ISL75052SEH

Neutron Testing

TR028
Rev 0.00
April 15, 2016

Introduction

This report summarizes results of 1MeV equivalent neutron testing of the ISL75052SEH Low Droput (LDO) regulator. The test was conducted in order to determine the sensitivity of the part to Displacement Damage (DD) caused by neutron or proton environments. Neutron fluences ranged from $2\text{x}10^{12}\text{n/cm}^2$ to $1\text{x}10^{14}\text{n/cm}^2$. This project was carried out in collaboration with VPT, Inc. (Blacksburg, VA), and their support is gratefully acknowledged.

Reference Documents

- MIL-STD-883 test method 1017
- ISL75052SEH datasheet
- Standard Microcircuit Drawing (SMD) 5962-13220

Part Description

The ISL75052SEH is a radiation hardened, single output Low Dropout (LDO) regulator specified for an output current of 1.5A. The device operates from an input voltage range of 4.0V to 13.2V and an output voltage range of 0.6V to 12.7V. The output voltage is adjustable based on an external resistor divider setting. Dropout voltages as low as 75mV (at 0.5A) typical can be realized, allowing the user to improve system efficiency by lowering V_{IN} to nearly V_{OUT}. An ENABLE feature allows the part to be placed into a low shutdown current mode of 165µA (typical). When enabled, the ISL75052SEH operates with a low ground current of 11mA (typical), which provides operation with low quiescent power consumption. The device has superior transient response and is designed for predictable operation in the Single-Event Effects (SEE) environment, including reduced Single-Event Transient (SET) magnitude seen on the output. There is no need for additional SET protection diodes and filters.

A compensation (COMP) pin is provided to enable the use of external compensation. This is achieved by connecting a resistor and capacitor from the COMP pin to ground. The device is stable with tantalum capacitors as low as 47µF (KEMET T525 series) and provides excellent voltage regulation from no load to full load. The programmable soft-start function allows the user to program the inrush current by means of the decoupling capacitor used on the Bypass (BYP) pin. The Overcurrent Protection (OCP) pin allows the short-circuit output current limit threshold to be programmed by means of a resistor from the OCP pin to ground. The OCP setting range is from 0.16A minimum to 3.2A maximum.

A thermal shutdown function disables the output if the device temperature exceeds a specified value; the ISL75052SEH will subsequently enter an ON/OFF (hiccup) cycle until the fault is removed. The ISL75052SEH is available in a 16 Ld hermetic ceramic flatpack and in die form. The part offers guaranteed performance across the full -55°C to +125°C military temperature range.

The ISL75052SEH is hardened to achieve a Total Dose (TID) rating of 100krads(Si) at both high (50-300rad(Si)/s) and low (< 0.01rad(Si)/s) dose rates as specified in MIL-STD-883 test method 1019. The part is acceptance tested on a wafer-by-wafer basis at a low dose rate to 50krad(Si) and at a high dose rate to 100krad(Si).

The ISL75052SEH is also SEE tolerant to a Linear Energy Transfer (LET) value of $86.4\text{MeV}\bullet\text{cm}^2/\text{mg}$. Single-Event Transients (SETs) have evolved into a major issue in power management parts driving voltage-sensitive loads, and the part provides superior performance in this environment. The ISL75052SEH is implemented in a submicron BiCMOS process optimized for power management applications. The process is in volume production under MIL-PRF-38535 certification and is used for a wide range of commercial power management devices.

Specifications for Radiation Hardened QML devices are controlled by the Defense Logistics Agency (DLA) in Columbus, OH. The SMD is the controlling document and must be cited when ordering.

Block Diagram

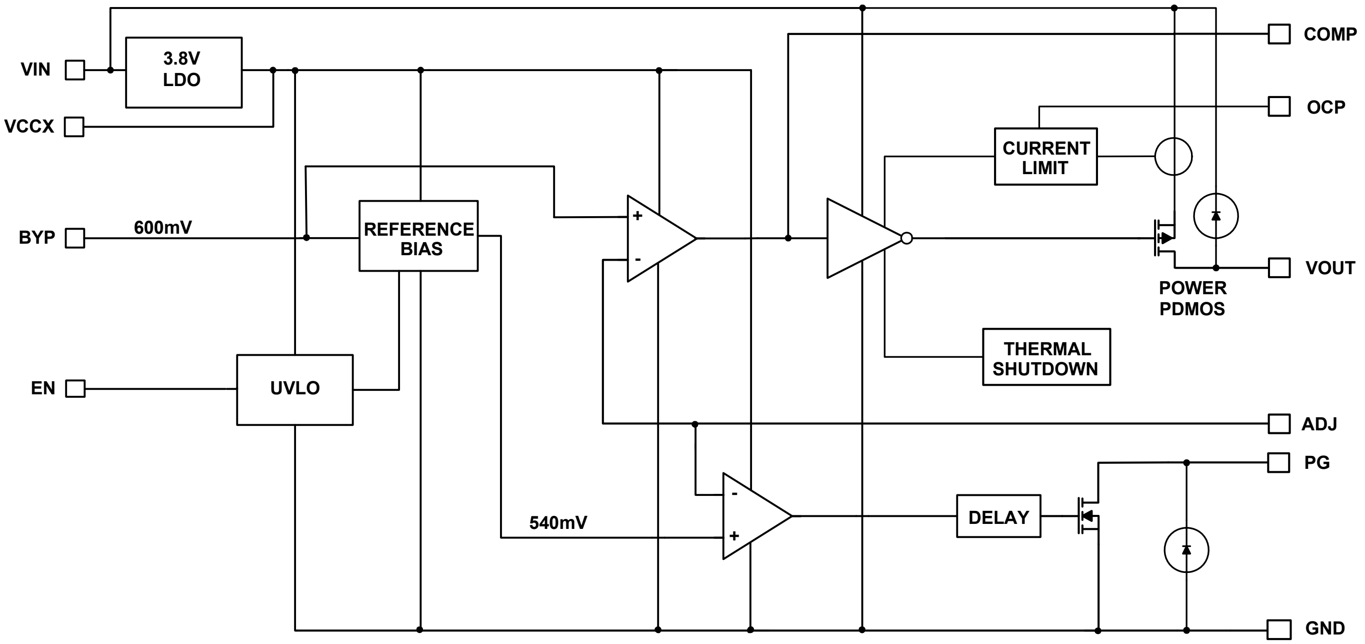

FIGURE 1. ISL75052SEH BLOCK DIAGRAM

Test Description

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 Test Method 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 ‘cool-down’ time before being shipped back to Intersil (Palm Bay, FL) for electrical testing.

Test Fixturing

No formal irradiation test fixturing was involved, as these DD tests are ‘bag tests’ in the sense that the parts are irradiated in an electrically inactive state with all leads shorted together.

Characterization Equipment and Procedures

Electrical testing was performed before and after irradiation using the Intersil production Automated Test Equipment (ATE). All electrical testing was performed at room temperature.

Experimental Matrix

Testing proceeded in general accordance with the guidelines of MIL-STD-883 Test Method 1017. The experimental matrix consisted of 5 samples irradiated at $2x10^{12}n/cm^2$, 5 irradiated at $1x10^{13}n/cm^2$, 5 irradiated at $3x10^{13}n/cm^2$ and 5 irradiated at $1x10^{14}n/cm^2$. Two control units (serial numbers 68 and 70) were used.

ISL75052SEHF/PROTO samples were drawn from Lot WXW8MA. Samples were packaged in the standard hermetic 16 Ld ceramic flatpack production package, code K16.E. Samples were screened to the SMD limits over temperature before the start of neutron testing.

Results

Neutron testing of the ISL75052SEH is complete and the results are reported in the balance of this report. It should be carefully realized when interpreting the data 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 downpoints.

Attributes Data

TABLE 1. ISL75052SEH ATTRIBUTES DATA

PART	SERIAL	SAMPLE SIZE	FLUENCE N/CM^2	PASS (Note 1)	FAIL	NOTES
ISL75052SEH	379 through 383	5	$2x10^{12}$	5	0	All passed
ISL75052SEH	384, 385, 406, 407, 409	5	$1x10^{13}$	5	5	All passed
ISL75052SEH	410 through 414	5	$3x10^{13}$	0	5	All failed parametrically, V_{REF} and V_{OUT} at ±1.5% specification
ISL75052SEH	416, 417, 419 through 421	5	$1x10^{14}$	0	5	All failed parametrically, V_{REF} and V_{OUT} outside ±2.0% range

NOTE:

1. 'Pass' indicates a sample that passes all SMD limits.

Variables Data

The plots in Figures 2 through 26 show data plots for key parameters before and after irradiation to each level. The reported parameters and their datasheet limits are shown in Table 2 on page 17. The plots show the median of each parameter as a function of neutron irradiation. We chose to plot the median because of the small sample sizes (five per cell) involved. We also show the applicable electrical limits taken from the SMD; it should be carefully noted that these limits are provided for *guidance only* as the ISL75052SEH is not specified or guaranteed for the neutron environment. Intersil does not design, qualify or guarantee its parts for the DD environment, but has done some limited neutron testing for customer guidance.

Variables Data Plots

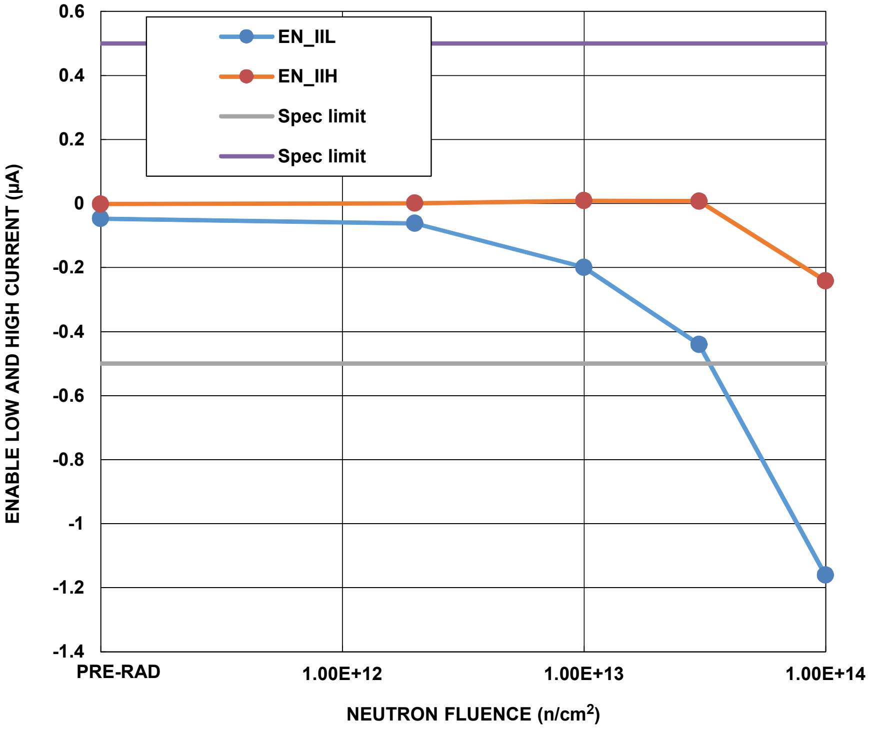

FIGURE 2. ISL75052SEH enable LOW and enable HIGH current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are -0.5µA to 0.5µA.

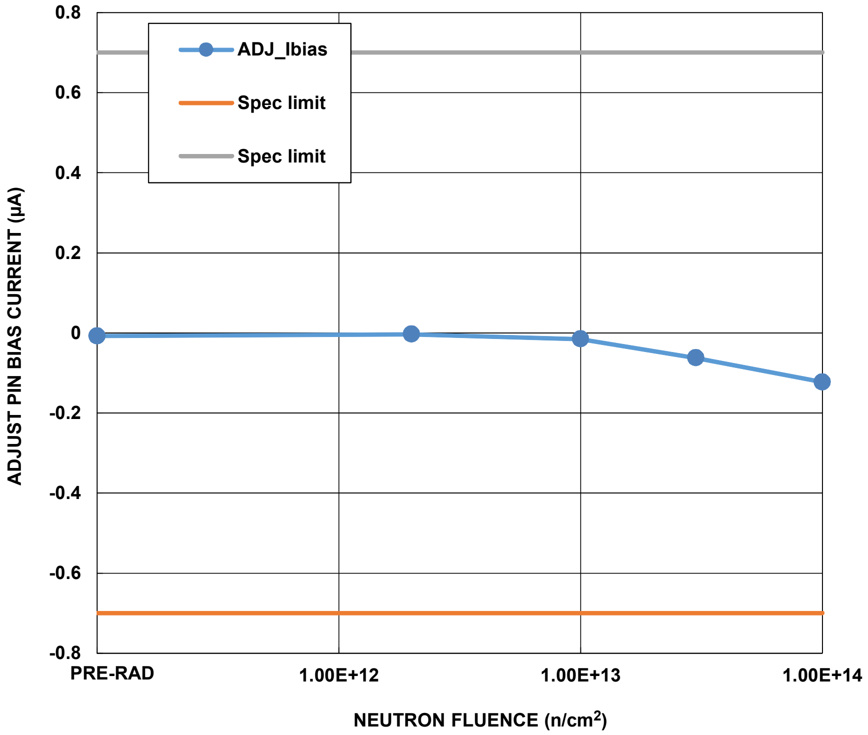

FIGURE 3. ISL75052SEH adjust pin bias current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are -0.7µA to 0.7µA.

Variables Data Plots (Continued)

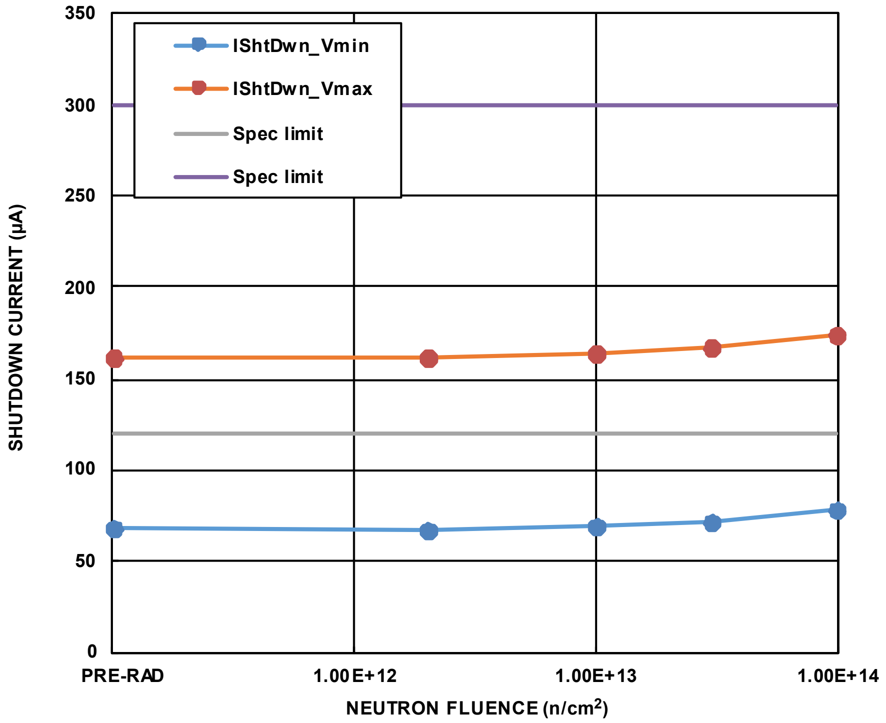

FIGURE 4. ISL75052SEH shutdown current at maximum and minimum input voltage as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are 120.0µA (maximum) at 4.0V input and 300.0µA (maximum) at 13.2V input.

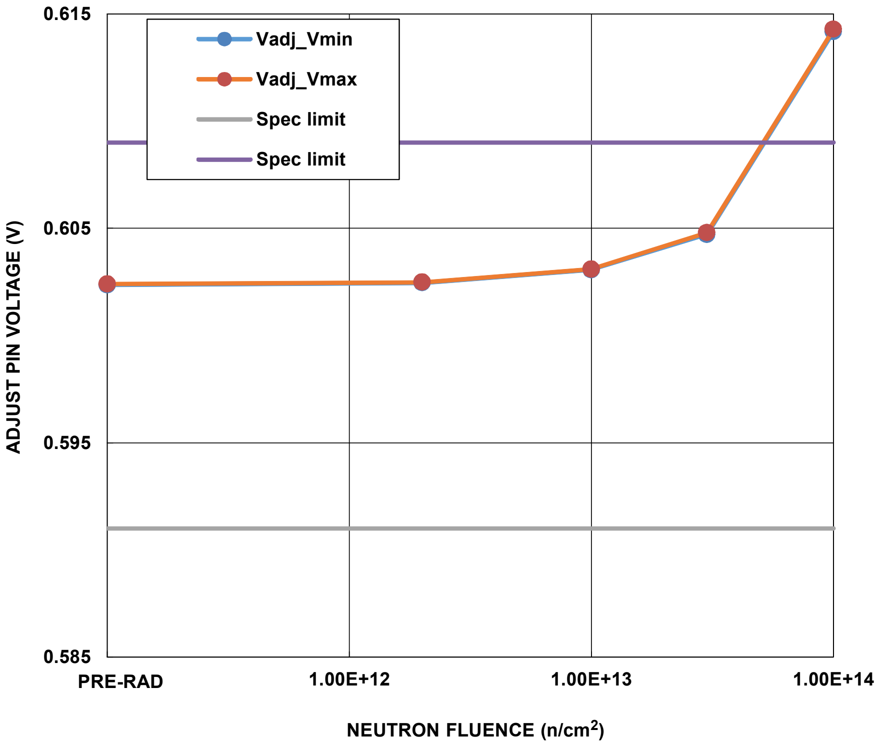

FIGURE 5. ISL75052SEH adjust pin voltage as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are 0.591V to 0.609V.

Variables Data Plots (Continued)

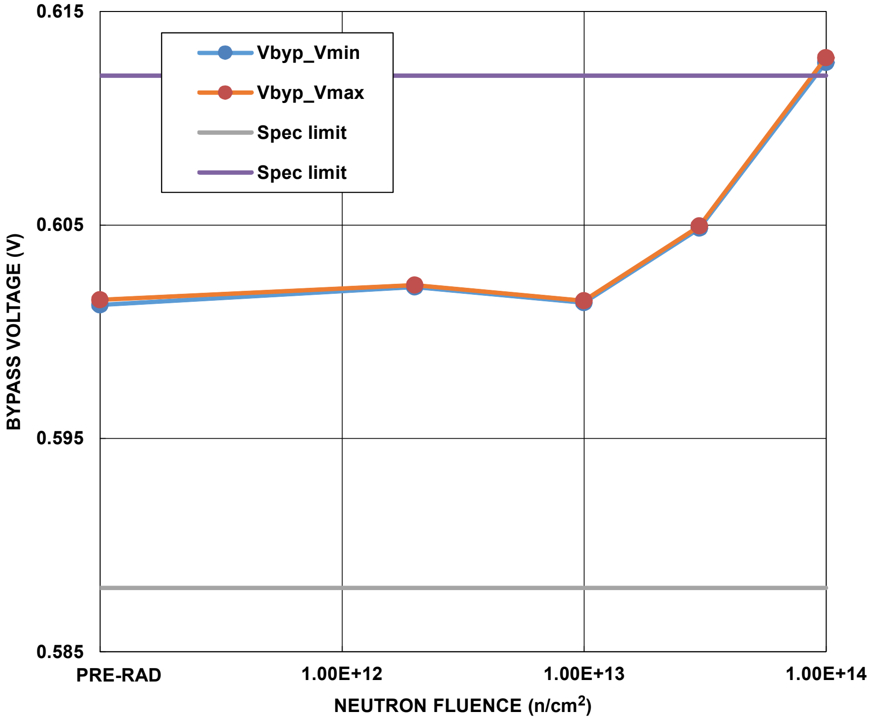

FIGURE 6. **ISL75052SEH bypass voltage at an input voltage of 3.6V as a function of 1MeV equivalent neutron irradiation at 2x10^{12}n/cm^2, 1x10^{13}n/cm^2, 3x10^{13}n/cm^2 and 1x10^{14}n/cm^2. Sample size for each cell was 5. The datasheet limits are 0.588V to 0.612V.**

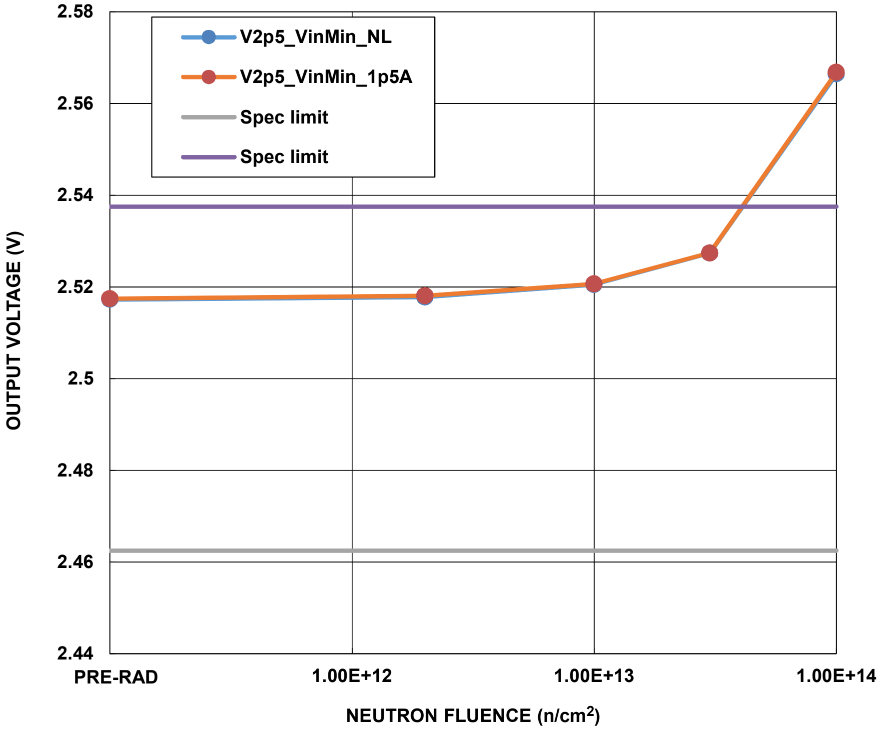

FIGURE 7. **ISL75052SEH output voltage at minimum input voltage, 2.5V output voltage, no load and 1.5A output current, as a function of 1MeV equivalent neutron irradiation at 2x10^{12}n/cm^2, 1x10^{13}n/cm^2, 3x10^{13}n/cm^2 and 1x10^{14}n/cm^2. Sample size for each cell was 5. The datasheet limits are 2.4625V to 2.5375V.**

Variables Data Plots (Continued)

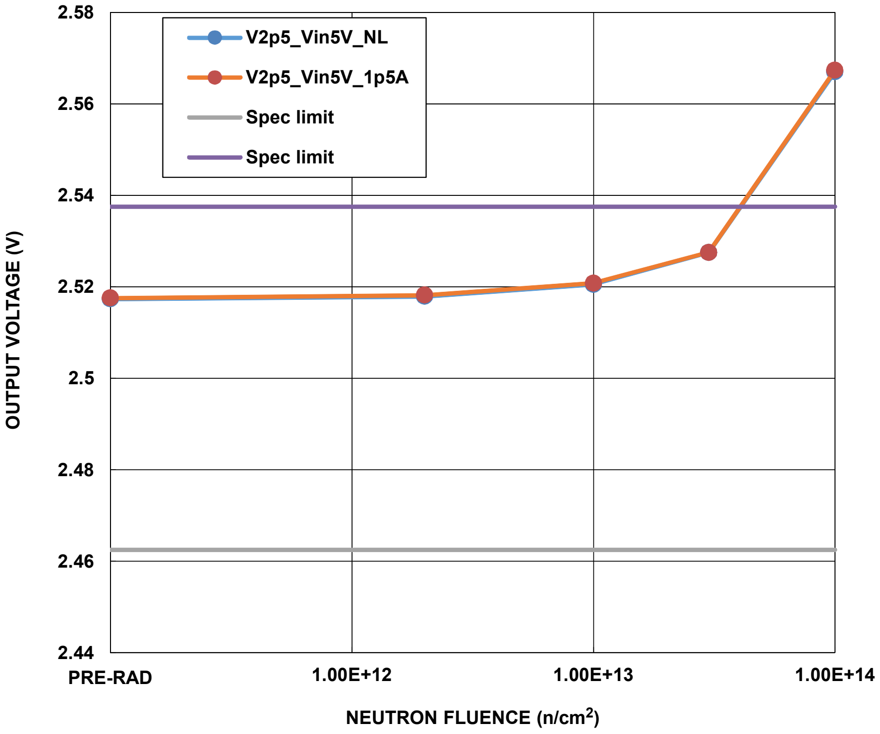

FIGURE 8. ISL75052SEH output voltage at 5.0V input voltage, 2.5V output voltage, no load and 1.5A output current, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are 2.4625V to 2.5375V.

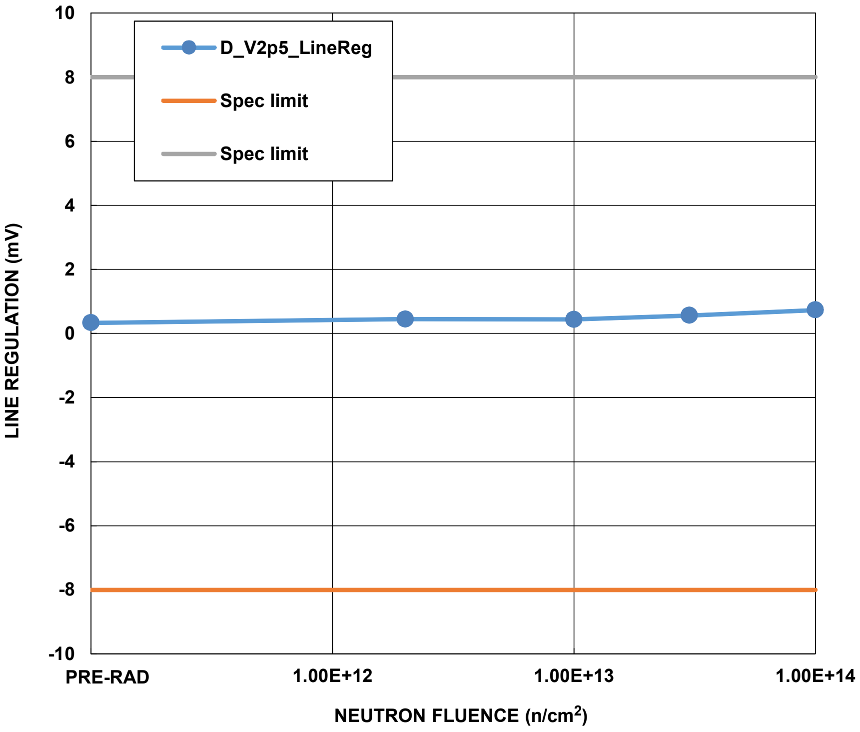

FIGURE 9. ISL75052SEH line regulation, 4.0V to 13.2V input voltage, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are -8.0mV to 8.0mV.

Variables Data Plots (Continued)

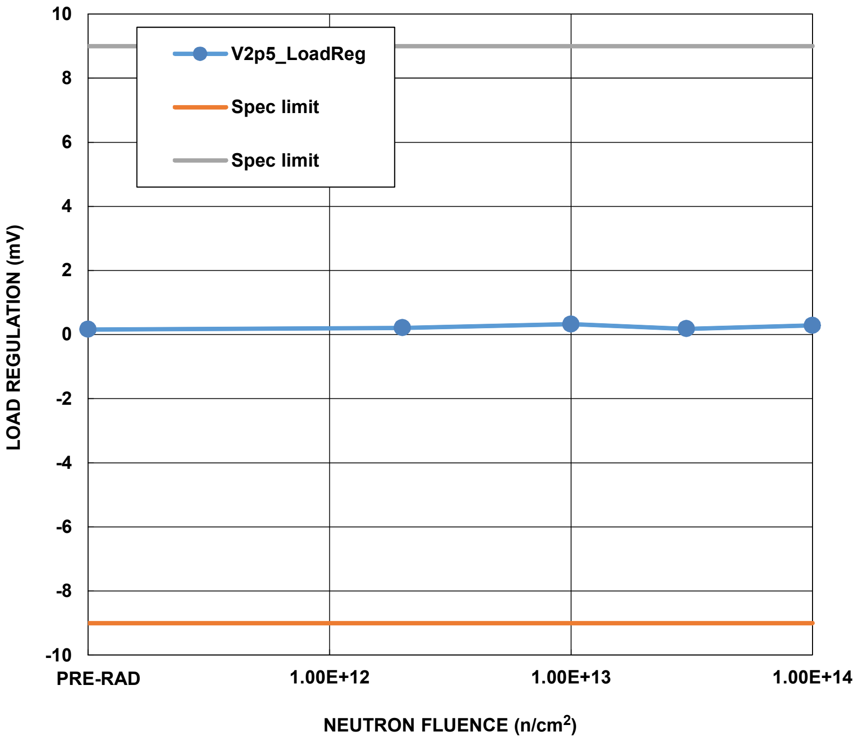

FIGURE 10. ISL75052SEH load regulation, 2.5V output voltage, 4.0V input voltage, 0 to 1.5A load, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}$n/cm^2, $1x10^{13}$n/cm^2, $3x10^{13}$n/cm^2 and $1x10^{14}$n/cm^2. Sample size for each cell was 5. The datasheet limits are -9.0mV to 9.0mV.

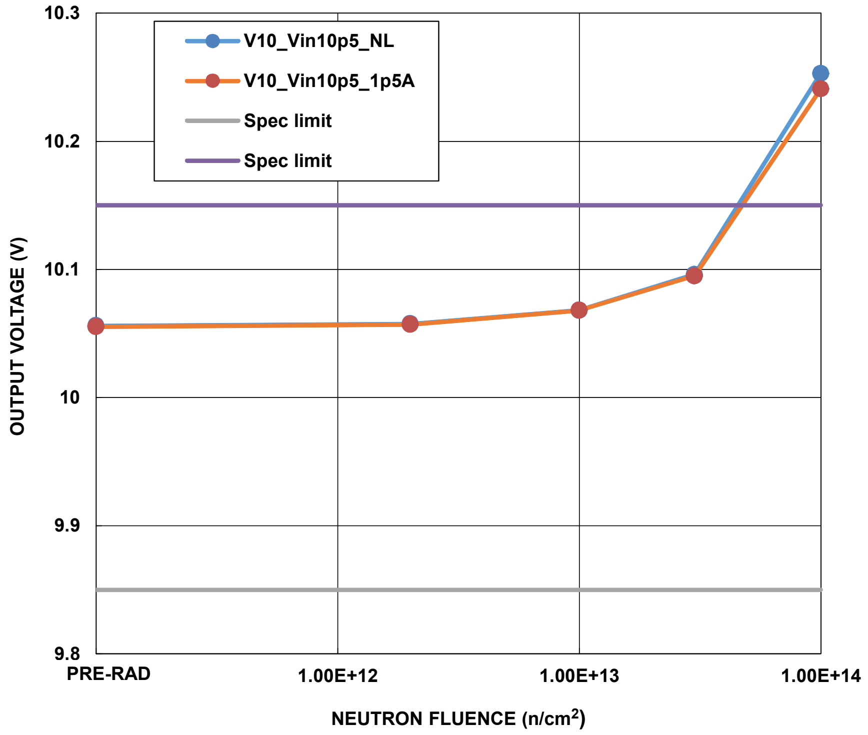

FIGURE 11. ISL75052SEH output voltage at 10.5V input voltage, 10.0V output voltage, no load and 1.5A output current, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}$n/cm^2, $1x10^{13}$n/cm^2, $3x10^{13}$n/cm^2 and $1x10^{14}$n/cm^2. Sample size for each cell was 5. The datasheet limits are 9.85V to 10.15V.

Variables Data Plots (Continued)

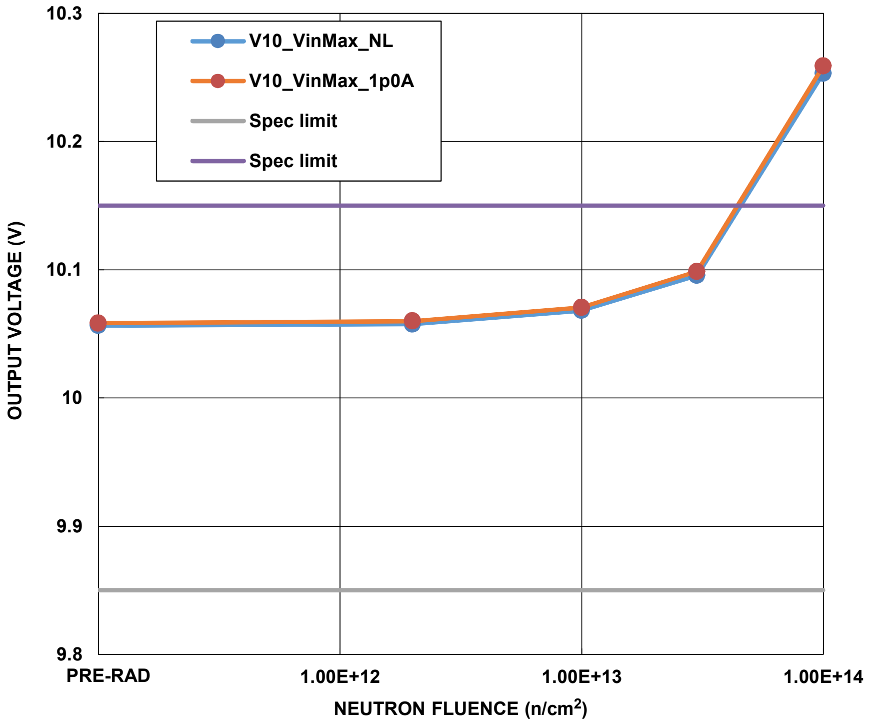

FIGURE 12. ISL75052SEH output voltage at 13.2V input voltage, 10.0V output voltage, no load and 1.5A output current, as a function of 1MeV equivalent neutron irradiation at 2×10^{12}n/cm^2, 1×10^{13}n/cm^2, 3×10^{13}n/cm^2 and 1×10^{14}n/cm^2. Sample size for each cell was 5. The datasheet limits are 9.85V to 10.15V.

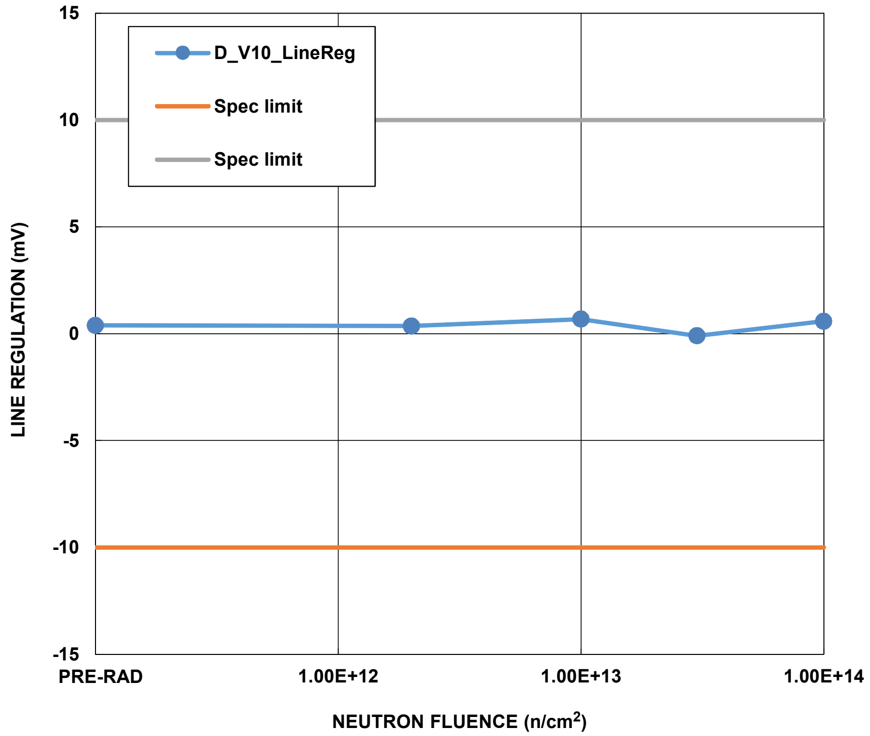

FIGURE 13. ISL75052SEH line regulation, 10.0V to 13.2V input voltage, as a function of 1MeV equivalent neutron irradiation at 2×10^{12}n/cm^2, 1×10^{13}n/cm^2, 3×10^{13}n/cm^2 and 1×10^{14}n/cm^2. Sample size for each cell was 5. The datasheet limits are -10.0mV to 10.0mV.

Variables Data Plots (Continued)

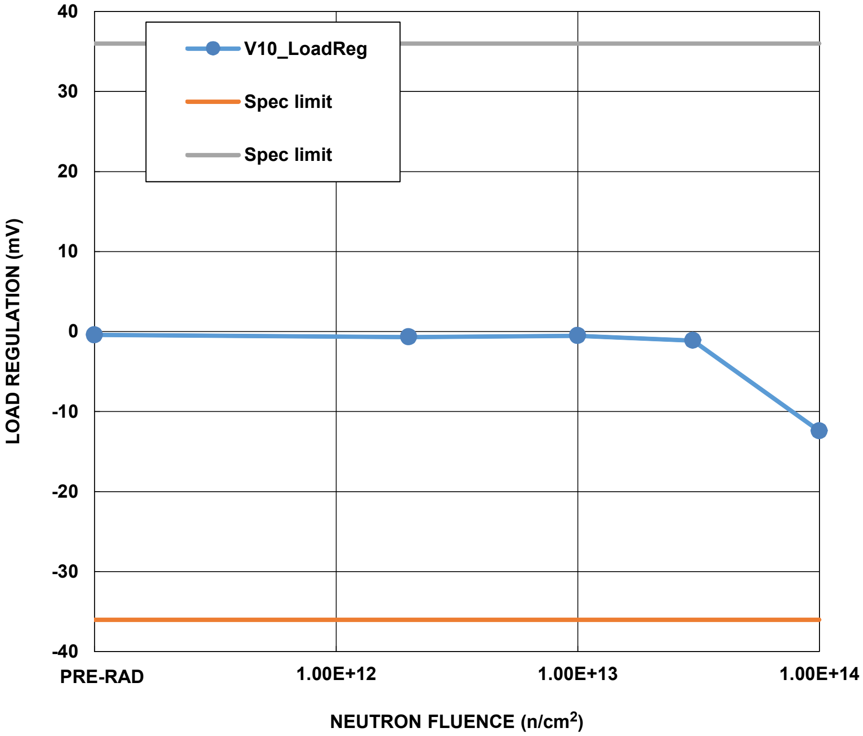

FIGURE 14. ISL75052SEH load regulation, 10.0V output voltage, 10.5V input voltage, 0 to 1.5A load, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are -36.0mV to 36.0mV.

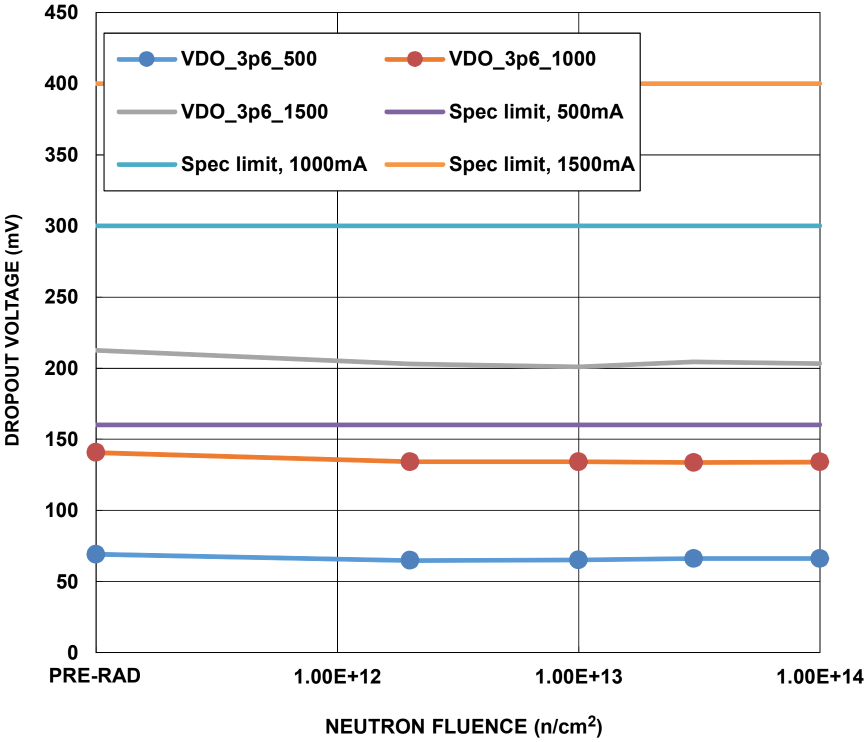

FIGURE 15. ISL75052SEH dropout voltage at 3.6V output, 500mA, 1000mA and 1500mA output current, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are 160.0mV maximum at 500mA, 300.0mV at 1000mA and 400.0mV at 1500mA.

Variables Data Plots (Continued)

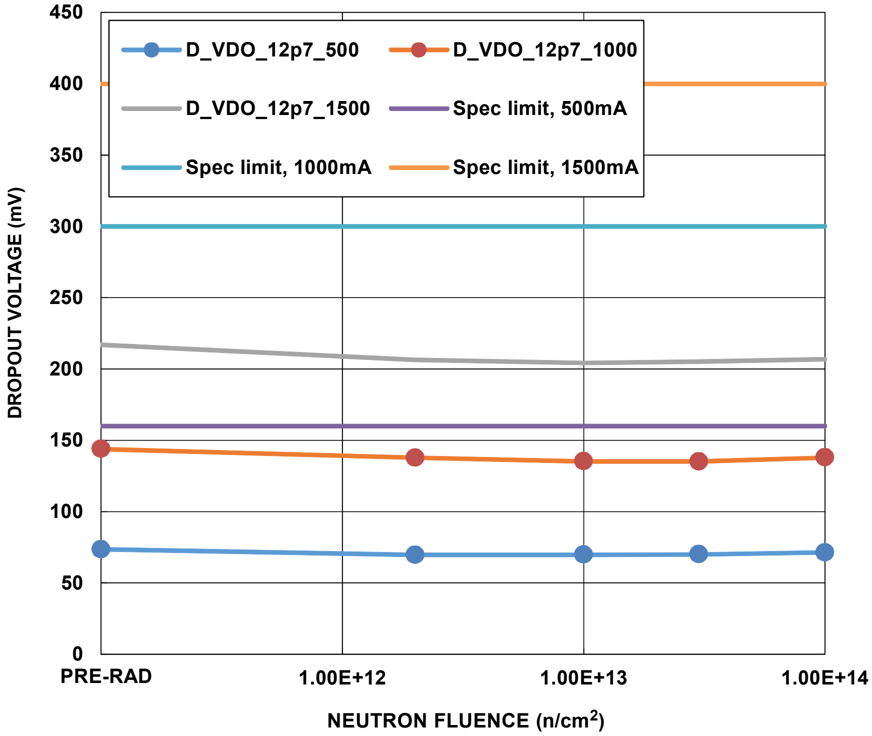

FIGURE 16. ISL75052SEH dropout voltage at 12.7V output, 500mA, 1000mA and 1500mA output current, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}$n/cm^2, $1x10^{13}$n/cm^2, $3x10^{13}$n/cm^2 and $1x10^{14}$n/cm^2. Sample size for each cell was 5. The datasheet limits are 160.0mV maximum at 500mA, 300.0mV at 1000mA and 400.0mV at 1500mA.

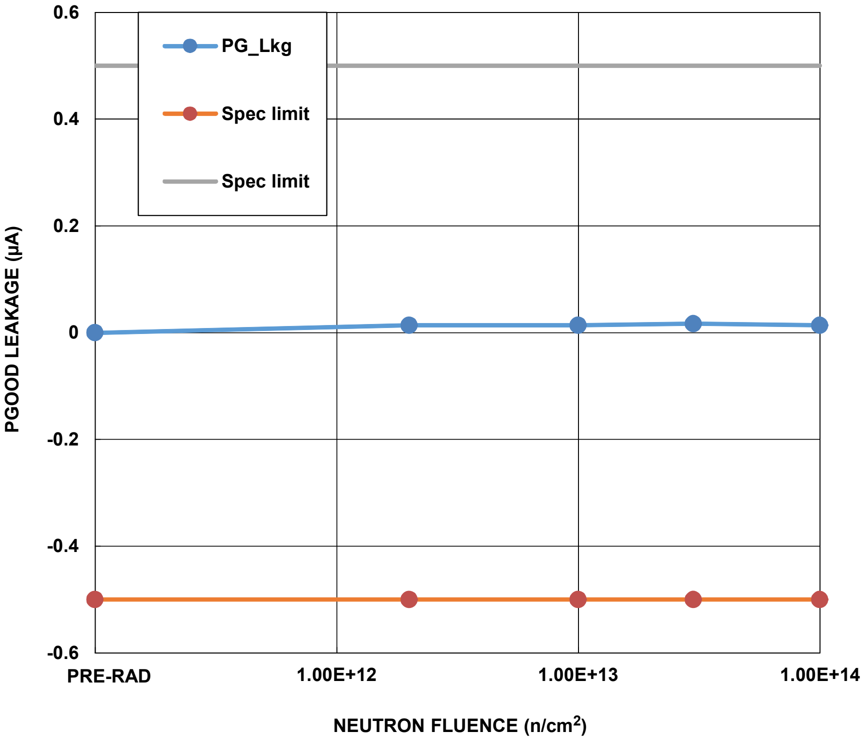

FIGURE 17. ISL75052SEH PGOOD leakage as a function of 1MeV equivalent neutron irradiation at $2x10^{12}$n/cm^2, $1x10^{13}$n/cm^2, $3x10^{13}$n/cm^2 and $1x10^{14}$n/cm^2. Sample size for each cell was 5. The datasheet limits are -0.5µA to 0.5µA.

Variables Data Plots (Continued)

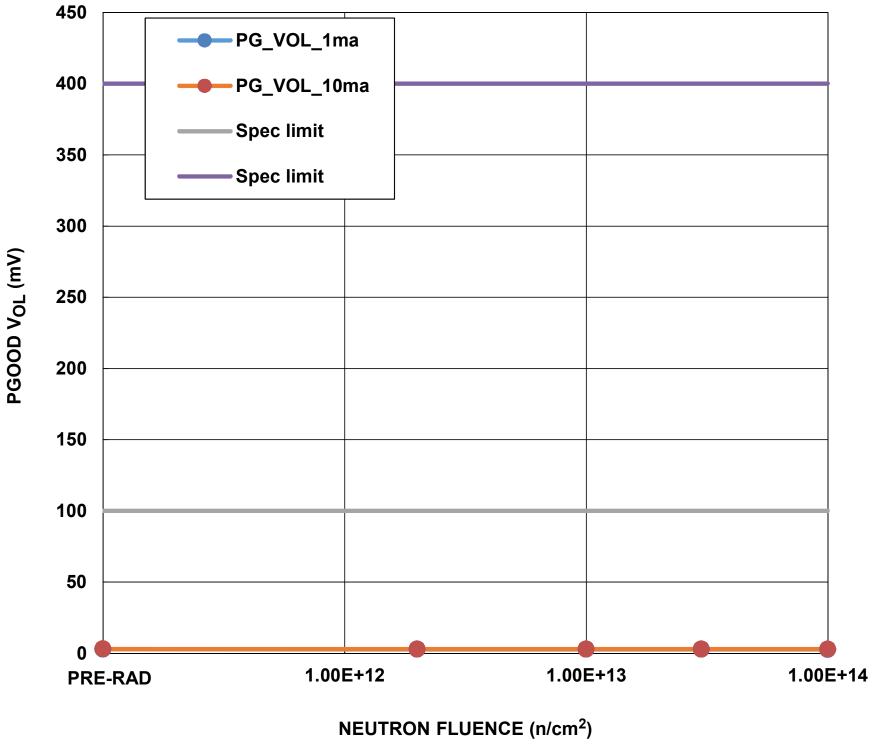

FIGURE 18. ISL75052SEH PGOOD LOW and HIGH output voltage as a function of 1MeV equivalent neutron irradiation at $2 \times 10^{12} n/cm^2$, $1 \times 10^{13} n/cm^2$, $3 \times 10^{13} n/cm^2$ and $1 \times 10^{14} n/cm^2$. Sample size for each cell was 5. The data sheet limits are 100.0mV maximum (V_{OL}) and 400.0mV (V_{OH}).

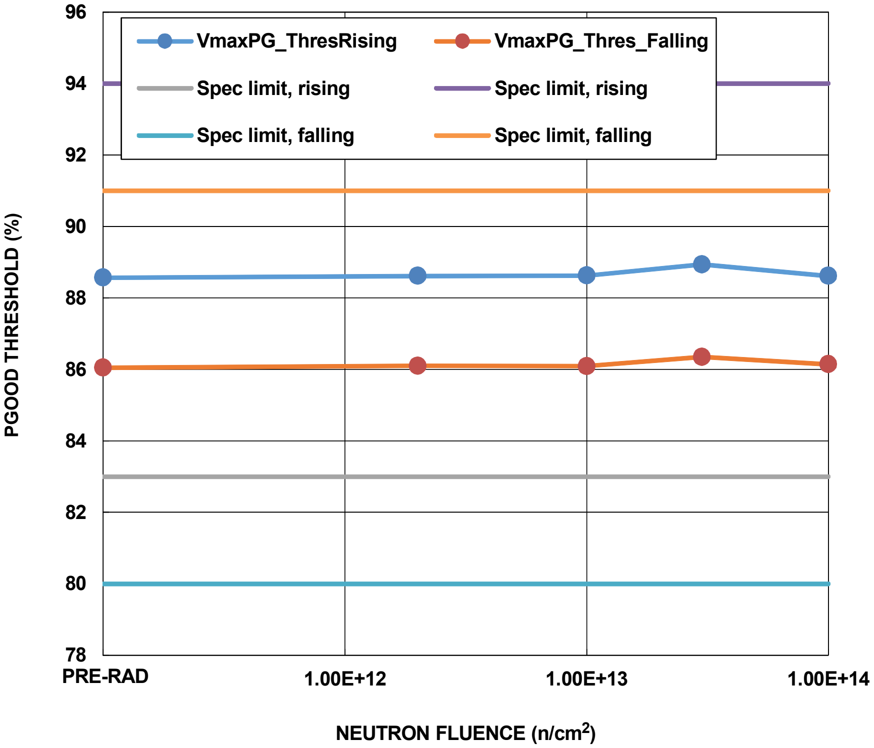

FIGURE 19. ISL75052SEH PGOOD rising and falling threshold, 13.2V input voltage, as a function of 1MeV equivalent neutron irradiation at $2 \times 10^{12} n/cm^2$, $1 \times 10^{13} n/cm^2$, $3 \times 10^{13} n/cm^2$ and $1 \times 10^{14} n/cm^2$. Sample size for each cell was 5. The datasheet limits are 83% to 94% (rising) and 80% to 91% (falling).

Variables Data Plots (Continued)

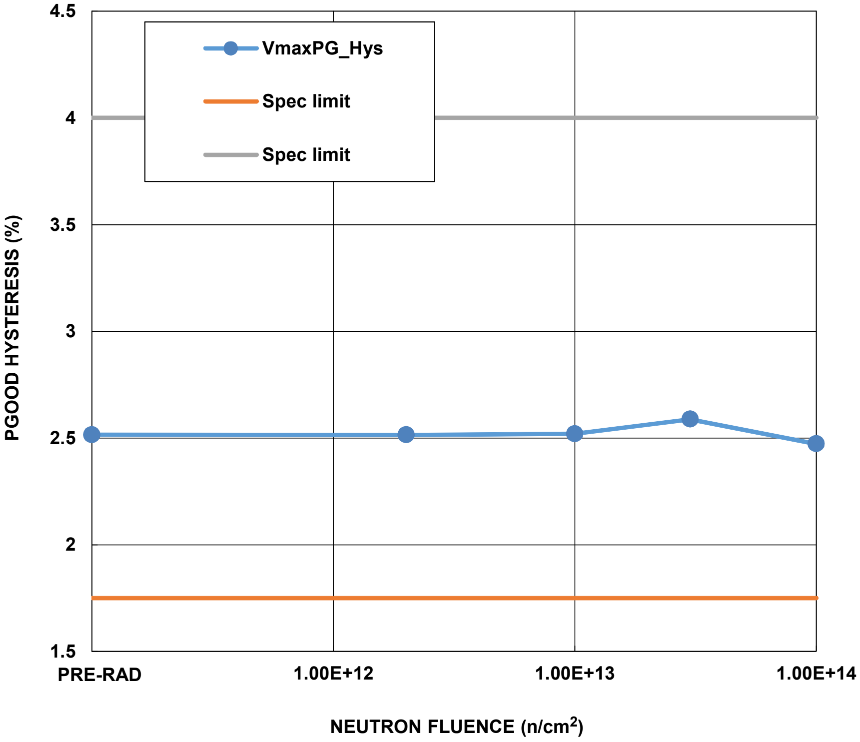

FIGURE 20. ISL75052SEH PGOOD hysteresis, 13.2V input voltage, as a function of 1MeV equivalent neutron irradiation at 2×10^{12}n/cm^2, 1×10^{13}n/cm^2, 3×10^{13}n/cm^2 and 1×10^{14}n/cm^2. Sample size for each cell was 5. The datasheet limits are 1.75% to 4.0%.

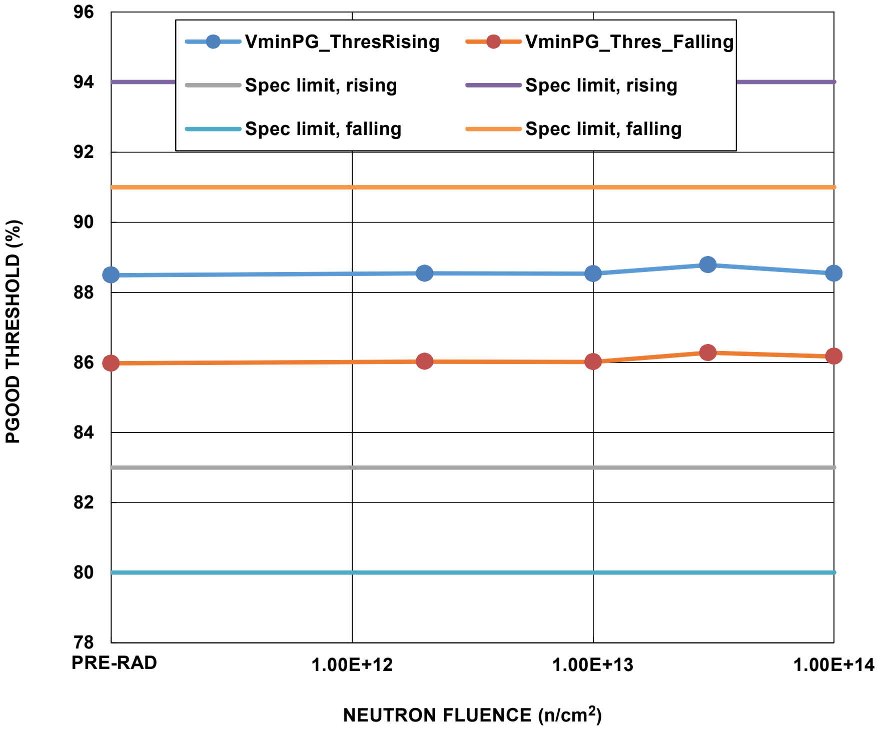

FIGURE 21. ISL75052SEH PGOOD rising and falling threshold, 4.0V input voltage, as a function of 1MeV equivalent neutron irradiation at 2×10^{12}n/cm^2, 1×10^{13}n/cm^2, 3×10^{13}n/cm^2 and 1×10^{14}n/cm^2. Sample size for each cell was 5. The datasheet limits are 83% to 94% (rising) and 80% to 91% (falling).

Variables Data Plots (Continued)

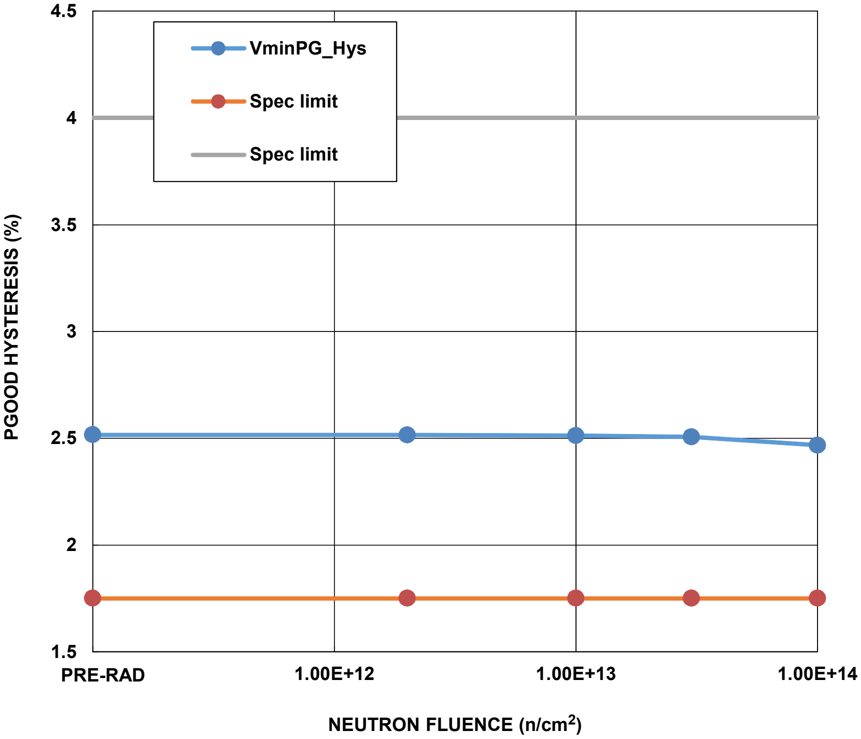

FIGURE 22. ISL75052SEH PGOOD hysteresis, 4.0V input voltage, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are 1.75% to 4.0%.

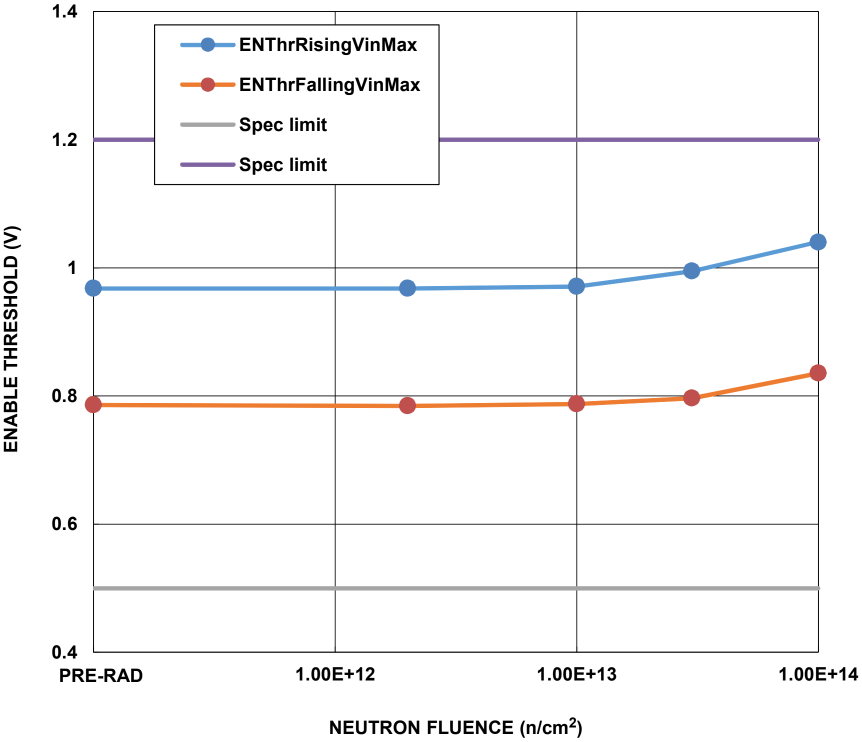

FIGURE 23. ISL75052SEH Enable rising and falling threshold, 13.2V input voltage, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are 0.5V to 1.2V.

Variables Data Plots (Continued)

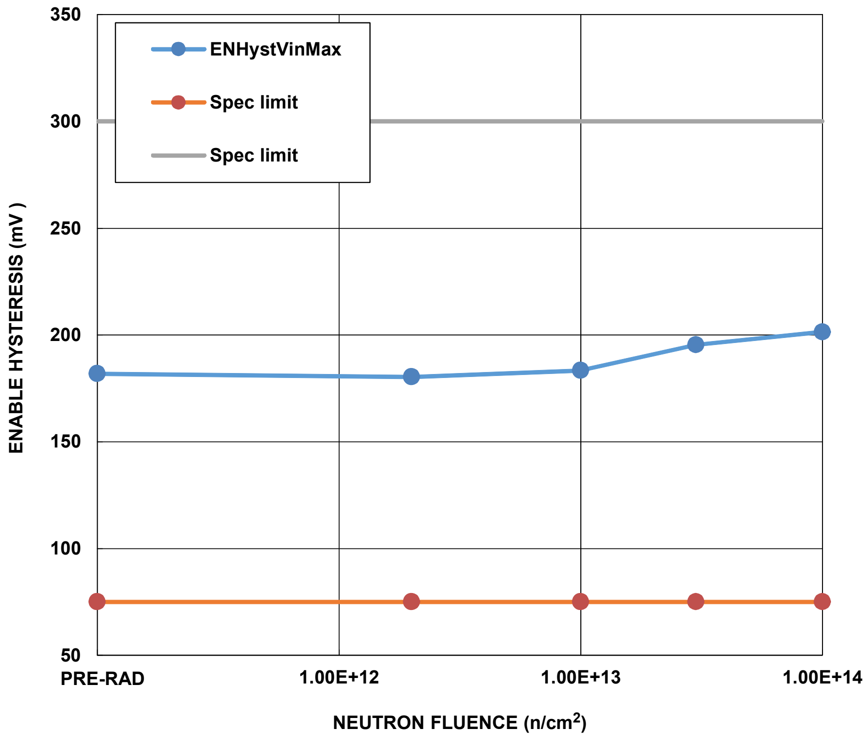

FIGURE 24. ISL75052SEH Enable hysteresis, 13.2V input voltage, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are 75.0mV to 300.0mV.

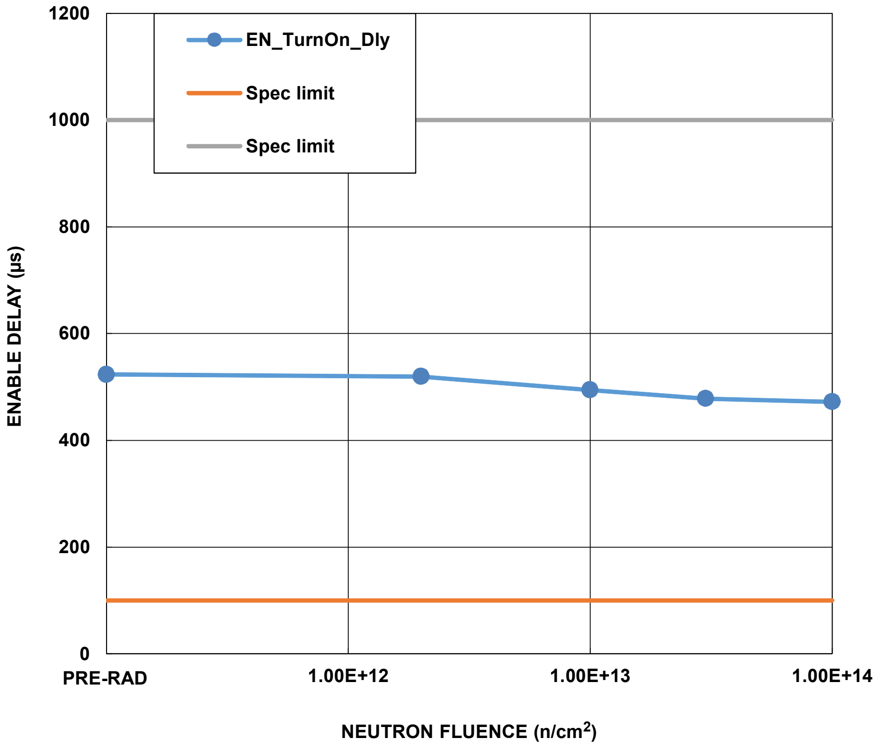

FIGURE 25. ISL75052SEH Enable turnon delay as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The datasheet limits are 100.0µs to 1000µs.

Variables Data Plots (Continued)

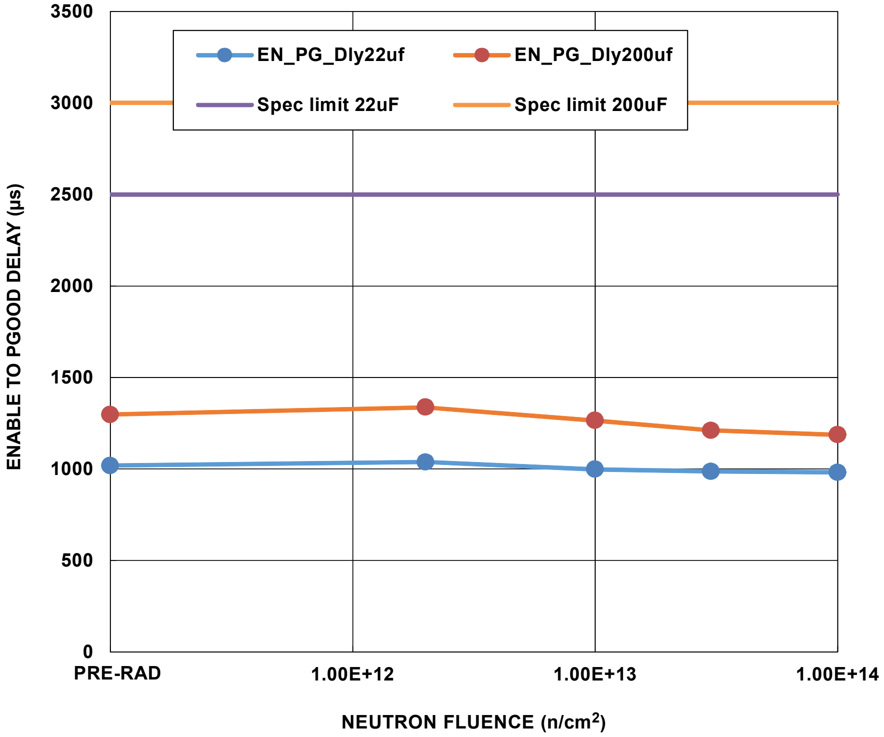

FIGURE 26. ISL75052SEH Enable to PGOOD delay, 22µF and 200µF, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. Sample size for each cell was 5. The data sheet limits are 2500µs (22µF) and 3000µs (200µF).

Conclusion

This report summarizes results of 1MeV equivalent neutron testing of the ISL75052SEH low dropout voltage linear regulator. The test was conducted in order to determine the sensitivity of the part to Displacement Damage (DD) caused by neutron or proton environments in space. Neutron fluences ranged from $2x10^{12}n/cm^2$ to $1x10^{14}n/cm^2$. This project was carried out in collaboration with VPT, Inc. (Blacksburg, VA), and their support is gratefully acknowledged.

The samples met all specifications (Bin 1) after $2x10^{11}n/cm^2$ and $1x10^{13}n/cm^2$. ATE testing showed rejects to the datasheet limits after $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. These were parametric failures, notably of the reference and output voltage, which were at the ±1.5% specification after $3x10^{13}n/cm^2$ and exceeded a ±2.0% range after $1x10^{14}n/cm^2$. The part may be usable at $3x10^{13}n/cm^2$ with some derating.

Appendices

Reported Parameters

The limits are from the SMD and are provided for guidance only as the part is not designed or guaranteed for the neutron environment. A number of parameters are plotted in the same figure (see for example Figure 2 on page 4, which plots the neutron response of both the enable LOW and enable HIGH currents) in order to save space.

TABLE 2. REPORTED PARAMETERS AND DATASHEET LIMITS

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNITS	NOTES
2	Enable LOW Current	-0.5	0.5	µA	
	Enable HIGH Current	-0.5	0.5	µA	
3	Adjust Pin Bias Current	-0.7	0.7	µA	
4	Shutdown Current	-	120.0	µA	4.0V in
	Shutdown Current	-	300.0	µA	13.2V in
5	Adjust Pin Voltage	0.591	0.609	V	4.0V in
	Adjust Pin Voltage	0.591	0.609	V	13.2V in
6	Bypass Pin Voltage	0.588	0.612	V	4.0V in
	Bypass Pin Voltage	0.588	0.612	V	13.2V in
7	Output Voltage, 2.5V	2.4625	2.5375	V	4.0V in, no load
	Output Voltage, 2.5V	2.4625	2.5375	V	4.0V in, 1.5A
8	Output Voltage, 2.5V	2.4625	2.5375	V	5V, no load
	Output Voltage, 2.5V	2.4625	2.5375	V	5V, 1.5A
9	Line Regulation, 2.5V	-8.0	8.0	mV	4.0V to 13.2V
10	Load Regulation, 2.5V	-9.0	9.0	mV	4.0V in, 0 to 1.5A
11	Output Voltage, 10.0V	9.85	10.15	V	10.5V in, no load
	Output Voltage, 10.0V	9.85	10.15	V	10.5V in, 1.5A
12	Output Voltage, 10.0V	9.85	10.15	V	13.2V in, no load
	Output Voltage, 10.0V	9.85	10.15	V	13.2V in, 1.5A
13	Line Regulation, 10.0V	-10.0	10.0	mV	10.0V to 13.2V
14	Load Regulation, 10.0V	-36.0	36.0	mV	1.5V in, 0 to 1.5A
15	Dropout Voltage, 3.6V	-	160.0	mV	500mA output current
	Dropout Voltage, 3.6V	-	300.0	mV	1000mA output current
	Dropout Voltage, 3.6V	-	400.0	mV	1500mA output current
16	Dropout Voltage, 12.7V	-	160.0	mV	500mA output current
	Dropout Voltage, 12.7V	-	300.0	mV	1000mA output current
	Dropout Voltage, 12.7V	-	400.0	mV	1500mA output current
17	PGOOD Leakage	-0.5	0.5	µA	13.2V in, PGOOD at 5.5V
18	PGOOD V_{OL}	-	100.0	mV	1.0mA load
	PGOOD V_{OL}	-	400.0	mV	10.0mA load
19	PGOOD Threshold, Rising	83	94	%	13.2V in, rising
	PGOOD Threshold, Falling	80	91	%	13.2V in, falling
20	PGOOD Hysteresis	1.75	4.0	%	13.2V in

TABLE 2. REPORTED PARAMETERS AND DATASHEET LIMITS (Continued)

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNITS	NOTES
21	PGOOD Threshold, Rising	83	94	%	4.0V in, rising
	PGOOD Threshold, Falling	80	91	%	4.0V in, falling
22	PGOOD Hysteresis	1.75	4.0	%	13.2V in
23	Enable Threshold, Rising	0.5	1.2	V	13.2V in, rising
	Enable Threshold, Falling	0.5	1.2	V	13.2V in, falling
24	Enable Hysteresis	75	300	mV	13.2V in
25	Enable Turn-On Delay	-	1000	µs	
26	Enable to PGOOD Delay	-	2500	µs	
	Enable to PGOOD Delay	-	3000	µs	

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Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338

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