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TEST REPORT

ISL72991RH

Neutron Test Report

TR063
Rev. 0.00
Mar 21, 2018

Introduction

This report summarizes results of 1MeV equivalent neutron testing of the ISL72991RH low dropout adjustable negative 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 $1x10^{11}n/cm^2$ to $1x10^{14}n/cm^2$. This project was carried out in collaboration with the Advanced Technology Laboratories Division of Northrop Grumman Corporation and their support is gratefully acknowledged.

Part Description

The radiation hardened ISL72991RH is a low dropout adjustable negative regulator with an output voltage range of -2.25V to -26V. The device features a 1A output current capability, an adjustable current limit pin (ILIM), and a shutdown pin (SD) for easy on/off control.

The ISL72991RH incorporates unique circuitry that enables precision performance across the -55°C to +125°C temperature range and post-irradiation. Specifications across the full temperature range include an internal reference voltage of -1.25V +40mV/-50mV (maximum), line regulation of ±25mV (maximum), and load regulation of ±15mV (maximum). The reference voltage is the ADJ to GND voltage.

Constructed with the Renesas dielectrically isolated Rad Hard Silicon Gate (RSG) BiCMOS process, these devices are immune to single event latch-up and have been specifically designed to provide highly reliable performance in harsh radiation environments.

Specifications for Rad Hard 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.

Related Literature

For a full list of related documents, visit our website

- ISL72991RH product page
- MIL-STD-883 test method 1017

1. Test Description

1.1 Irradiation Facility

Neutron fluence irradiations were performed on the test samples on June 25, 2015, at the WSMR Fast Burst Reactor (FBR) per MIL-STD-883G, Method 1017.2, with each part unpowered during irradiation and all leads shorted. The target irradiation levels were $1x10^{11}n/cm^2$, $5x10^{11}n/cm^2$, $1x10^{12}n/cm^2$, $1x10^{12}n/cm^2$, and $1x10^{14}n/cm^2$. 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 the Renesas Palm Bay facility for electrical testing.

1.2 Test Fixturing

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

1.3 Radiation Dosimetry

Table 1 shows the TLD and Sulfur pellet dosimetry from WSMR indicating the total accumulated gamma dose and actual neutron fluence exposure levels for each sets of samples. This dosimetry process is traceable to NIST (IAW ASTM E722).

Table 1. ISL72991RH Neutron Fluence Dosimetry Data

TLD		Sulfur Pellet						
TLD Number	cGy(Si)	Pellet Number	Distance (inches)	Exposure ID	Flu >3MeV (n/cm^2)	% Unc	Total Fluence (n/cm^2)	1Mev Si (n/cm^2)
81	2.760E+01	3263	49	Free Field	1.536E+10	7.1	1.335E+11	1.087E+11
82	1.315E+02	3264	21.65	Free Field	8.779E+10	7.1	7.016E+11	6.105E+11
83	5.403E+02	3265	11	Free Field	3.334E+11	7.1	2.620E+12	2.337E+12
85	2.954E+03	3267	31.15	Free Field	1.528E+12	7.1	1.253E+13	1.066E+13
84	2.997E+04	3266	10	Free Field	1.990E+13	7.1	1.562E+14	1.395E+14

Notes:
1. 1cGy(Si) = 1rad(Si)
2. The Uncertainty (% Unc) column is applicable only to the Fluence > 3MeV.

1.4 Characterization Equipment and Procedures

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

1.5 Experimental Matrix

Testing proceeded in general accordance with the guidelines of MIL-STD-883 test method 1017. The experimental matrix consisted of ten samples irradiated at $1x10^{11}n/cm^2$, five samples irradiated at $5x10^{11}n/cm^2$, five irradiated at $1x10^{12}n/cm^2$, five irradiated at $1x10^{13}n/cm^2$, and five irradiated at $1x10^{14}$n/cm2. Six control units were used.

ISL72991RH samples were drawn from Lot DD4T4CB. Samples were packaged in the standard hermetic 28 Ld Ceramic Flatpack (CFP) production package, code K28.A. Samples were processed through burnin before irradiation and were screened to the SMD limits at room, low, and high temperatures before the start of neutron testing.

2. Results

Neutron testing of the ISL72991RH is complete and the results are reported in the balance of this report. It should be understood when interpreting the data that each neutron irradiation was performed on a different set of samples; this is *not* total dose testing, where the damage is cumulative.

2.1 Attributes Data

Table 2. Attributes Data

Fluence (n/cm^2)		Sample Size	Pass (Note 1)	Fail
Planned	Actual			
$1x10^{11}$	$1.1x10^{11}$	10	10	0
$5x10^{11}$	$6.1x10^{11}$	5	5	0
$1x10^{12}$	$2.3x10^{12}$	5	5	0
$1x10^{13}$	$1.1x10^{13}$	5	5	0
$1x10^{14}$	$1.4x10^{14}$	5	0	5

Note:

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

2.2 Variables Data

Figures 1 through 11 show data plots for key parameters before and after irradiation to each level. The plots show the mean of each parameter as a function of neutron irradiation. Also, they include error bars at each downpoint, representing the minimum and maximum measured values of the samples, although in some plots the error bars might not be visible due to their values compared to the scale of the graph. While the applicable electrical limits taken from the SMD are also shown, it should be noted that these limits are provided for guidance only as the ISL72991RH is not specified for the neutron environment.

All samples passed the post-irradiation SMD limits after all exposures up to and including $1x10^{13}n/cm^2$, but failed the SMD post-irradiation limits after $1x10^{14}n/cm^2$.

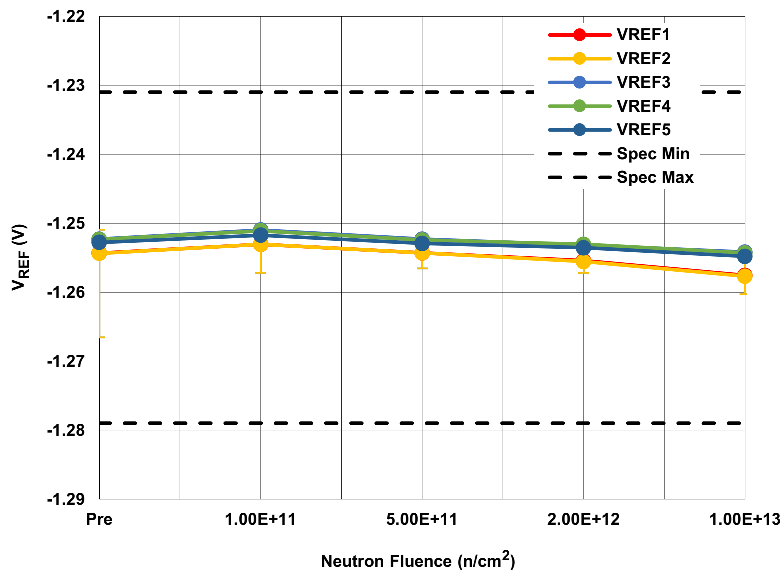

Figure 1. ISL72991RH reference voltage (V_{REF}) at five different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. V_{REF1} denotes V_{IN} = 30V, no load, V_{REF2} denotes V_{IN} = 30V, 1A, V_{REF3} denotes V_{IN} = 3.5V, no load, V_{REF4} denotes V_{IN} = 3.5V, 1A, and V_{REF5} denotes V_{IN} = 7V, 1A. The error bars represent the minimum and maximum measured values. The SMD limits are -1.279V minimum and -1.231V maximum.

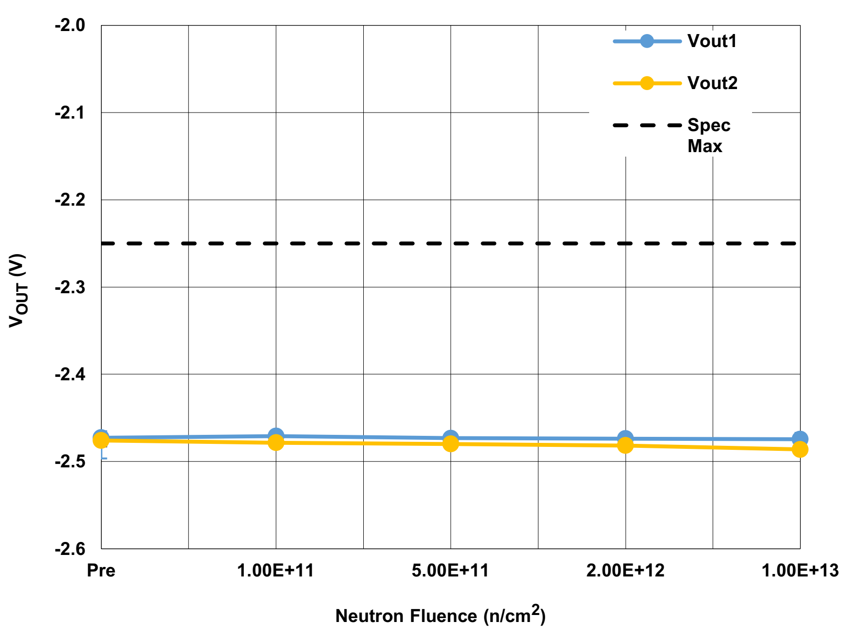

Figure 2. ISL72991RH minimum output voltage (V_{OUT}) with V_{IN} = 3V at two different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. V_{OUT1} denotes a 10mA load, and V_{OUT2} denotes no load. The error bars represent the minimum and maximum measured values. The SMD limit is -2.25V maximum.

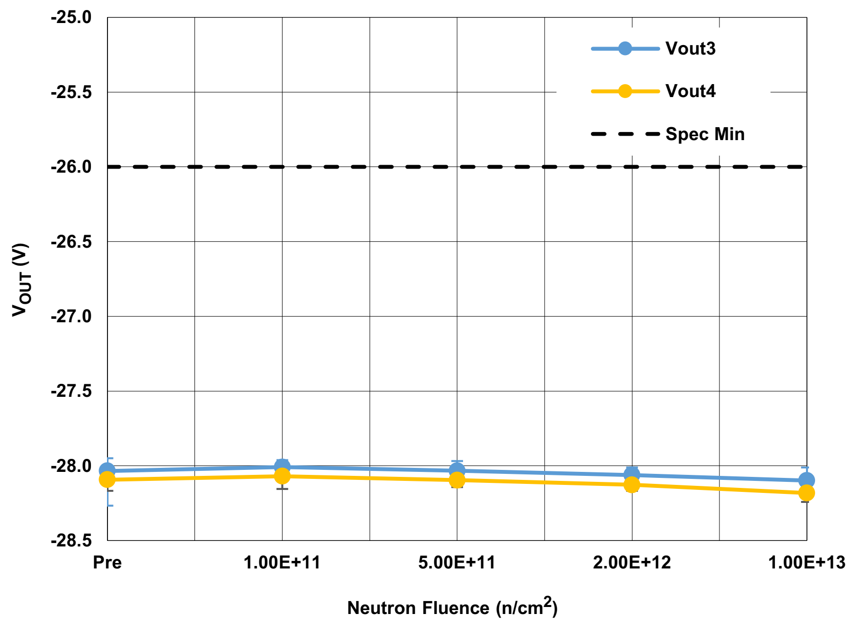

Figure 3. ISL72991RH maximum output voltage (V_{OUT}) with V_{IN} = 30V at two different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. V_{OUT3} denotes a 10mA load, and V_{OUT4} denotes no load. The error bars represent the minimum and maximum measured values. The SMD limit is -26.0V maximum.

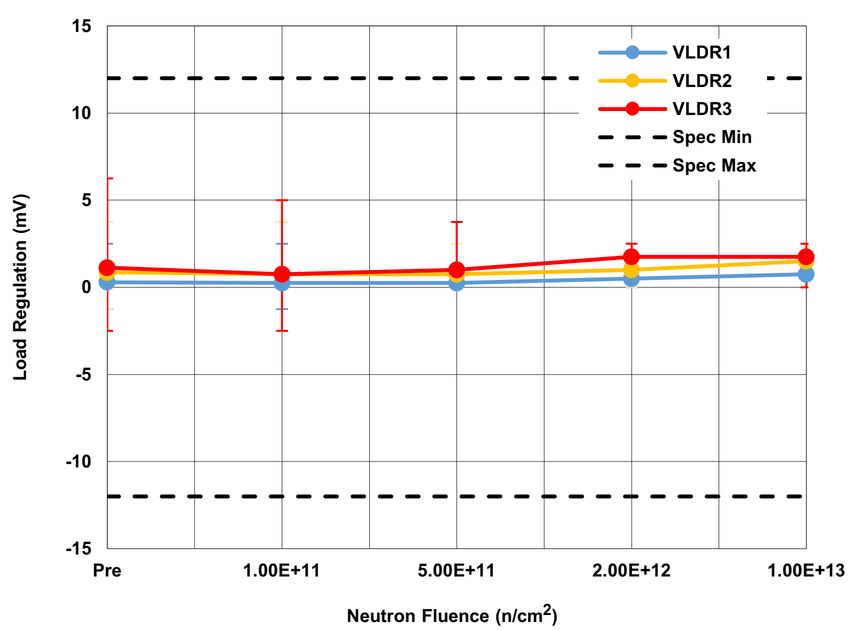

Figure 4. ISL72991RH load regulation (V_{LDR}) with V_{IN} = -7V, V_O = -5V, at three different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. V_{LDR1} denotes a 100mA load, V_{LDR2} denotes a 700mA load, and V_{LDR3} denotes a 1A load. The error bars represent the minimum and maximum measured values. The SMD limits are -12.0V minimum and 12.0V maximum.

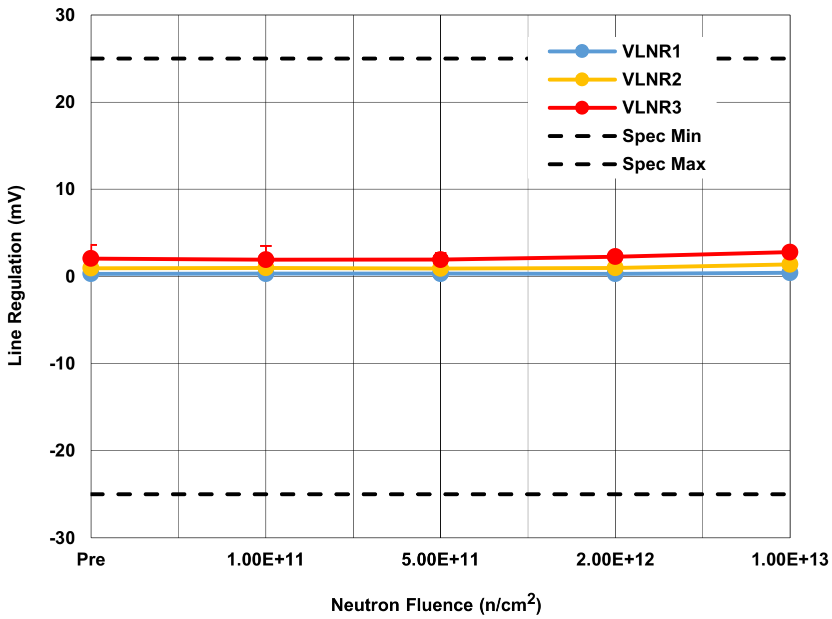

Figure 5. ISL72991RH line regulation (V_{LNR}) with I_O = 100mA at three different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. V_{LNR1} denotes V_{OUT} at 4V - V_{OUT} at 7V, V_{LNR2} denotes V_{OUT} at 4V - V_{OUT} at 15V, and V_{LNR3} denotes V_{OUT} at 4V - V_{OUT} at 30V. The error bars represent the minimum and maximum measured values. The SMD limits are -25.0mV minimum and 25.0mV maximum.

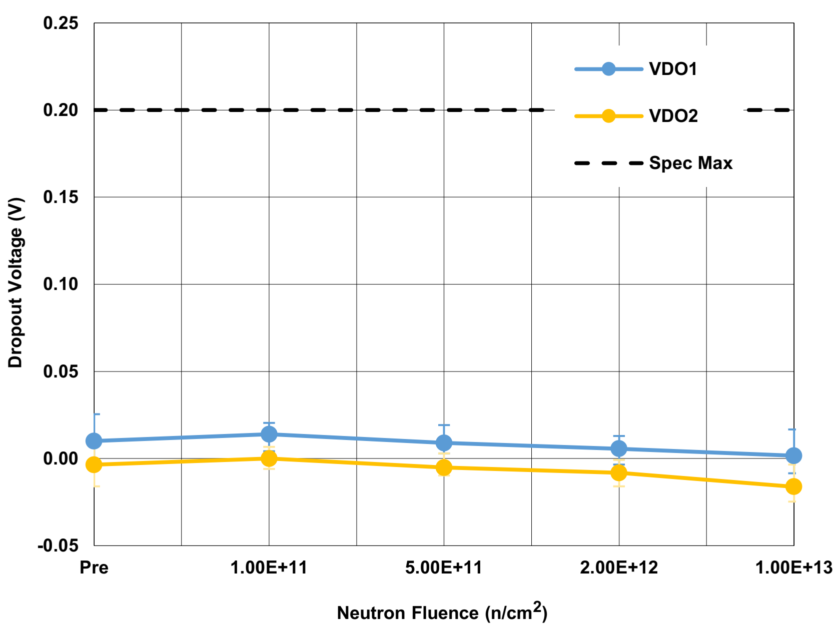

Figure 6. ISL72991RH dropout voltage (V_{DO}) at two different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. V_{DO1} denotes I_O = 100mA, and V_{DO2} denotes I_O = 1A. The error bars represent the minimum and maximum measured values. The SMD limit is 0.2V maximum for V_{DO1} and 1.0V maximum for V_{DO2} (not shown).

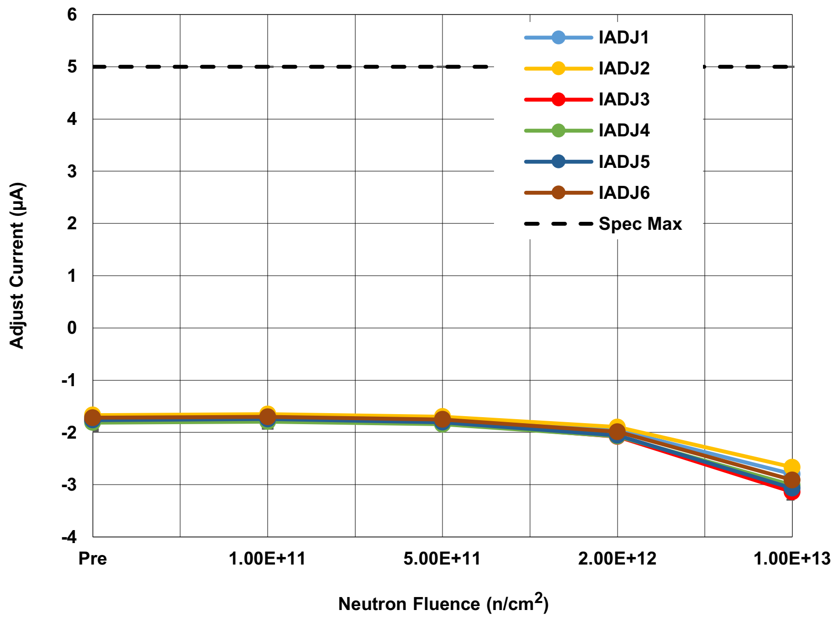

Figure 7. ISL72991RH adjust current (I_{ADJ}) at six different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. I_{ADJ1} denotes V_{IN} = 30V, no load, I_{ADJ2} denotes V_{IN} = 30V, 500mA, I_{ADJ3} denotes V_{IN} = 4V, no load, I_{ADJ4} denotes V_{IN} = 4V, 500mA, I_{ADJ5} denotes V_{IN} = 7V, no load, and I_{ADJ6} denotes V_{IN} = 7V, 500mA. The error bars represent the minimum and maximum measured values. The SMD limit is 5µA maximum.

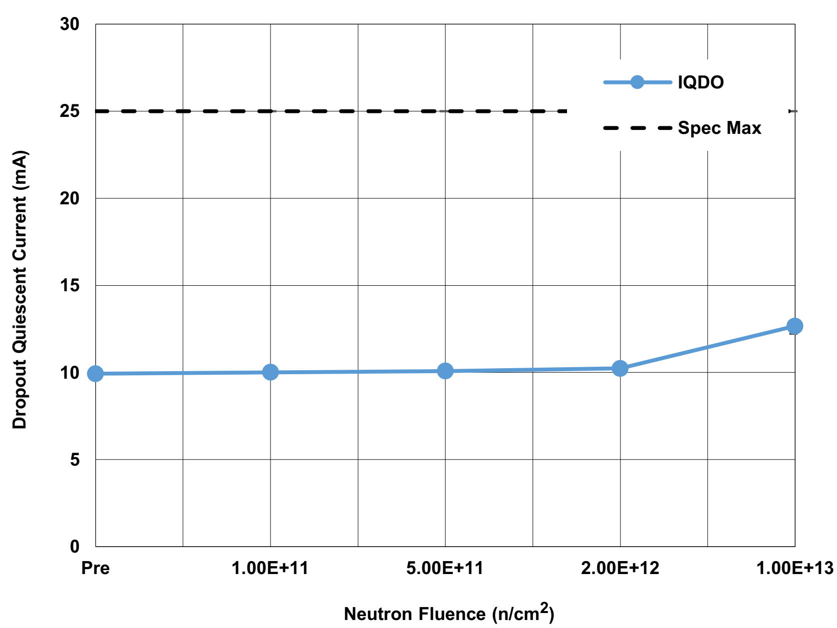

Figure 8. ISL72991RH dropout quiescent current (I_{QDO}) at I_O = 500mA following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. The error bars represent the minimum and maximum measured values. The SMD limit is 25mA maximum.

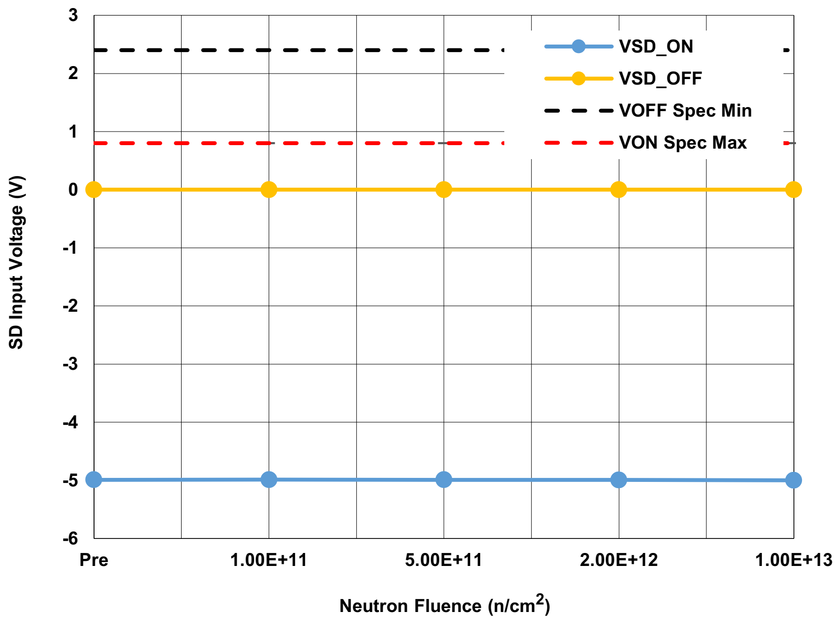

Figure 9. ISL72991RH shutdown input voltage (V_{SD}) at two different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. V_{SD_ON} denotes V_O = ON, and V_{SD_OFF} denotes V_O = OFF. The error bars represent the minimum and maximum measured values. The SMD limits are 0.8V maximum for V_{SD_ON} and 2.4V minimum for V_{SD_OFF}.

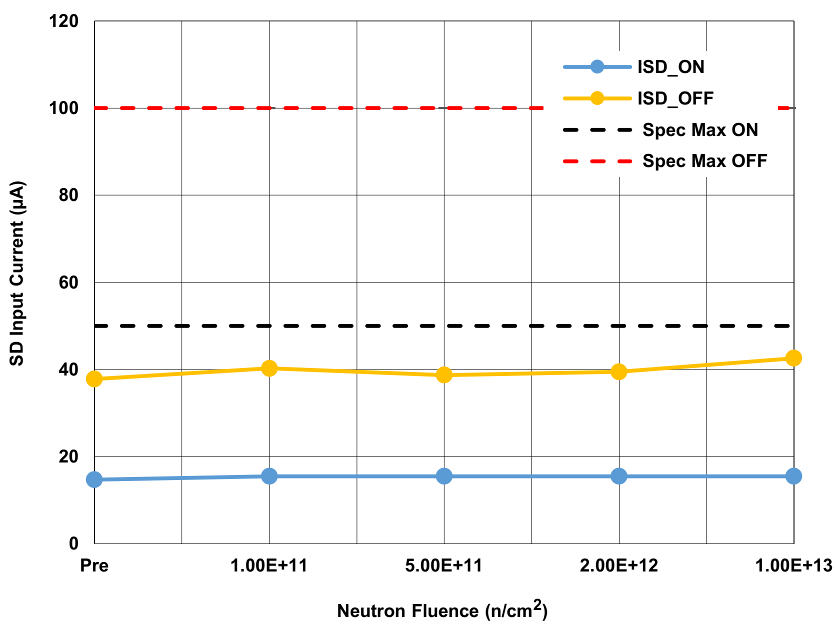

Figure 10. ISL72991RH shutdown input current (I_{SD}) at two different conditions following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. I_{SD_ON} denotes V_{SD} = 0.8V, and I_{SD_OFF} denotes V_{SD} = 2.4V. The error bars represent the minimum and maximum measured values. The SMD limits are 50µA maximum for I_{SD_ON} and 100µA maximum for I_{SD_OFF}.

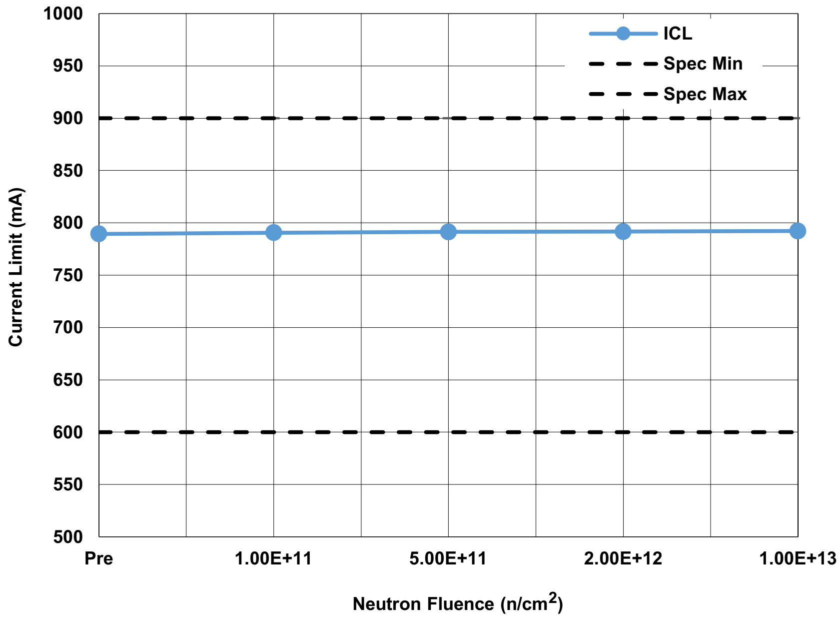

Figure 11. ISL72991RH current limit (I_{CL}), with R_{CL} = 3.7kΩ following irradiation to each level. Parts were non-functional after 1E14n/cm^2 and the results are not plotted. The error bars represent the minimum and maximum measured values. The SMD limits are 600mA minimum and 900mA maximum.

3. Discussion and conclusion

This document reports the results of 1MeV equivalent neutron testing of the ISL72991RH radiation hardened low dropout adjustable negative voltage regulator. Parts were tested at 1x10^{11}n/cm^2, 5x10^{11}n/cm^2, 1x10^{12}n/cm^2, 1x10^{13}n/cm^2, and 1x10^{14}n/cm^2. All samples passed the SMD limits after all exposures up to and including 1x10^{13}n/cm^2, but failed after 1x10^{14}n/cm^2. The results of key parameters before and after irradiation to each level are plotted in Figures 1 through 11. The plots show the mean of each parameter as a function of neutron irradiation, with error bars that represent the minimum and maximum measured values. The figures also show the applicable electrical limits taken from the SMD, but it should be noted that these limits are provided for guidance only as the ISL72991RH is not specified for the neutron environment.

4. Appendix

4.1 Reported Parameters

Figure	Parameter	Limit, Low	Limit, High	Units	Notes
1	Reference Voltage	-1.279	-1.231	V	3mA ≤ I_O ≤ 1A, V_O – 1.0V ≥ V_{IN} ≥ -30V
2	Output Voltage Range		-2.25	V	V_{IN} = -3.0V, I_O ≤ 100mA
3		-26.0			V_{IN} = -30V, I_O ≤ 100mA
4	Load Regulation	-12	12	mV	3mA ≤ I_O ≤ 1A, V_{IN} = -30V, V_O = -5V
5	Line Regulation	-25	25	mV	I_O = 100mA, V_O – 1.0V ≥ V_{IN} ≥ -30V
6	Dropout Voltage		0.2	V	I_O = 100mA, ΔV ≤ 50mV
			1.0		I_O = 1A, ΔV ≤ 50mV
7	Adjust Current		5	µA	I_O ≤ 500mA, V_O – 1.0V ≥ V_{IN} ≥ -30V
8	Dropout Quiescent Current		25	mA	I_O ≤ 500mA, V_O – V_{IN} = 0.2V
9	SD Input Voltage		0.8	V	V_O: ON
		2.4		V	V_O: OFF
10	SD Input Current		50	µA	V_{SD} = 0.8V
			100		V_{SD} = 2.4V
11	Current Limit	600	900	mA	R_{CL} = 3.7kΩ

5. Revision History

Date	Rev.	Description
Mar 21, 2018	0.00	Initial release

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(Rev.4.0-1 November 2017)

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