ISL70040SEH

Neutron Test Report

Introduction

This report documents the results of Displacement Damage (DD) testing of the ISL70040SEH GaN FET driver using 1MeV neutrons. The test was conducted to determine the ISL70040SEH's sensitivity to DD caused by neutron or proton environments. Neutron fluences ranged from 5×10^{11}n/cm^2 to 1×10^{14}n/cm^2. This project was carried out in close collaboration with VPT, Inc. (Blacksburg, VA), and their support is gratefully acknowledged.

Part Description

The ISL70040SEH is a low-side driver designed to drive enhancement mode gallium nitride (GaN) Field Effect Transistors (FETs) in isolated topologies and boost type power management configurations. The ISL70040SEH operates with a supply voltage from 4.5V to 13.2V and has both inverting inputs (INB) and non-inverting inputs (IN) to satisfy requirements for inverting and non-inverting gate drives with a single device. The ISL70040SEH features a 4.5V gate drive voltage (VDRV) generated using an internal regulator that prevents the gate voltage from exceeding the maximum gate-source rating of enhancement mode GaN FETs. The gate drive voltage also features Undervoltage Lockout (UVLO) protection that ignores the inputs (IN/INB) and keeps OUTL turned on to ensure the GaN FET is in an OFF state whenever VDRV is below the UVLO threshold.

The ISL70040SEH inputs can withstand voltages up to 14.7V regardless of the V_{DD} voltage, which allows the ISL70040SEH's inputs to connect directly to most PWM controllers. The ISL70040SEH's split outputs offer the flexibility to adjust the turn-on and turn-off speed independently by adding impedance in the turn-on and turn-off paths. The ISL70040SEH operates across the military temperature range from -55°C to +125°C and is offered in an 8 Ld hermetically sealed ceramic Surface Mount Device (SMD) package or in die form. The ISL70040SEH is implemented in the Renesas P6 power management and mixed signal process, which is a junction-isolated 5V BiCMOS flow with added high voltage DMOS devices. The fabrication process is QML certified and is in volume commercial production.

Related Literature

For a full list of related documents, visit our website:

- ISL70040SEH device page

1. Test Description

1.1 Irradiation Facilities

Neutron irradiation was performed by the VPT team at the University of Massachusetts Lowell Fast Neutron Irradiation (FNI) facility, which provides a controlled 1MeV equivalent neutron flux. Parts were tested in an unbiased configuration with all leads shorted together in accordance with TM 1017 of MIL-STD-883. As neutron irradiation activates many of the heavier elements found in a packaged integrated circuit, the parts exposed at the higher neutron levels required (as expected) some cooldown time before being shipped back to Renesas (Palm Bay, FL) for electrical testing.

1.2 Test Fixturing

No formal irradiation test fixturing was involved, as neutron tests are bag tests, which means that the parts are irradiated in an electrically inactive state with all leads shorted together.

1.3 Characterization Equipment and Procedures

Electrical testing was performed before and after irradiation using Renesas production Automated Test Equipment (ATE). All electrical testing was performed at room temperature. Three control units were used to ensure repeatable data.

1.4 Experimental Matrix

Irradiation was performed in accordance with the guidelines of MIL-STD-883 Test Method 1017. The experimental matrix consisted of five samples irradiated at $5x10^{11}n/cm^2$, five samples irradiated at $1x10^{12}n/cm^2$, five samples irradiated at $1x10^{13}n/cm^2$, and five samples irradiated at $1x10^{14}n/cm^2$. When interpreting the data, note that each neutron irradiation was performed on a different five-unit sample; this is *not* total dose testing, where the damage is cumulative over a number of consecutive downpoints. The ISL70040SEH samples were drawn from wafer fabrication lot 5VD7BDB. All samples were packaged in the hermetic 6mmx6mm 8 Ld surface mount package (package code J8.A) and were processed through the standard burn-in cycle before irradiation.

2. Test Results

2.1 Attributes Data

Part	Sample Size	Fluence, n/cm^2	Pass (Note 1)	Fail	Notes
ISL70040SEH	5	$5x10^{11}$	5	0	All passed.
ISL70040SEH	5	$1x10^{12}$	5	0	All passed.
ISL70040SEH	5	$1x10^{13}$	0	5	All failed parametrically, output voltage.
ISL70040SEH	5	$1x10^{14}$	0	5	All failed parametrically, power supply current and peak output source current.

Note:

1. ‘Pass’ indicates a sample that passes all pre-irradiation and post-irradiation SMD limits, which are identical.

2.2 Critical Parameter Listing

Table 1 lists 19 critical parameters that are considered indicative of part performance. These parameters are discussed in detail in the following sections, including the SMD parameter symbols for clarity, and are plotted in Figures 1 through 19.

All parametric limits are in accordance with the ISL70040SEH SMD (5962 – 17233) pre-irradiation and post-irradiation limits, which are identical. Most plots show both the 4.5V and 13.2V supply voltage cases.

Table 1. ISL70040SEH Performance

Figure	Parameter	Symbol	Limit (Low)	Limit (High)	Unit	Notes
1	Quiescent Power Supply Current	I_{DDQ}	-	2.5	mA	4.5V supply
			-	2.5	mA	13.2V supply
2	Operating Supply Current	I_{DDO}	-	13.0	mA	4.5V supply
			-	15.0	mA	13.2V supply
3	Output Voltage	V_{DRV}	4.29	-	V	4.5V supply
			4.34	4.71	V	13.2V supply
4	Input HIGH Level Threshold	V_{IH}	-	2.0	V	4.5V supply
			-	2.0	V	13.2V supply
5	Input LOW Level Threshold	V_{IL}	1.0	-	V	4.5V supply
			1.0	-	V	13.2V supply
6	Input B HIGH Level Threshold	V_{IH}	-	2.0	V	4.5V supply
			-	2.0	V	13.2V supply
7	Input B LOW Level Threshold	V_{IL}	1.0	-	V	4.5V supply
			1.0	-	V	13.2V supply
8	Output Rise Time	t_{RISE}	21	90	ns	C_L = 10nF
9	Output Fall Time	t_{FALL}	16	50	ns	C_L = 10nF
10	Input to Output Turn-On Propagation Delay	t_{DON}	15	65	ns	C_L = 1nF
11	Input to Output Turn-Off Propagation Delay	t_{DOFF}	15	65	ns	C_L = 1nF
12	B Input to Output Turn-On Propagation Delay	t_{DON}	15	65	ns	C_L = 1nF
13	B Input to Output Turn-Off Propagation Delay	t_{DOFF}	15	65	ns	C_L = 1nF
14	Input to Output Propagation Delay Match	t_{DM}	-8	8	ns	
15	B Input to Output Propagation Delay Match	t_{DM}	-8	8	ns	
16	Driver Output Resistance	R_{ONP}	-	3.2	Ω	I_{OUTH} = 45mA
17	Driver Output Resistance	R_{ONN}	-	1.0	Ω	OUTH = VDRV, I_{OUTL} = - 45mA
			-	3.0	Ω	OUTH = OUTL, I_{OUTL} = - 45mA
18	Peak Source Current	I_{SRC}	1.0	3.0	A	C_L = 220nF
19	Peak Sink Current	I_{SNK}	1.5	4.0	A	C_L = 220nF

2.3 Critical Parameter Variables Data

The plots in Figures 1 through 19 show the neutron irradiation response of the critical parameters outlined in "Critical Parameter Listing" on page 2. The figures plot the median only as the data was tightly grouped. The figures also show the SMD parametric limits, which are the same for the pre-irradiation and post-irradiation cases.

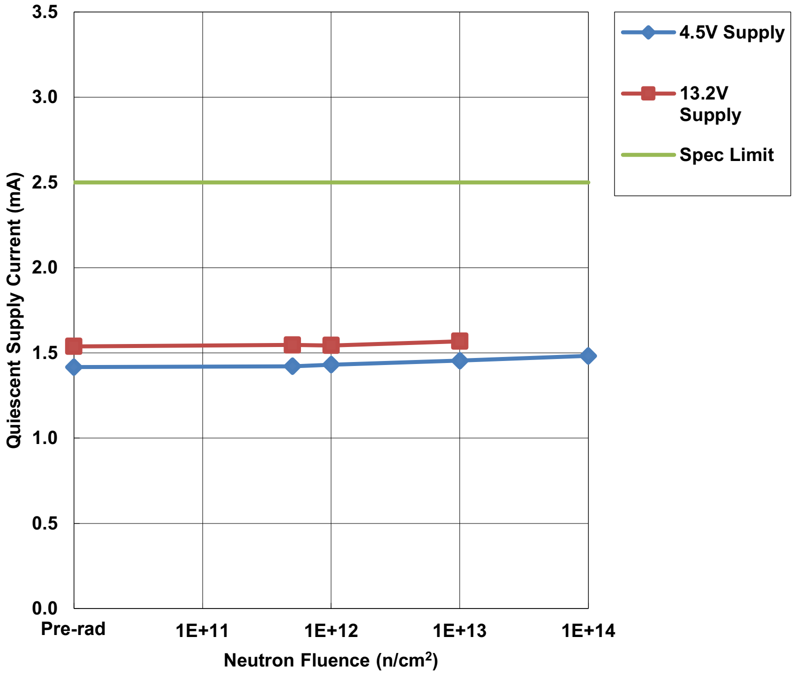

Figure 1. ISL70040SEH median quiescent power supply current (I_{DDQ}), 4.5V and 13.2V supply, as a function of neutron irradiation at 5×10^{11}, 1×10^{12}, 1×10^{13}, and 1×10^{14}n/cm^2. The sample size of all four cells was five per cell. This parameter was out of specification (median value of 77.3mA) after 1×10^{14}n/cm^2 and is not plotted at that level. The SMD limit is 2.5mA maximum (4.5V supply and 13.2V supply).

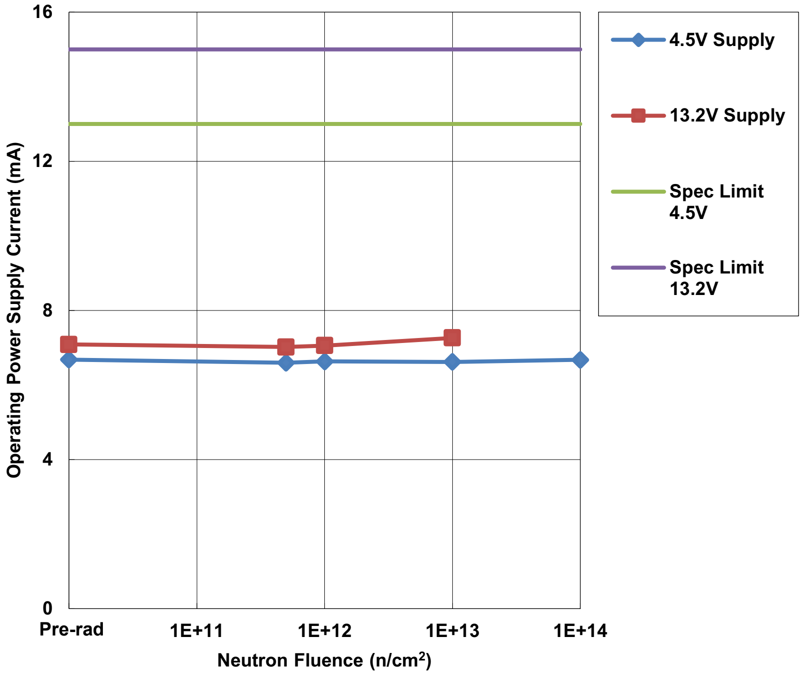

Figure 2. ISL70040SEH median operating power supply current (I_{DDO}), 4.5V and 13.2V supply, as a function of neutron irradiation at 5×10^{11}, 1×10^{12}, 1×10^{13}, and 1×10^{14}n/cm^2. The sample size of all four cells was five per cell. This parameter was out of specification (median value 82.7mA) after 1×10^{14}n/cm^2 and is not plotted at that level. The SMD limits are 13mA maximum (4.5V supply) and 15mA maximum (13.2V supply).

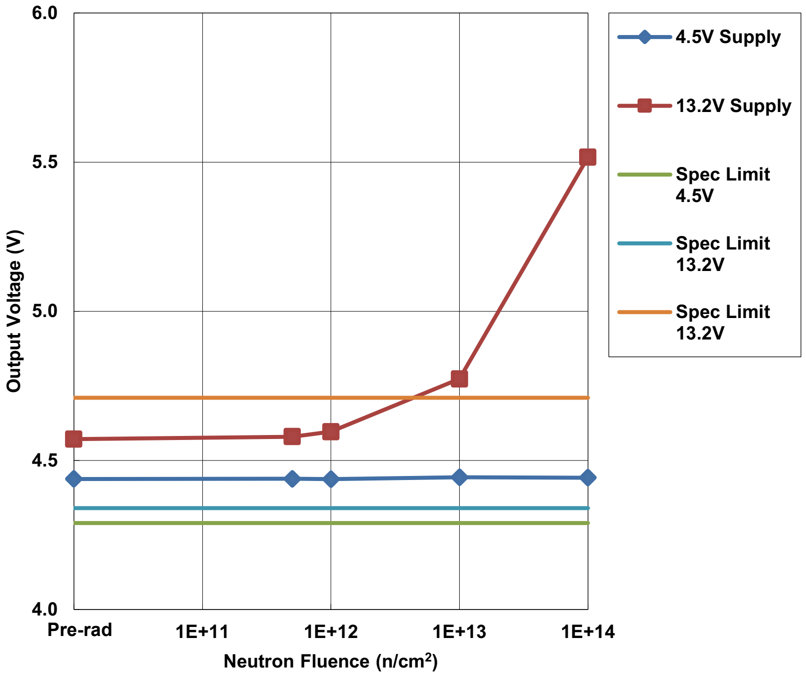

Figure 3. **ISL70040SEH median output voltage (VDRV), 4.5V and 13.2V supply, as a function of neutron irradiation at 5×10^{11}, 1×10^{12}, 1×10^{13}, and 1×10^{14}n/cm^2. The sample size of all four cells was five per cell. This parameter was out of specification after 1×10^{13}n/cm^2. The SMD limits are 4.29V minimum (4.5V supply) and 4.34V to 4.71V (13.2V supply).**

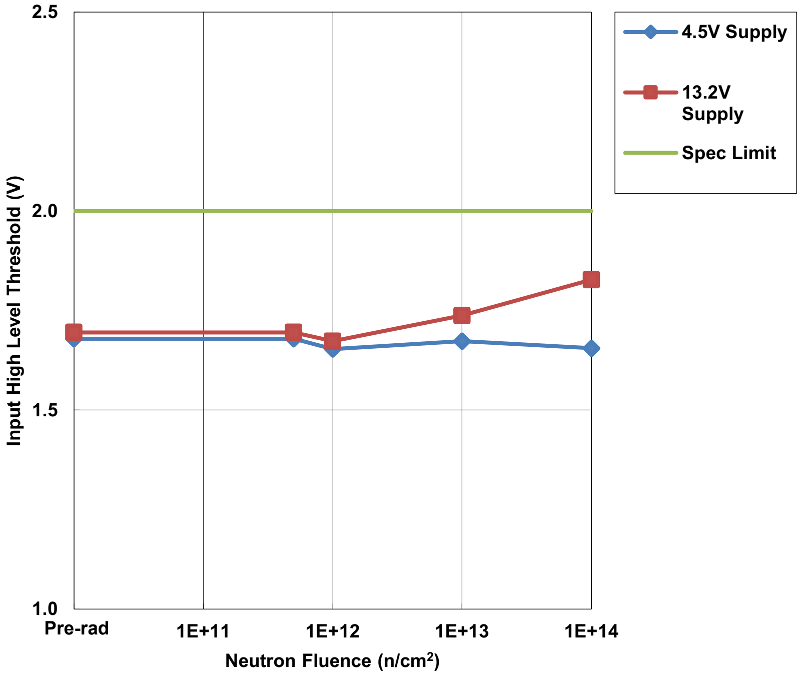

Figure 4. **ISL70040SEH median input HIGH level threshold (V_{IH}), 4.5V and 13.2V supply, as a function of neutron irradiation at 5×10^{11}, 1×10^{12}, 1×10^{13}, and 1×10^{14}n/cm^2. The sample size of all four cells was five per cell. The SMD limit is 2.0V maximum (4.5V supply and 13.2V supply).**

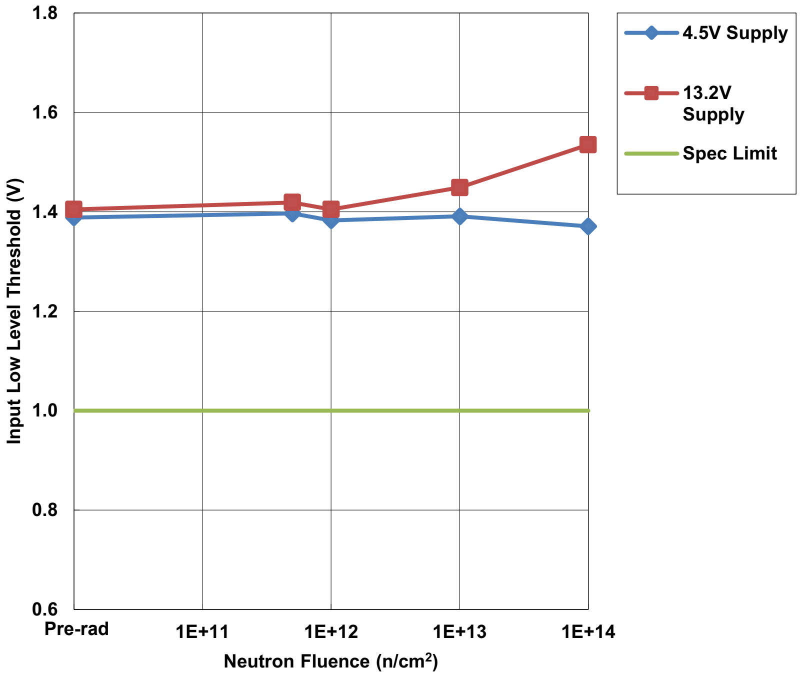

Figure 5. ISL70040SEH median input LOW level threshold (V_{IL}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limit is 1.0V minimum (4.5V supply and 13.2V supply).

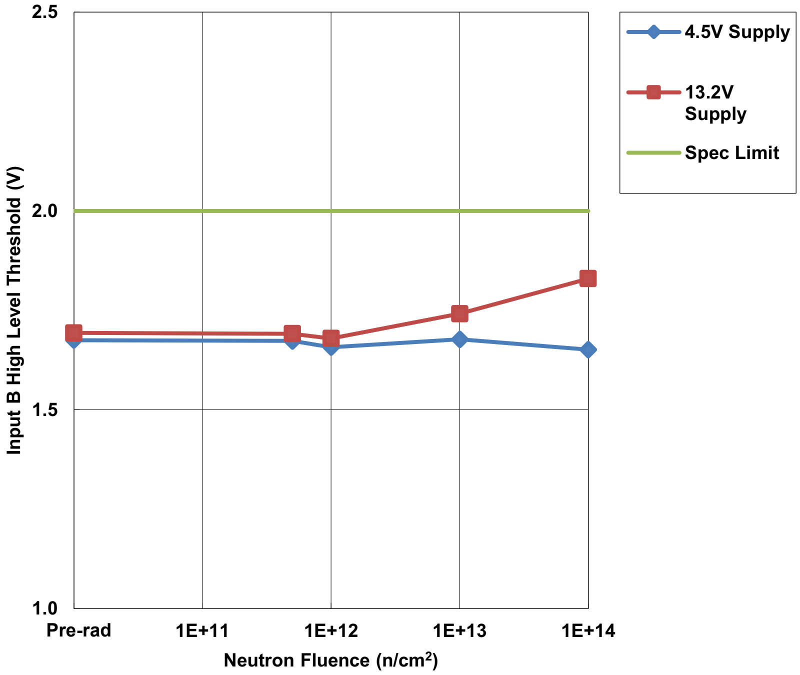

Figure 6. ISL70040SEH median input B HIGH level threshold (V_{IH}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limit is 2.0V maximum (4.5V supply and 13.2V supply).

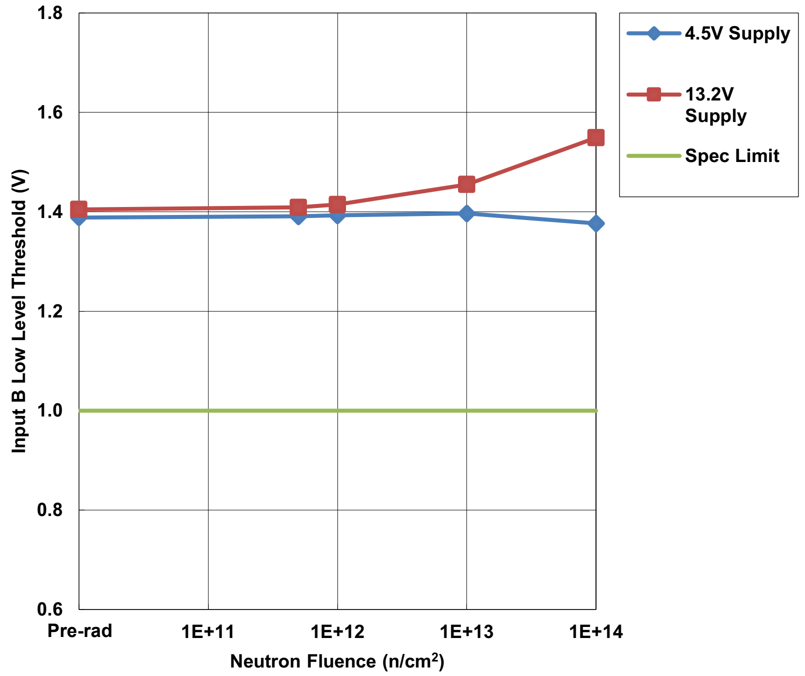

Figure 7. ISL70040SEH median input B LOW level threshold (V_{IL}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limit is 1.0V minimum (4.5V supply and 13.2V supply).

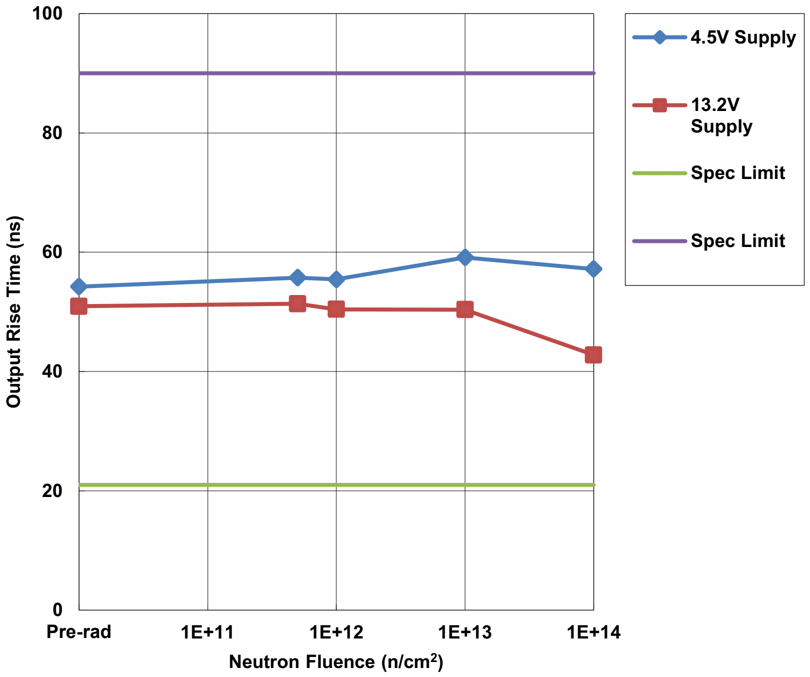

Figure 8. ISL70040SEH median rise time (t_{RISE}) as a function of total dose irradiation at low and at high dose rate, 10nF load capacitance, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limits are 21ns to 90ns.

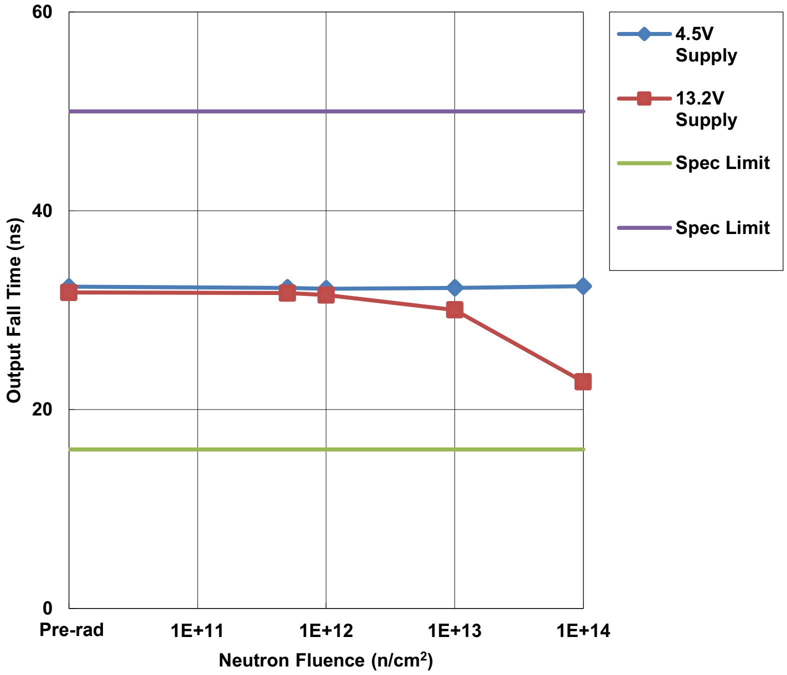

Figure 9. ISL70040SEH median fall time (t_{FALL}) as a function of total dose irradiation at low and at high dose rate, 10nF load capacitance, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limits are 16ns to 50ns.

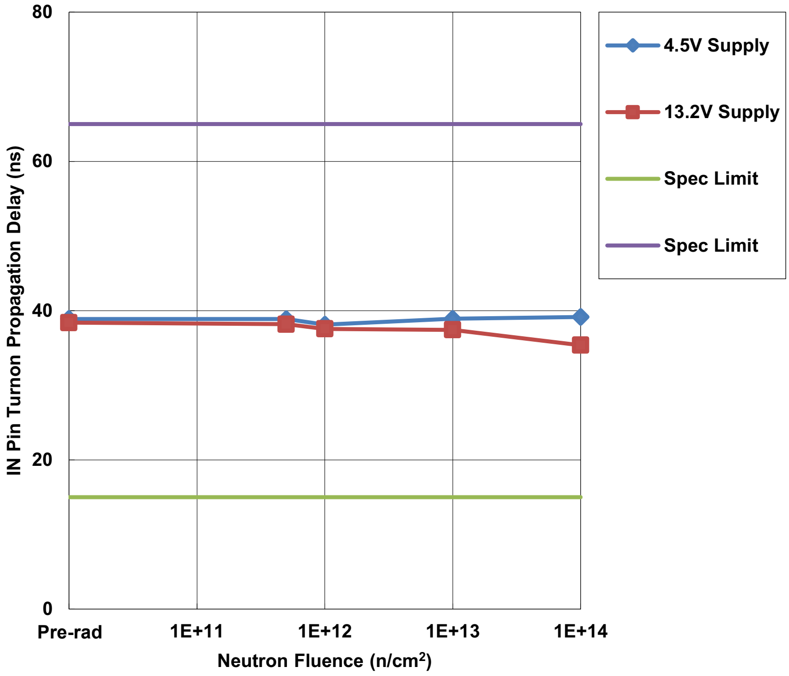

Figure 10. ISL70040SEH median input to output turn-on propagation delay (t_{DON}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limits are 15ns to 65ns.

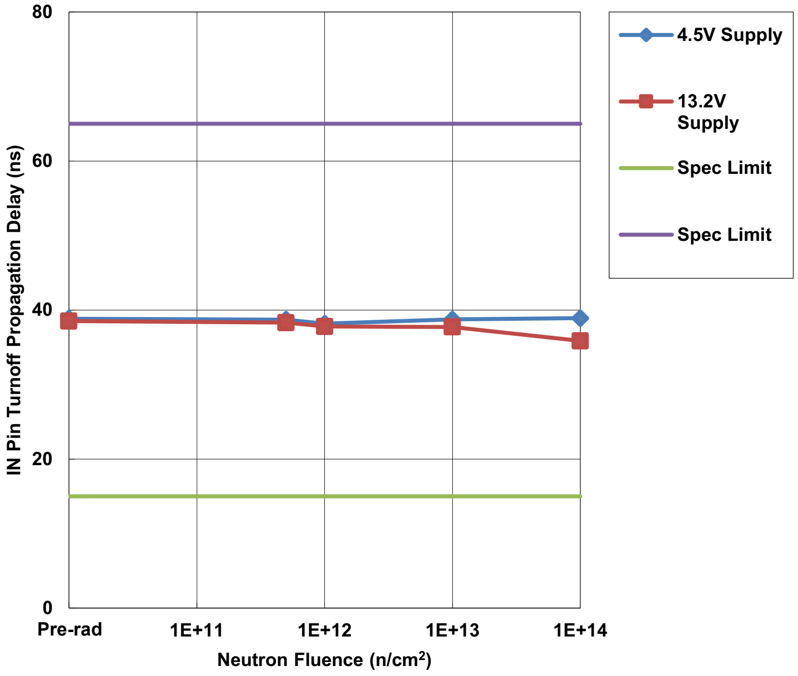

Figure 11. ISL70040SEH median input to output turn-off propagation delay (t_{DOFF}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}n/cm^2$. The sample size of all four cells was five per cell. The SMD limits are 15ns to 65ns.

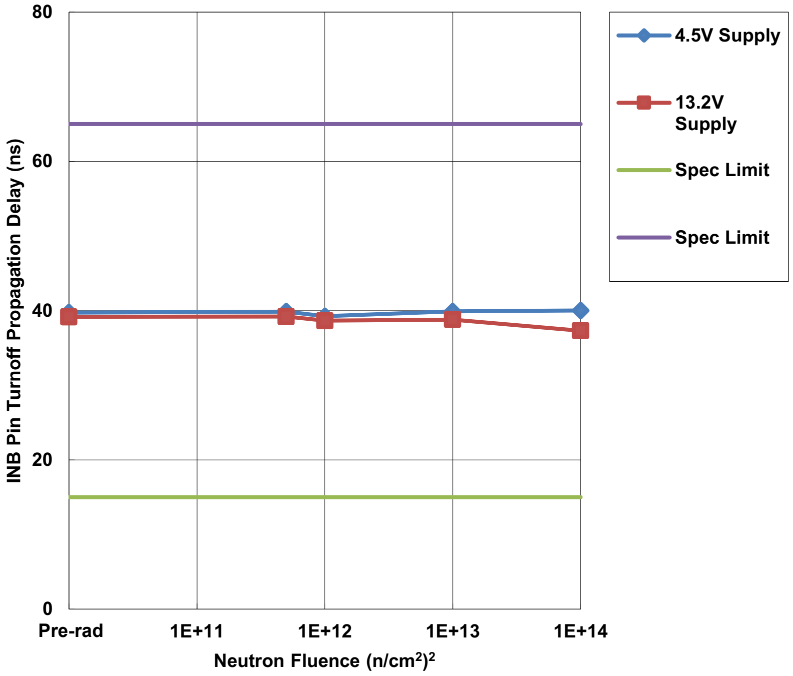

Figure 12. ISL70040SEH median B input to output turn-on propagation delay (t_{DON}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}n/cm^2$. The sample size of all four cells was five per cell. The SMD limits are 15ns to 65ns.

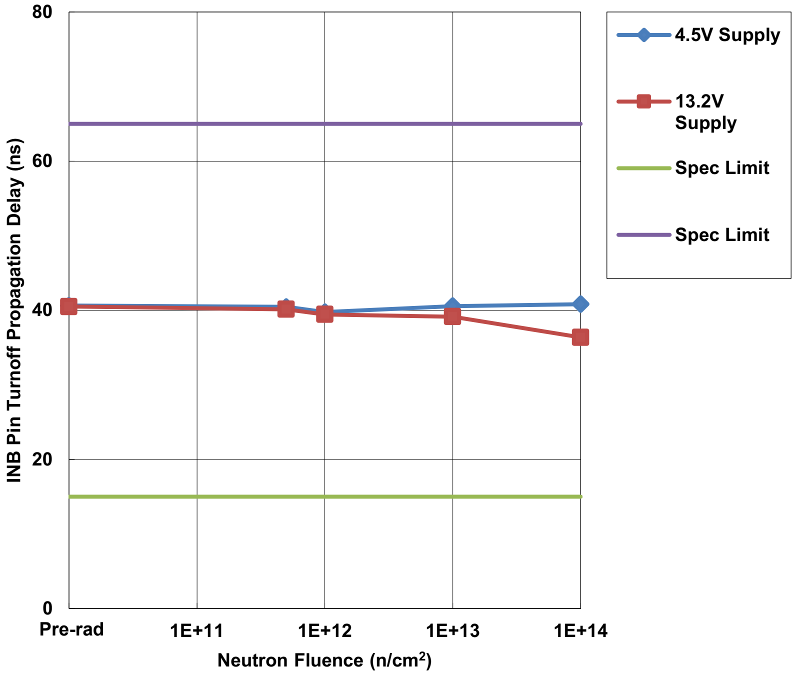

Figure 13. ISL70040SEH median B input to output turn-off propagation delay (t_{DOFF}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limits are 15ns to 65ns.

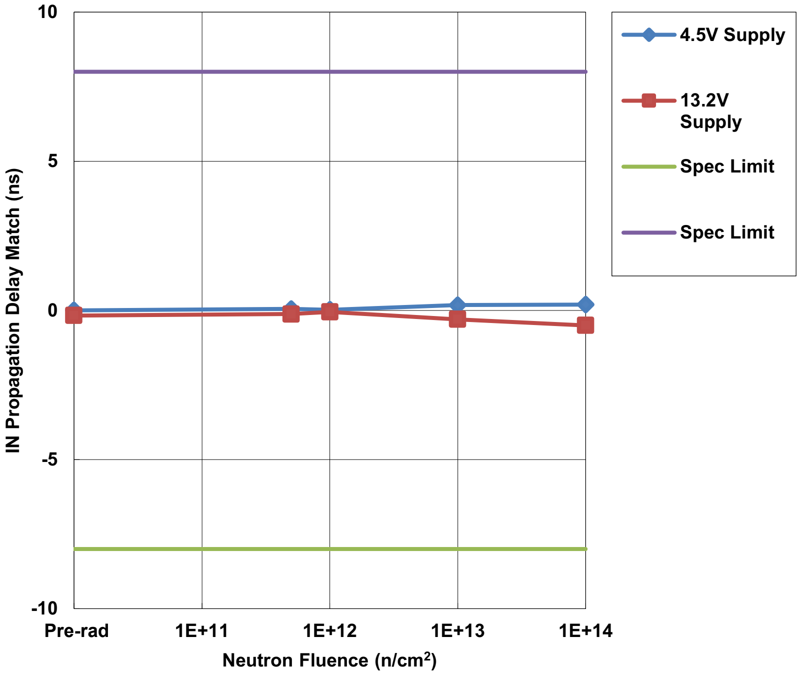

Figure 14. ISL70040SEH median input to output propagation delay match (t_{DM}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limits are -8ns to 8ns.

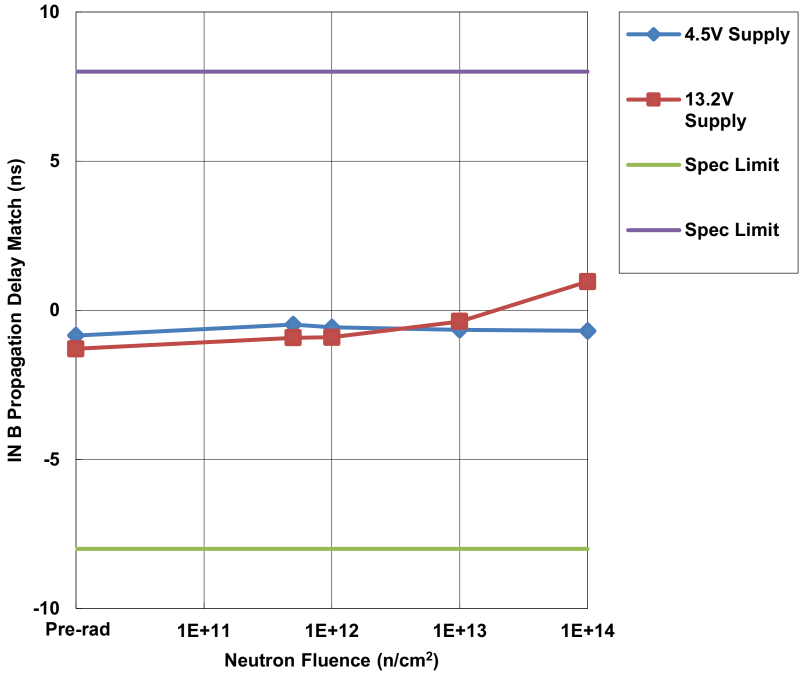

Figure 15. ISL70040SEH median B input to output propagation delay match (t_{DM}), 4.5V and 13.2V supply, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limits are -8ns to 8ns.

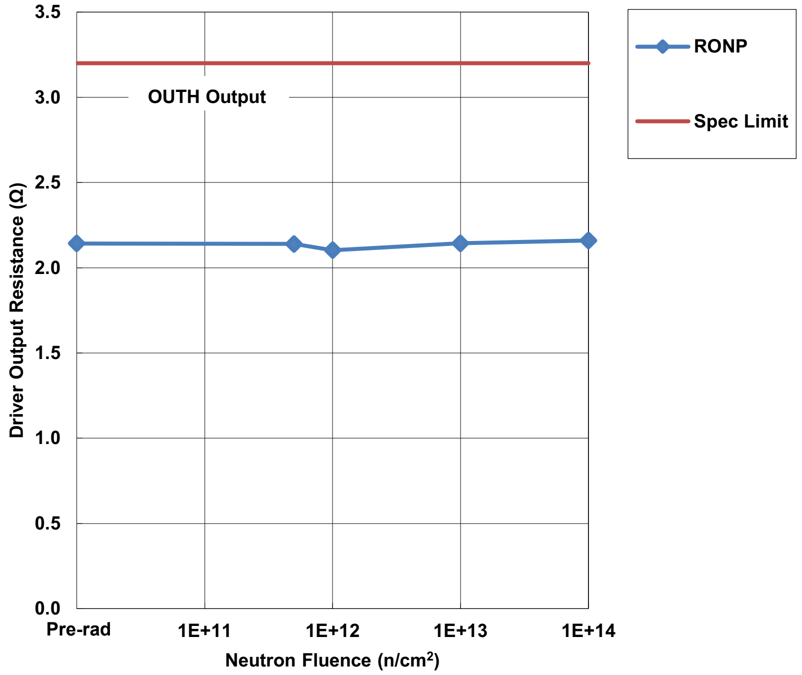

Figure 16. ISL70040SEH median driver output resistance (r_{ONP}), output HIGH current 45mA, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limit is 3.2Ω maximum.

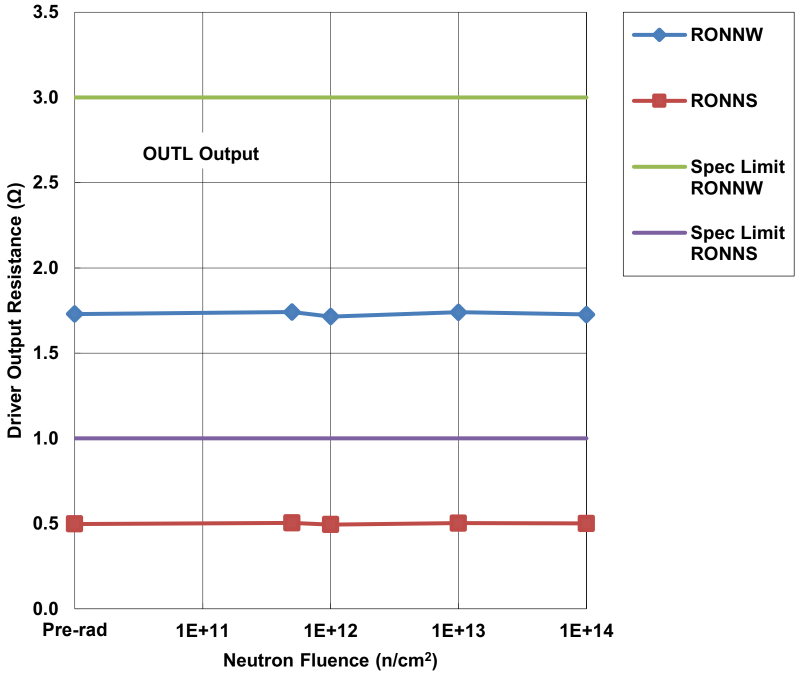

Figure 17. ISL70040SEH median driver output resistance (r_{ONN}), output LOW current -45mA, HIGH output at VDRV and at OUTL cases, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}n/cm^2$. The sample size of all four cells was five per cell. The SMD limits are 1.0Ω maximum (OUTH = VDRV) and 3.0Ω maximum (OUTH = OUTL).

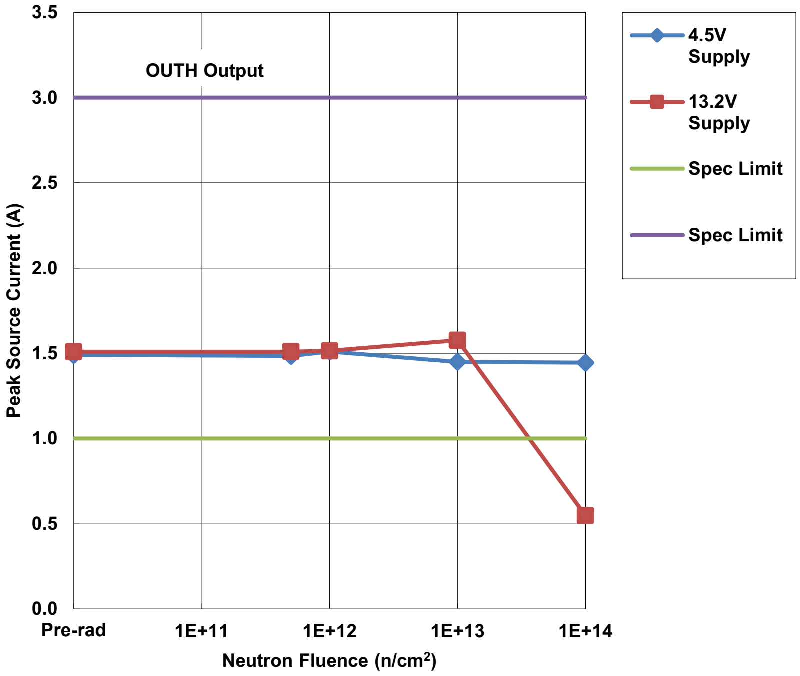

Figure 18. ISL70040SEH median OUTH peak source current (I_{SRC}), C_L = 220nF, as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}n/cm^2$. The sample size of all four cells was five per cell. This parameter was out of specification after $1x10^{14}n/cm^2$. The SMD limits are 1.0A to 3.0A.

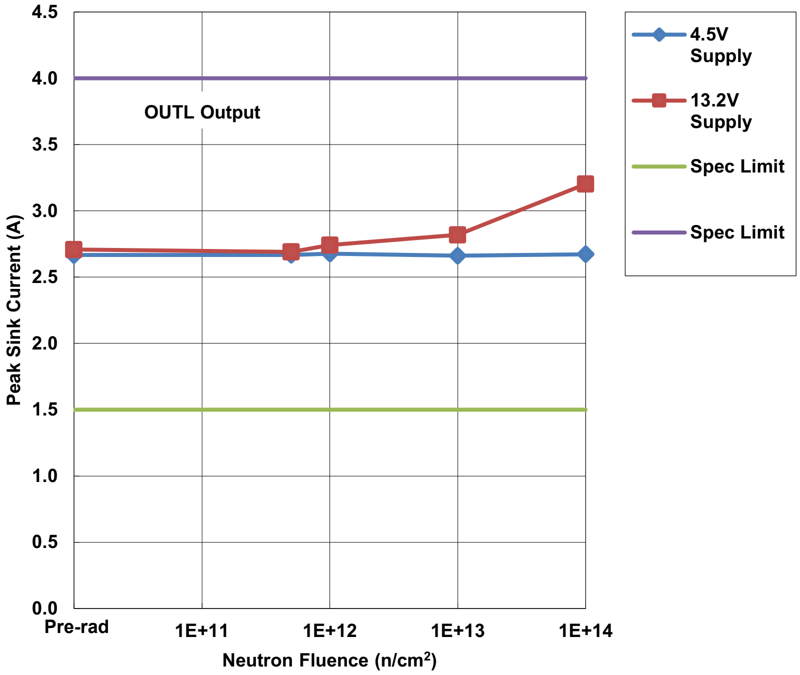

Figure 19. ISL70040SEH median OUTL peak sink current (I_{SNK}), C_L = 220nF, as a function of total dose irradiation at low and at high dose rate for the biased and as a function of neutron irradiation at $5x10^{11}$, $1x10^{12}$, $1x10^{13}$, and $1x10^{14}$n/cm^2. The sample size of all four cells was five per cell. The SMD limits are 1.5A to 4.0A.

3. Discussion and Conclusion

We report the results of Displacement Damage (DD) testing of the ISL70040SEH GaN FET driver using 1MeV neutrons. The test was conducted to determine the ISL70040SEH's sensitivity to DD caused by neutron or proton environments. Neutron fluences ranged from $5x10^{11}$n/cm^2 to $1x10^{14}$n/cm^2. This project was carried out in collaboration with VPT, Inc. (Blacksburg, VA), and their close support is gratefully acknowledged.

The ISL70040SEH is not formally DD hardened and the data presented in this report is intended for customer guidance only. The part performed very well after $5x10^{11}$ and $1x10^{12}$n/cm^2, but all five $1x10^{13}$n/cm^2 samples failed output voltage (V_{DRV}, see Figure 3). All five $1x10^{14}$n/cm^2 samples failed quiescent power supply current (I_{DDQ}, see Figure 1), operating power supply current (I_{DDO}, see Figure 2), and peak output source current (I_{SRC}, see Figure 18).

The two power supply current parameters were far out of specification, with an I_{DDQ} median value of 77.3mA and an I_{DDO} median value of 82.7mA; plotting them (Figures 1 and 2) made little sense, as this would require a major scale change and the parametric response at the lower neutron levels would then be impossible to interpret. At these high levels the parts were effectively nonfunctional. When interpreting the data, note that each neutron irradiation was performed on a different five-unit sample; this is *not* total dose testing, where the damage is cumulative over a number of consecutive downpoints.

We conclude that the part performed well after neutron irradiation to $5x10^{11}$ and $1x10^{12}$n/cm^2. After neutron irradiation to $1x10^{13}$ and $1x10^{14}$n/cm^2 the part showed various failure modes, including high power supply currents and greatly reduced output source current.

4. Revision History

Rev.	Date	Description
1.00	May.14.19	Initial release.

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