

IRHMS9A97160 (JANSR2N7665T1)

PD-97983A

Radiation Hardened Power MOSFET Thru-Hole (TO-254AA Low Ohmic) 100V, 45A, P-channel, R9 Superjunction Technology

Features

- Single event effect (SEE) hardened (up to LET of 91MeV·cm²/mg)
- Low $R_{DS(on)}$
- Improved SOA for linear mode operation
- Fast switching
- Low total gate charge
- Simple drive requirements
- Hermetically sealed
- Electrically isolated
- Ceramic eyelets
- Light weight
- ESD rating: Class 3B per MIL-STD-750, Method 1020

Potential Applications

- DC-DC converter
- Motor drives
- Protection circuits

Product Validation

Qualified according to MIL-PRF-19500 for space applications

Description

IR HiRel R9 technology provides superior power MOSFETs for space applications. This family of p-channel MOSFETs are the first radiation hardened devices that are based on a superjunction technology. These devices have improved immunity to Single Event Effect (SEE) and have been characterized for useful performance with Linear Energy Transfer (LET) up to 91MeV·cm²/mg. Their combination of low $R_{DS(on)}$ and improved SOA allows for better performance in applications such as Latching Current Limiters (LCL), Solid-State Power Controllers (SSPC) or DC-DC converters. These devices retain all of the well-established advantages of MOSFETs such as voltage control, fast switching and temperature stability of electrical parameters.

Ordering Information

Table 1 Ordering options

Part number	Package	Screening Level	TID Level
IRHMS9A97160	Low-Ohmic TO-254AA	COTS	100 krad (Si)
JANSR2N7665T1	Low-Ohmic TO-254AA	JANS	100 krad (Si)
IRHMS9A93160	Low-Ohmic TO-254AA	COTS	300 krad (Si)
JANSF2N7665T1	Low-Ohmic TO-254AA	JANS	300 krad (Si)

Product Summary

- B_{VDS} : -100V
- I_D : -45A*
- $R_{DS(on), max}$: 19.5mΩ
- $Q_G max$: 230nC
- REF: MIL-PRF-19500/791



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Absolute Maximum Ratings

1 Absolute Maximum Ratings

Table 2 Absolute Maximum Ratings (Pre-Irradiation)

Symbol	Parameter	Value	Unit
$I_{D1} @ V_{GS} = -12V, T_C = 25^{\circ}C$	Continuous Drain Current	- 45*	A
$I_{D2} @ V_{GS} = -12V, T_C = 100^{\circ}C$	Continuous Drain Current	- 45*	A
$I_{DM} @ T_C = 25^{\circ}C$	Pulsed Drain Current ¹	-180	A
$P_D @ T_C = 25^{\circ}C$	Maximum Power Dissipation	208	W
	Linear Derating Factor	1.7	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
E_{AS}	Single Pulse Avalanche Energy ²	4556	mJ
I_{AR}	Avalanche Current ¹	-45	A
E_{AR}	Repetitive Avalanche Energy ¹	20.8	mJ
dv/dt	Peak Diode Reverse Recovery ³	6.1	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Lead Temperature	300 (0.063 in. /1.6 mm from case for 10s)	
	Weight	9.3 (Typical)	g

*Current is limited by package

¹ Repetitive Rating; Pulse width limited by maximum junction temperature.² $V_{DD} = -100V$, starting $T_J = 25^{\circ}C$, $L = 4.5mH$, Peak $I_L = -45A$, $V_{GS} = -20V$ ³ $I_{SD} \leq -45A$, $di/dt \leq -360A/\mu s$, $V_{DD} \leq -100V$, $T_J \leq 150^{\circ}C$

Device Characteristics

2 Device Characteristics

2.1 Electrical Characteristics (Pre-Irradiation)

Table 3 Static and Dynamic Electrical Characteristics @ $T_j = 25^\circ\text{C}$ (Unless Otherwise Specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit	Test Conditions
BV_{DSS}	Drain-to-Source Breakdown Voltage	-100	—	—	V	$V_{GS} = 0V, I_D = -1.0mA$
$\Delta BV_{DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	-0.12	—	V/ $^\circ\text{C}$	Reference to 25°C , $I_D = -1.0mA$
$R_{DS(on)}$	Static Drain-to-Source On-State Resistance	—	—	19.5	m Ω	$V_{GS} = -12V, I_{D2} = -45A^1$
$V_{GS(th)}$	Gate Threshold Voltage	-2.0	—	-4.0	V	$V_{DS} \geq V_{GS}, I_D = -5mA$
$\Delta V_{GS(th)}/\Delta T_J$	Gate Threshold Voltage Coefficient	—	6.0	—	mV/ $^\circ\text{C}$	
G_{fs}	Forward Transconductance	32	—	—	S	$V_{DS} = -15V, I_{D2} = -45A^1$
I_{DSS}	Zero Gate Voltage Drain Current	—	—	-10	μA	$V_{DS} = -80V, V_{GS} = 0V$
		—	—	-25		$V_{DS} = -80V, V_{GS} = 0V, T_J = 125^\circ\text{C}$
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	—	—	230	nC	$I_{D1} = -45A$
Q_{GS}	Gate-to-Source Charge	—	—	65		$V_{DS} = -50V$
Q_{GD}	Gate-to-Drain ('Miller') Charge	—	—	40		$V_{GS} = -12V$
$t_{d(on)}$	Turn-On Delay Time	—	—	32	ns	$I_{D1} = -45A^{**}$ $V_{DD} = -50V$ $R_G = 2.4\Omega$ $V_{GS} = -12V$
t_r	Rise Time	—	—	69		
$t_{d(off)}$	Turn-Off Delay Time	—	—	266		
t_f	Fall Time	—	—	116		
$L_s + L_D$	Total Inductance	—	6.8	—	nH	Measured from Drain lead (6mm / 0.25in from package) to Source lead (6mm / 0.25in from package) with Source wire internally bonded from Source pin to Drain pad
C_{iss}	Input Capacitance	—	12140	—	pF	$V_{GS} = 0V$
C_{oss}	Output Capacitance	—	2420	—		$V_{DS} = -25V$
C_{rss}	Reverse Transfer Capacitance	—	60	—		$f = 100KHz$
R_G	Gate Resistance	—	3.2	—	Ω	$f = 1.0MHz$, open drain

** Switching speed maximum limits are based on manufacturing test equipment and capability.

¹ Pulse width $\leq 300 \mu s$; Duty Cycle $\leq 2\%$

Device Characteristics

2.2 Source-Drain Diode Ratings and Characteristics (Pre-Irradiation)

Table 4 Source-Drain Diode Characteristics

Symbol	Parameter	Min.	Typ.	Max.	Unit	Test Conditions
I _S	Continuous Source Current (Body Diode)	—	—	- 45	A	
I _{SM}	Pulsed Source Current (Body Diode) ¹	—	—	- 180	A	
V _{SD}	Diode Forward Voltage	—	—	-1.3	V	T _J = 25°C, I _S = - 45A, V _{GS} = 0V ²
t _{rr}	Reverse Recovery Time	—	128	192	ns	T _J = 25°C, I _F = -45A, V _{DD} ≤ -25V di/dt = -100A/μs
Q _{rr}	Reverse Recovery Charge	—	670	—	nC	
t _{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L _S +L _D)				

2.3 Thermal Characteristics

Table 5 Thermal Resistance

Symbol	Parameter	Min.	Typ.	Max.	Unit
$R_{\theta JC}$	Junction-to-Case	—	—	0.6	$^\circ\text{C}/\text{W}$
$R_{\theta CS}$	Junction-to-Sink	—	0.21	—	
$R_{\theta JA}$	Junction-to-Ambient (Typical socket mount)	—	—	48	

2.4 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 3 and 4) 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.

2.4.1 Electrical Characteristics — Post Total Dose Irradiation

Table 6 Electrical Characteristics @ $T_J = 25^\circ\text{C}$, Post Total Dose Irradiation ^{3, 4}

Symbol	Parameter	Up to 300 krad (Si) ⁵		Unit	Test Conditions
		Min.	Max.		
BV_{DSS}	Drain-to-Source Breakdown Voltage	-100	—	V	$V_{GS} = 0\text{V}$, $I_D = -1.0\text{mA}$
$V_{GS(th)}$	Gate Threshold Voltage	-2.0	-4.0	V	$V_{DS} \geq V_{GS}$, $I_D = -5.0\text{mA}$
I_{GSS}	Gate-to-Source Leakage Forward	—	-100	nA	$V_{GS} = -20\text{V}$
	Gate-to-Source Leakage Reverse	—	100		$V_{GS} = 20\text{V}$
I_{DSS}	Zero Gate Voltage Drain Current	—	-10	μA	$V_{DS} = -80\text{V}$, $V_{GS} = 0\text{V}$
$R_{DS(on)}$	Static Drain-to-Source On-State Resistance (TO-3) ²	—	18	$\text{m}\Omega$	$V_{GS} = -12\text{V}$, $I_{D2} = -45\text{A}$
$R_{DS(on)}$	Static Drain-to-Source On-State Resistance (TO-254AA) ²	—	19.5	$\text{m}\Omega$	$V_{GS} = -12\text{V}$, $I_{D2} = -45\text{A}$
V_{SD}	Diode Forward Voltage	—	-1.3	V	$V_{GS} = 0\text{V}$, $I_F = -45\text{A}$

¹ Repetitive Rating; Pulse width limited by maximum junction temperature.

² Pulse width $\leq 300 \mu\text{s}$; Duty Cycle $\leq 2\%$

³ Total Dose Irradiation with V_{GS} Bias. $V_{GS} = -12\text{V}$ applied and $V_{DS} = 0$ during irradiation per MIL-STD-750, Method 1019, condition A.

⁴ Total Dose Irradiation with V_{DS} Bias. $V_{DS} = -80\text{V}$ applied and $V_{GS} = 0$ during irradiation per MIL-STD-750, Method 1019, condition A.

⁵ Part numbers IRHMS9A97160 (JANSR2N7665T1) and IRHMS9A93160 (JANSF2N7665T1)

IRHMS9A97160 (JANSR2N7665T1)

Radiation Hardened Power MOSFET Thru-Hole (TO-254AA Low Ohmic)

Device Characteristics

2.4.2 Single Event Effects — Safe Operating Area

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. 1 and Table 7.

Table 7 Typical Single Event Effects Safe Operating Area

LET (MeV·cm ² /mg)	Energy (MeV)	Range (μm)	V _{DS} (V)			
			V _{GS} = 0V	V _{GS} = 3V	V _{GS} = 5V	V _{GS} = 10V
38.3 ± 5%	348 ± 5%	42.7 ± 7.5%	-100	-100	-100	-100
62.0 ± 10%	642 ± 10%	52.8 ± 5%	-100	-100	-100	—
91.0 ± 5%	1350 ± 7.5%	74.2 ± 5%	-100	-100	—	—

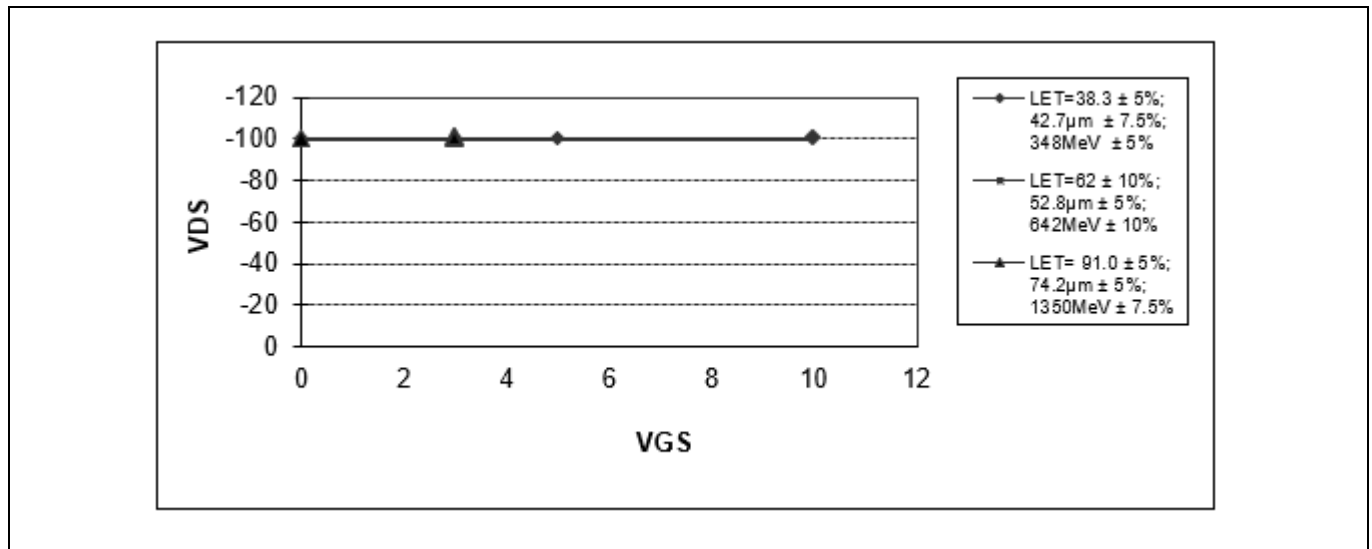


Figure 1 Typical Single Event Effect, Safe Operating Area

IRHMS9A97160 (JANSR2N7665T1)

Radiation Hardened Power MOSFET Thru-Hole (TO-254AA Low Ohmic)

Electrical Characteristics Curves (Pre-irradiation)

3 Electrical Characteristics Curves (Pre-irradiation)

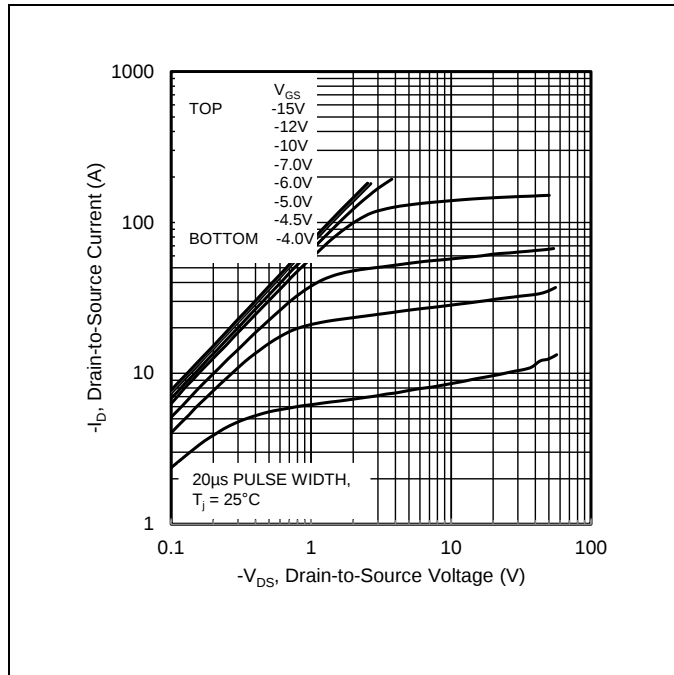


Figure 2 Typical Output Characteristics

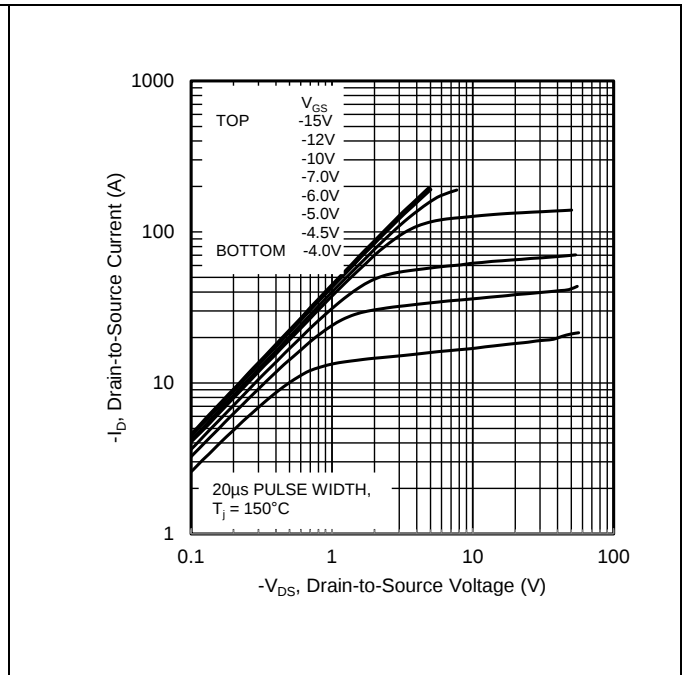


Figure 3 Typical Output Characteristics

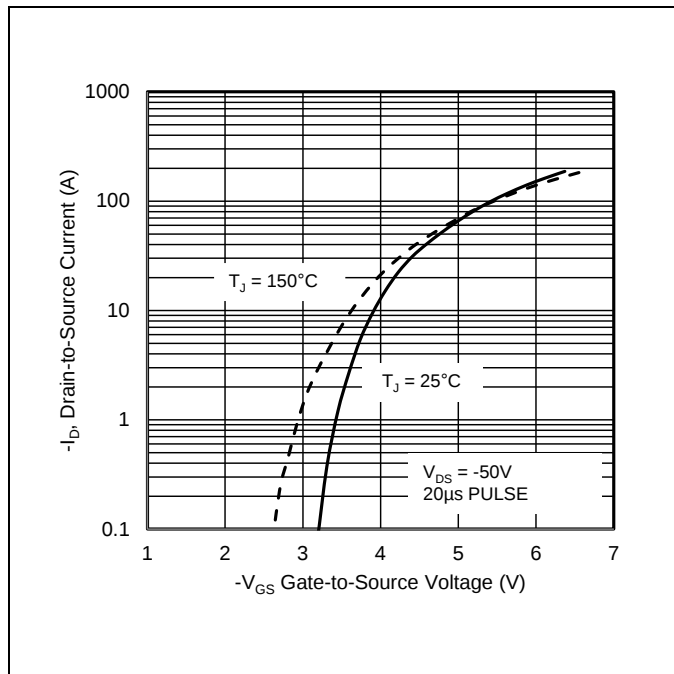


Figure 4 Typical Transfer Characteristics

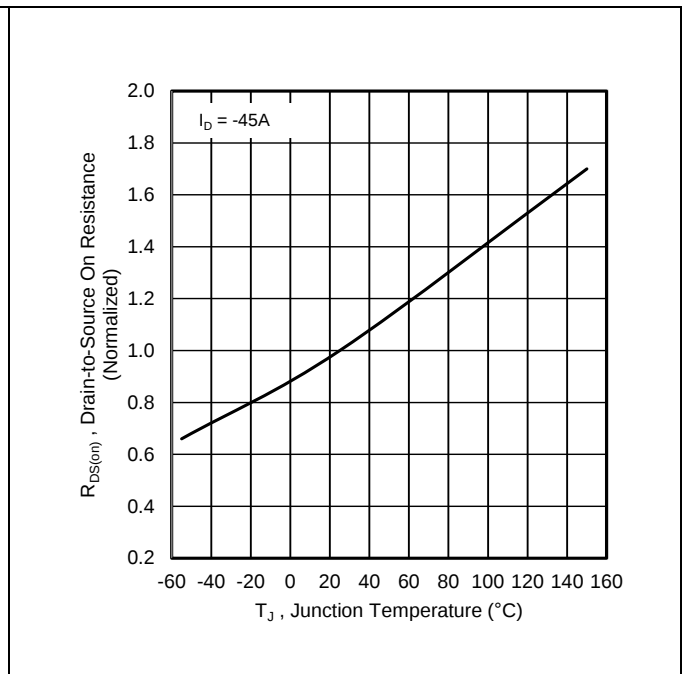


Figure 5 Normalized On-Resistance Vs. Temperature

IRHMS9A97160 (JANSR2N7665T1)

Radiation Hardened Power MOSFET Thru-Hole (TO-254AA Low Ohmic)

Electrical Characteristics Curves (Pre-irradiation)

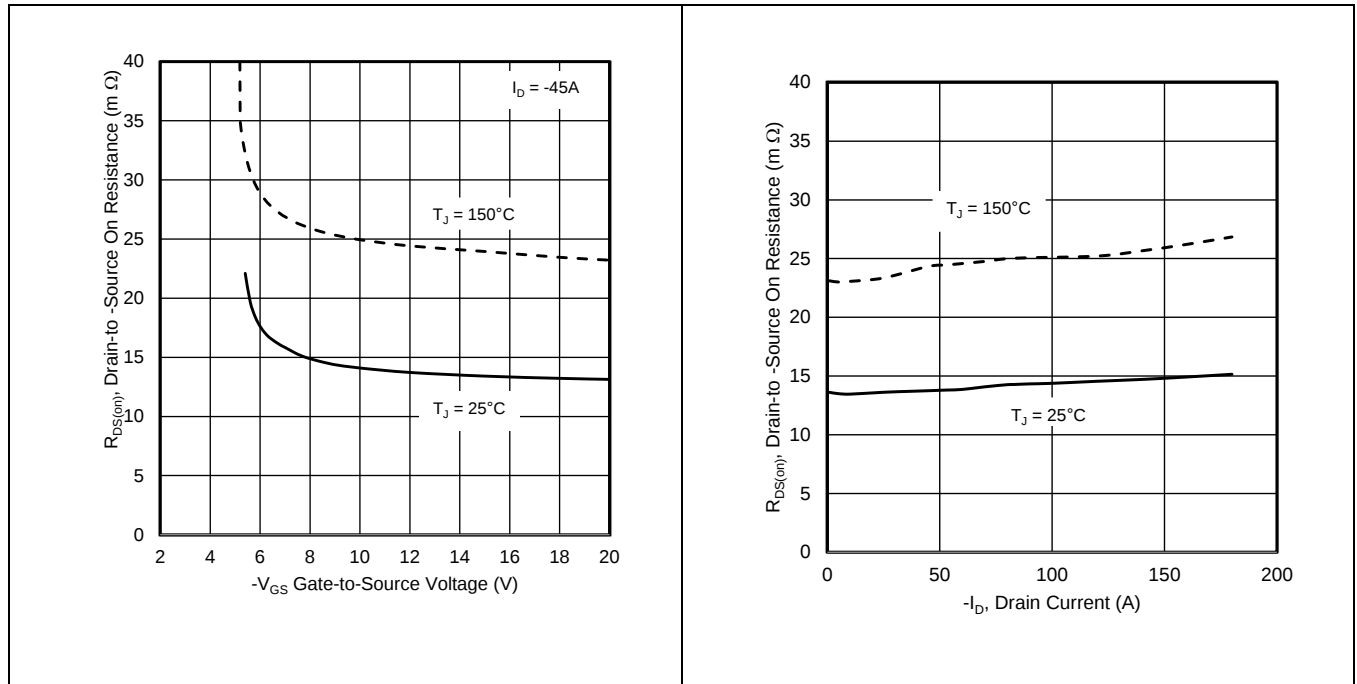


Figure 6 Typical On-Resistance Vs Gate Voltage

Figure 7 Typical On-Resistance Vs Drain Current

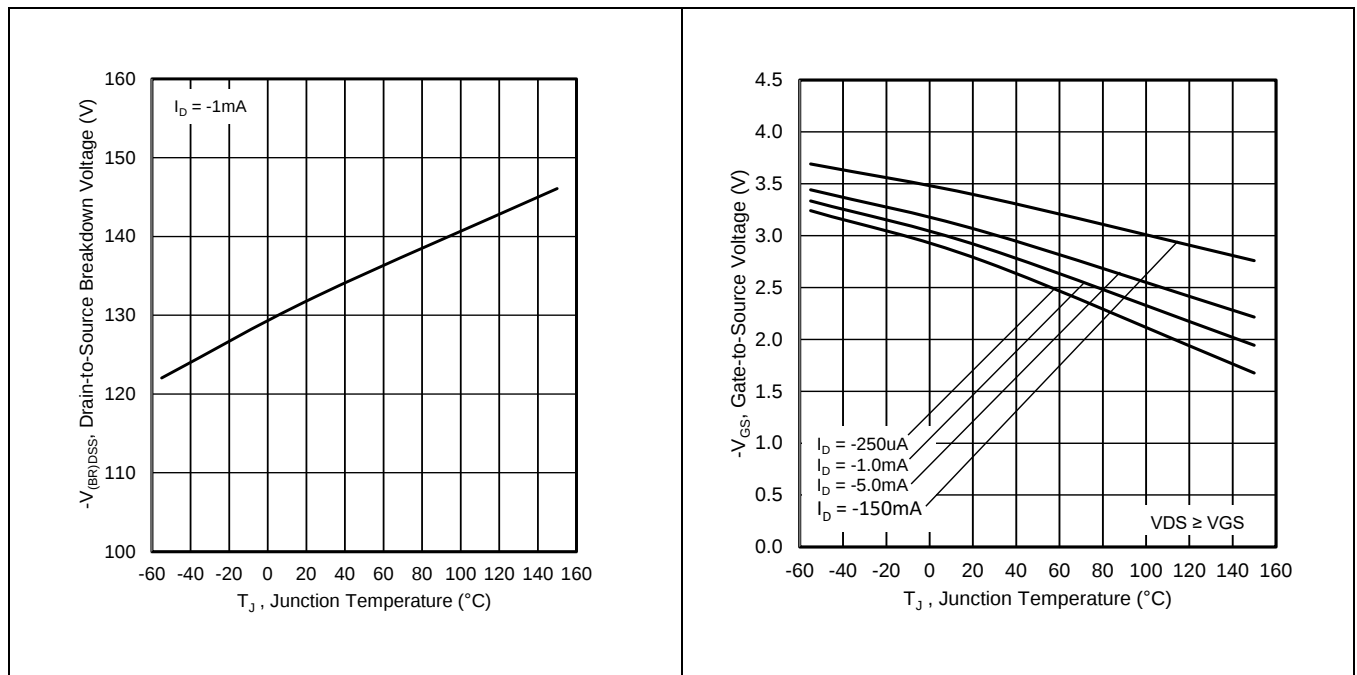


Figure 8 Typical Drain-to-Source Breakdown Voltage Vs. Temperature

Figure 9 Typical Gate-to-Source Voltage Vs. Temperature

IRHMS9A97160 (JANSR2N7665T1)

Radiation Hardened Power MOSFET Thru-Hole (TO-254AA Low Ohmic)

Electrical Characteristics Curves (Pre-irradiation)

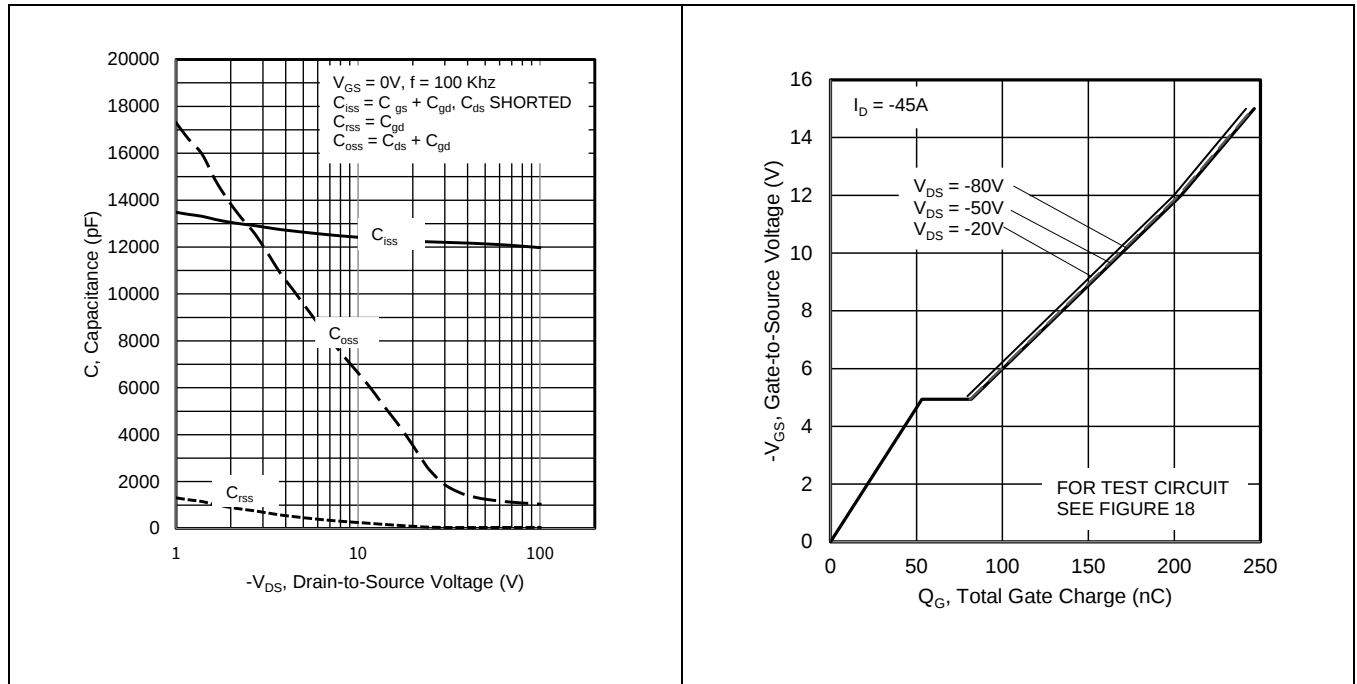


Figure 10 Typical Capacitance Vs. Drain-to-Source Voltage

Figure 11 Gate-to-Source Voltage Vs. Typical Gate Charge

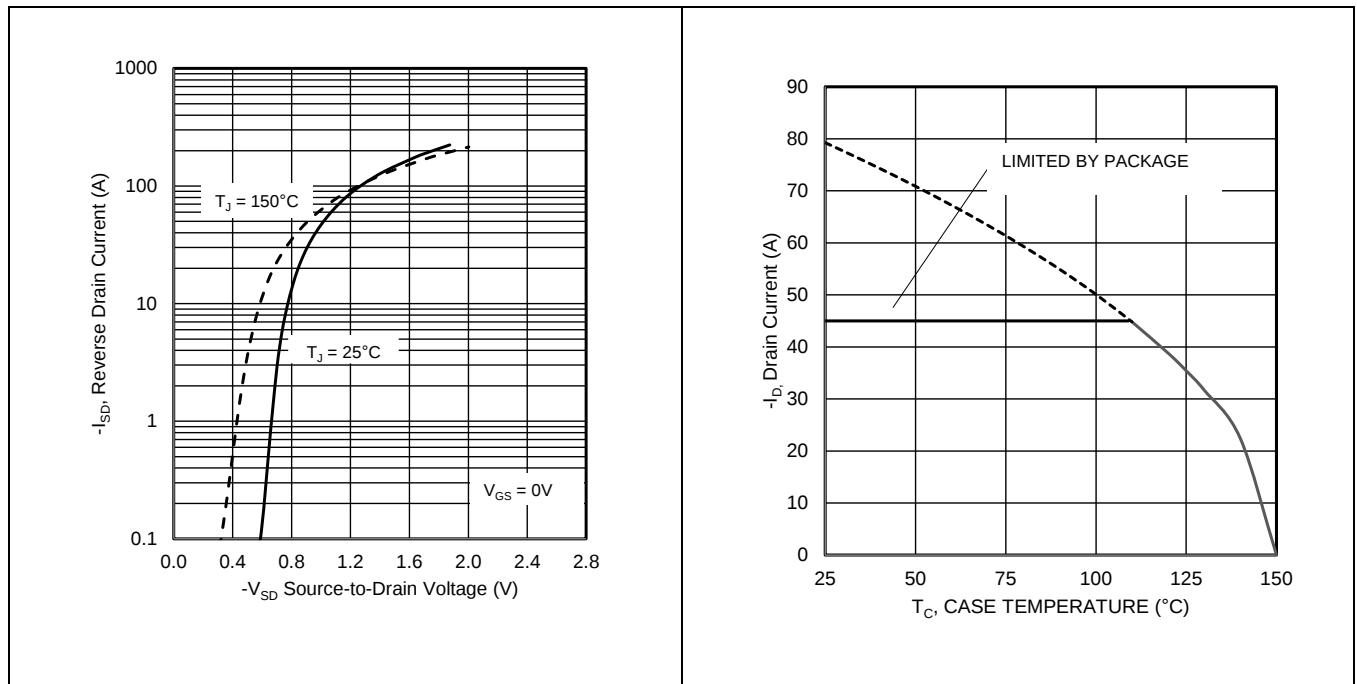


Figure 12 Typical Source-Drain Current Vs. Diode Forward Voltage

Figure 13 Maximum Drain Current Vs. Temperature

IRHMS9A97160 (JANSR2N7665T1)

Radiation Hardened Power MOSFET Thru-Hole (TO-254AA Low Ohmic)

Electrical Characteristics Curves (Pre-irradiation)

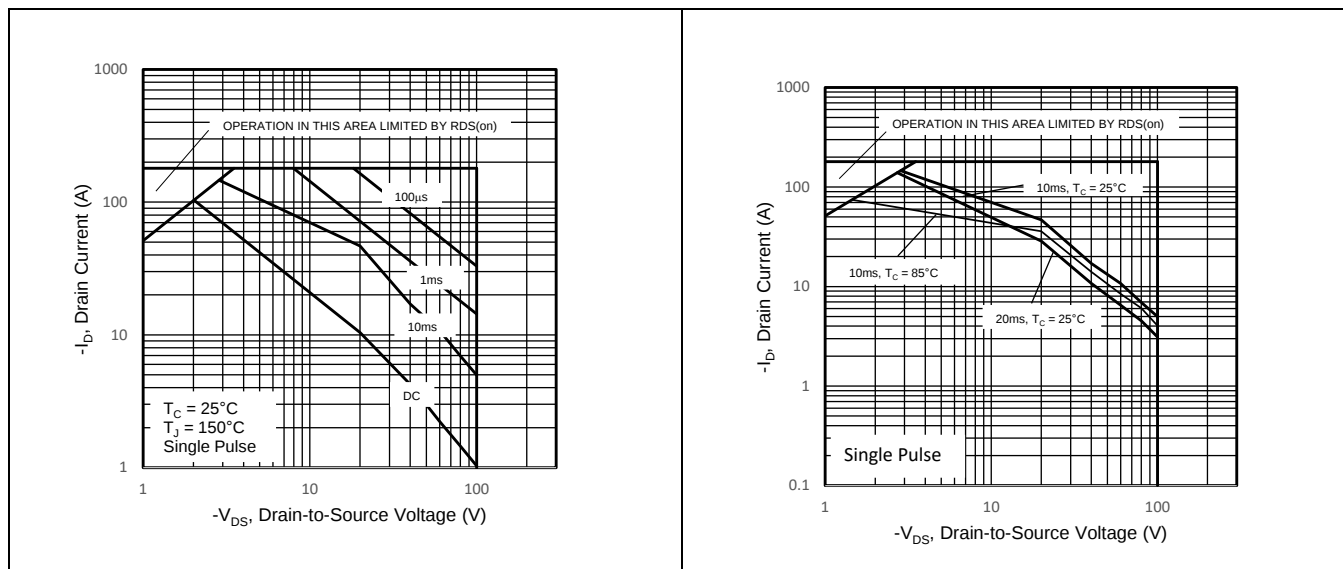


Figure 14 Maximum Safe Operating Area

Figure 15 Maximum Safe Operating Area

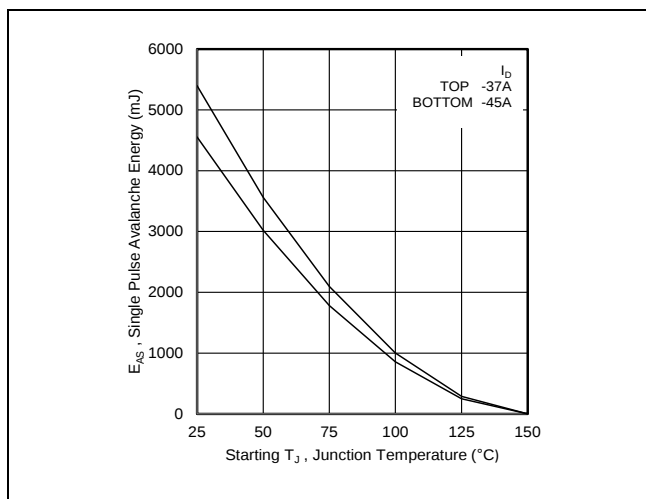


Figure 16 Maximum Avalanche Energy Vs. Junction Temperature

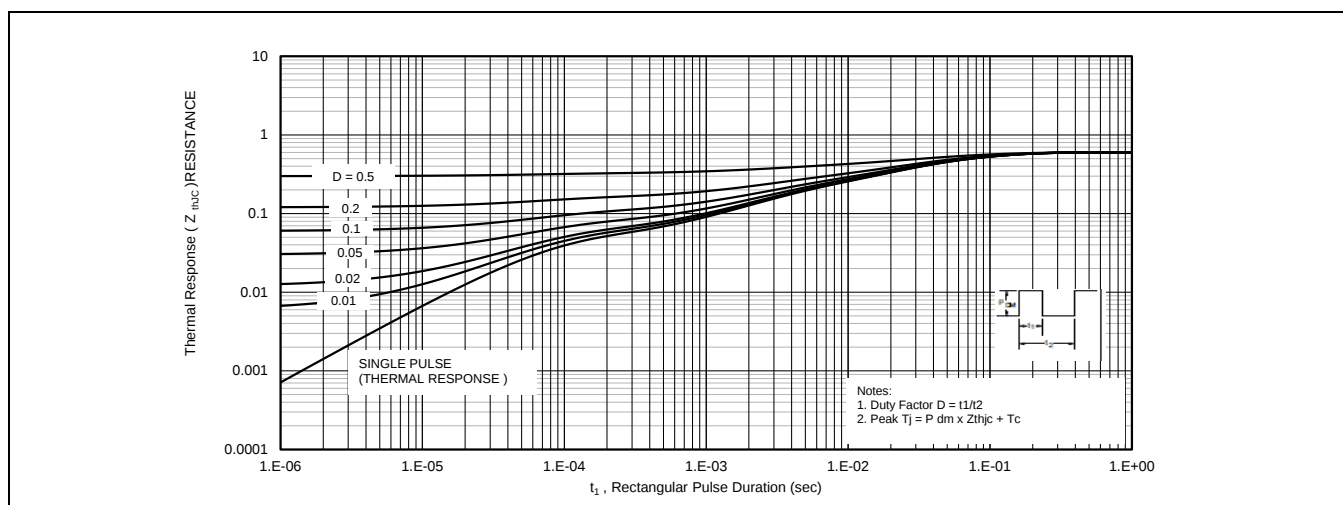


Figure 17 Maximum Effective Transient Thermal Impedance, Junction-to-Case

IRHMS9A97160 (JANSR2N7665T1)

Radiation Hardened Power MOSFET Thru-Hole (TO-254AA Low Ohmic)

Test Circuits (Pre-irradiation)

4 Test Circuits (Pre-irradiation)

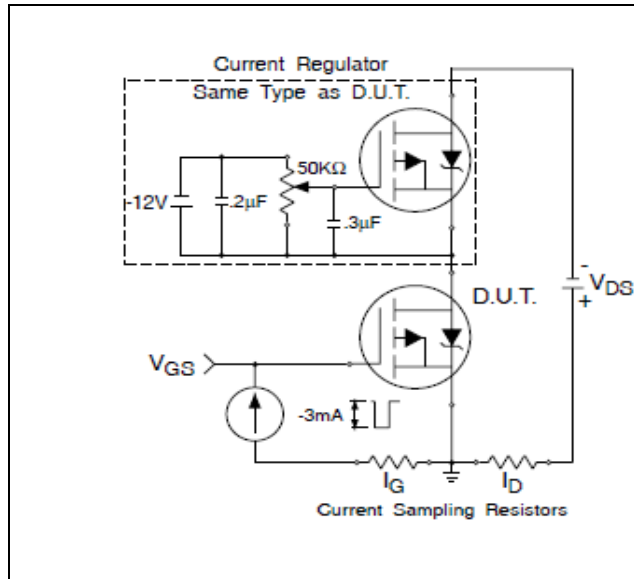


Figure 18 Gate Charge Test Circuit

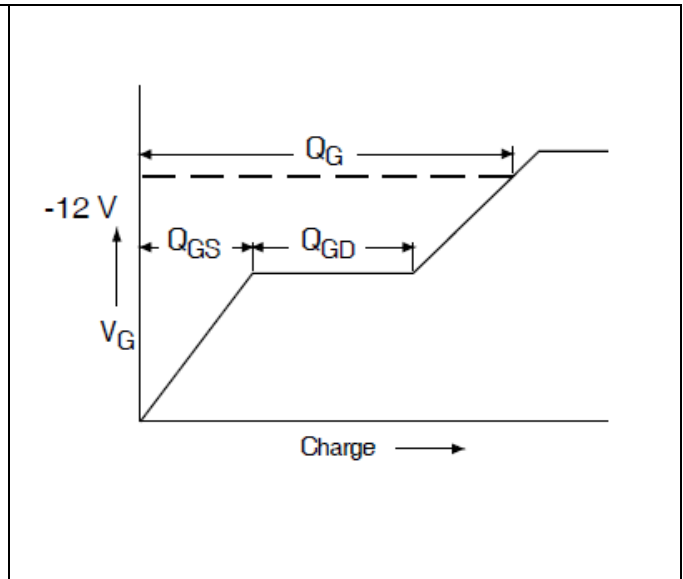


Figure 19 Gate Charge Waveform

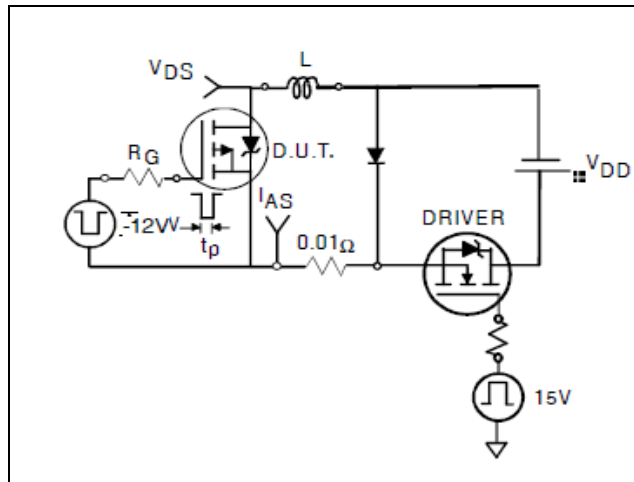


Figure 20 Unclamped Inductive Test Circuit

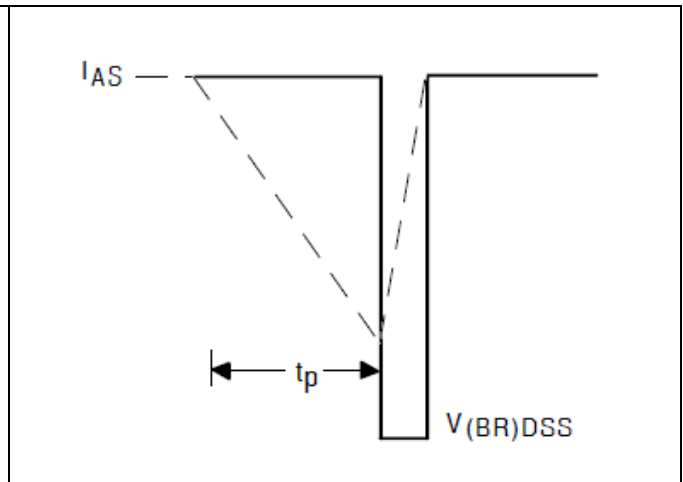


Figure 21 Unclamped Inductive Waveform

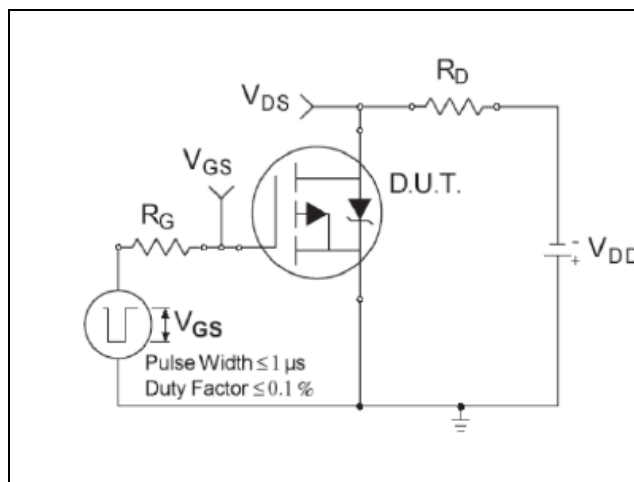


Figure 22 Switching Time Test Circuit

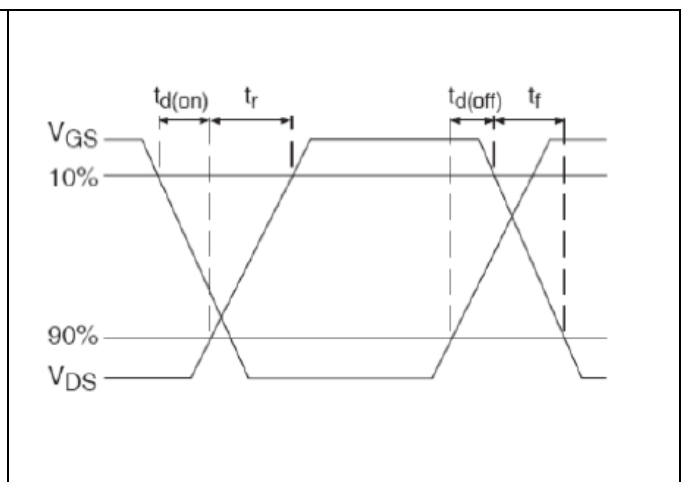


Figure 23 Switching Time Waveforms

Revision history**Revision history**

Document version	Date of release	Description of changes
	03/21/2023	Preliminary datasheet with PPD number (PPD-97983)
Rev A	06/13/2023	Final datasheet with PD number (PD-97983A)

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