Neutron Irradiation Test Results of the RH1021CMW-5 Precision 5V Reference

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Acknowledgements

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Neutron Radiation Test Results of the RH1021CMW-5 Precision 5V Reference

Part Type Tested: RH1021CMW-5 Precision 5V Reference.

Traceability Information: Fab Lot# 10222458.1; Wafer # 13; Assembly Lot # 560218.1, D/C 1007A.

Quantity of Units: 7 units received, 2 units for control, and 5 units for unbiased irradiation. Serial numbers 580 to 584, were placed in an anti-static bag during irradiation. Serial numbers 577 and 579 were used as control. See Appendix A for the radiation bias connection table..

Radiation Dose: Total fluence of 1E12 neutron/cm^2.

Radiation Test Standard: MIL-STD-883 TM1017

Test Hardware and Software: LTX pre-rad test program: EQCM10215.02 and post-rad test program: ERHC10215.00

Facility and Radiation Source: University of Massachusetts, Lowell and Reactor Facility-FNI.

Irradiation and Test Temperature: Room temperature controlled to 24°C±6°C per MIL-STD-883 and MIL-STD-750.

SUMMARY

ALL FIVE PARTS PASSED THE ELECTRICAL TEST LIMITS AS SPECIFIED IN THE DATASHEET AFTER IRRADIATION TO 1E12 N/cm^2. ADDITIONAL INFORMATION CAN BE PROVIDED PER REQUEST.

1.0 Overview and Background

Neutron particles incident on semiconductor materials lose energy along their paths. The energy loss produces electron-hole pairs (ionization) and displaces atoms in the material lattice (displacement damage defects or DDD). DDD induces a mixture of isolated and clustered defects or broken bonds. Such defects elevate the energy level of the material and consequently change material and electrical properties. The altering energy level creates the combination of any of the following processes, thermal generation of electron-hole pairs, recombination, trapping, compensation, tunneling, affecting hence the device's basic features.

Bipolar technology is susceptible to neutron displacement damage around a fluence level of 1E12 neutron/cm^2. The neutron radiation test for the RH1021CMW-5 determines the change in device performance as a function of neutrons' fluence.

2.0 Radiation Facility:

Five samples were irradiated unbiased at the University of Massachusetts, Lowell, using the Reactor Facility-FNI. The neutron flux was determined by system S/P-32, method ASTM E-265, to be 4.05E9 N/cm^2-s (1MeV equivalent) for each irradiation step. Refer to Appendix B for the certificate of dosimetry.

3.0 Test Conditions

Five samples and two control units were electrically tested at 25°C prior to irradiation. The testing was performed on the two control units to confirm the operation of the test system prior to the electrical testing of the 7 units (5 irradiated and 2 control). During irradiation, devices were placed into an anti-static bag. Devices were then vertically aligned with the radiation source.

The criteria to pass the neutron displacement damage test is that five irradiated samples must pass the datasheet limits. If any of the tested parameters of these five units do not meet the required limits then a failure-analysis of the part should be conducted in accordance with method 5004, MIL-STD-883, and if valid the lot will be scrapped.

4.0 Tested Parameters

The following parameters were measured pre- and post-irradiations:

- Output Voltage (V)
- Output Voltage Temperature Coefficient (ppm/°C)
- Line Regulation with condition 7.2V ≤ V_{IN} ≤ 10V (ppm/V)
- Line Regulation with condition 10V ≤ V_{IN} ≤ 40V (ppm/V)
- Load Regulation (Sourcing Current) (ppm/mA)
- Load Regulation (Sinking Current) (ppm/mA)
- Supply Current (Series Mode) (mA)

Appendix C details the test conditions, minimum and maximum values at different accumulated doses.

5.0 Test Results

All five samples passed the post-irradiation electrical tests. All measurements of the seven listed parameters in section 4.0 are within the specification limits.

The used statistics in this report are based on the tolerance limits, which are bounds to gage the quality of the manufactured products. It assumes that if the quality of the items is normally distributed with known mean and known standard deviation, the two-sided tolerance limits can be calculated as follows:

$+K_{TL}$ = mean + (K_{TL}) (standard deviation)

$-K_{TL}$ = mean - (K_{TL}) (standard deviation)

Where $+K_{TL}$ is the upper tolerance limit and $-K_{TL}$ is the lower tolerance limit.
These tolerance limits are defined in a table of inverse normal probability distribution.

However, in most cases, mean and standard deviations are unknown and therefore it is practical to estimate both of them from a sample. Hence the tolerance limit depends greatly on the sample size. The Ps90%/90% K_{TL} factor for a lot quality P of 0.9, confidence C of 0.9 with a sample size of 5, can be found from the tabulated table (MIL-HDBK-814, page 94, table IX-B). The K_{TL} factor in this report is 2.742.

In the plots, the dashed lines with X-markers are the measured data points of five post-irradiated samples. The solid lines with square symbols are the computed KTL values of five post-irradiated samples with the application of the K_{TL} statistics. The orange solid lines with circle markers are the datasheet specification limits.

The post-irradiation test limits are taken from the Linear Technology datasheet's 100 Krads(Si) specification limits.

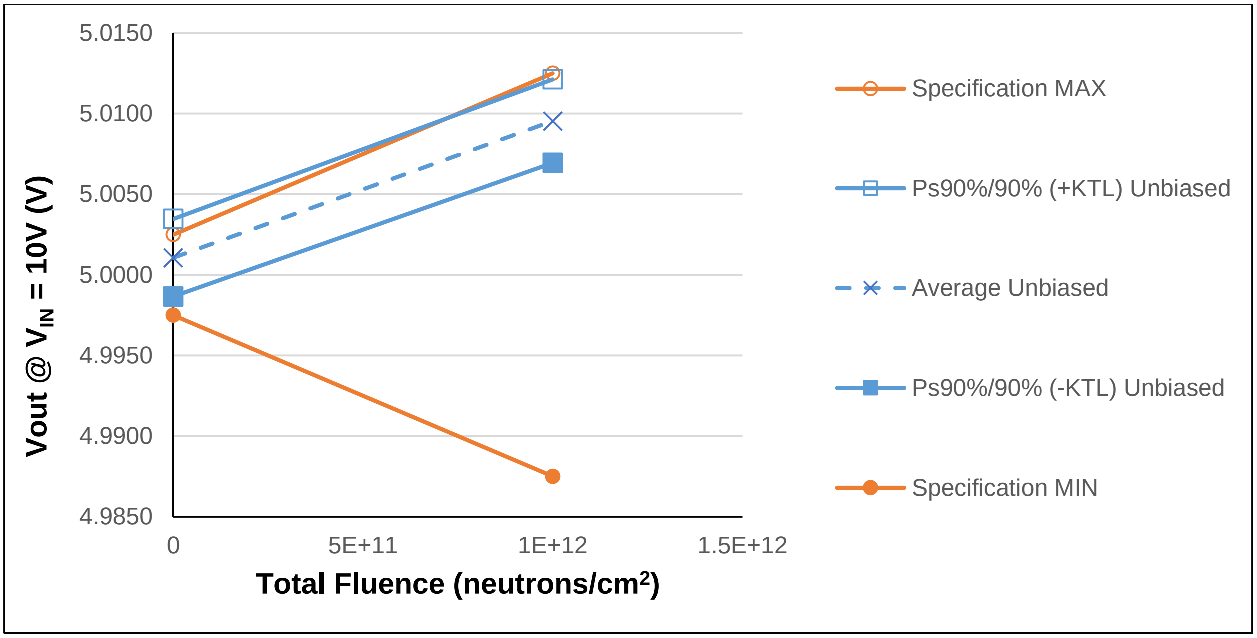

Figure 5.1 Plot of V_{OUT} @ V_{IN} = 10V versus Total Fluence

Note: the pre-irradiation +KTL average is slightly higher than the maximum limit due to small sample-size of 5 units.

Table 5.1: Raw data table for V_{OUT} of pre- and post-irradiation (1E12 N/cm^2)

Parameter	V_{OUT} @ V_{IN} = 10V	Total Fluences (N/cm^2)	
Units	(V)	0	1E+12
580	Unbiased Irradiation	5.00101	5.01020
581	Unbiased Irradiation	5.00179	5.00990
582	Unbiased Irradiation	5.00075	5.00910
583	Unbiased Irradiation	4.99980	5.00810
584	Unbiased Irradiation	5.00198	5.01040
577	Control Unit	5.00131	5.00120
579	Control Unit	5.00174	5.00170
	Unbiased Irradiation Statistics		
	Average Unbiased	5.00107	5.00954
	Std Dev Unbiased	0.00088	0.00094
	Ps90%/90% (+KTL) Unbiased	5.00347	5.01213
	Ps90%/90% (-KTL) Unbiased	4.99866	5.00695
	Specification MIN	4.9975	4.9875
	Status (Measurements) Unbiased	PASS	PASS
	Specification MAX	5.0025	5.0125
	Status (Measurements) Unbiased	PASS	PASS
	Status (-KTL) Unbiased	PASS	PASS
	Status (+KTL) Unbiased	FAIL	PASS

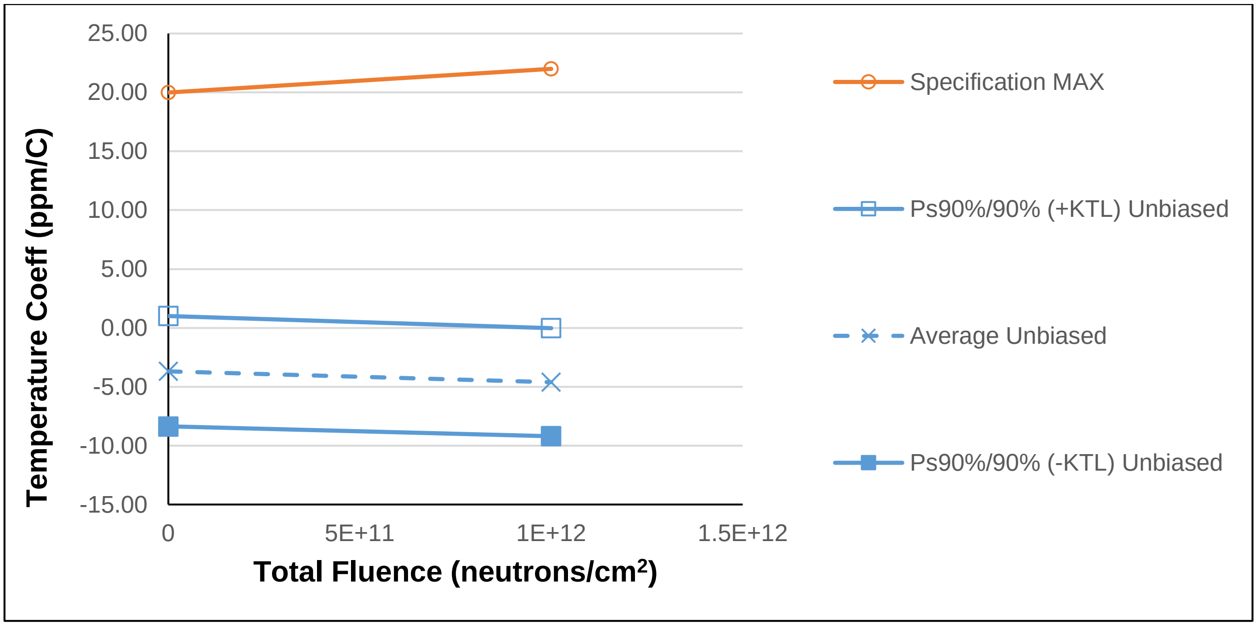

Figure 5.2: Plot of V_{OUT} Temperature Coefficient versus Total Fluence

Table 5.2: Raw data table for V_{OUT} Temperature Coefficient of pre- and post-irradiation (1E12 N/cm^2)

Parameter	V_{OUT} Temperature Coefficient	Total Fluences (N/cm^2)	
Units	(PPM)	0	1E+12
580	Unbiased Irradiation	-1.00251	-2.04000
581	Unbiased Irradiation	-2.99407	-3.83000
582	Unbiased Irradiation	-5.13504	-5.96000
583	Unbiased Irradiation	-4.26634	-5.23000
584	Unbiased Irradiation	-4.95507	-5.94000
577	Control Unit	0.10959	-0.57700
579	Control Unit	2.04312	1.66000
	Unbiased Irradiation Statistics		
	Average Unbiased	-3.67061	-4.60000
	Std Dev Unbiased	1.71214	1.67247
	Ps90%/90% (+KTL) Unbiased	1.02409	-0.01409
	Ps90%/90% (-KTL) Unbiased	-8.36530	-9.18591
	Specification MIN		
	Status (Measurements) Unbiased		
	Specification MAX	20	22
	Status (Measurements) Unbiased	PASS	PASS
	Status (-KTL) Unbiased		
	Status (+KTL) Unbiased	PASS	PASS

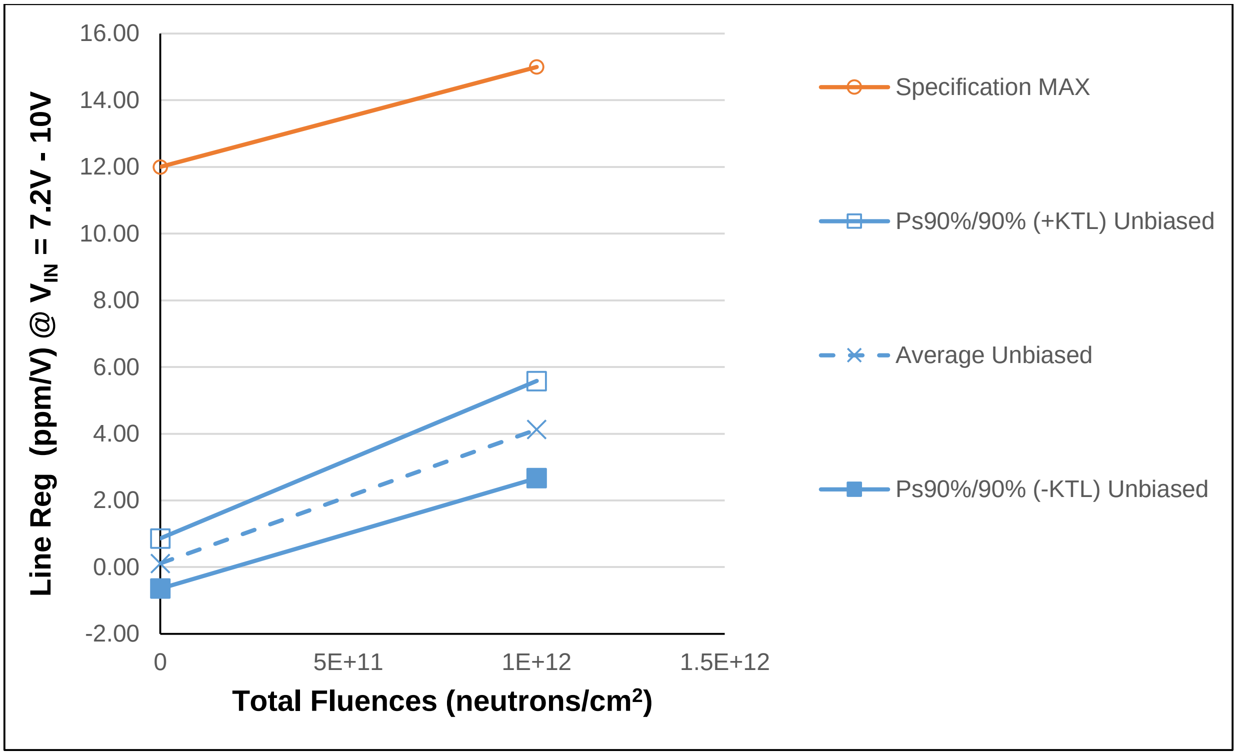

Figure 5.3: Plot of Line Regulation @ V_{IN} = 7.2V to 10V versus Total Fluence

Table 5.3: Raw data table for Line Regulation @ V_{IN} = 7.2V to 10V of pre- and post-irradiation (1E12 N/cm²)

Parameter	Line Reg @ V_{IN} = 7.2V-10V	Total Fluences (N/cm²)	
Units	(ppm/V)	0	1E+12
580	Unbiased Irradiation	0.01917	3.97143
581	Unbiased Irradiation	0.01659	3.79286
582	Unbiased Irradiation	-0.25142	3.52143
583	Unbiased Irradiation	0.36896	4.55000
584	Unbiased Irradiation	0.40129	4.79286
577	Control Unit	0.32812	0.16857
579	Control Unit	-0.07060	-0.32429
	Unbiased Irradiation Statistics		
	Average Unbiased	0.11092	4.12571
	Std Dev Unbiased	0.27364	0.53030
	Ps90%/90% (+KTL) Unbiased	0.86123	5.57979
	Ps90%/90% (-KTL) Unbiased	-0.63940	2.67164
	Specification MIN		
	Status (Measurements) Unbiased		
	Specification MAX	12	15
	Status (Measurements) Unbiased	PASS	PASS
	Status (-KTL) Unbiased		
	Status (+KTL) Unbiased	PASS	PASS

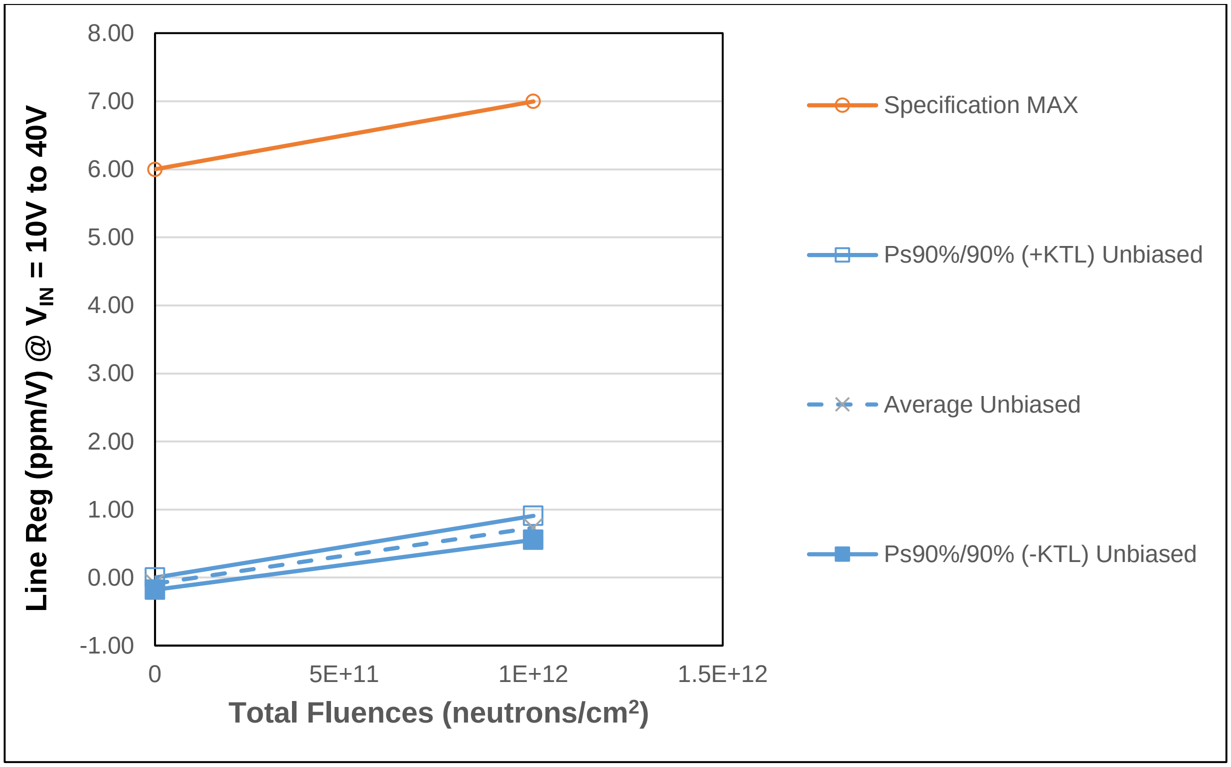

Figure 5.4: Plot of Line Regulation @ V_{IN} = 10V to 40V versus Total Fluence

Table 5.4: Raw data table for Line Regulation @ V_{IN} = 10V to 40V of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Line Reg @ V_{IN} = 10V to 40V	Total Fluences (N/cm^2)	
Units	(ppm/V)	0	1E+12
580	Unbiased Irradiation	-0.10949	0.67333
581	Unbiased Irradiation	-0.03120	0.78667
582	Unbiased Irradiation	-0.10897	0.70667
583	Unbiased Irradiation	-0.09228	0.68000
584	Unbiased Irradiation	-0.10050	0.81333
577	Control Unit	-0.12834	-0.08067
579	Control Unit	-0.08260	-0.08533
	Unbiased Irradiation Statistics		
	Average Unbiased	-0.08849	0.73200
	Std Dev Unbiased	0.03279	0.06401
	Ps90%/90% (+KTL) Unbiased	0.00142	0.90753
	Ps90%/90% (-KTL) Unbiased	-0.17840	0.55647
	Specification MIN		
	Status (Measurements) Unbiased		
	Specification MAX	6	7
	Status (Measurements) Unbiased	PASS	PASS
	Status (-KTL) Unbiased		
	Status (+KTL) Unbiased	PASS	PASS

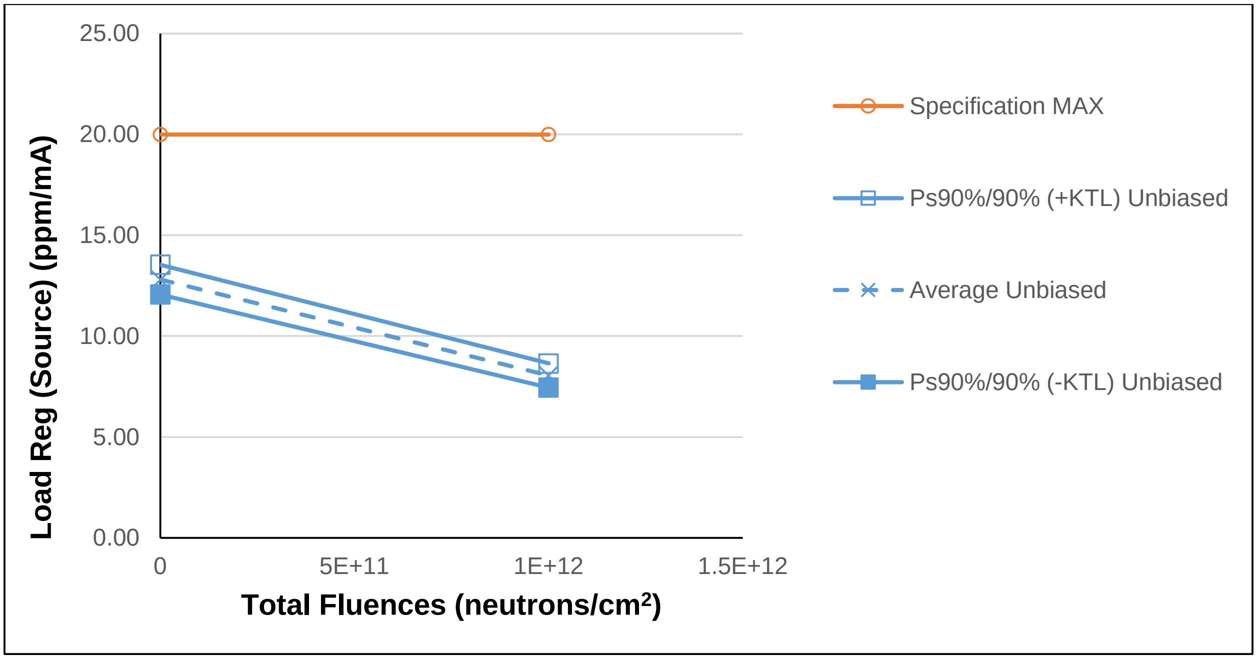

Figure 5.5: Plot of Load Regulation @ V_{IN} = 10V versus Total Fluence

Table 5.5: Raw data table for Load Reg. (Source) of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Load Reg @ (Source)	Total Fluences (N/cm^2)	
Units	(ppm/mA)	0	1E+12
580	Unbiased Irradiation	12.55468	7.92000
581	Unbiased Irradiation	12.62498	7.86000
582	Unbiased Irradiation	12.92092	8.42000
583	Unbiased Irradiation	12.69647	8.00000
584	Unbiased Irradiation	13.21816	8.04000
577	Control Unit	12.81485	7.98000
579	Control Unit	11.94882	7.32000
	Unbiased Irradiation Statistics		
	Average Unbiased	12.80304	8.04800
	Std Dev Unbiased	0.26971	0.21936
	Ps90%/90% (+KTL) Unbiased	13.54258	8.64949
	Ps90%/90% (-KTL) Unbiased	12.06350	7.44651
	Specification MIN		
	Status (Measurements) Unbiased		
	Specification MAX	20	20
	Status (Measurements) Unbiased	PASS	PASS
	Status (-KTL) Unbiased		
	Status (+KTL) Unbiased	PASS	PASS

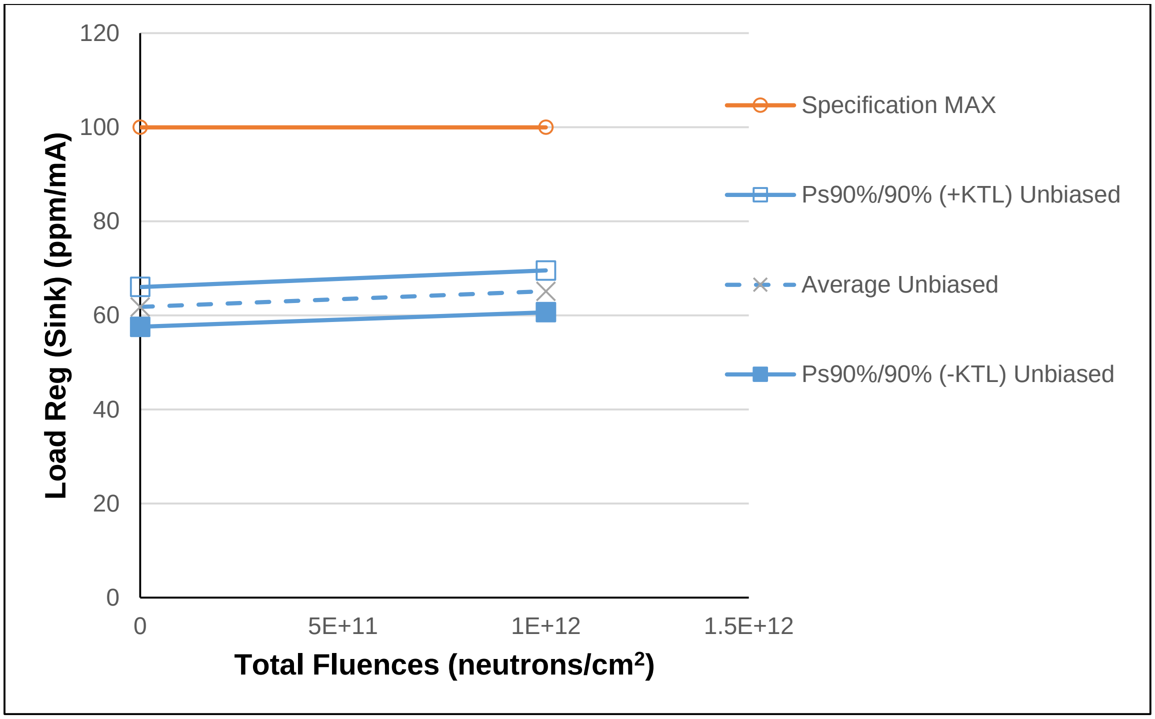

Figure 5.6: Plot of Load Reg (Sink) versus Total Fluence

Table 5.6: Raw data table for Load Reg (Sink) of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Load Reg (Sink)	Total Fluences (N/cm^2)	
Units	(ppm/mA)	0	1E+12
580	Unbiased Irradiation	61.78642	64.80000
581	Unbiased Irradiation	62.48580	65.60000
582	Unbiased Irradiation	62.03612	65.60000
583	Unbiased Irradiation	59.28658	62.60000
584	Unbiased Irradiation	63.45256	67.00000
577	Control Unit	61.94730	63.40000
579	Control Unit	58.19030	59.40000
	Unbiased Irradiation Statistics		
	Average Unbiased	61.80950	65.12000
	Std Dev Unbiased	1.54710	1.61617
	Ps90%/90% (+KTL) Unbiased	66.05164	69.55153
	Ps90%/90% (-KTL) Unbiased	57.56735	60.68847
	Specification MIN		
	Status (Measurements) Unbiased		
	Specification MAX	100	100
	Status (Measurements) Unbiased	PASS	PASS
	Status (-KTL) Unbiased		
	Status (+KTL) Unbiased	PASS	PASS

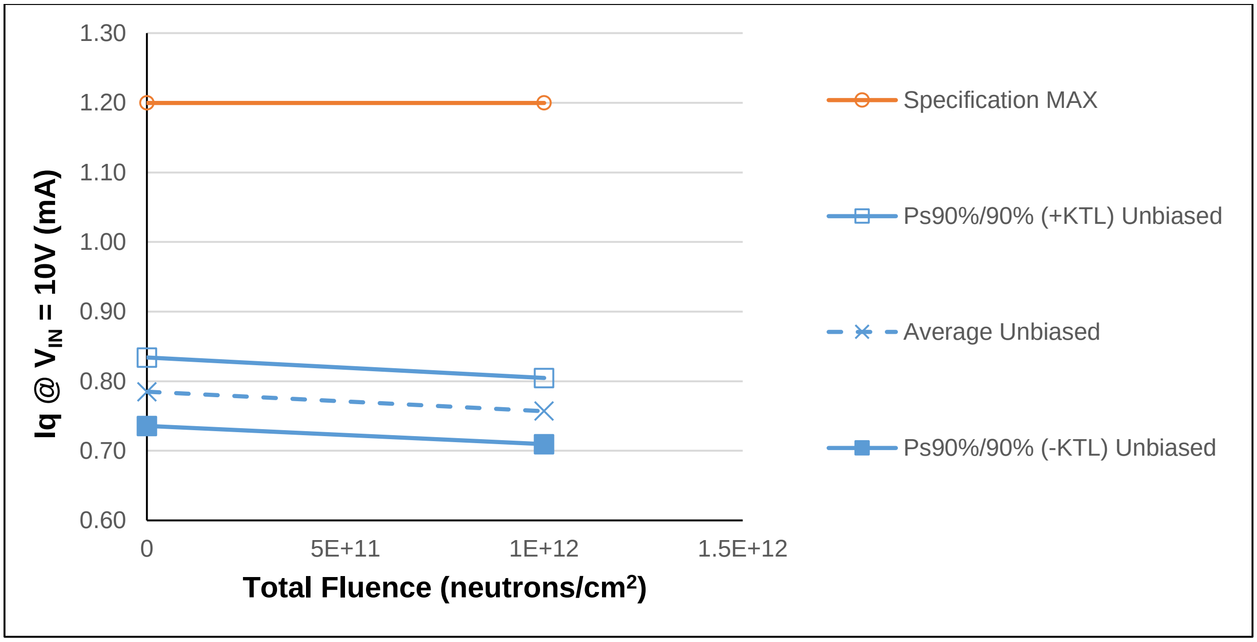

Figure 5.7: Plot of I_q @ V_{IN} = 10V *versus Total Fluence*

Table 5.7: Raw data table for Supply Current of pre- and post-irradiation (1E12 N/cm²)

Parameter	I_Q @ V_{IN} = 10V	Total Fluences (N/cm²)	
Units	(mA)	0	1E+12
580	Unbiased Irradiation	0.79265	0.76300
581	Unbiased Irradiation	0.80302	0.77400
582	Unbiased Irradiation	0.78114	0.75300
583	Unbiased Irradiation	0.79130	0.76600
584	Unbiased Irradiation	0.75585	0.72900
577	Control Unit	0.78836	0.78500
579	Control Unit	0.81419	0.81200
	Unbiased Irradiation Statistics		
	Average Unbiased	0.78479	0.75700
	Std Dev Unbiased	0.01794	0.01736
	Ps90%/90% (+KTL) Unbiased	0.83398	0.80461
	Ps90%/90% (-KTL) Unbiased	0.73560	0.70939
	Specification MIN		
	Status (Measurements) Unbiased		
	Specification MAX	1.2	1.2
	Status (Measurements) Unbiased	PASS	PASS
	Status (-KTL) Unbiased		
	Status (+KTL) Unbiased	PASS	PASS

Appendix A

Radiation Bias Connection Table

Table A1: Unbiased condition

Pin	Function	Bias
1	NC	Float
2	V_{IN}	Float
3	NC	Float
4	GND	Float
5	TRIM	Float
6	V_{OUT}	Float
7	NC	Float
8	NC	Float

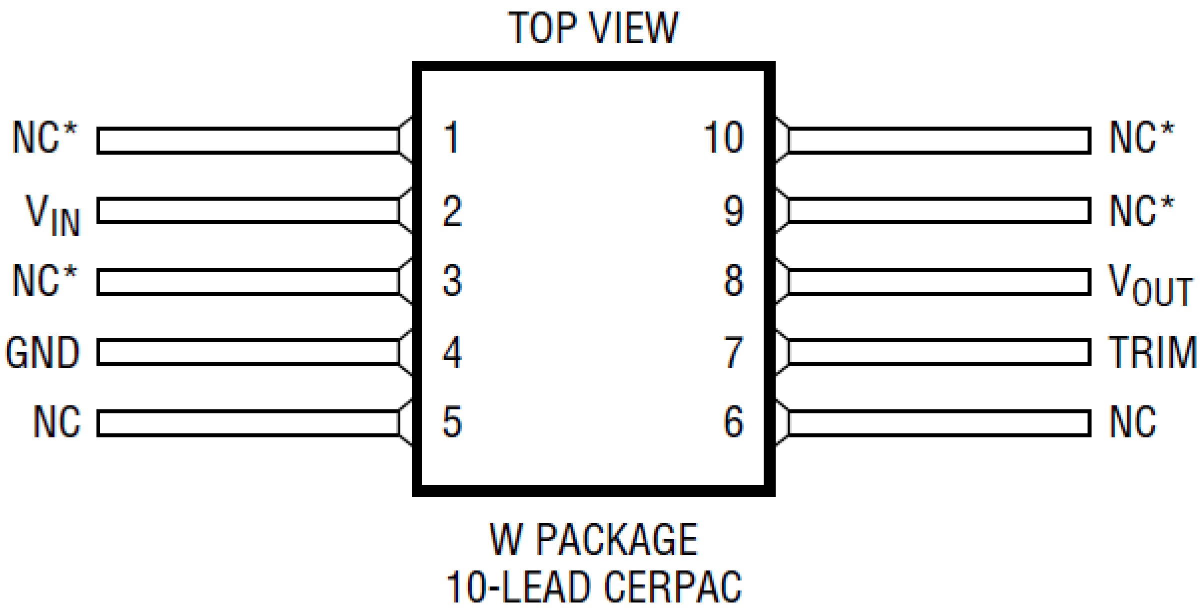

Figure A1: Pin-Out

Appendix B

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Thomas Regan
Reactor Engineering

University of Massachusetts
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RADIATION LABORATORY

7/2/2012
Linear Technology Corporation
Attention: Sana Rezgui
1530 Buckeye Drive
Milpitas, CA 95035

Subject: **Certificate of Neutron Exposure**

Product: Multiple products see attached table

Irradiation Date: June, 27th, 2012
Irradiation Facility: Reactor Facility- FNI
Dosimetry system: S/P-32, ASTM E-265

Neutron Dosimetry Results:

Irradiation	Requested Fluence (n/cm^2)	Reactor Power (kW)	Time (s)	Fluence Rate (n/cm^2-s)$^{(2,3)}$	Gamma Dose rad (Si) $^{(1)}$	Measured Fluence (n/cm^2)$^{(4)}$	Total Integral Fluence (n/cm^2)
Group 1	1.00E+12	45.0	228	4.05E+09	117	1.03E+12	1.03E+12
Group 2	1.00E+12	45.0	228	4.05E+09	117	9.41E+11	9.41E+11
Group 3	1.00E+13	475	234	4.28E+10	1266	9.22E+12	9.22E+12
Group 4	1.00E+13	90	1235	8.10E+09	1266	9.03E+12	9.03E+12

(1) Based on reactor power at 1,000kW, the gamma dose is 41+/- 5.3% krad(Si)/hr as mapped by TLD-based dosimetry
(2) Dosimetry method: ASTM E-265
(3) The neutron fluence rate is determined from "Initial Testing of the New Ex-Core Fast Neutron Irradiator at UMass Lowell " (6/18/02)
(4) Validated by S-32 flux monitors

The neutron fluence for this irradiation was determined using the previously measured neutron radiation field for this facility, measured with ASTM E-265 "Measuring Reaction Rates and Fast Neutron Fluence by Radioactivation of Sulfur-32" and correlated to the measured reactor power level.

Group 1 **Average Integrated Neutron Fluence (1 MeV Si Eq.) =1.03E12 n/cm^2**
Group 2 **Average Integrated Neutron Fluence (1 MeV Si Eq.) =9.41E11 n/cm^2**
Group 3 **Average Integrated Neutron Fluence (1 MeV Si Eq.) =9.22E12 n/cm^2**
Group 4 **Average Integrated Neutron Fluence (1 MeV Si Eq.) =9.03E12 n/cm^2**

Reviewed by Thomas M Regan
Thomas Regan
Reactor Engineer

Appendix C

Table C1: Electrical Characteristics of Device-Under-Test

Parameter	Pre-irradiation MIN	Pre-irradiation MAX	10 Krad(Si) MIN	10 Krad(Si) MAX	20 Krad(Si) MIN	20 Krad(Si) MAX	50 Krad(Si) MIN	50 Krad(Si) MAX	100 Krad(Si) MIN	100 Krad(Si) MAX	Units
Output Voltage	4.9975	5.0025	4.9945	5.0055	4.9993	5.0070	4.9910	5.0090	4.9875	5.0125	V
Output Voltage Temperature Coefficient		20		20		20		20		22	ppm/°C
Line Regulation ($7.2V \le V_{IN} \le 10V$)		12		12		12		13.5		15	ppm/V
Line Regulation ($10V \le V_{IN} \le 40V$)		6		6		6		6		7	ppm/V
Load Regulation (Source)*		20		20		20		20		20	ppm/mA
Load Regulation (Sink)*		100		100		100		100		100	ppm/mA
Supply Current		1.2		1.2		1.2		1.2		1.2	mA