

# IRHNKC9A97034 (JANSR2N7659U3CE)

PD-97997B

## Radiation Hardened Power MOSFET Surface Mount (SMD-0.5e Ceramic Lid) -60V, -32A, P-channel, R9 Superjunction Technology

### Features

- Single event effect (SEE) hardened (up to LET of 91.3 MeV·cm<sup>2</sup>/mg)
- Low R<sub>DS(on)</sub>
- Rugged SOA
- Improved Avalanche Energy
- Simple drive requirements
- Hermetically sealed
- Ceramic package
- Light weight
- Surface mount
- ESD rating: Class 2 per MIL-STD-750, Method 1020

### Product Summary

- **BV<sub>DSS</sub>**: -60V
- **I<sub>D</sub>**: -32A
- **R<sub>DS(on),max</sub>**: 45mΩ
- **Q<sub>Gmax</sub>**: 48nC
- **REF**: MIL-PRF-19500/780



### Potential Applications

- Power distribution
- Latching current limiter
- Motor drives
- DC-DC converter

### Product Validation

Qualified according to MIL-PRF-19500 for space applications

### Description

IR HiRel R9 technology provides superior power MOSFETs for space applications. These devices have improved immunity to Single Event Effect (SEE) and have been characterized for useful performance with Linear Energy Transfer (LET) up to 91.3 MeV·cm<sup>2</sup>/mg. Their combination of low R<sub>DS(on)</sub> and improved SOA will allow for better performance in applications such as Latching Current Limiters or Solid-State Power Controllers. 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
IRHNKC9A97034	SMD-0.5e (Ceramic Lid)	COTS	100 krad(Si)
JANSR2N7659U3CE	SMD-0.5e (Ceramic Lid)	JANS	100 krad(Si)
IRHNKC9A93034	SMD-0.5e (Ceramic Lid)	COTS	300 krad(Si)
JANSF2N7659U3CE	SMD-0.5e (Ceramic Lid)	JANS	300 krad(Si)

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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	-32	A
$I_{D2} @ V_{GS} = -12V, T_C = 100^\circ C$	Continuous Drain Current	-20	A
$I_{DM} @ T_C = 25^\circ C$	Pulsed Drain Current <sup>1</sup>	-128	A
$P_D @ T_C = 25^\circ C$	Maximum Power Dissipation	75	W
	Linear Derating Factor	0.6	W/°C
$V_{GS}$	Gate-to-Source Voltage	± 20	V
$E_{AS}$	Single Pulse Avalanche Energy <sup>2</sup>	1200	mJ
$I_{AR}$	Avalanche Current <sup>1</sup>	-20	A
$E_{AR}$	Repetitive Avalanche Energy <sup>1</sup>	7.5	mJ
dv/dt	Peak Diode Reverse Recovery <sup>3</sup>	-9.7	V/ns
$T_J$ $T_{STG}$	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Lead Temperature	300 (for 5s)	
	Weight	1.0 (Typical)	g

<sup>1</sup> Repetitive Rating; Pulse width limited by maximum junction temperature.

<sup>2</sup>  $V_{DD} = -60V$ , starting  $T_J = 25^\circ C$ ,  $L = 6mH$ , Peak  $I_L = -20A$ ,  $V_{GS} = -20V$

<sup>3</sup>  $I_{SD} \leq -32A$ ,  $di/dt \leq -885A/\mu s$ ,  $V_{DD} \leq -60V$ ,  $T_J \leq 150^\circ C$

**Device Characteristics**

**2 Device Characteristics**

**2.1 Electrical Characteristics (Pre-Irradiation)**

**Table 3 Static and Dynamic Electrical Characteristics @ T<sub>j</sub> = 25°C (Unless Otherwise Specified)**

Symbol	Parameter	Min.	Typ.	Max.	Unit	Test Conditions
BV <sub>DSS</sub>	Drain-to-Source Breakdown Voltage	-60	—	—	V	V <sub>GS</sub> = 0V, I <sub>D</sub> = -1.0mA
ΔBV <sub>DSS</sub> /ΔT <sub>J</sub>	Breakdown Voltage Temp. Coefficient	—	0.07	—	V/°C	Reference to 25°C, I <sub>D</sub> = -1.0mA
R <sub>DS(on)</sub>	Static Drain-to-Source On-State Resistance	—	—	45	mΩ	V <sub>GS</sub> = -12V, I <sub>D2</sub> = -20A <sup>1</sup>
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> = -1mA
ΔV <sub>GS(th)</sub> /ΔT <sub>J</sub>	Gate Threshold Voltage Coefficient	—	5.5	—	mV/°C	
G <sub>fs</sub>	Forward Transconductance	14	—	—	S	V <sub>DS</sub> = -15V, I <sub>D2</sub> = -20A <sup>1</sup>
I <sub>DSS</sub>	Zero Gate Voltage Drain Current	—	—	-10	μA	V <sub>DS</sub> = -48V, V <sub>GS</sub> = 0V
		—	—	-25		V <sub>DS</sub> = -48V, 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	—	—	48	nC	I <sub>D1</sub> = -32A
Q <sub>GS</sub>	Gate-to-Source Charge	—	—	17		V <sub>DS</sub> = -30V
Q <sub>GD</sub>	Gate-to-Drain ('Miller') Charge	—	—	14		V <sub>GS</sub> = -12V
t <sub>d(on)</sub>	Turn-On Delay Time	—	—	18	ns	I <sub>D1</sub> = -32A ** V <sub>DD</sub> = -30V R <sub>G</sub> = 7.5Ω V <sub>GS</sub> = -12V
t <sub>r</sub>	Rise Time	—	—	51		
t <sub>d(off)</sub>	Turn-Off Delay Time	—	—	75		
t <sub>f</sub>	Fall Time	—	—	44		
L <sub>S</sub> + L <sub>D</sub>	Total Inductance	—	4.0	—	nH	Measured from center of Drain pad to center of Source pad
C <sub>iss</sub>	Input Capacitance	—	2475	—	pF	V <sub>GS</sub> = 0V
C <sub>oss</sub>	Output Capacitance	—	724	—		V <sub>DS</sub> = -25V
C <sub>rss</sub>	Reverse Transfer Capacitance	—	26	—		f = 1.0MHz
R <sub>G</sub>	Gate Resistance	—	5.6	—	Ω	f = 1.0MHz, open drain

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

<sup>1</sup> Pulse width ≤ 300 μs; Duty Cycle ≤ 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)	—	—	-32	A	
$I_{SM}$	Pulsed Source Current (Body Diode) <sup>1</sup>	—	—	-128	A	
$V_{SD}$	Diode Forward Voltage	—	—	-1.3	V	$T_J = 25^\circ\text{C}$ , $I_S = -32\text{A}$ , $V_{GS} = 0\text{V}$ <sup>2</sup>
$t_{rr}$	Reverse Recovery Time	—	61	92	ns	$T_J = 25^\circ\text{C}$ , $I_F = -32\text{A}$ , $V_{DD} \leq -25\text{V}$ $di/dt = -100\text{A}/\mu\text{s}$
$Q_{rr}$	Reverse Recovery Charge	—	178	—	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	—	—	1.67	$^\circ\text{C}/\text{W}$

**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<sup>3, 4</sup>**

Symbol	Parameter	Up to 300 krad (Si) <sup>5</sup>		Unit	Test Conditions
		Min.	Max.		
$BV_{DSS}$	Drain-to-Source Breakdown Voltage	-60	—	V	$V_{GS} = 0\text{V}$ , $I_D = -1.0\text{mA}$
$V_{GS(th)}$	Gate Threshold Voltage	-2.0	-4.0	V	$V_{DS} \geq V_{GS}$ , $I_D = -1.0\text{mA}$
$I_{GSS}$	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	$\mu\text{A}$	$V_{DS} = -48\text{V}$ , $V_{GS} = 0\text{V}$
$R_{DS(on)}$	Static Drain-to-Source On-State Resistance (TO-3) <sup>2</sup>	—	46	m $\Omega$	$V_{GS} = -12\text{V}$ , $I_{D2} = -20\text{A}$
$R_{DS(on)}$	Static Drain-to-Source On-State Resistance (SMD-0.5e) <sup>2</sup>	—	45	m $\Omega$	$V_{GS} = -12\text{V}$ , $I_{D2} = -20\text{A}$
$V_{SD}$	Diode Forward Voltage	—	-1.3	V	$V_{GS} = 0\text{V}$ , $I_F = -32\text{A}$

<sup>1</sup> Repetitive Rating; Pulse width limited by maximum junction temperature.

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

<sup>3</sup> 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.

<sup>4</sup> Total Dose Irradiation with  $V_{DS}$  Bias.  $V_{DS} = -48\text{V}$  applied and  $V_{GS} = 0$  during irradiation per MIL-STD-750, Method 1019, condition A.

<sup>5</sup> Part numbers IRHNKC9A97034 (JANSR2N7659U3CE) and IRHNKC9A93034 (JANSF2N7659U3CE)

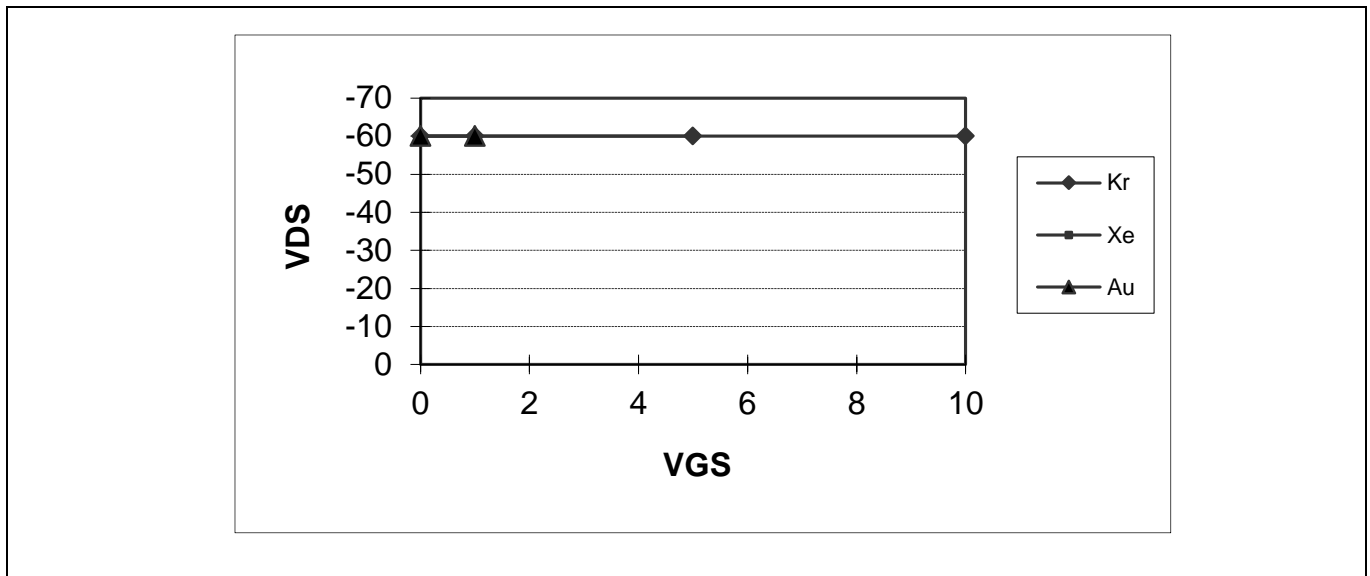
**Device Characteristics**

**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**

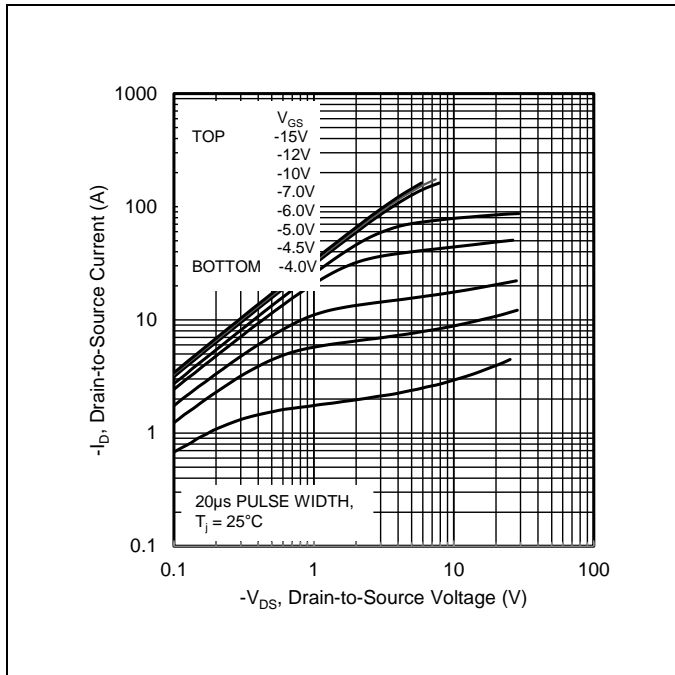
Ion	LET (MeV·cm <sup>2</sup> /mg)	Energy (MeV)	Range (μm)	V <sub>DS</sub> (V)			
				V <sub>GS</sub> = 0V	V <sub>GS</sub> = 1V	V <sub>GS</sub> = 5V	V <sub>GS</sub> = 10V
Kr	38.7	325	40.1	-60	-60	-60	-60
Xe	61.5	605	50.2	-60	-60	-60	—
Au	91.3	1295	71.6	-60	-60	—	—



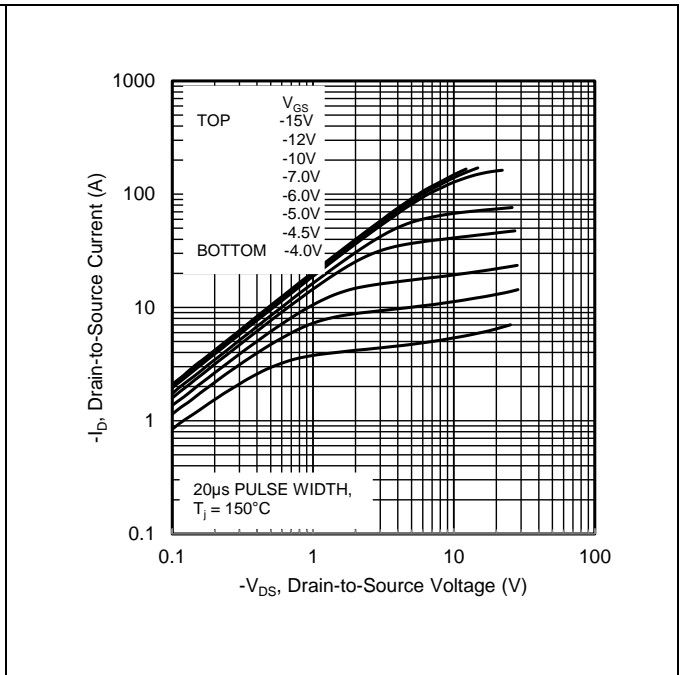
**Figure 1 Typical Single Event Effect, Safe Operating Area**

**Electrical Characteristics Curves (Pre-irradiation)**

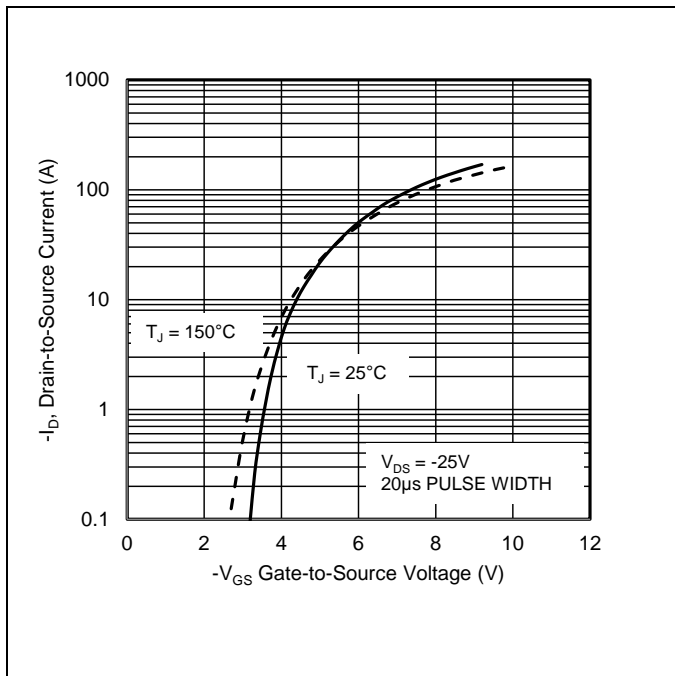
**3 Electrical Characteristics Curves (Pre-irradiation)**



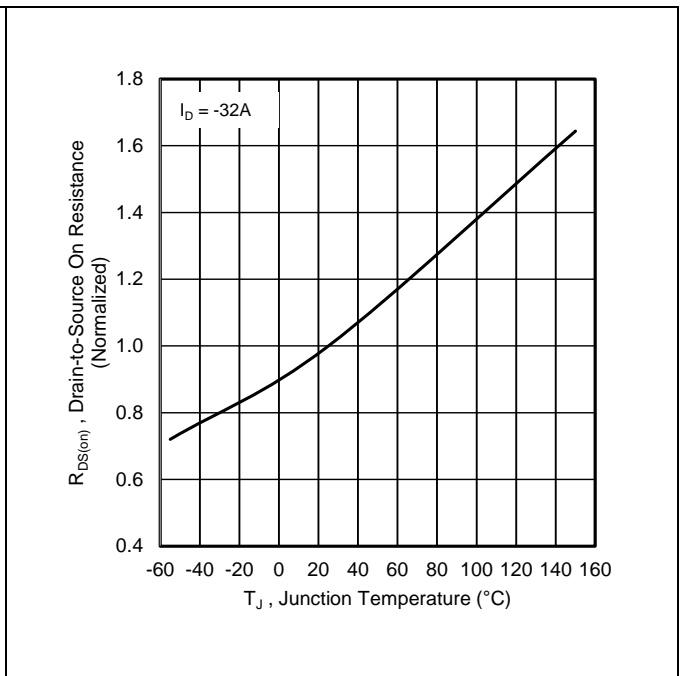
**Figure 2 Typical Output Characteristics**



**Figure 3 Typical Output Characteristics**



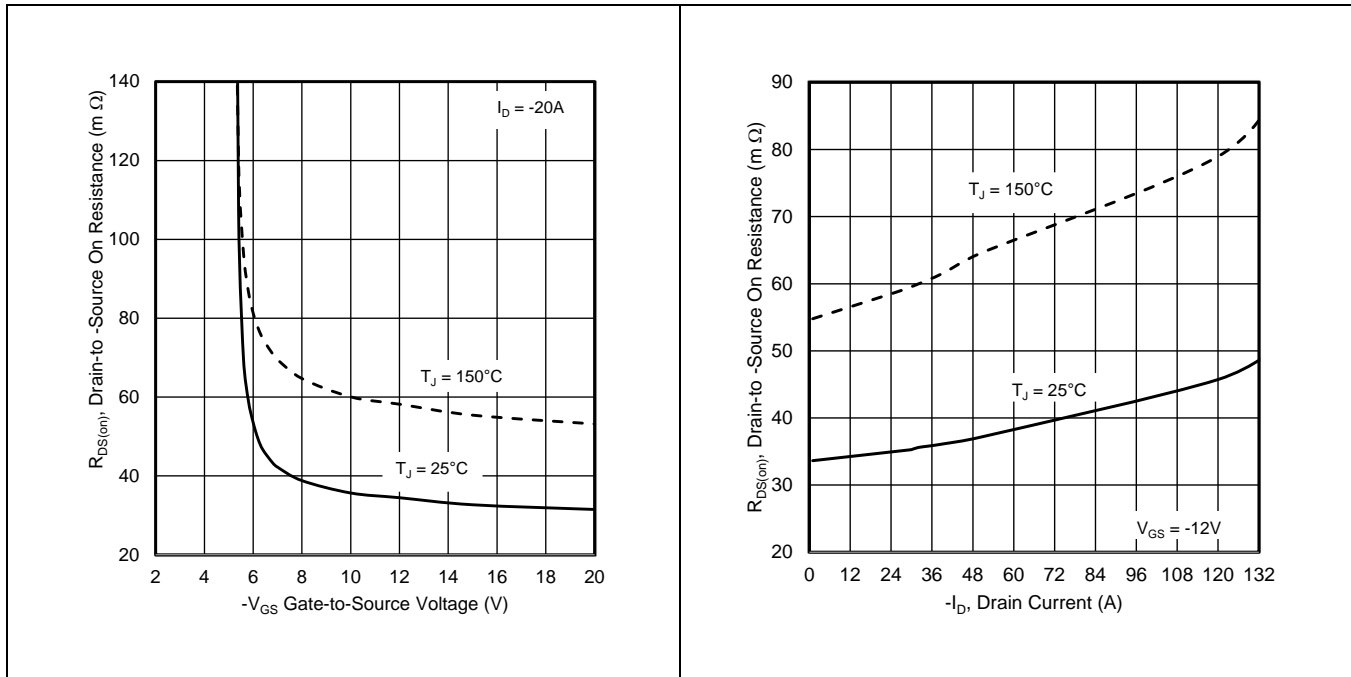
**Figure 4 Typical Transfer Characteristics**



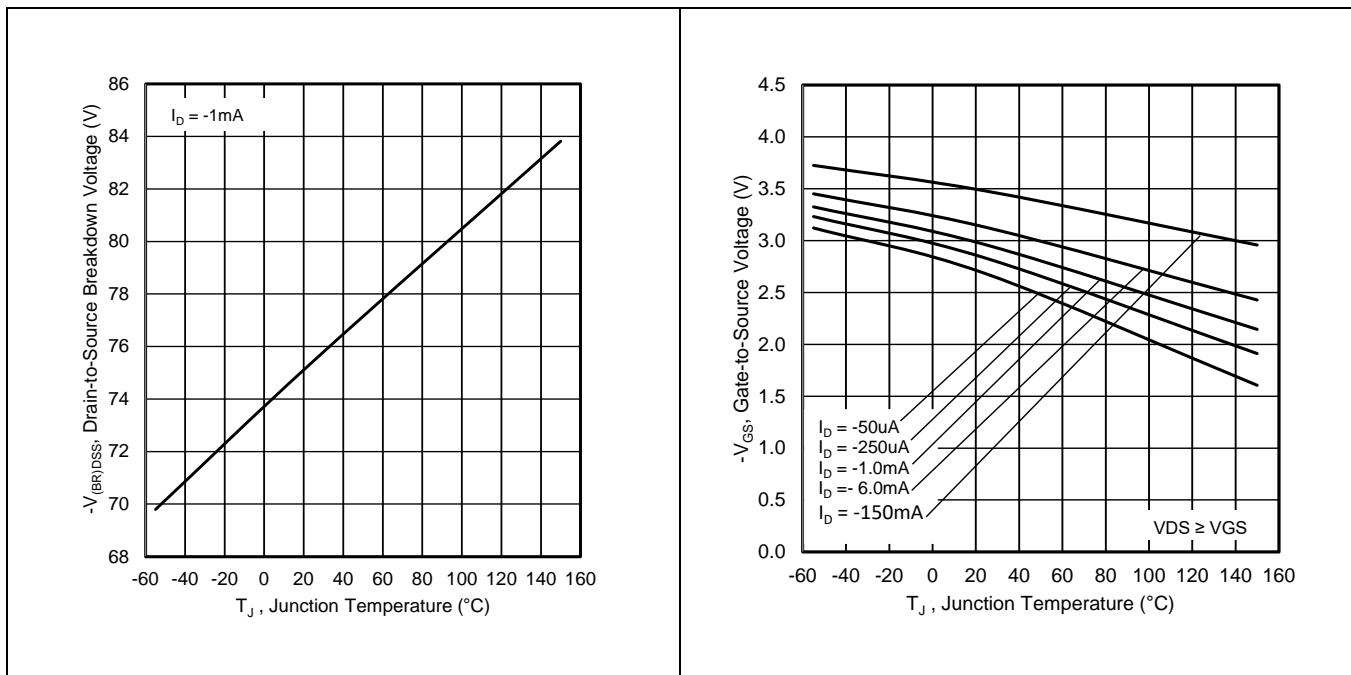
**Figure 5 Normalized On-Resistance Vs. Temperature**

**IRHNKC9A97034 (JANSR2N7659U3CE)**  
**Radiation Hardened Power MOSFET (SMD-0.5e)**

**Electrical Characteristics Curves (Pre-irradiation)**



**Figure 6 Typical On-Resistance Vs Gate Voltage** **Figure 7 Typical On-Resistance Vs Drain Current**

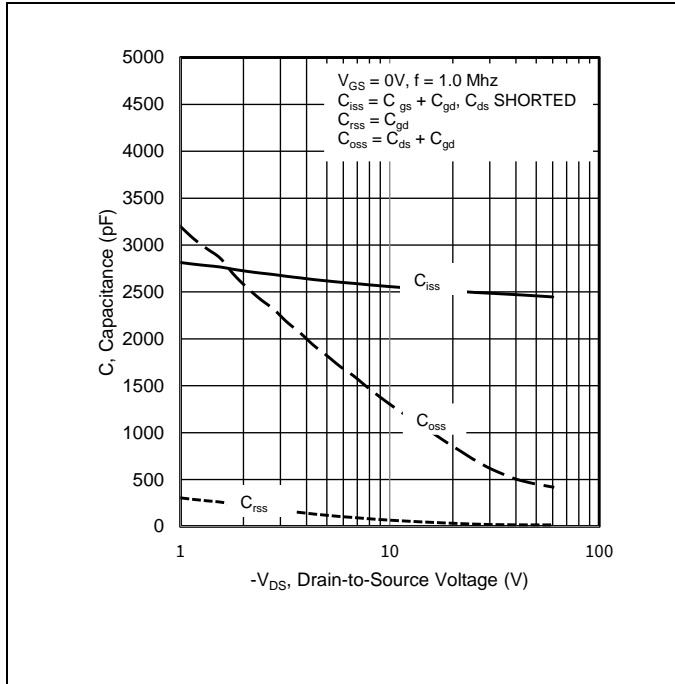


**Figure 8 Typical Drain-to-Source Breakdown Voltage Vs. Temperature** **Figure 9 Typical Threshold Voltage Vs. Temperature**

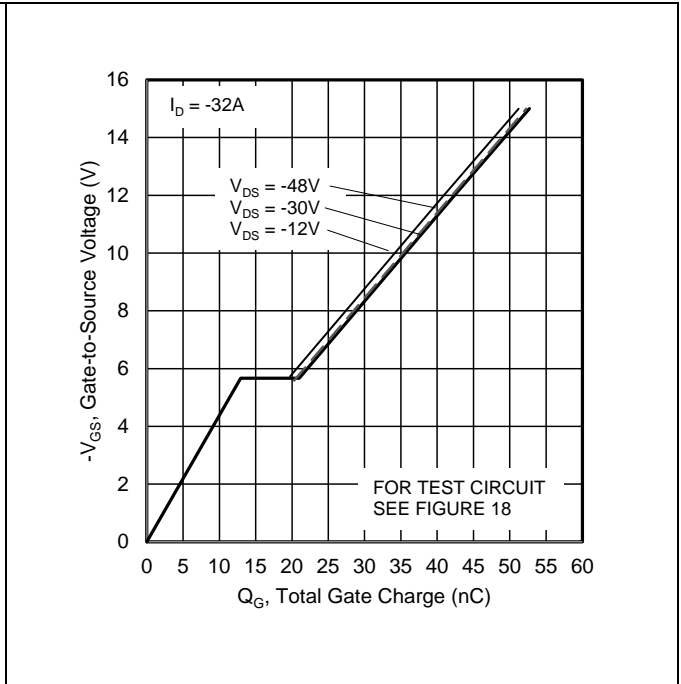


**IRHNKC9A97034 (JANSR2N7659U3CE)**  
**Radiation Hardened Power MOSFET (SMD-0.5e)**

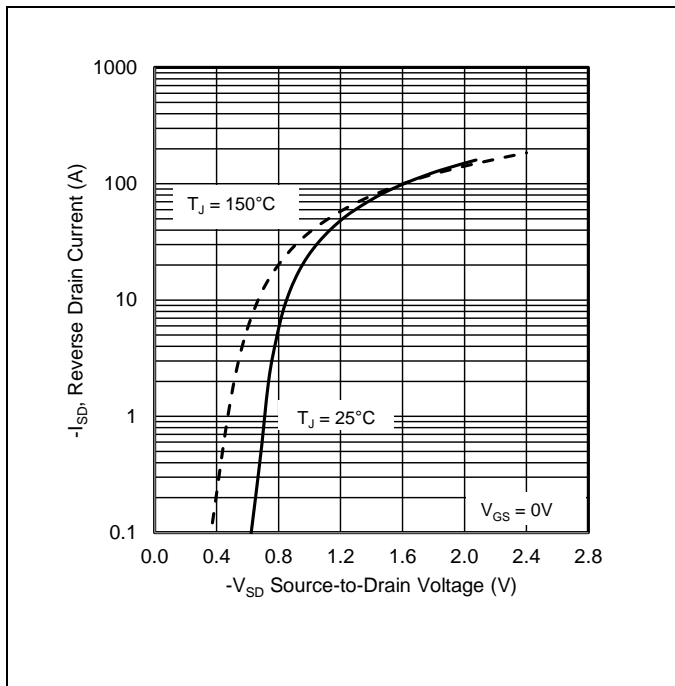
**Electrical Characteristics Curves (Pre-irradiation)**



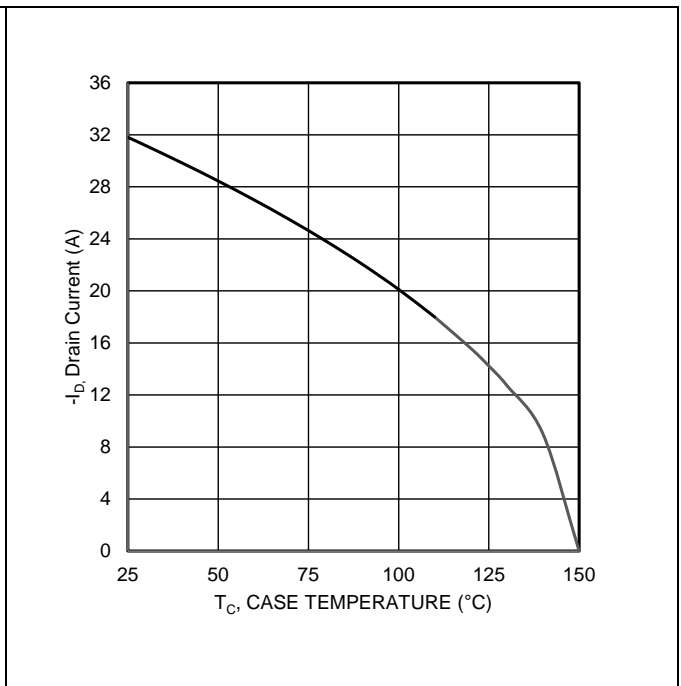
**Figure 10 Typical Capacitance Vs. Drain-to-Source Voltage**



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

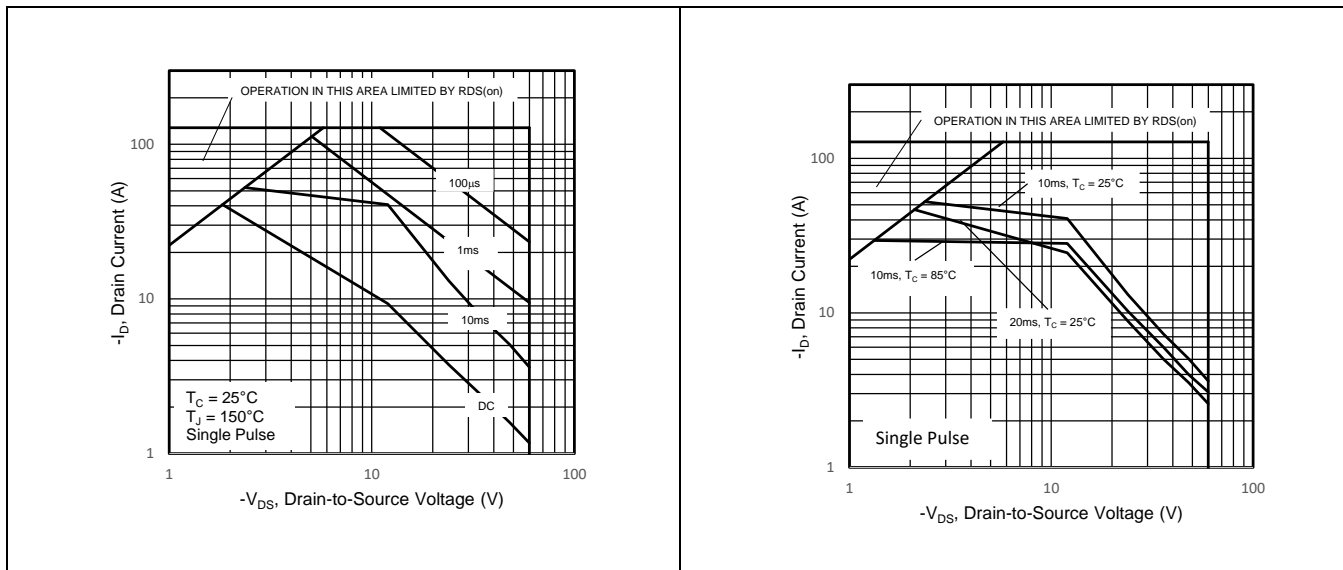


**Figure 12 Typical Source-Drain Current Vs. Diode Forward Voltage**



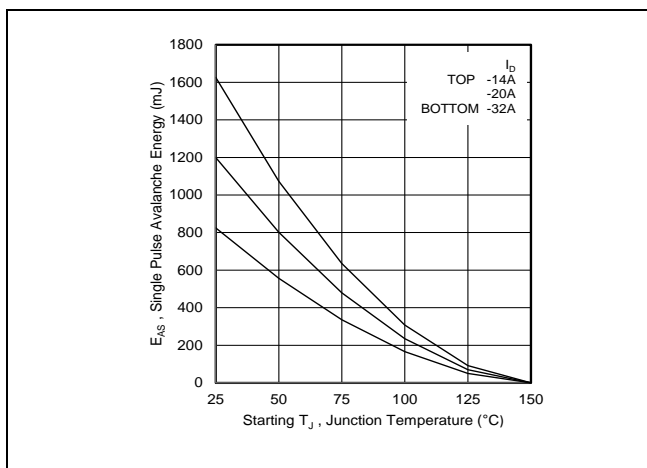
**Figure 13 Maximum Drain Current Vs. Case Temperature**

**IRHNKC9A97034 (JANSR2N7659U3CE)**  
**Radiation Hardened Power MOSFET (SMD-0.5e)**  
**Electrical Characteristics Curves (Pre-irradiation)**

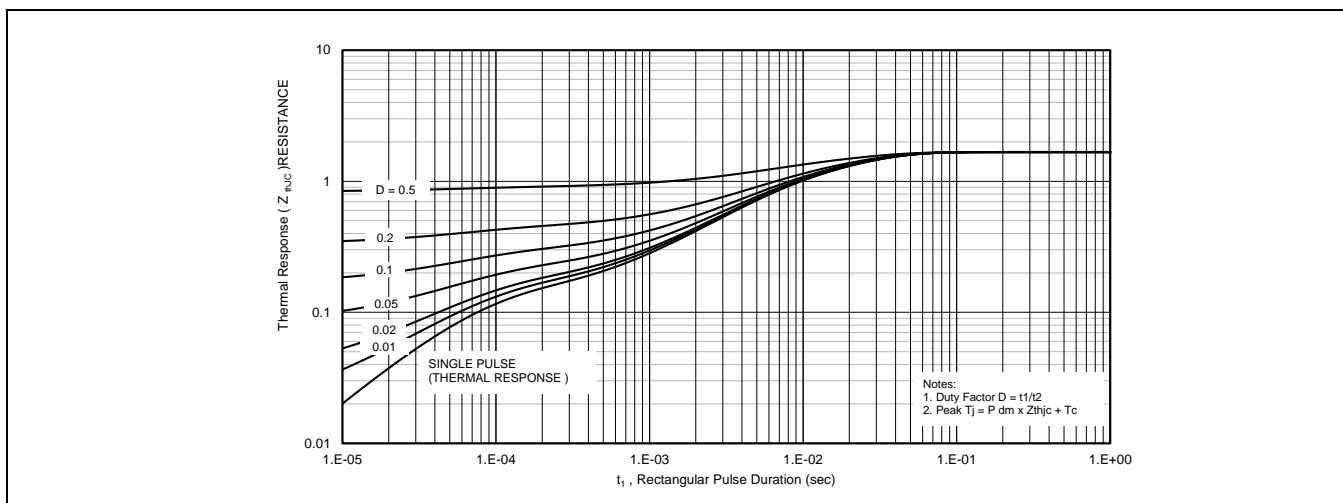


**Figure 14 Maximum Safe Operating Area**

**Figure 15 Maximum Safe Operating Area**



**Figure 16 Maximum Avalanche Energy Vs. Junction Temperature**

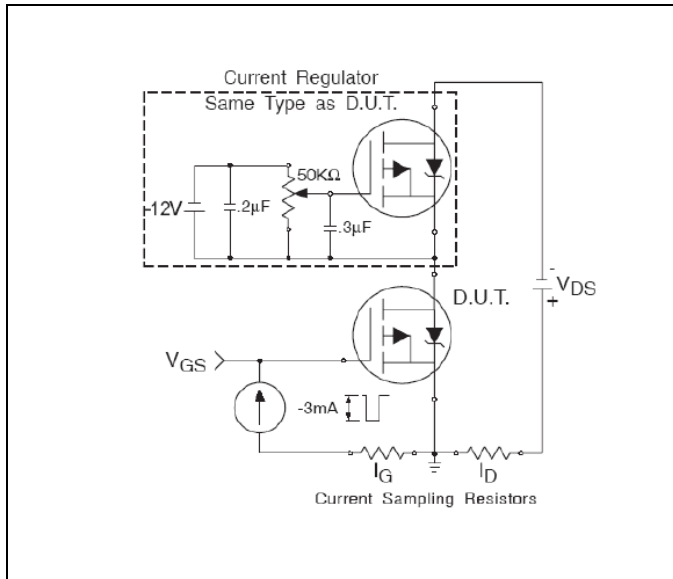


**Figure 17 Maximum Effective Transient Thermal Impedance, Junction-to-Case**

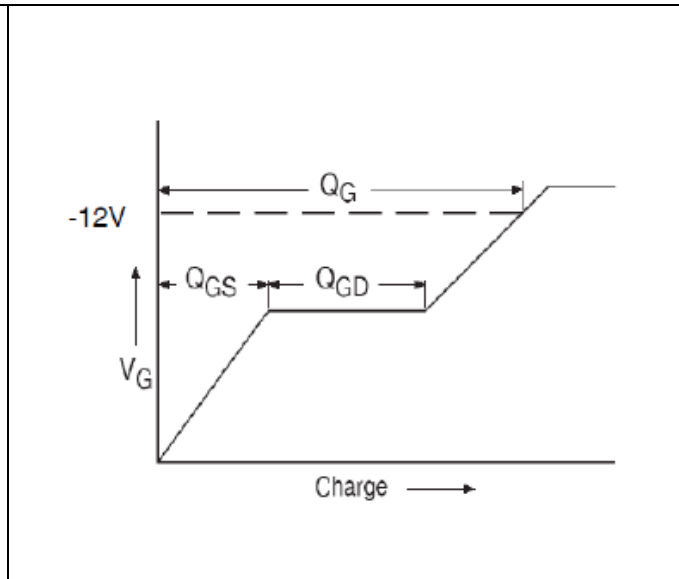
**IRHNKC9A97034 (JANSR2N7659U3CE)**  
**Radiation Hardened Power MOSFET (SMD-0.5e)**

**Test Circuits (Pre-irradiation)**

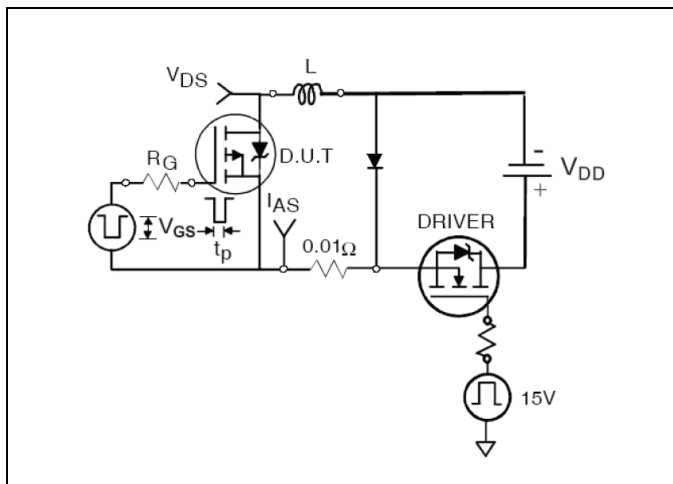
**4 Test Circuits (Pre-irradiation)**



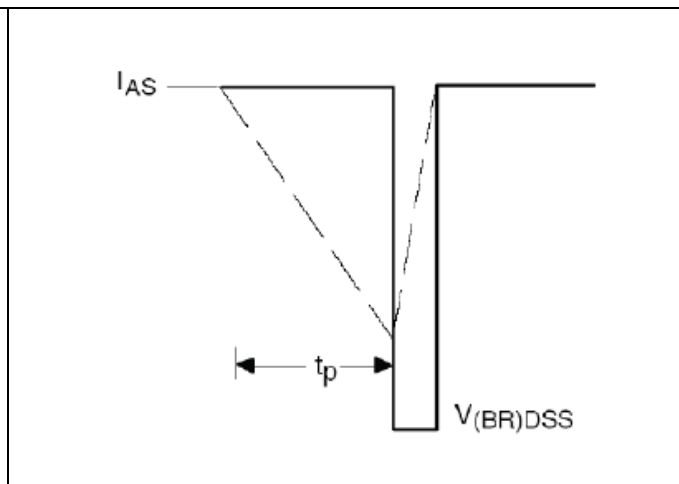
**Figure 18 Gate Charge Test Circuit**



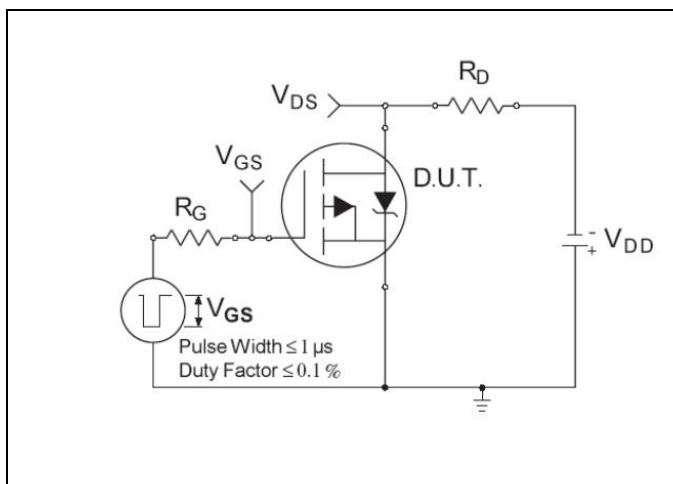
**Figure 19 Gate Charge Waveform**



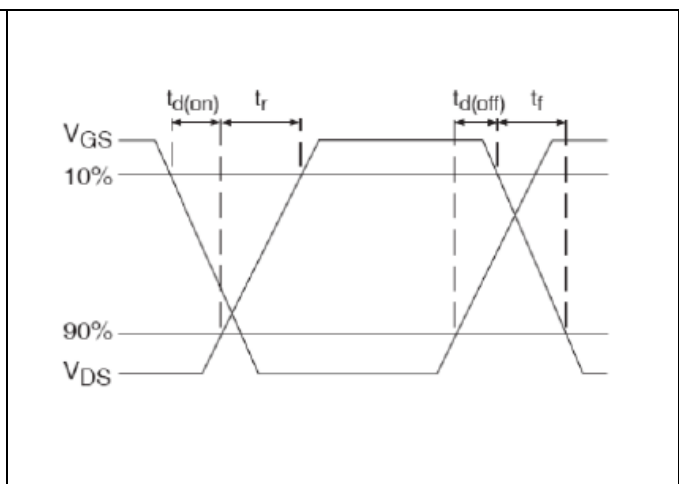
**Figure 20 Unclamped Inductive Test Circuit**



**Figure 21 Unclamped Inductive Waveform**



**Figure 22 Switching Time Test Circuit**



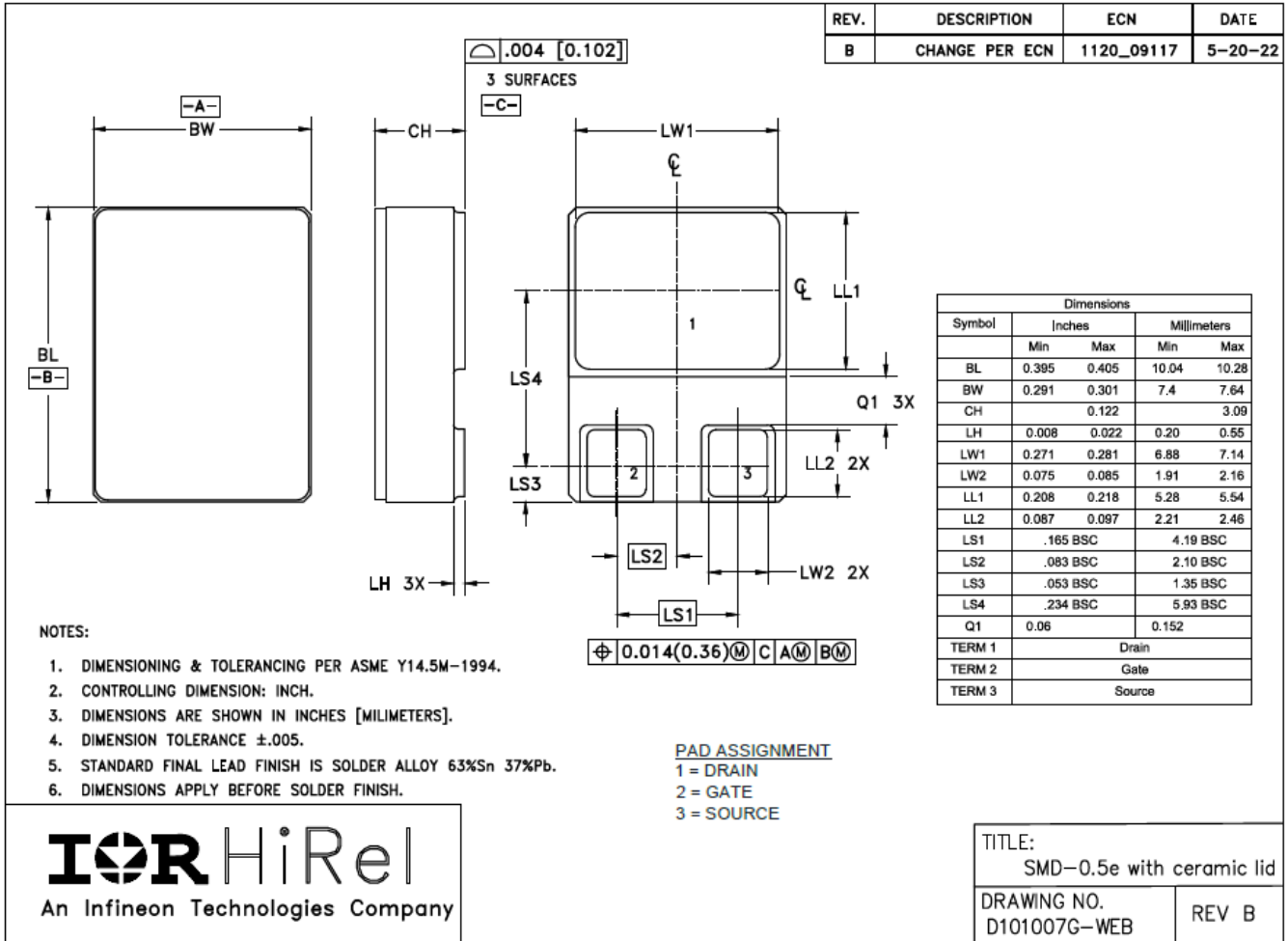
**Figure 23 Switching Time Waveforms**

**IRHNKC9A97034 (JANSR2N7659U3CE)**  
**Radiation Hardened Power MOSFET (SMD-0.5e)**

**Package Outline**

**5 Package Outline**

Note: For the most updated package outline, please see the website: [SMD-0.5e \(Ceramic Lid\)](#)



**IRHNKC9A97034 (JANSR2N7659U3CE)**  
**Radiation Hardened Power MOSFET (SMD-0.5e)**

**Revision history**

**Revision history**

<b>Document version</b>	<b>Date of release</b>	<b>Description of changes</b>
	10/24/2022	Preliminary datasheet with PPD number (PPD-97997)
Rev A	11/10/2022	Final datasheet with PD number (PD-97997A)
Rev B	07/26/2023	Updated based on ECN-1120_09644

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