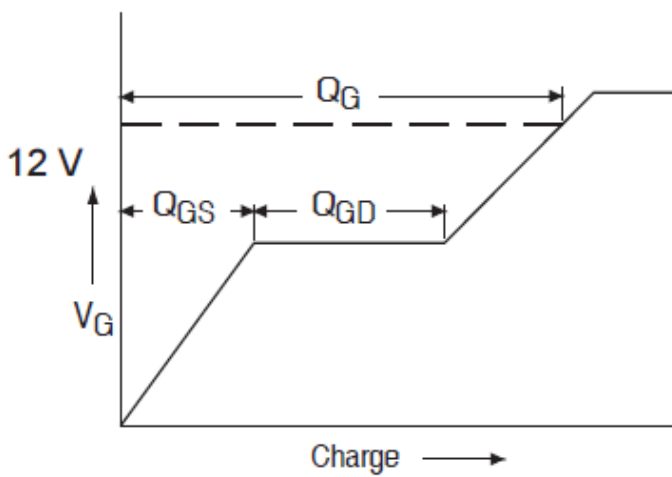
**N-Channel  
Q1, Q4**



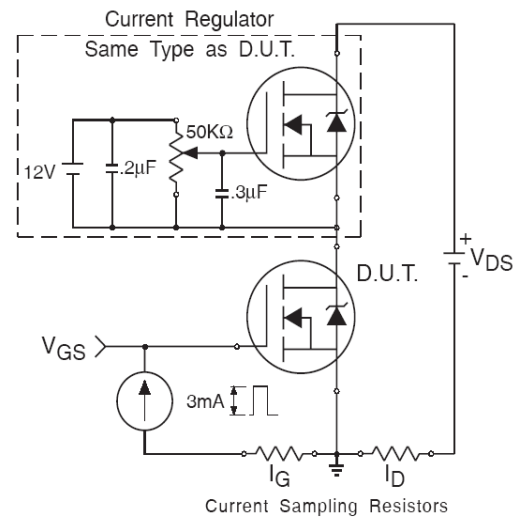
**Fig 12a.** Unclamped Inductive Test Circuit



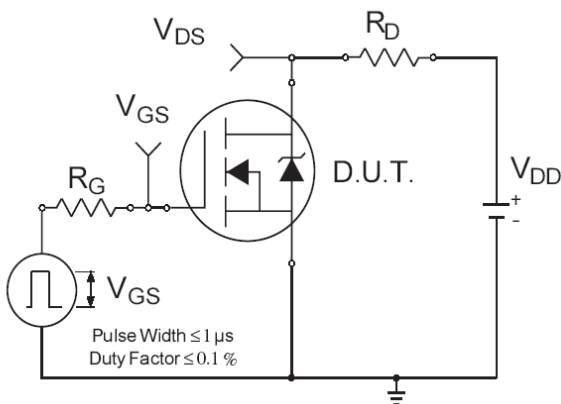
**Fig 12b.** Unclamped Inductive Waveforms



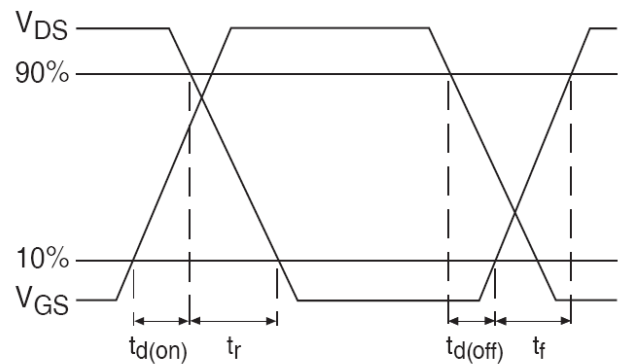
**Fig 13a.** Gate Charge Waveform



**Fig 13b.** Gate Charge Test Circuit



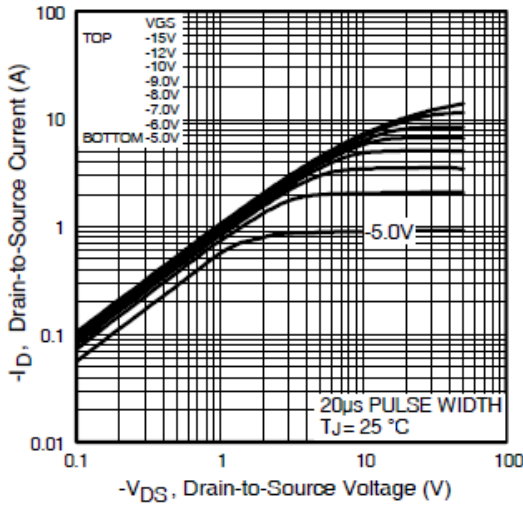
**Fig 14a.** Switching Time Test Circuit



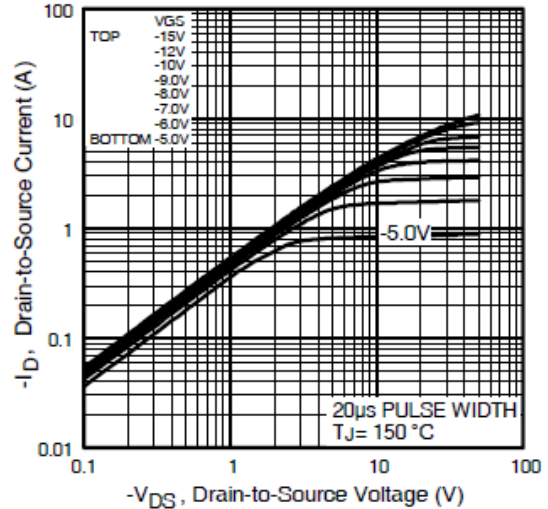
**Fig 14b.** Switching Time Waveforms



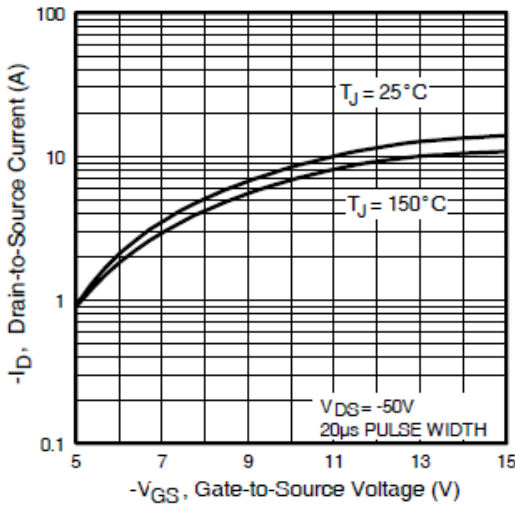
**P-Channel  
Q2, Q3**



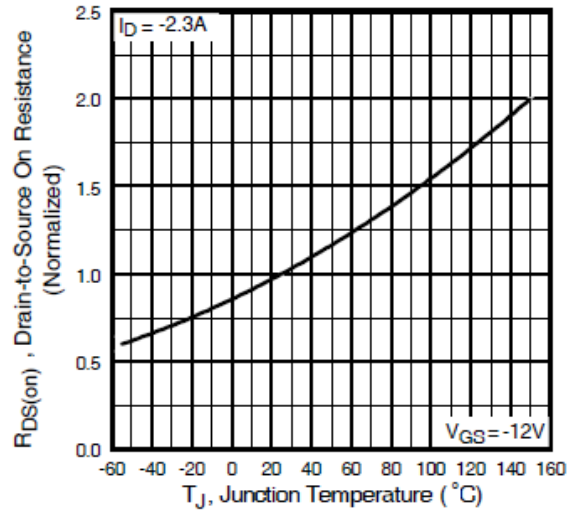
**Fig 1.** Typical Output Characteristics



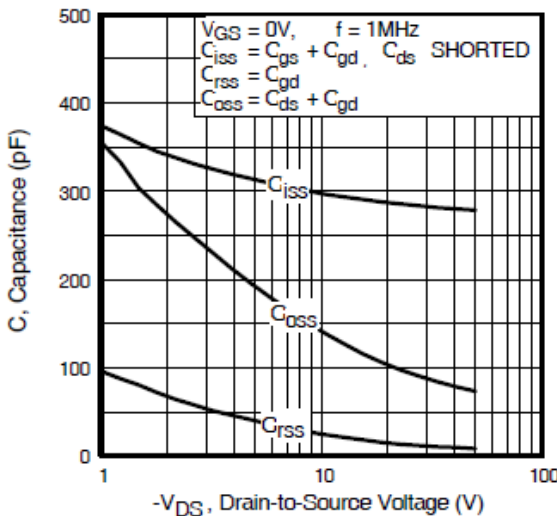
**Fig 2.** Typical Output Characteristics



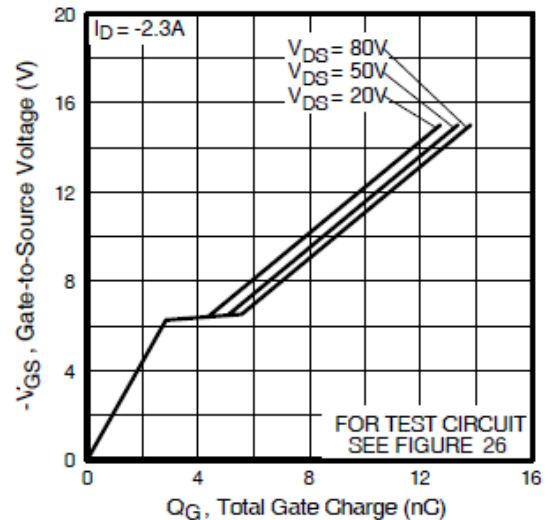
**Fig 3.** Typical Transfer Characteristics



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

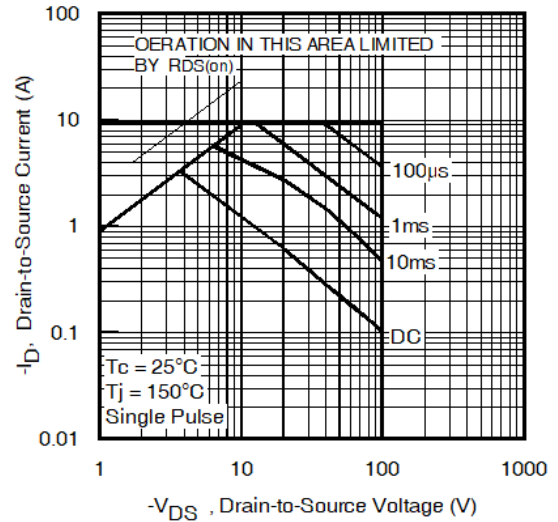
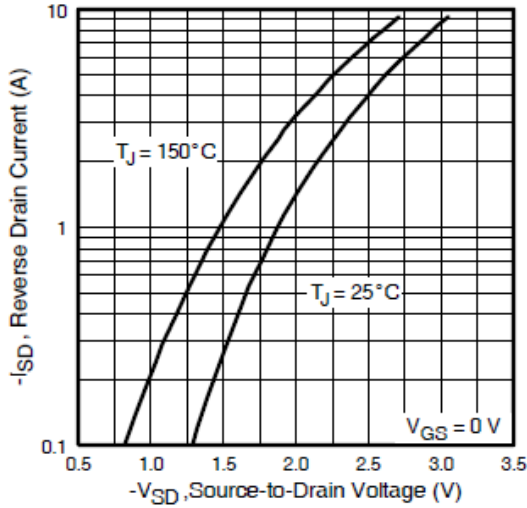


**Fig 5.** Typical Capacitance Vs. Drain-to-Source Voltage



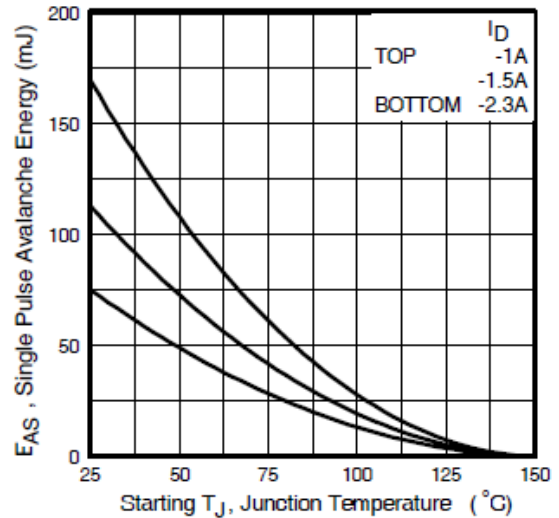
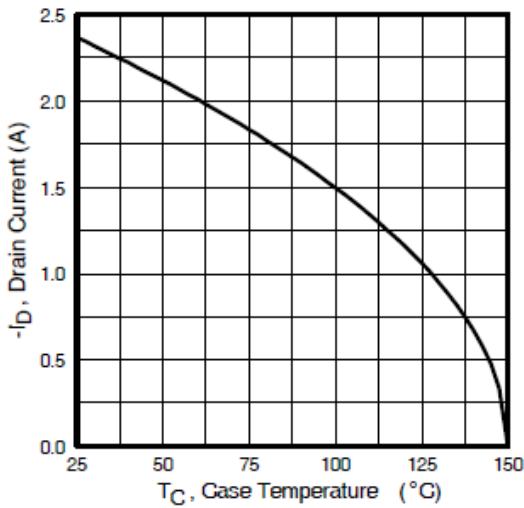
**Fig 6.** Typical Gate Charge Vs. Gate-to-Source Voltage

**P-Channel  
Q2, Q3**



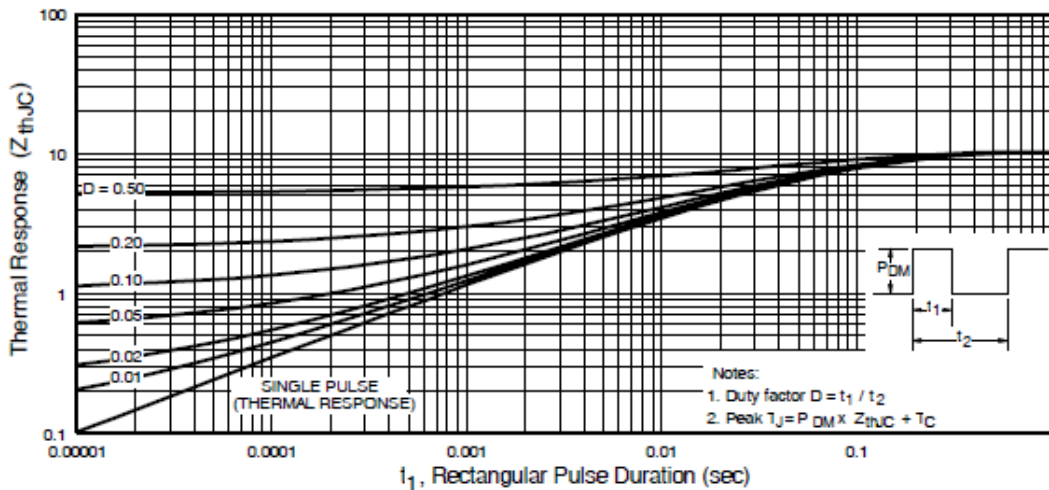
**Fig 7.** Typical Source-Drain Diode Forward Voltage

**Fig 8.** Maximum Safe Operating Area



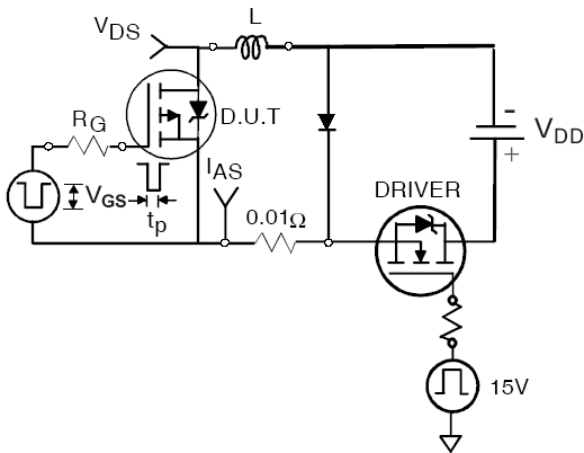
**Fig 9.** Maximum Drain Current Vs. Case Temperature

**Fig 10.** Maximum Avalanche Energy Vs. Drain Current

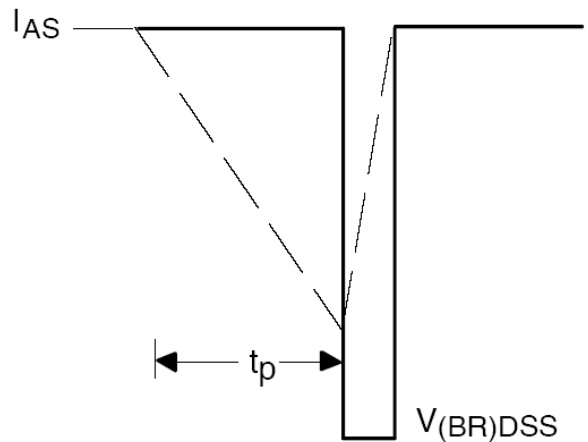


**Fig 11.** Maximum Effective Transient Thermal Impedance, Junction-to-Ambient

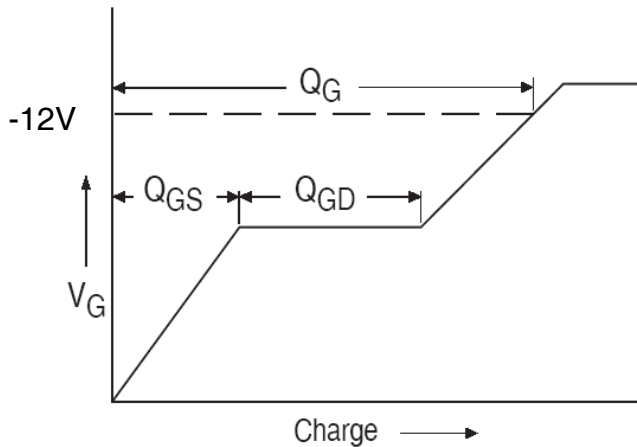
**P-Channel  
Q2, Q3**



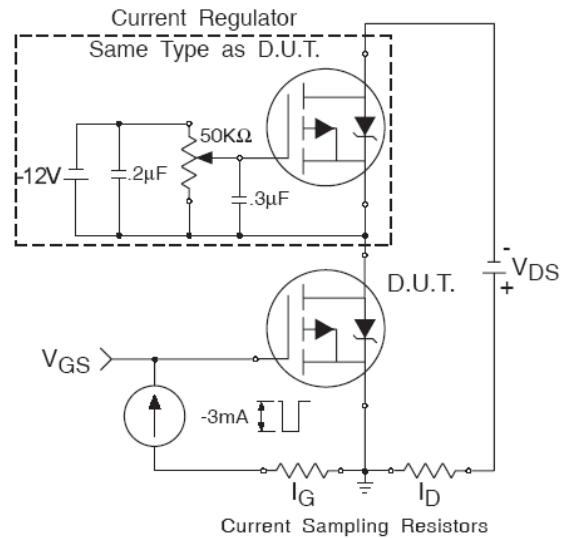
**Fig 12a.** Unclamped Inductive Test Circuit



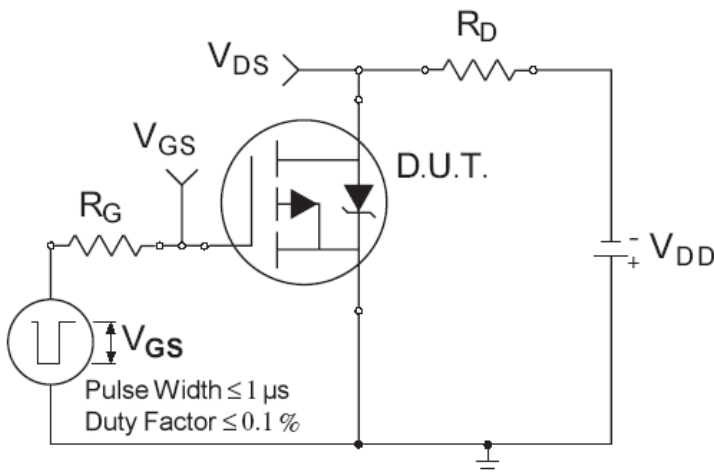
**Fig 12b.** Unclamped Inductive Waveforms



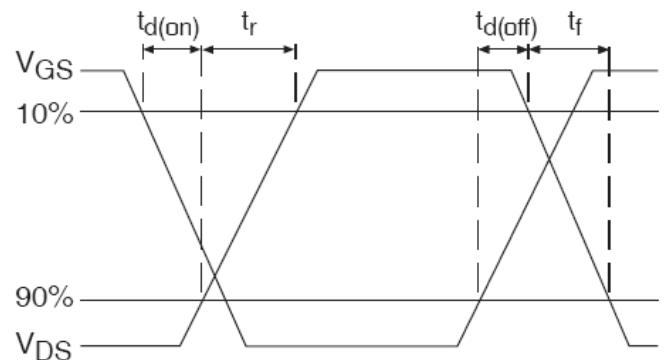
**Fig 13a.** Basic Gate Charge Waveform



**Fig 13b.** Gate Charge Test Circuit



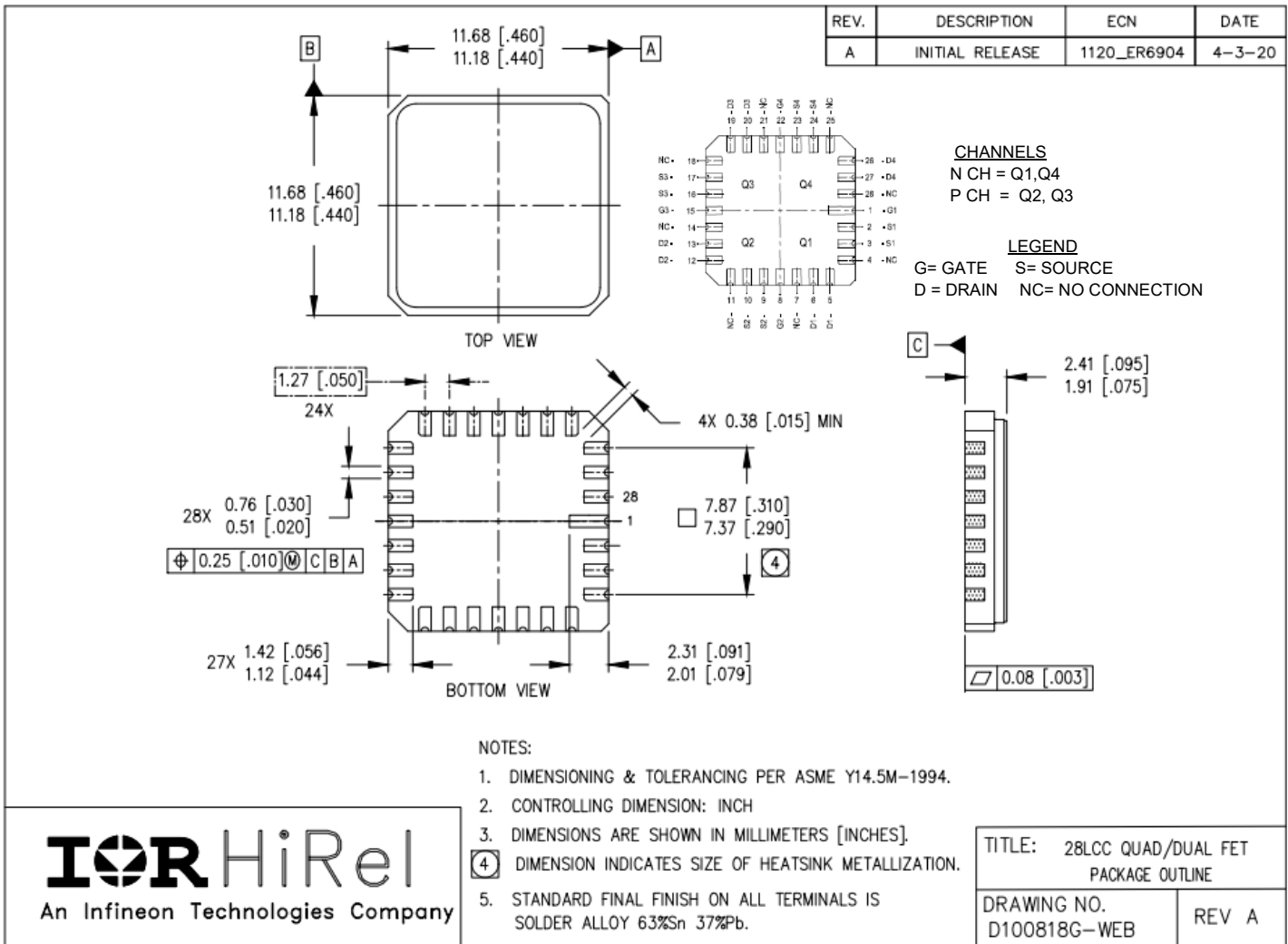
**Fig 14a.** Switching Time Test Circuit



**Fig 14b.** Switching Time Waveforms

Note: For the most updated package outline, please see the website: [LCC-28](#)

**Case Outline and Dimensions – LCC-28**



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