

**RADIATION HARDENED
POWER MOSFET
THRU-HOLE (MO-036AB)**

**100V, Combination 2N-2P CHANNEL
RAD-Hard™ HEXFET®
TECHNOLOGY**

Product Summary

Part Number	Radiation Level	RDS(on)	I _D	Channel
IRHG6110	100 kRads(Si)	0.6Ω	1.0A	N
IRHG63110	300 kRads(Si)	0.6Ω	1.0A	N
IRHG6110	100 kRads(Si)	1.1Ω	-0.75A	P
IRHG63110	300 kRads(Si)	1.1Ω	-0.75A	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
- Light Weight

Absolute Maximum Ratings (Per Die)

Symbol	Parameter	N-Channel	P-Channel	Units
I _{D1} @ V _{GS} = ±12V, T _C = 25°C	Continuous Drain Current	1.0	-0.75	A
I _{D2} @ V _{GS} = ±12V, T _C = 100°C	Continuous Drain Current	0.6	-0.5	
I _{DM} @ T _C = 25°C	Pulsed Drain Current ①	4.0	-3.0	
P _D @ T _C = 25°C	Maximum Power Dissipation	1.4	1.4	W
	Linear Derating Factor	0.011	0.011	W/°C
V _{GS}	Gate-to-Source Voltage	± 20	± 20	V
E _{AS}	Single Pulse Avalanche Energy ②	56②	75②	mJ
I _{AR}	Avalanche Current ①	1.0	-0.75	A
E _{AR}	Repetitive Avalanche Energy ①	0.14	0.14	mJ
dv/dt	Peak Diode Recovery dv/dt ③	2.4③	2.4③	V/ns
T _J T _{STG}	Operating Junction and Storage Temperature Range	-55 to +150		°C
	Lead Temperature	300 (0.63in/1.6mm from case for 10s)		
	Weight	1.3 (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_J = 25°C (Unless Otherwise Specified)

Symbol	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV _{DSS}	Drain-to-Source Breakdown Voltage	100	—	—	V	V _{GS} = 0V, I _D = 1.0mA
ΔBV _{DSS} /ΔT _J	Breakdown Voltage Temp. Coefficient	—	0.125	—	V/°C	Reference to 25°C, I _D = 1.0mA
R _{DS(on)}	Static Drain-to-Source On-State Resistance	—	—	0.7	Ω	V _{GS} = 12V, I _D = 1.0A ④
		—	—	0.6		V _{GS} = 12V, I _D = 0.6A ④
V _{GS(th)}	Gate Threshold Voltage	2.0	—	4.0	V	V _{DS} = V _{GS} , I _D = 1.0mA
G _{fs}	Forward Transconductance	0.7	—	—	S	V _{DS} = 15V, I _{D2} = 0.6A ④
I _{DSS}	Zero Gate Voltage Drain Current	—	—	25	μA	V _{DS} = 80V, V _{GS} = 0V
		—	—	250		V _{DS} = 80V, V _{GS} = 0V, T _J = 125°C
I _{GSS}	Gate-to-Source Leakage Forward	—	—	100	nA	V _{GS} = 20V
	Gate-to-Source Leakage Reverse	—	—	-100		V _{GS} = -20V
Q _G	Total Gate Charge	—	—	11	nC	I _{D1} = 1.0A
Q _{GS}	Gate-to-Source Charge	—	—	3.0		V _{DS} = 50V
Q _{GD}	Gate-to-Drain ('Miller') Charge	—	—	4.0		V _{GS} = 12V
t _{d(on)}	Turn-On Delay Time	—	—	20	ns	V _{DD} = 50V
t _r	Rise Time	—	—	16		I _{D1} = 1.0A
t _{d(off)}	Turn-Off Delay Time	—	—	65		R _G = 7.5Ω
t _f	Fall Time	—	—	45		V _{GS} = 12V
L _S + L _D	Total Inductance	—	10	—	nH	Measured from Drain lead (6mm / 0.25 in from package) to Source lead (6mm / 0.25 in from package) with Source wire internally bonded from Source pin to Drain pad
C _{iSS}	Input Capacitance	—	300	—	pF	V _{GS} = 0V
C _{oSS}	Output Capacitance	—	100	—		V _{DS} = 25V
C _{rSS}	Reverse Transfer Capacitance	—	16	—		f = 1.0MHz

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

Symbol	Parameter	Min.	Typ.	Max.	Units	Test Conditions
I _S	Continuous Source Current (Body Diode)	—	—	1.0	A	
I _{SM}	Pulsed Source Current (Body Diode) ①	—	—	4.0		
V _{SD}	Diode Forward Voltage	—	—	1.5	V	T _J = 25°C, I _S = 1.0A, V _{GS} = 0V ④
t _{rr}	Reverse Recovery Time	—	—	110	ns	T _J = 25°C, I _F = 1.0A, V _{DD} ≤ 25V
Q _{rr}	Reverse Recovery Charge	—	—	390	nC	di/dt = 100A/μs ④
t _{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L _S +L _D)				

Thermal Resistance for Each N-Channel Device

Symbol	Parameter	Min.	Typ.	Max.	Units
R _{θJC}	Junction-to-Case *	—	—	17	°C/W
R _{θJA}	Junction-to-Ambient (Typical socket mount)	—	—	90	°C/W

Footnotes:

- ① Repetitive Rating; Pulse width limited by maximum junction temperature.
- ② V_{DD} = 25V, starting T_J = 25°C, L = 112mH, Peak I_L = 1.0A, V_{GS} = 12V
- ③ I_{SD} ≤ 1.0A, di/dt ≤ 187A/μs, V_{DD} ≤ 100V, T_J ≤ 150°C
- ④ Pulse width ≤ 300 μs; Duty Cycle ≤ 2%
- ⑤ Total Dose Irradiation with V_{GS} Bias. 12 volt V_{GS} applied and V_{DS} = 0 during irradiation per MIL-STD-750, Method 1019, condition A.
- ⑥ Total Dose Irradiation with V_{DS} Bias. 80volt V_{DS} applied and V_{GS} = 0 during irradiation per MIL-STD-750, Method 1019, condition A.

Pre-Irradiation

Electrical Characteristics for Each P-Channel Device @ T_J = 25°C (Unless Otherwise Specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV _{DSS}	Drain-to-Source Breakdown Voltage	-100	—	—	V	V _{GS} = 0V, I _D = -1.0mA
ΔBV _{DSS} /ΔT _J	Breakdown Voltage Temp. Coefficient	—	-0.11	—	V/°C	Reference to 25°C, I _D = -1.0mA
R _{DS(on)}	Static Drain-to-Source On-State Resistance	—	—	1.2	Ω	V _{GS} = -12V, I _{D2} = -0.75A ④
		—	—	1.1		V _{GS} = -12V, I _{D2} = -0.5A ④
V _{GS(th)}	Gate Threshold Voltage	-2.0	—	-4.0	V	V _{DS} = V _{GS} , I _D = -1.0mA
G _{fs}	Forward Transconductance	0.6	—	—	S	V _{DS} = -15V, I _{D2} = -0.5A ④
I _{DSS}	Zero Gate Voltage Drain Current	—	—	-25	μA	V _{DS} = -80V, V _{GS} = 0V
		—	—	-250		V _{DS} = -80V, V _{GS} = 0V, T _J = 125°C
I _{GSS}	Gate-to-Source Leakage Forward	—	—	-100	nA	V _{GS} = -20V
	Gate-to-Source Leakage Reverse	—	—	100		V _{GS} = 20V
Q _G	Total Gate Charge	—	—	15	nC	I _{D1} = -0.75A
Q _{GS}	Gate-to-Source Charge	—	—	4.0		V _{DS} = -50V
Q _{GD}	Gate-to-Drain ('Miller') Charge	—	—	4.3		V _{GS} = -12V
t _{d(on)}	Turn-On Delay Time	—	—	22	ns	V _{DD} = -50V
t _r	Rise Time	—	—	19		I _{D1} = -0.75A
t _{d(off)}	Turn-Off Delay Time	—	—	66		R _G = 24Ω
t _f	Fall Time	—	—	51		V _{GS} = -12V
L _S + L _D	Total Inductance	—	10	—	nH	Measured from Drain lead (6mm / 0.25 in from package) to Source lead (6mm/ 0.25 in from package) with Source wire internally bonded from Source pin to Drain pad
C _{iss}	Input Capacitance	—	335	—	pF	V _{GS} = 0V
C _{oss}	Output Capacitance	—	100	—		V _{DS} = -25V
C _{rss}	Reverse Transfer Capacitance	—	22	—		f = 1.0MHz

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
I _S	Continuous Source Current (Body Diode)	—	—	-0.75	A	
I _{SM}	Pulsed Source Current (Body Diode) ①	—	—	-3.0		
V _{SD}	Diode Forward Voltage	—	—	-2.5	V	T _J = 25°C, I _S = -0.75A, V _{GS} = 0V ④
t _{rr}	Reverse Recovery Time	—	—	90	ns	T _J = 25°C, I _F = 0.75A, V _{DD} ≤ -25V
Q _{rr}	Reverse Recovery Charge	—	—	257	nC	di/dt = 100A/μs ④
t _{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L _S + L _D)				

Thermal Resistance for Each N-Channel Device

Symbol	Parameter	Min.	Typ.	Max.	Units
R _{θJC}	Junction-to-Case *	—	—	17	°C/W
R _{θJA}	Junction-to-Ambient (Typical socket mount)	—	—	90	°C/W

Footnotes:

- ① Repetitive Rating; Pulse width limited by maximum junction temperature.
- ② V_{DD} = -25V, starting T_J = 25°C, L = 267mH, Peak I_L = -0.75A, V_{GS} = -12V
- ③ I_{SD} ≤ -0.75A, di/dt ≤ -132A/μs, V_{DD} ≤ -100V, T_J ≤ 150°C
- ④ Pulse width ≤ 300 μs; Duty Cycle ≤ 2%
- ⑤ Total Dose Irradiation with V_{GS} Bias. -12 volt V_{GS} applied and V_{DS} = 0 during irradiation per MIL-STD-750, Method 1019, condition A.
- ⑥ Total Dose Irradiation with V_{DS} Bias. -80volt V_{DS} applied and V_{GS} = 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.

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

Symbol	Parameter	100 kRads (Si) ¹		300 kRads (Si) ²		Units	Test Conditions
		Min.	Max.	Min.	Max.		
BV _{DSS}	Drain-to-Source Breakdown Voltage	100	—	100	—	V	V _{GS} = 0V, I _D = 1.0mA
V _{GS(th)}	Gate Threshold Voltage	2.0	4.0	1.25	4.5	V	V _{DS} = V _{GS} , I _D = 1.0mA
I _{GSS}	Gate-to-Source Leakage Forward	—	100	—	100	nA	V _{GS} = 20V
I _{GSS}	Gate-to-Source Leakage Reverse	—	-100	—	-100	nA	V _{GS} = -20V
I _{DSS}	Zero Gate Voltage Drain Current	—	25	—	25	μA	V _{DS} = 80V, V _{GS} = 0V
R _{DS(on)}	Static Drain-to-Source ④ On-State Resistance (TO-3)	—	0.56	—	0.66	Ω	V _{GS} = 12V, I _{D2} = 0.6A
R _{DS(on)}	Static Drain-to-Source ④ On-State Resistance (MO-036AB)	—	0.60	—	0.70	Ω	V _{GS} = 12V, I _{D2} = 0.6A
V _{SD}	Diode Forward Voltage ④	—	1.5	—	1.5	V	V _{GS} = 0V, I _S = 1.0A

- 1. Part number IRHG6110
- 2. Part numbers IRHG63110

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 for Each N-Channel Device

Ion	LET (MeV/(mg/cm ²))	Energy (MeV)	Range (μm)	V _{DS} (V)				
				@V _{GS} =0V	@V _{GS} =-5V	@V _{GS} =-10V	@V _{GS} =-15V	@V _{GS} =-20V
Cu	28.0	285	43.0	100	100	100	80	60
Br	36.8	305	39.0	100	90	70	50	—

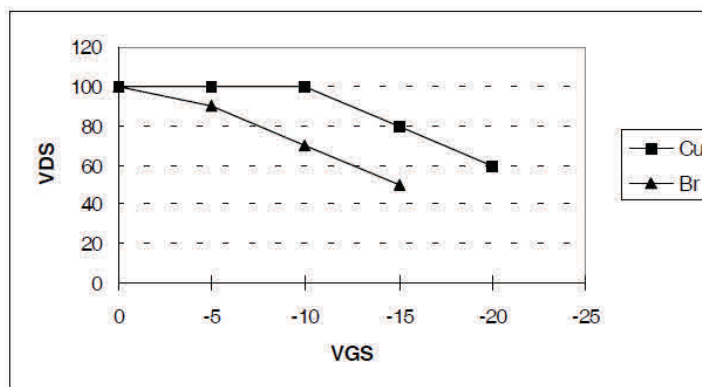


Fig a. Typical Single Event Effect, Safe Operating Area

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) ¹		300 kRads (Si) ²		Units	Test Conditions
		Min.	Max.	Min.	Max.		
BV _{DSS}	Drain-to-Source Breakdown Voltage	-100	—	-100	—	V	V _{GS} = 0V, I _D = -1.0mA
V _{GS(th)}	Gate Threshold Voltage	-2.0	-4.0	-2.0	-4.0	V	V _{DS} = V _{GS} , I _D = -1.0mA
I _{GSS}	Gate-to-Source Leakage Forward	—	-100	—	-100	nA	V _{GS} = -20V
I _{GSS}	Gate-to-Source Leakage Reverse	—	100	—	100	nA	V _{GS} = 20V
I _{DSS}	Zero Gate Voltage Drain Current	—	-25	—	-25	μA	V _{DS} = -80V, V _{GS} = 0V
R _{DS(on)}	Static Drain-to-Source ④ On-State Resistance (TO-3)	—	1.06	—	1.06	Ω	V _{GS} = -12V, I _{D2} = -0.5A
R _{DS(on)}	Static Drain-to-Source ④ On-State Resistance (MO-036AB)	—	1.1	—	1.1	Ω	V _{GS} = -12V, I _{D2} = -0.5A
V _{SD}	Diode Forward Voltage ④	—	-2.5	—	-2.5	V	V _{GS} = 0V, I _D = -0.75A

1. Part number IRHG6110
2. Part number IRHG63110

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 for Each N-Channel Device

Ion	LET (MeV/(mg/cm ²))	Energy (MeV)	Range (μm)	V _{DS} (V)				
				@V _{GS} =0V	@V _{GS} =5V	@V _{GS} =10V	@V _{GS} =15V	@V _{GS} =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	—	—	—	—

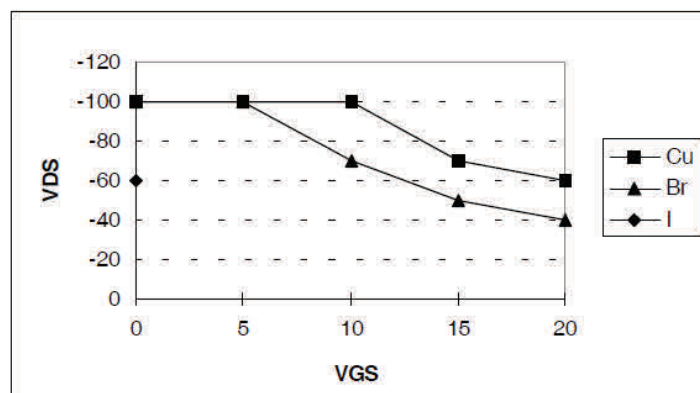


Fig a. Typical Single Event Effect, Safe Operating Area

For Footnotes, refer to the page 3.

**N-Channel
Q1, Q3**

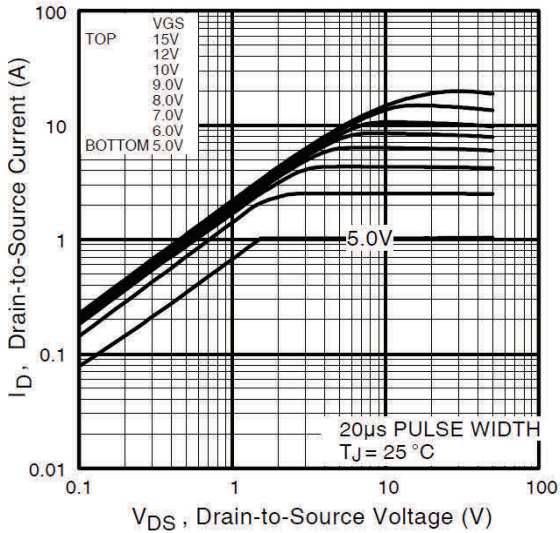


Fig 1. Typical Output Characteristics

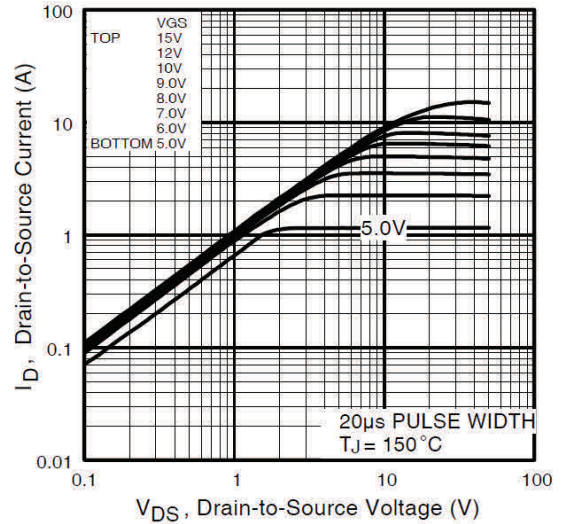


Fig 2. Typical Output Characteristics

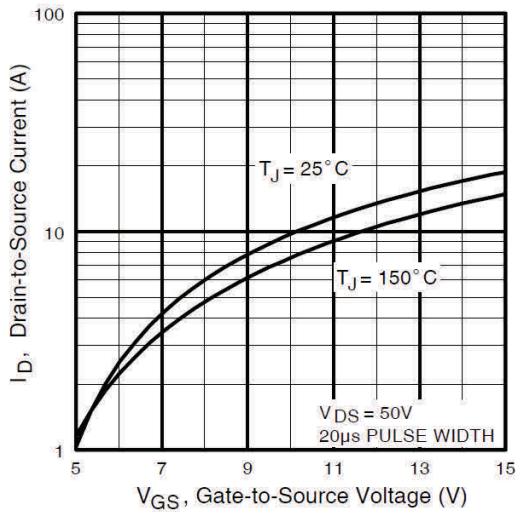


Fig 3. Typical Transfer Characteristics

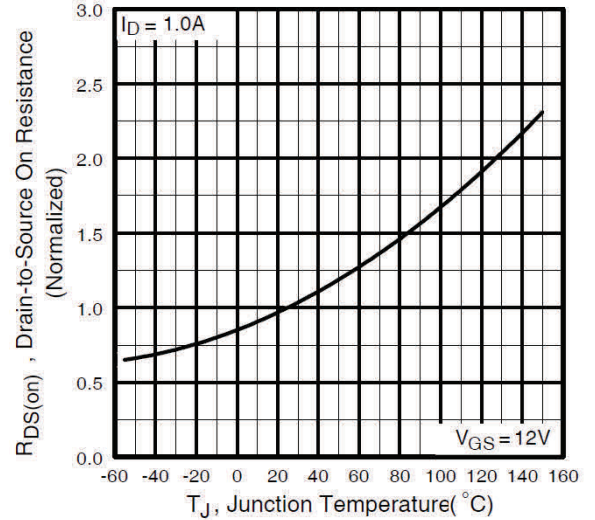


Fig 4. Normalized On-Resistance Vs. Temperature

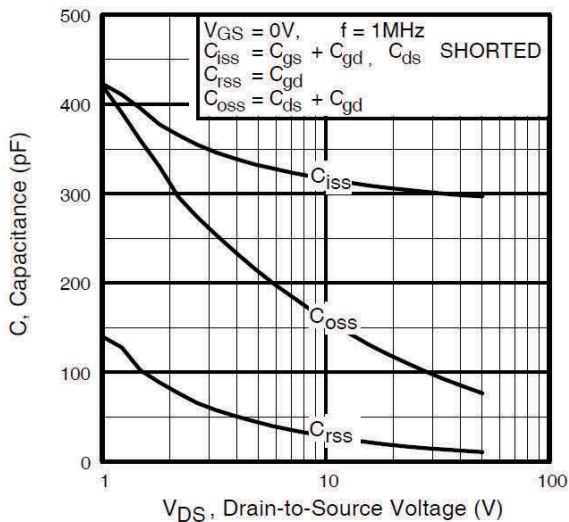


Fig 5. Typical Capacitance Vs. Drain-to-Source Voltage

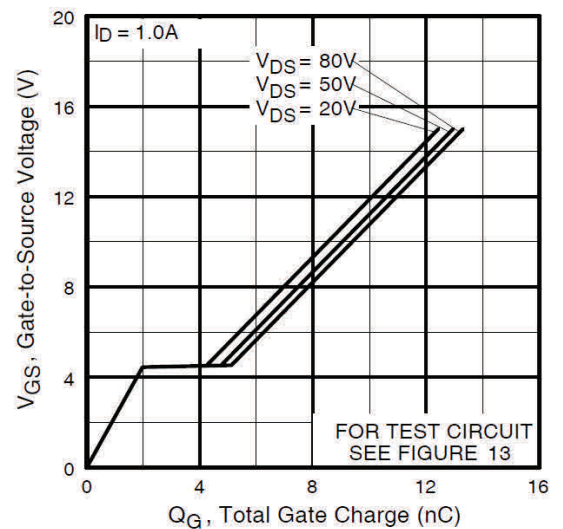


Fig 6. Typical Gate Charge Vs. Gate-to-Source Voltage

**N-Channel
Q1, Q3**

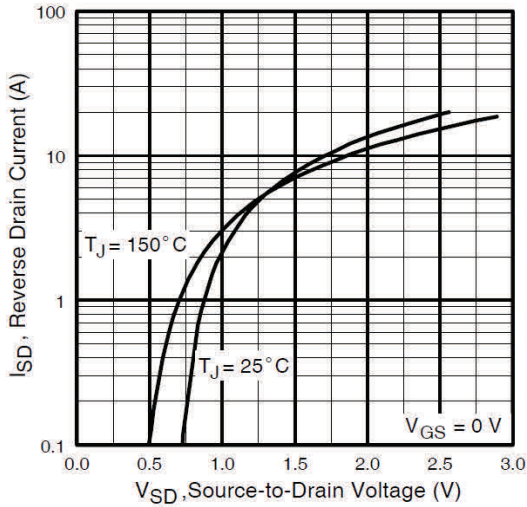


Fig 7. Typical Source-Drain Diode Forward Voltage

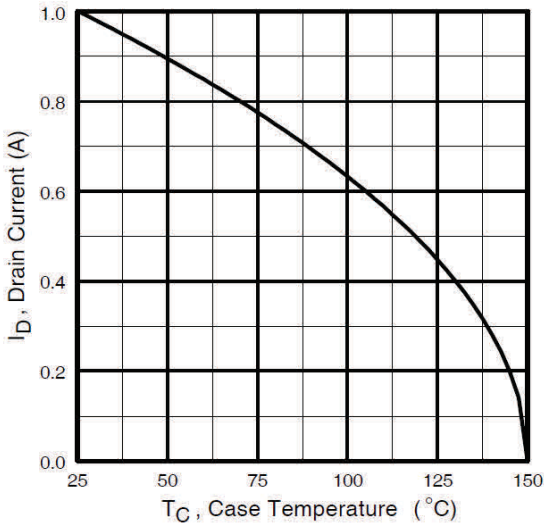


Fig 9. Maximum Drain Current Vs. Case Temperature

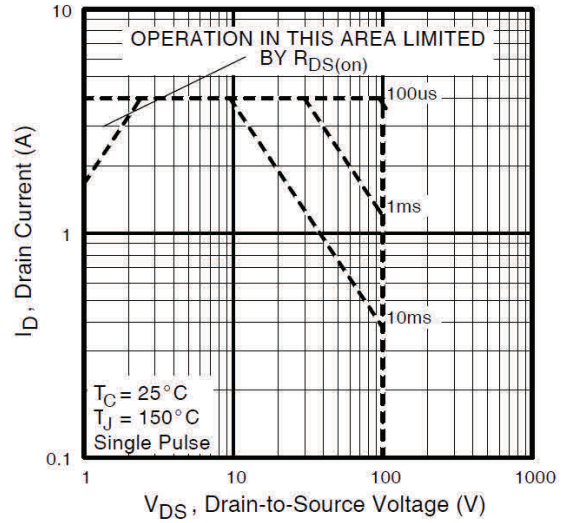


Fig 8. Maximum Safe Operating Area

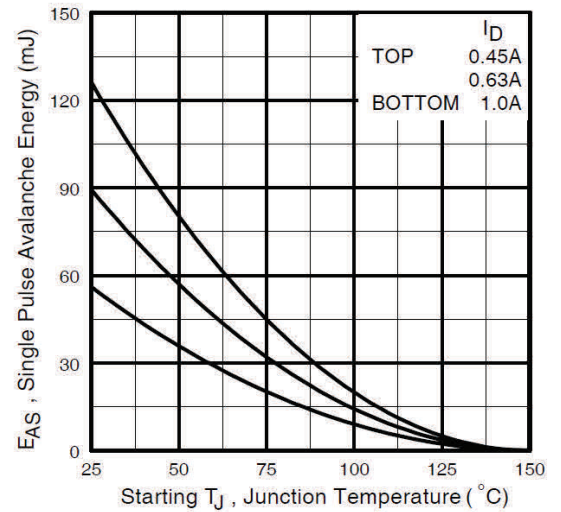


Fig 10. Maximum Avalanche Energy Vs. Drain Current

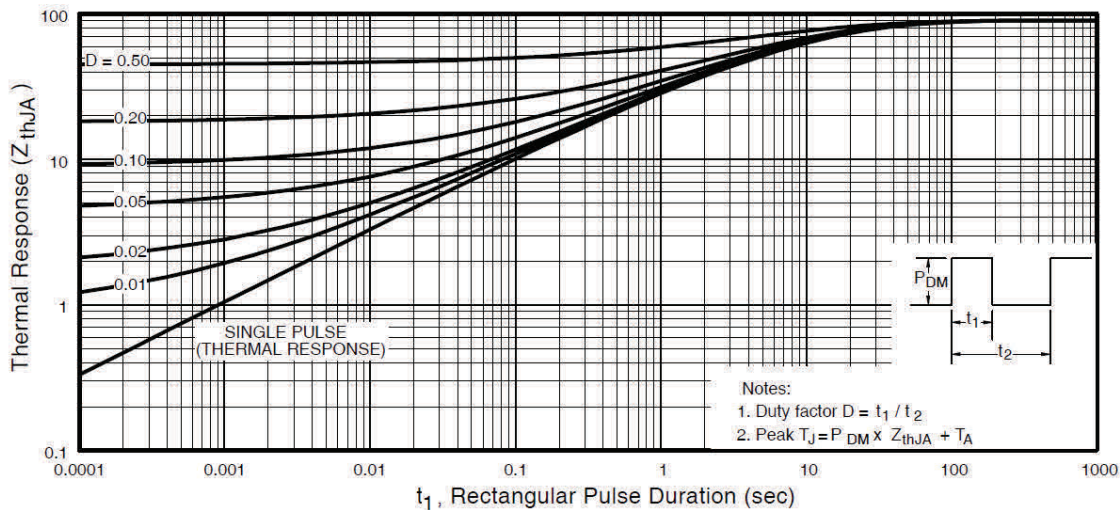


Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

**N-Channel
Q1, Q3**

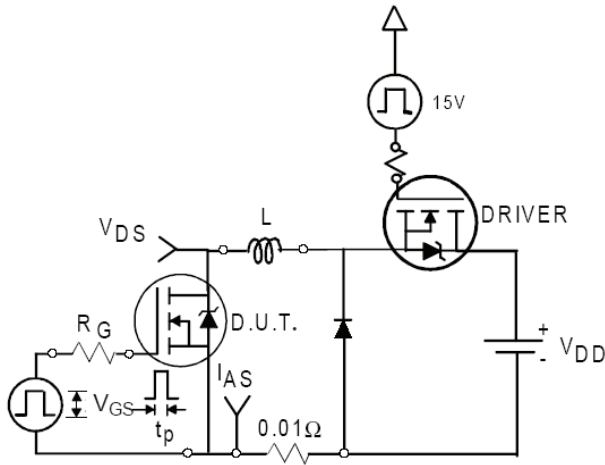


Fig 12a. Unclamped Inductive Test Circuit

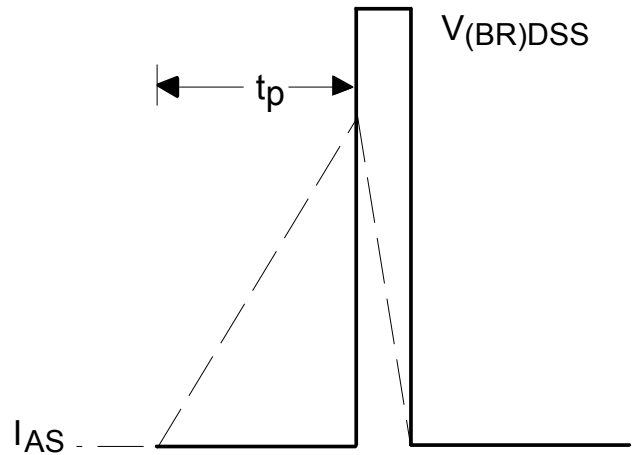


Fig 12b. Unclamped Inductive Waveforms

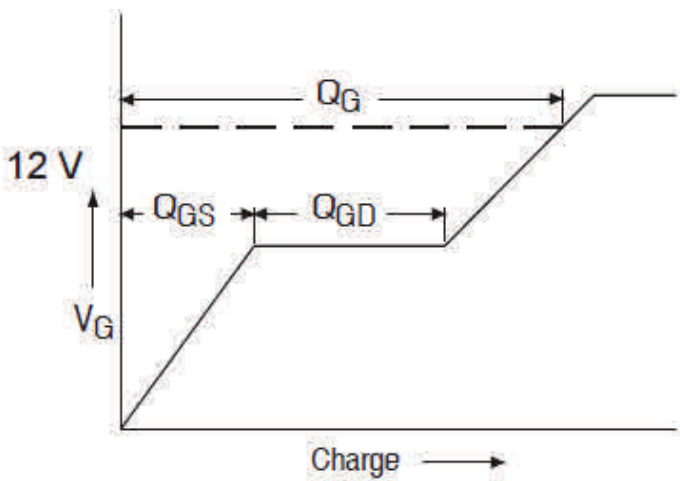


Fig 13a. Gate Charge Waveform

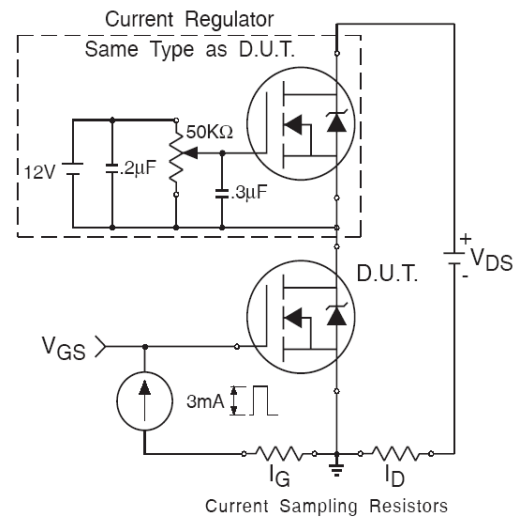


Fig 13b. Gate Charge Test Circuit

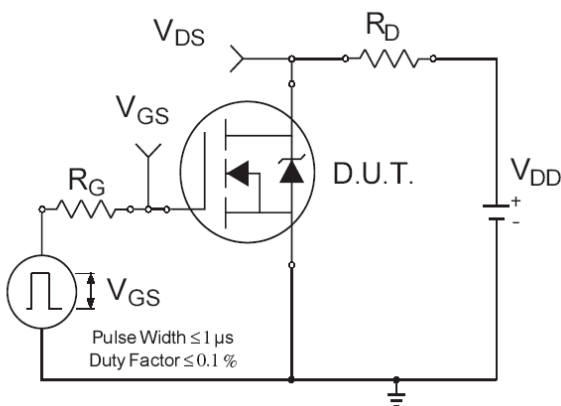


Fig 14a. Switching Time Test Circuit

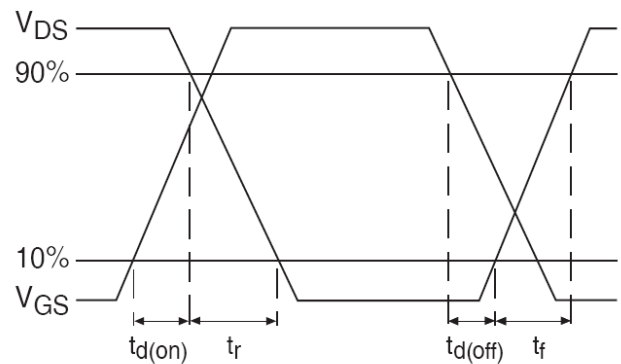


Fig 14b. Switching Time Waveforms

**P-Channel
Q2, Q4**

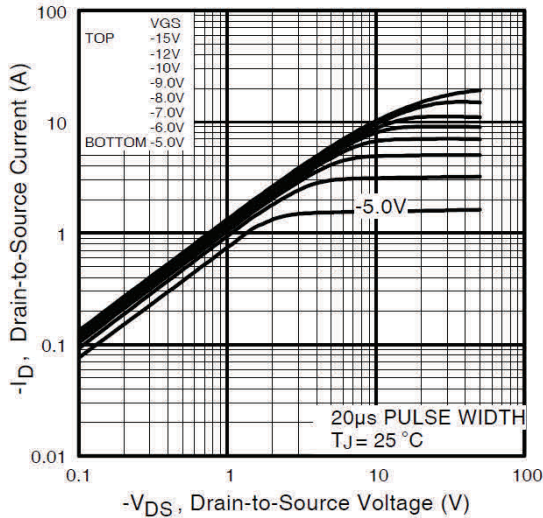


Fig 1. Typical Output Characteristics

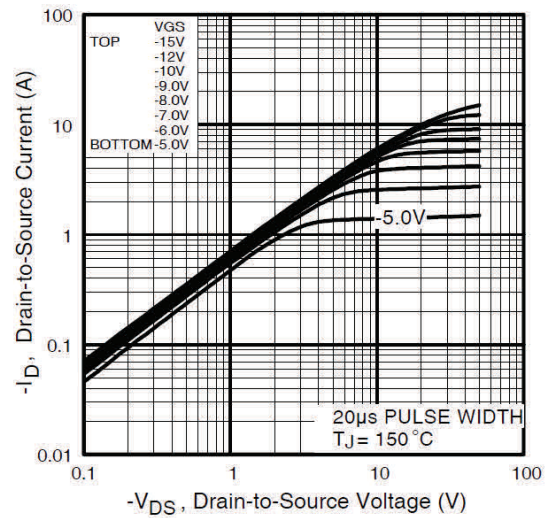


Fig 2. Typical Output Characteristics

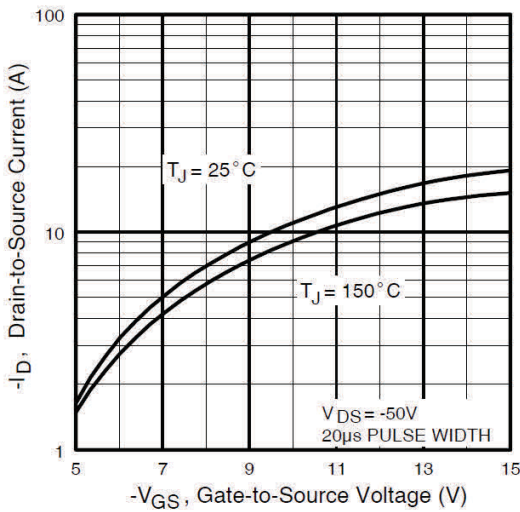


Fig 3. Typical Transfer Characteristics

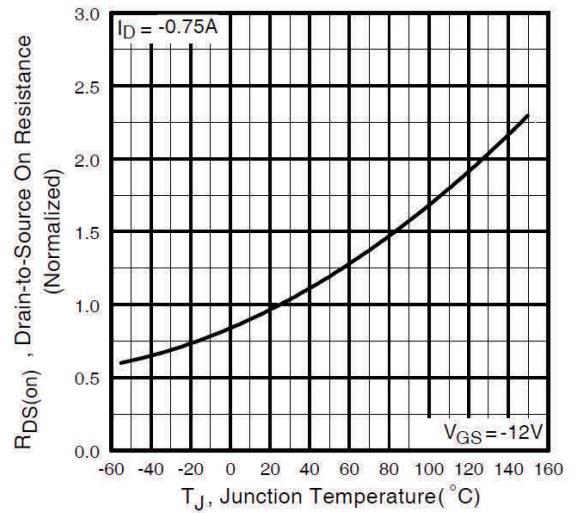


Fig 4. Normalized On-Resistance Vs. Temperature

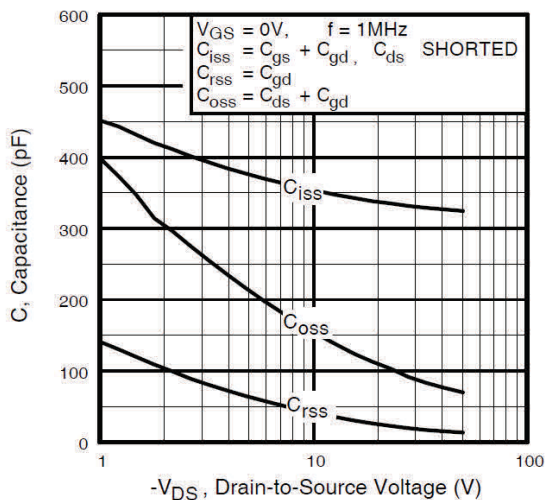


Fig 5. Typical Capacitance Vs. Drain-to-Source Voltage

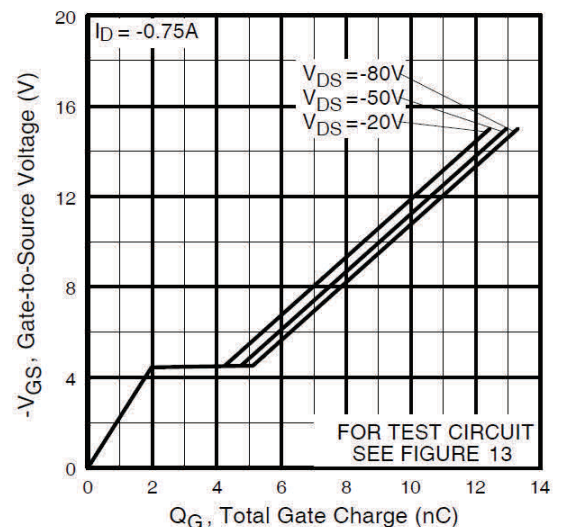


Fig 6. Typical Gate Charge Vs. Gate-to-Source Voltage

**P-Channel
Q2, Q4**

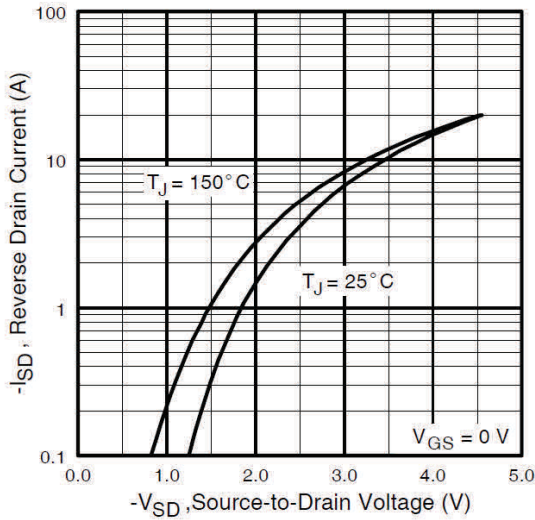


Fig 7. Typical Source-Drain Diode Forward Voltage

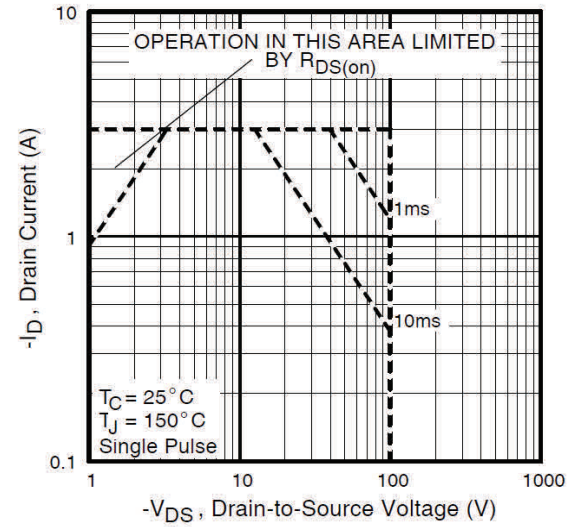


Fig 8. Maximum Safe Operating Area

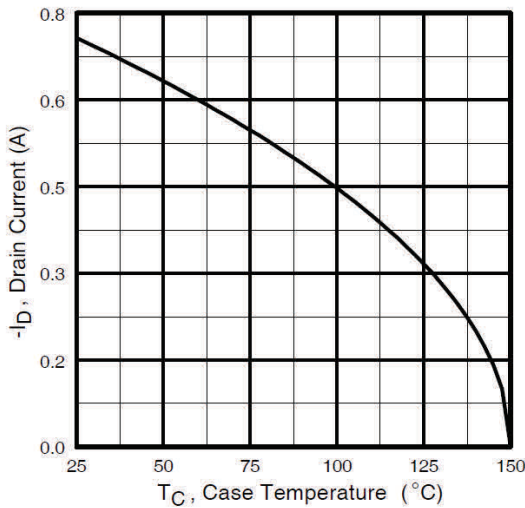


Fig 9. Maximum Drain Current Vs. Case Temperature

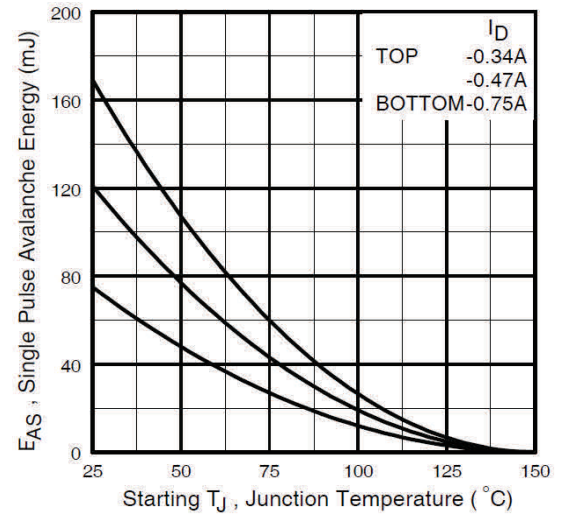


Fig 10. Maximum Avalanche Energy Vs. Drain Current

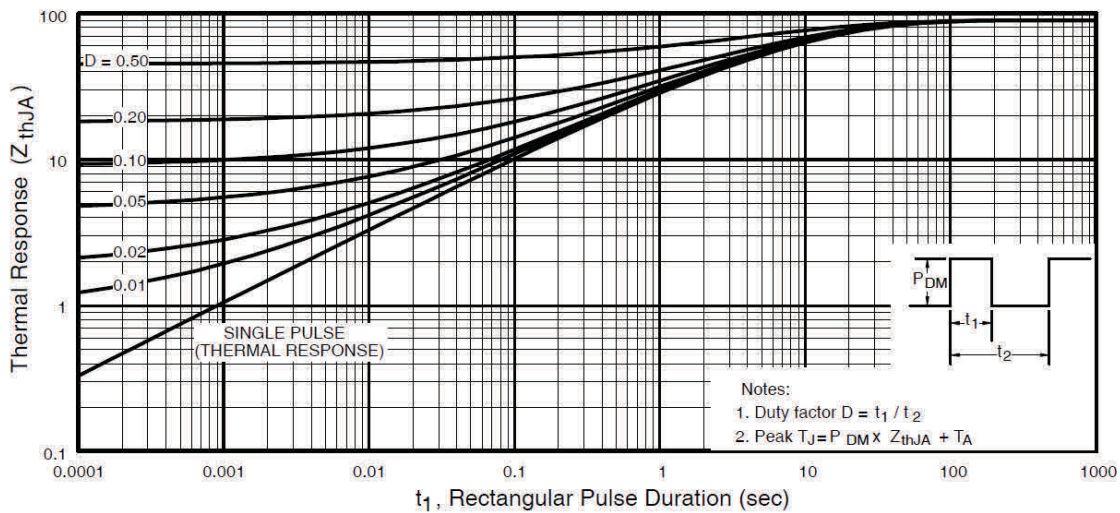


Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

**P-Channel
Q2, Q4**

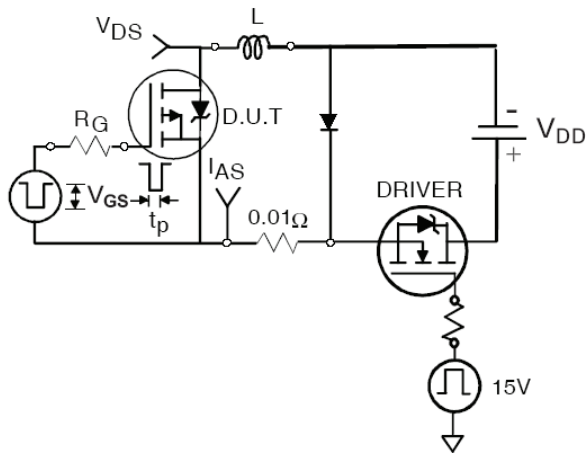


Fig 12a. Unclamped Inductive Test Circuit

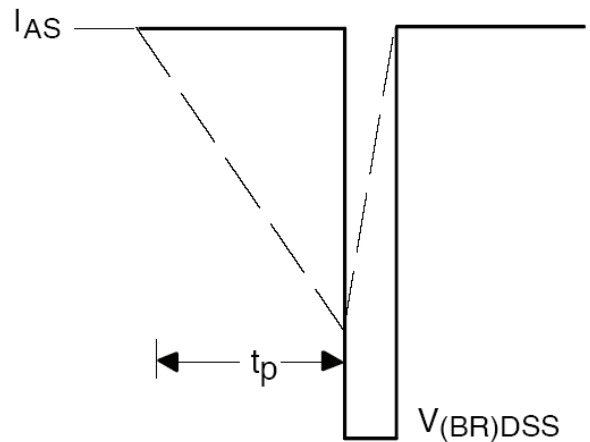


Fig 12b. Unclamped Inductive Waveforms

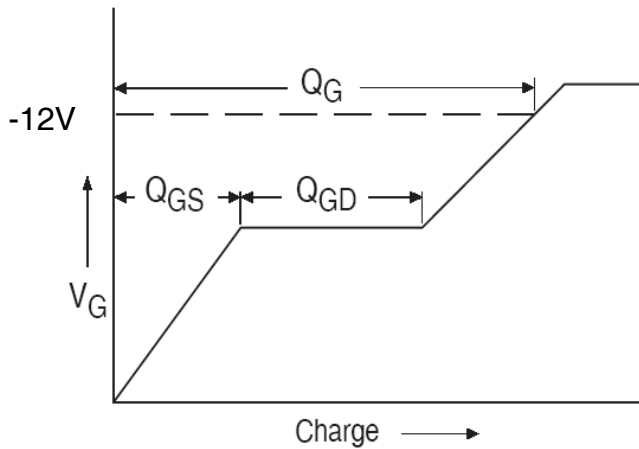


Fig 13a. Basic Gate Charge Waveform

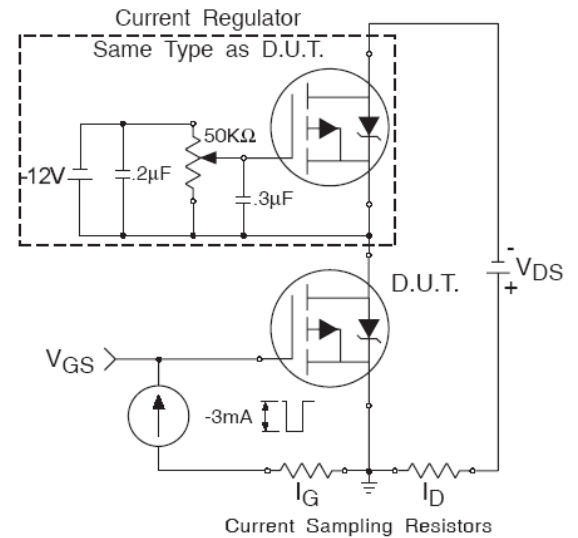


Fig 13b. Gate Charge Test Circuit

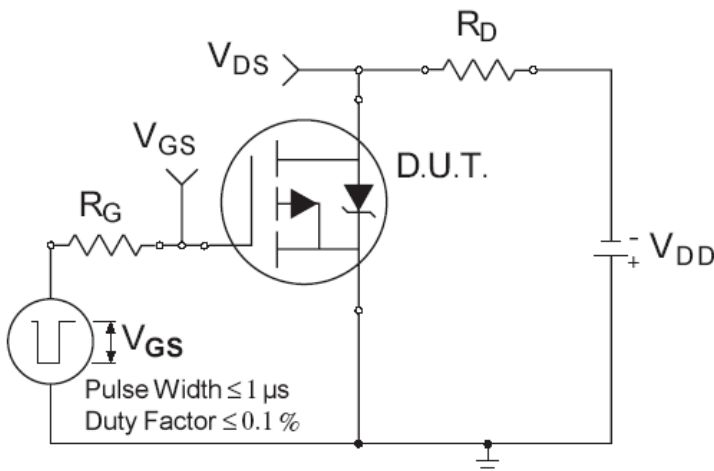


Fig 14a. Switching Time Test Circuit

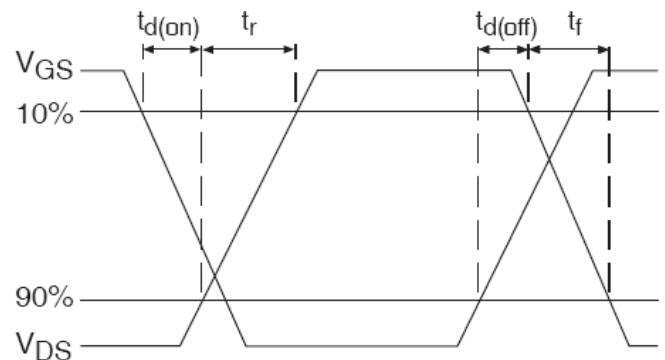
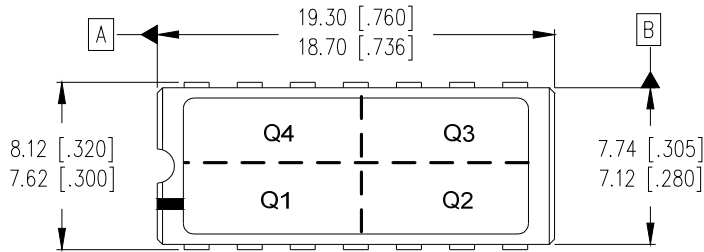
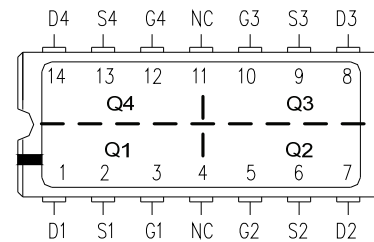


Fig 14b. Switching Time Waveforms

Case Outline and Dimensions — MO-036AB



LEAD ASSIGNMENTS



LEGEND

G = GATE
D = DRAIN

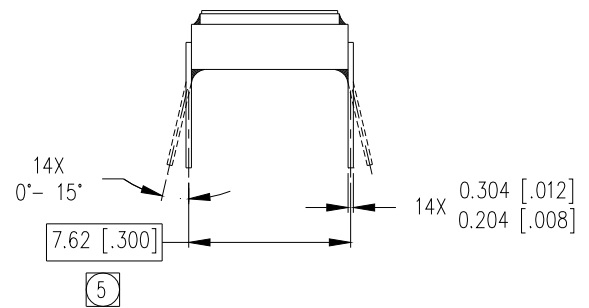
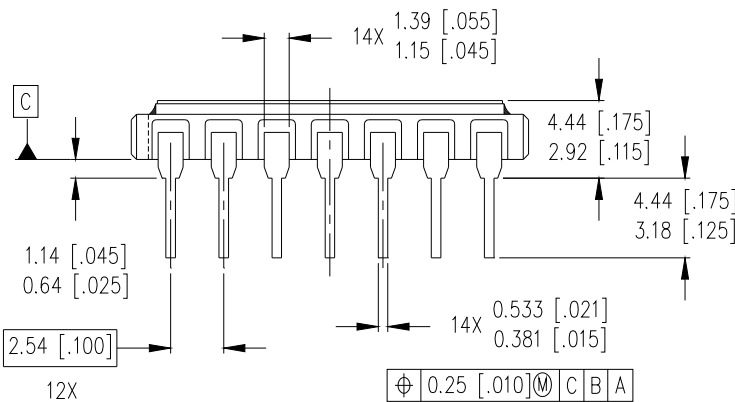
S = SOURCE

NC = NO CONNECTION

CHANNELS

N CH = Q1, Q3

P CH = Q2, Q4



NOTES:

1. DIMENSIONING & TOLERANCING PER ASME Y14.5M-1994.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSIONS ARE SHOWN IN MILLIMETERS [INCHES].
4. OUTLINE CONFORMS TO JEDEC OUTLINE MO-036AB.

⑤ MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO DATUM PLANE C.

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