Neutron Irradiation Test Results of the RH137K Negative Adjustable Regulator

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Part Type Tested: RH137K Negative Adjustable Regulator.

Traceability Information: Fab Lot# 10008104.1; Wafer # 7; Assembly Lot # 213941.1, D/C 0013A. See photograph of unit under test in Appendix A.

Quantity of Units: 7 units received, 2 units for control, and 5 units for unbiased irradiation. Leads of devices, serial numbers 1 to 5, were shorted together using anti-static foam during irradiation. Serial numbers 6 and 12 were used as control. See Appendix B 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 test program EQ2CR137K.02

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 RH137K 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 C 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:

- V_{REF} (V) @ $|V_{IN} – V_{OUT}| \leq 5V$, $I_{OUT} = 10mA$
- V_{REF} (V) @ $|V_{IN} – V_{OUT}| \leq 5V$, $I_{OUT} \leq 1.5A$
- V_{REF} (V) @ $|V_{IN} – V_{OUT}| \leq 3V$, $I_{OUT} = 10mA$
- V_{REF} (V) @ $|V_{IN} – V_{OUT}| \leq 30V$, $I_{OUT} = 10mA$
- V_{REF} (V) @ $|V_{IN} – V_{OUT}| \leq 30V$, $I_{OUT} = 150mA$
- V_{REF} (V) @ $|V_{IN} – V_{OUT}| \leq 10V$, $I_{OUT} = 10mA$
- V_{REF} (V) @ $|V_{IN} – V_{OUT}| \leq 18V$, $I_{OUT} = 1A$
- Line Regulation (%/V) @ $3V \leq |V_{IN} – V_{OUT}| \leq 30V$
- Load Regulation (mV) @ $V_{OUT} \leq 5V$, $10mA \leq I_{OUT} \leq 1.5A$
- Load Regulation (%) @ $V_{OUT} \geq 5V$, $10mA \leq I_{OUT} \leq 1.5A$
- Adjust Pin Current (uA)
- Adjust Pin Current Change (uA) @ $10mA \leq I_{OUT} \leq 1.5A$
- Adjust Pin Current Change (uA) @ $3V \leq |V_{IN} – V_{OUT}| \leq 30V$
- Minimum Load Current (mA) @ $|V_{IN} – V_{OUT}| = 30V$
- Minimum Load Current (mA) @ $|V_{IN} – V_{OUT}| \leq 10V$
- Current Limit (A) @ $|V_{IN} – V_{OUT}| \leq 15V$
- Current Limit (A) @ $|V_{IN} – V_{OUT}| = 30V$

Appendix D 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 seventeen 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.

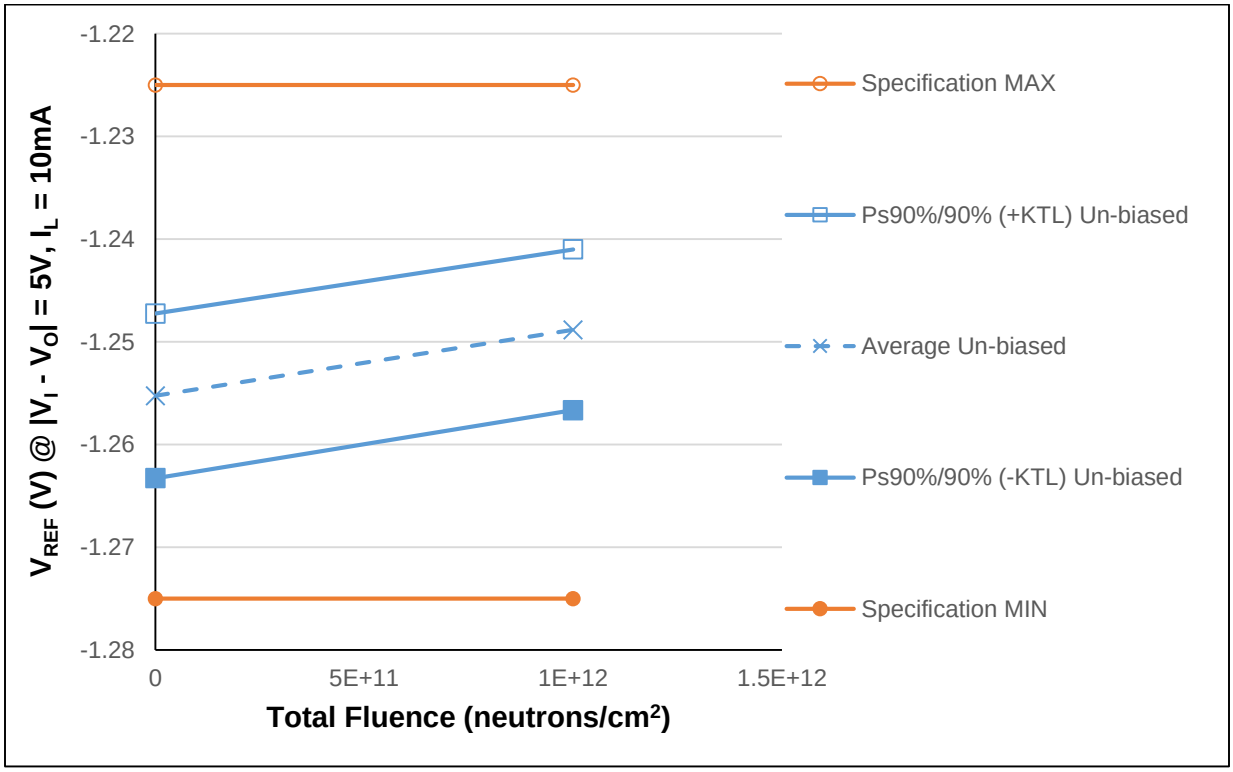

Figure 5.1 Plot of Reference Voltage @ $|V_I – V_O| \leq 5V$, $I_L = 10mA$ versus Total Fluence

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

Parameter	V_{REF} @ $\|V_I-V_O\| \leq 5V$; I_L =10mA	Total Fluence (neutrons/cm^2)	
Units	(V)	0	1.E+12
1	Un-biased Irradiation	-1.25966	-1.25320
2	Un-biased Irradiation	-1.25411	-1.24798
3	Un-biased Irradiation	-1.25582	-1.24935
4	Un-biased Irradiation	-1.25503	-1.24821
5	Un-biased Irradiation	-1.25164	-1.24535
6	Control Unit	-1.25511	-1.25503
12	Control Unit	-1.25527	-1.25513
	Un-biased Irradiation Statistics		
	Average Un-biased	-1.25525	-1.24882
	Std Dev Un-biased	0.00292	0.00285
	Ps90%/90% (+KTL) Un-biased	-1.24723	-1.24100
	Ps90%/90% (-KTL) Un-biased	-1.26327	-1.25664
	Specification MIN	-1.275	-1.275
	Status (Measurements)	PASS	PASS
	Specification MAX	-1.225	-1.225
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased	PASS	PASS

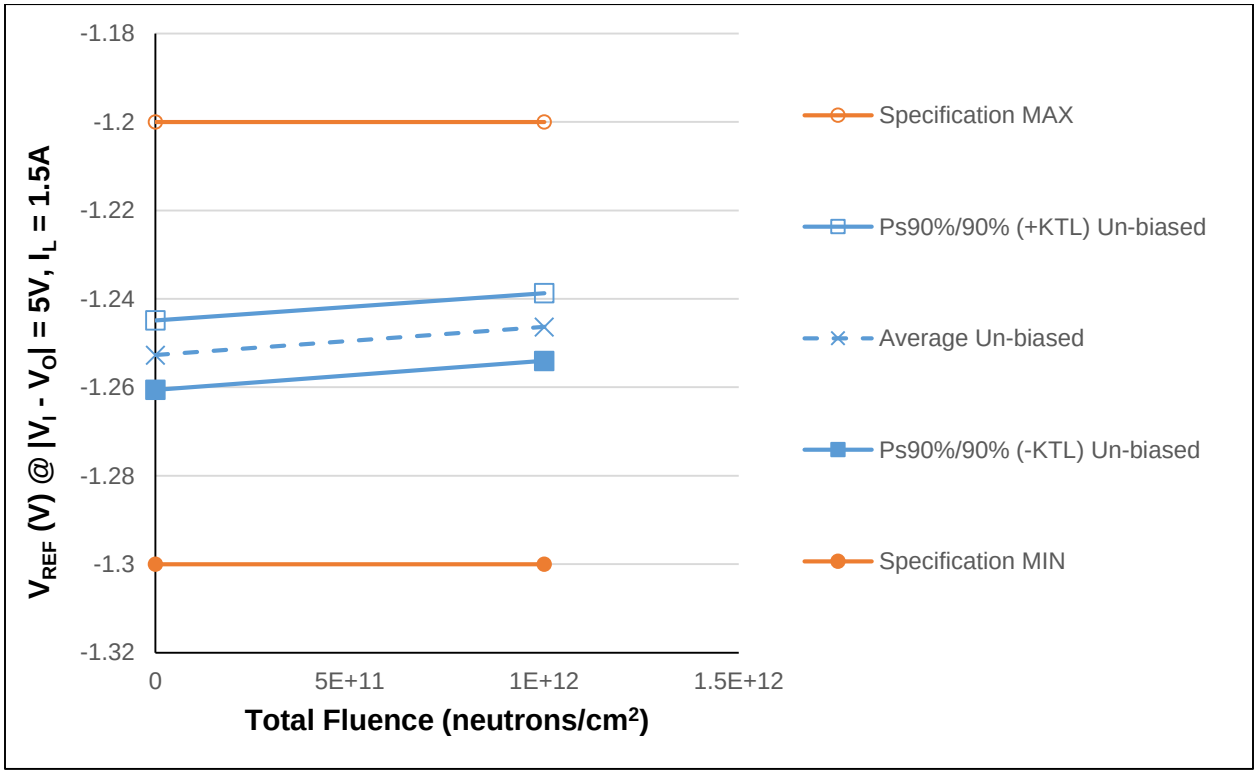

Figure 5.2: Plot of Reference Voltage @ $|V_I – V_O|$ = 5V, I_L = 1.5A versus Total Fluence

Table 5.2: Raw data table for reference voltage @ $|V_I – V_O|$ = 5V, I_L = 1.5A of pre- and post-irradiation (1E12 N/cm^2)

Parameter	V_{REF} @ $\|V_I-V_O\|$ = 5V,I_L = 1.5A	Total Fluence (neutrons/cm^2)	
Units	(V)	0	1.E+12
1	Un-biased Irradiation	-1.25662	-1.25057
2	Un-biased Irradiation	-1.25198	-1.24486
3	Un-biased Irradiation	-1.25381	-1.24737
4	Un-biased Irradiation	-1.25248	-1.24569
5	Un-biased Irradiation	-1.24875	-1.24325
6	Control Unit	-1.25243	-1.25279
12	Control Unit	-1.25191	-1.25303
	Un-biased Irradiation Statistics		
	Average Un-biased	-1.25273	-1.24635
	Std Dev Un-biased	0.00286	0.00279
	Ps90%/90% (+KTL) Un-biased	-1.24488	-1.23870
	Ps90%/90% (-KTL) Un-biased	-1.26058	-1.25400
	Specification MIN	-1.3	-1.3
	Status (Measurements)	PASS	PASS
	Specification MAX	-1.2	-1.2
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased	PASS	PASS

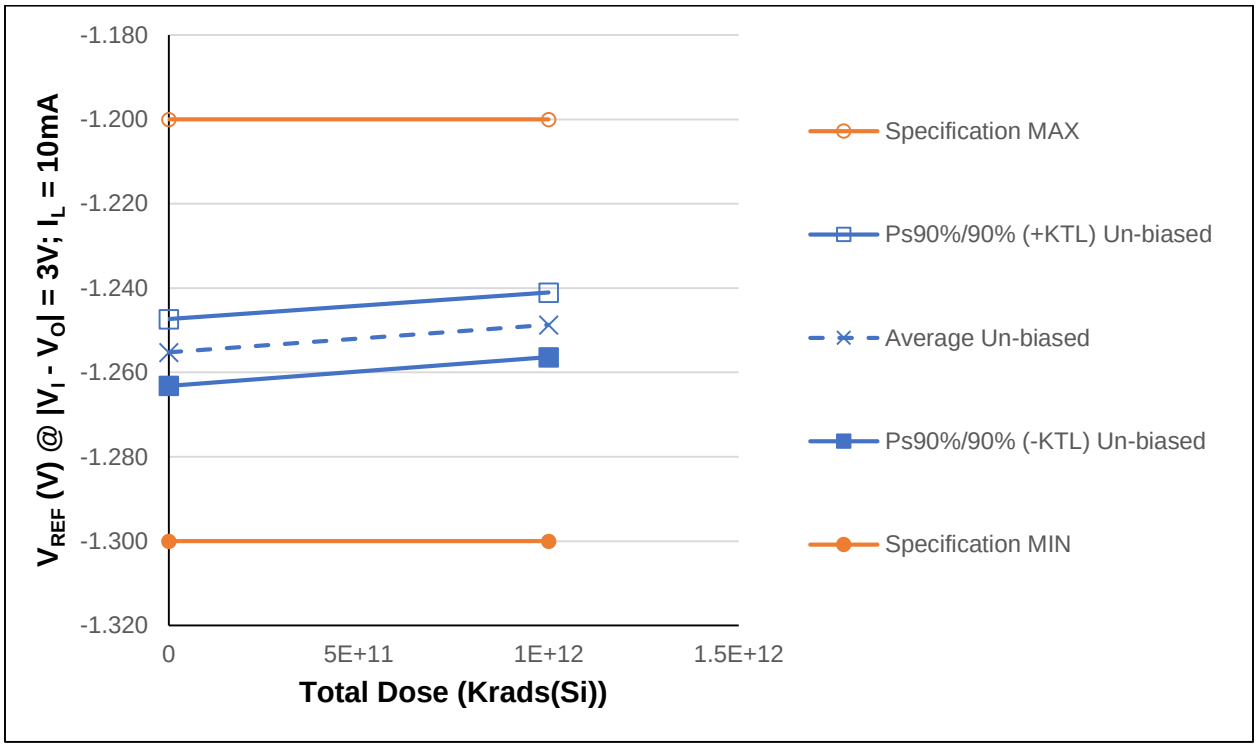

Figure 5.3: Plot of Reference Voltage @ $|V_I - V_O| = 3V$, $I_L = 10mA$ versus Total Fluence

Table 5.3: Raw data table for reference voltage @ $|V_I – V_O| = 3V$, $I_L = 10mA$ of pre- and post-irradiation (1E12 N/cm^2)

Parameter	V_{REF} @ $\|V_I - V_O\| = 3V$; I_L =10mA	Total Fluence (neutrons/cm^2)	
Units	(V)	0	1.E+12
1	Un-biased Irradiation	-1.25954	-1.25304
2	Un-biased Irradiation	-1.25428	-1.24784
3	Un-biased Irradiation	-1.25587	-1.24921
4	Un-biased Irradiation	-1.25502	-1.24814
5	Un-biased Irradiation	-1.25157	-1.24535
6	Control Unit	-1.25511	-1.25515
12	Control Unit	-1.25512	-1.25513
	Un-biased Irradiation Statistics		
	Average Un-biased	-1.25525	-1.24872
	Std Dev Un-biased	0.00289	0.00280
	Ps90%/90% (+KTL) Un-biased	-1.24734	-1.24103
	Ps90%/90% (-KTL) Un-biased	-1.26317	-1.25640
	Specification MIN	-1.3	-1.3
	Status (Measurements)	PASS	PASS
	Specification MAX	-1.2	-1.2
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased	PASS	PASS

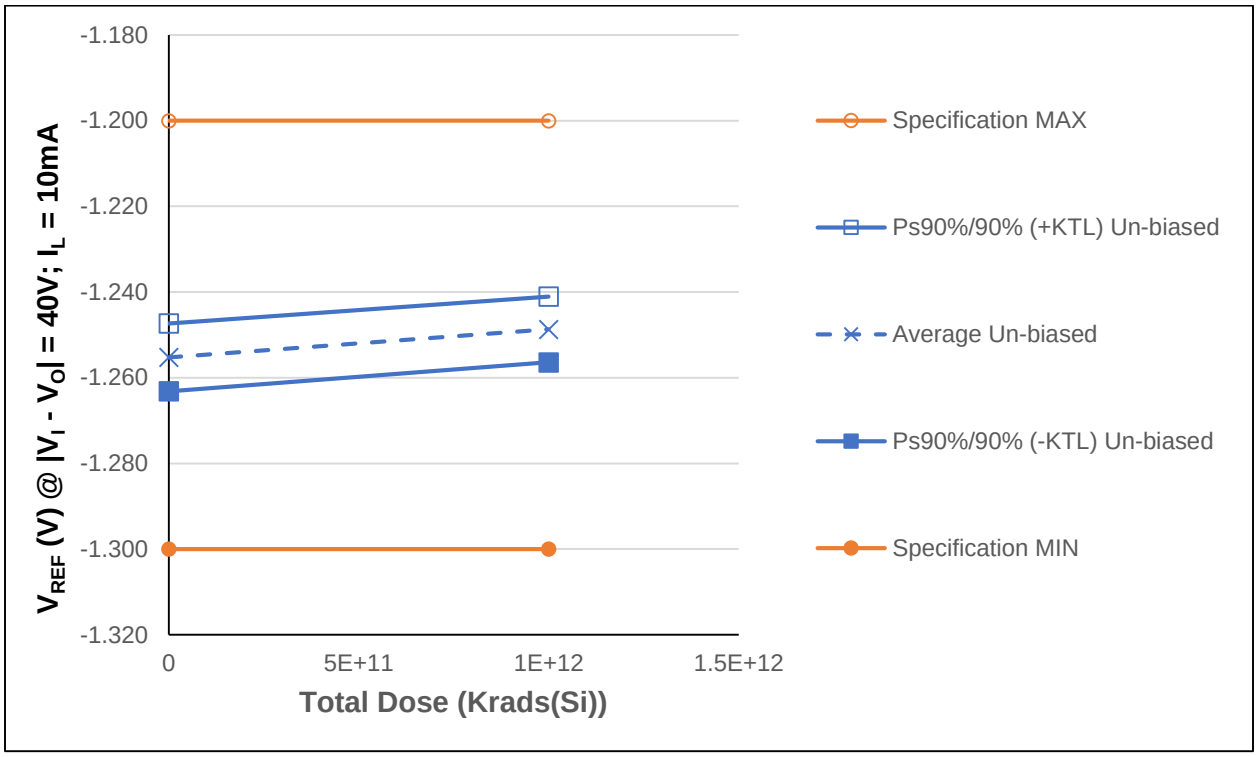

Figure 5.4: Plot of Reference Voltage @ $|V_I – V_O|$ = 40V, I_L = 10mA versus Total Fluence

Table 5.4: Raw data table for reference voltage @ $|V_I – V_O|$ = 40V, I_L = 10mA of pre- and post-irradiation (1E12 N/cm^2)

Parameter	V_{REF} @ $\|V_I - V_O\|$ = 40V; I_L = 10mA	Total Fluence (neutrons/cm^2)	
Units	(V)	0	1.E+12
1	Un-biased Irradiation	-1.26000	-1.25353
2	Un-biased Irradiation	-1.25435	-1.24842
3	Un-biased Irradiation	-1.25611	-1.24977
4	Un-biased Irradiation	-1.25515	-1.24859
5	Un-biased Irradiation	-1.25172	-1.24569
6	Control Unit	-1.25546	-1.25537
12	Control Unit	-1.25534	-1.25546
	Un-biased Irradiation Statistics		
	Average Un-biased	-1.25546	-1.24920
	Std Dev Un-biased	0.00301	0.00284
	Ps90%/90% (+KTL) Un-biased	-1.24720	-1.24140
	Ps90%/90% (-KTL) Un-biased	-1.26373	-1.25700
	Specification MIN	-1.3	-1.3
	Status (Measurements)	PASS	PASS
	Specification MAX	-1.2	-1.2
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased	PASS	PASS

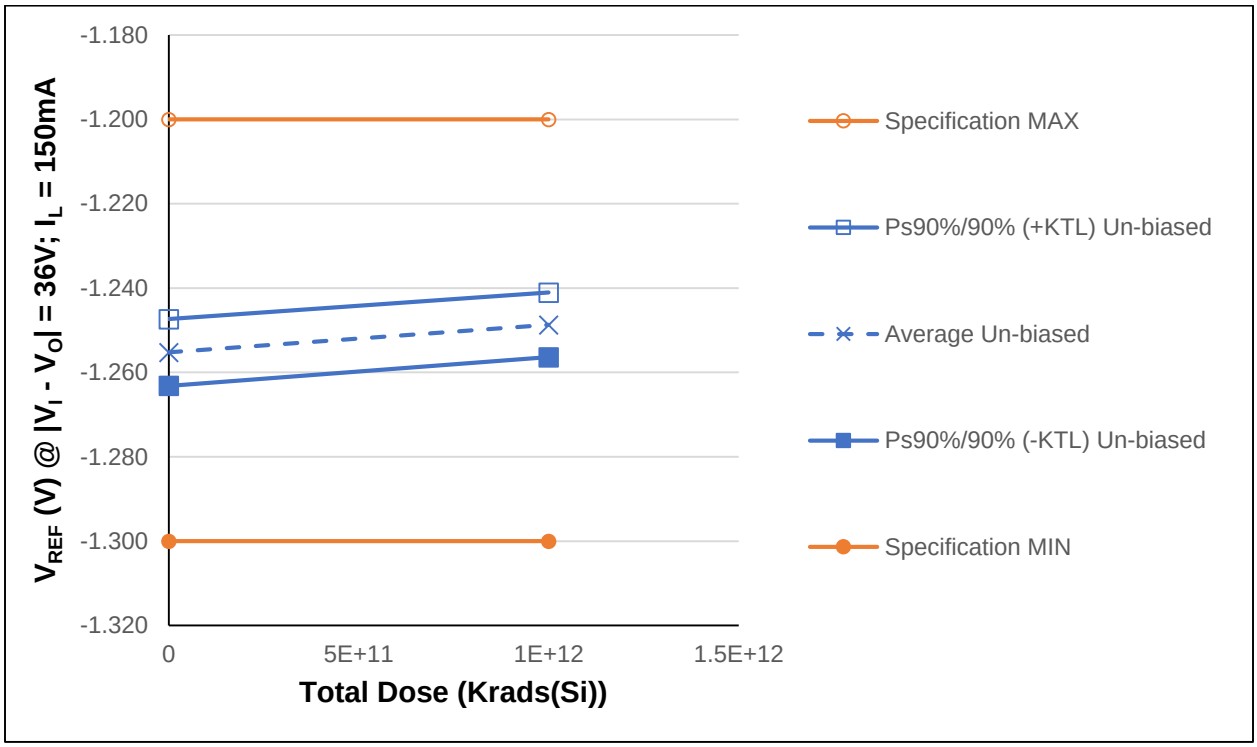

Figure 5.5: Plot of Reference Voltage @ $|V_I – V_O|$ = 36V, I_L = 150mA versus Total Fluence

Table 5.5: Raw data table for reference voltage @ $|V_I – V_O|$ = 36V, I_L = 150mA of pre- and post-irradiation (1E12 N/cm^2)

Parameter	V_{REF} @ $\|V_I - V_O\|$ = 36V; I_L = 150mA	Total Fluence (neutrons/cm^2)	
Units	(V)	0	1.E+12
1	Un-biased Irradiation	-1.25970	-1.25347
2	Un-biased Irradiation	-1.25432	-1.24821
3	Un-biased Irradiation	-1.25595	-1.24965
4	Un-biased Irradiation	-1.25499	-1.24842
5	Un-biased Irradiation	-1.25161	-1.24553
6	Control Unit	-1.25527	-1.25515
12	Control Unit	-1.25511	-1.25523
	Un-biased Irradiation Statistics		
	Average Un-biased	-1.25531	-1.24906
	Std Dev Un-biased	0.00294	0.00289
	Ps90%/90% (+KTL) Un-biased	-1.24726	-1.24113
	Ps90%/90% (-KTL) Un-biased	-1.26336	-1.25698
	Specification MIN	-1.3	-1.3
	Status (Measurements)	PASS	PASS
	Specification MAX	-1.2	-1.2
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased	PASS	PASS

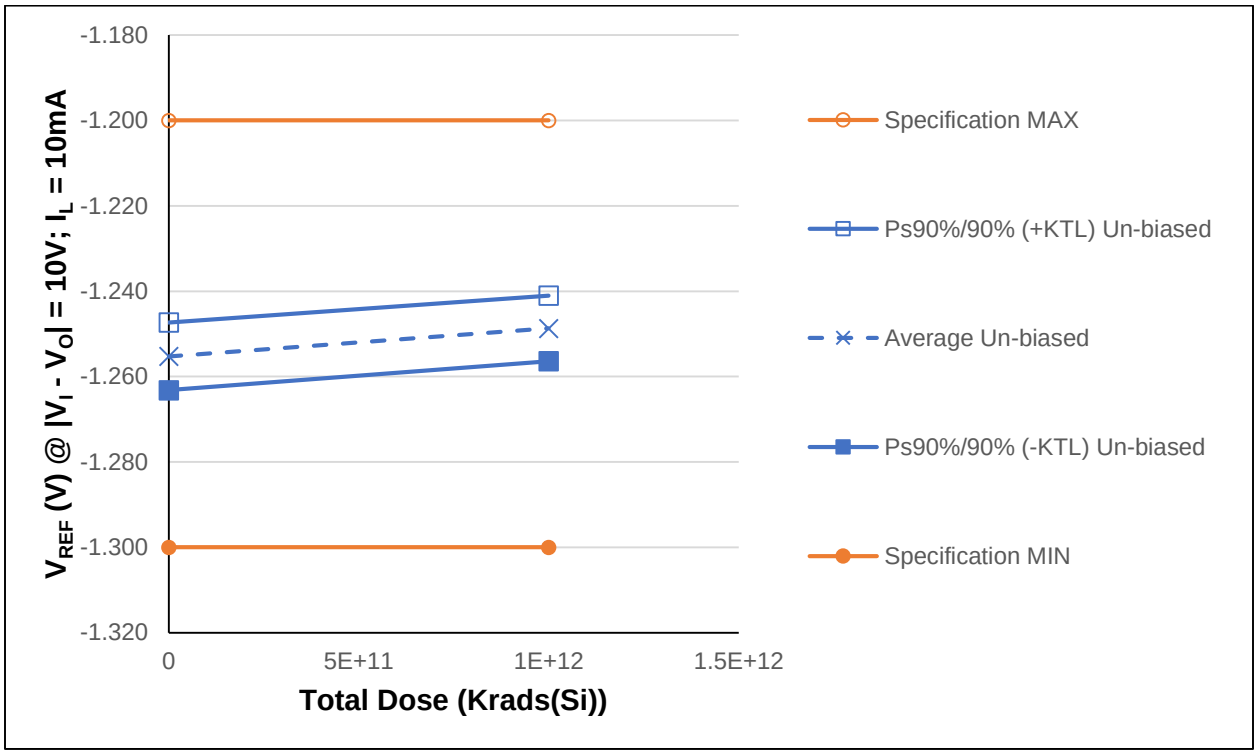

Figure 5.6: Plot of Reference Voltage @ $|V_I – V_O| = 10V$, $I_L = 10mA$ versus Total Fluence

Table 5.6: Raw data table for reference voltage @ $|V_I – V_O|$ = 10V, I_L = 10mA of pre- and post-irradiation (1E12 N/cm^2)

Parameter	V_{REF} @ $\|V_I - V_O\|$ = 10V; I_L = 10mA	Total Fluence (neutrons/cm^2)	
Units	(V)	0	1.E+12
1	Un-biased Irradiation	-1.25966	-1.25309
2	Un-biased Irradiation	-1.25418	-1.24798
3	Un-biased Irradiation	-1.25587	-1.24938
4	Un-biased Irradiation	-1.25512	-1.24821
5	Un-biased Irradiation	-1.25162	-1.24535
6	Control Unit	-1.25523	-1.25515
12	Control Unit	-1.25515	-1.25523
	Un-biased Irradiation Statistics		
	Average Un-biased	-1.25529	-1.24880
	Std Dev Un-biased	0.00292	0.00281
	Ps90%/90% (+KTL) Un-biased	-1.24727	-1.24109
	Ps90%/90% (-KTL) Un-biased	-1.26331	-1.25652
	Specification MIN	-1.3	-1.3
	Status (Measurements)	PASS	PASS
	Specification MAX	-1.2	-1.2
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased	PASS	PASS

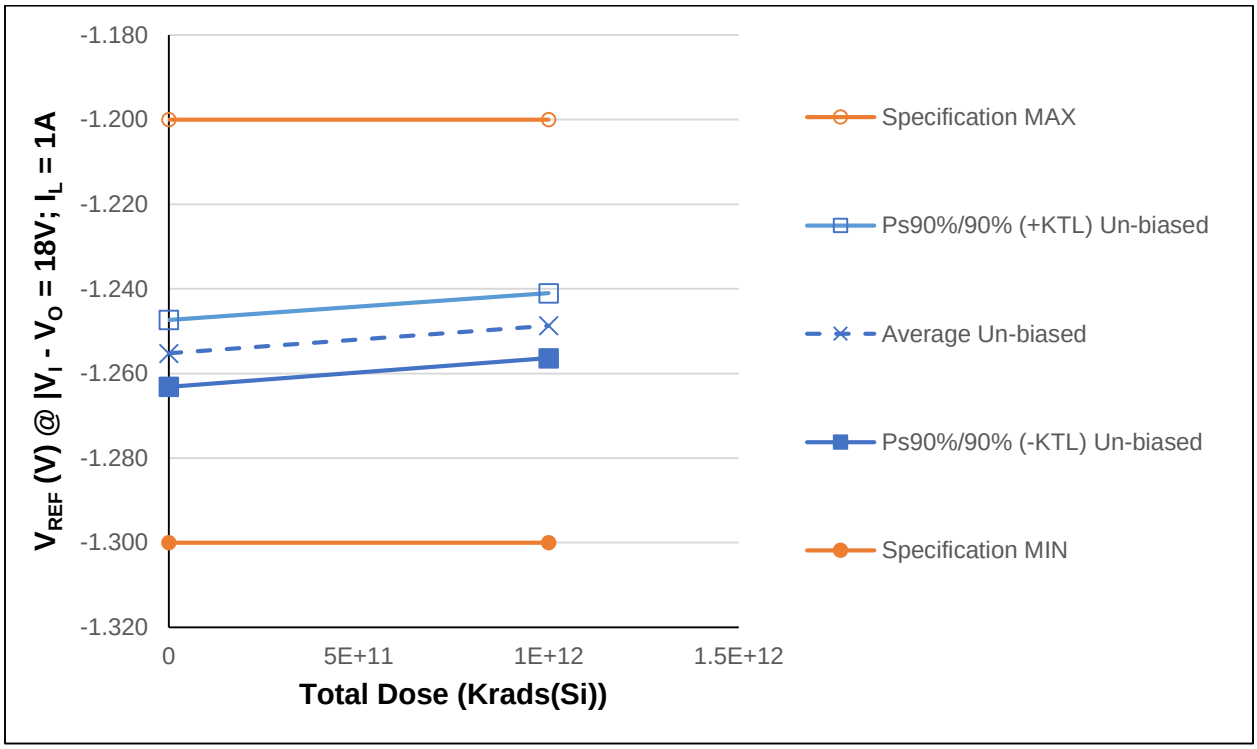

Figure 5.7: Plot of Reference Voltage @ $|V_I – V_O| = 18V$, $I_L = 1A$ versus Total Fluence

Table 5.7: Raw data table for reference voltage @ $|V_I – V_O|$ = 18V, I_L = 1A of pre- and post-irradiation (1E12 N/cm^2)

Parameter	V_{REF} @ $\|V_I - V_O\|$ = 18V; I_L = 1A	Total Fluence (neutrons/cm^2)	
Units	V	0	1.E+12
1	Un-biased Irradiation	-1.25855	-1.25241
2	Un-biased Irradiation	-1.25337	-1.24661
3	Un-biased Irradiation	-1.25508	-1.24866
4	Un-biased Irradiation	-1.25405	-1.24733
5	Un-biased Irradiation	-1.25038	-1.24463
6	Control Unit	-1.25401	-1.25424
12	Control Unit	-1.25367	-1.25442
	Un-biased Irradiation Statistics		
	Average Un-biased	-1.25429	-1.24793
	Std Dev Un-biased	0.00296	0.00290
	Ps90%/90% (+KTL) Un-biased	-1.24618	-1.23998
	Ps90%/90% (-KTL) Un-biased	-1.26239	-1.25587
	Specification MIN	-1.3	-1.3
	Status (Measurements)	PASS	PASS
	Specification MAX	-1.2	-1.2
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased	PASS	PASS

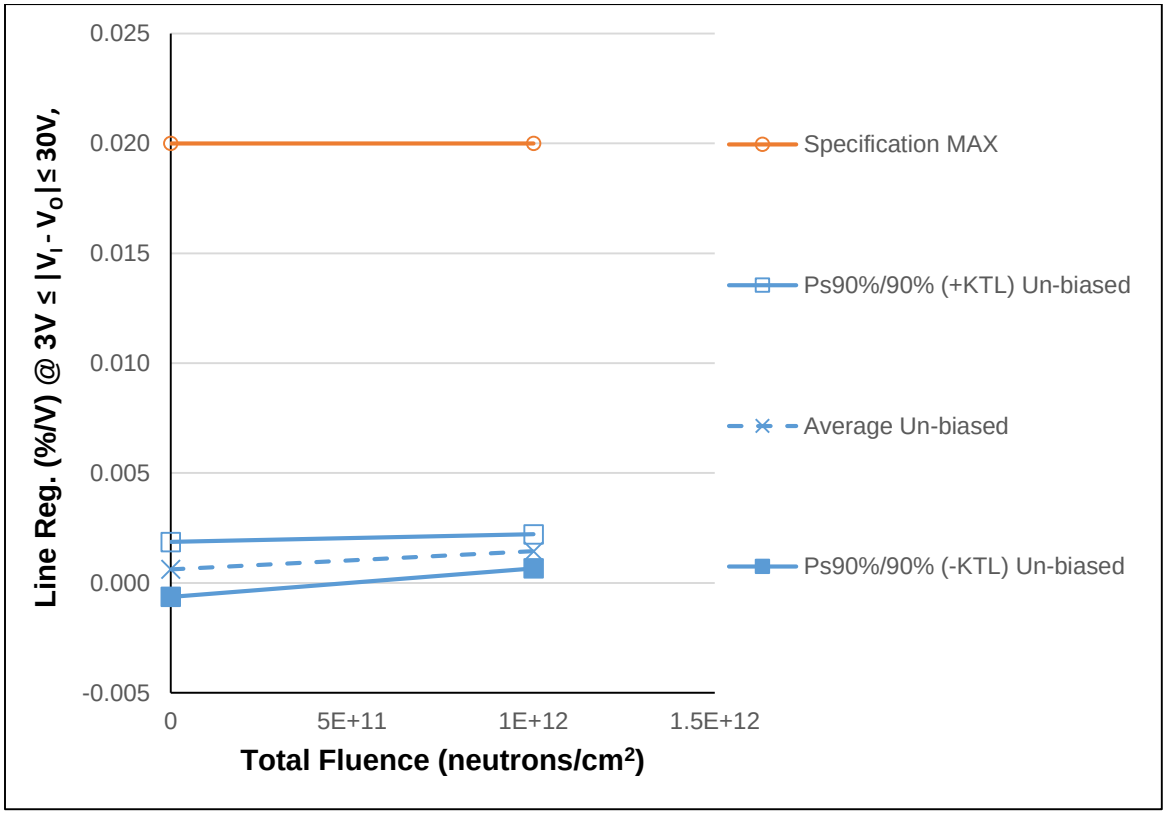

Figure 5.8: Plot of Line Regulation @ $3V \le |V_I - V_O| \le 30V$ *versus Total Fluence*

Table 5.8: Raw data table for Line Regulation @ 3V ≤ $|V_I – V_O|$ ≤ 30V of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Line Reg @ 3V ≤ $\|V_I - V_O\|$ ≤ 30V	Total Fluence (neutrons/cm^2)	
Units	(%/V)	0	1.E+12
1	Un-biased Irradiation	0.00137	0.00144
2	Un-biased Irradiation	0.00020	0.00172
3	Un-biased Irradiation	0.00069	0.00167
4	Un-biased Irradiation	0.00037	0.00134
5	Un-biased Irradiation	0.00045	0.00102
6	Control Unit	0.00101	0.00065
12	Control Unit	0.00065	0.00096
	Un-biased Irradiation Statistics		
	Average Un-biased	0.00062	0.00144
	Std Dev Un-biased	0.00046	0.00028
	Ps90%/90% (+KTL) Un-biased	0.00187	0.00222
	Ps90%/90% (-KTL) Un-biased	-0.00063	0.00066
	Specification MIN		
	Status (Measurements)		
	Specification MAX	0.020	0.020
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased		
	Status (+KTL) Un-biased	PASS	PASS

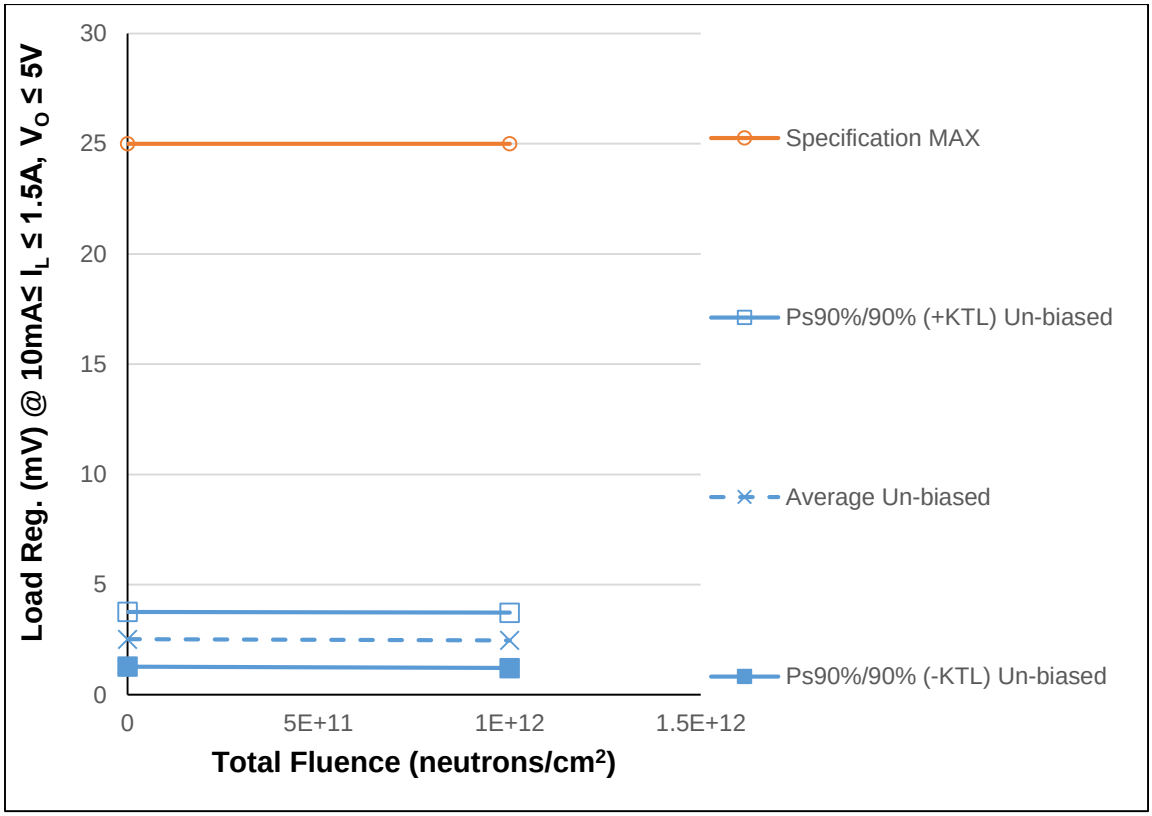

Figure 5.9: Plot of Load Regulation @ 10mA ≤ I_L ≤ 1.5A, V_O ≤ 5V *versus Total Fluence*

Table 5.9: Raw data table for Load Regulation @ 10mA ≤ I_L ≤ 1.5A, V_O ≤ 5V of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Load Reg. @ 10mA≤I_L≤1.5A,V_O≤5V	Total Fluence (neutrons/cm^2)	
Units	(mV)	0	1.E+12
1	Un-biased Irradiation	3.03555	2.62356
2	Un-biased Irradiation	2.12574	3.12901
3	Un-biased Irradiation	2.00558	1.97887
4	Un-biased Irradiation	2.54726	2.51961
5	Un-biased Irradiation	2.88391	2.09713
6	Control Unit	2.67983	2.24018
12	Control Unit	2.10762	2.10762
	Un-biased Irradiation Statistics		
	Average Un-biased	2.51961	2.46964
	Std Dev Un-biased	0.45250	0.45841
	Ps90%/90% (+KTL) Un-biased	3.76037	3.72660
	Ps90%/90% (-KTL) Un-biased	1.27885	1.21267
	Specification MIN		
	Status (Measurements)		
	Specification MAX	25	25
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased		
	Status (+KTL) Un-biased	PASS	PASS

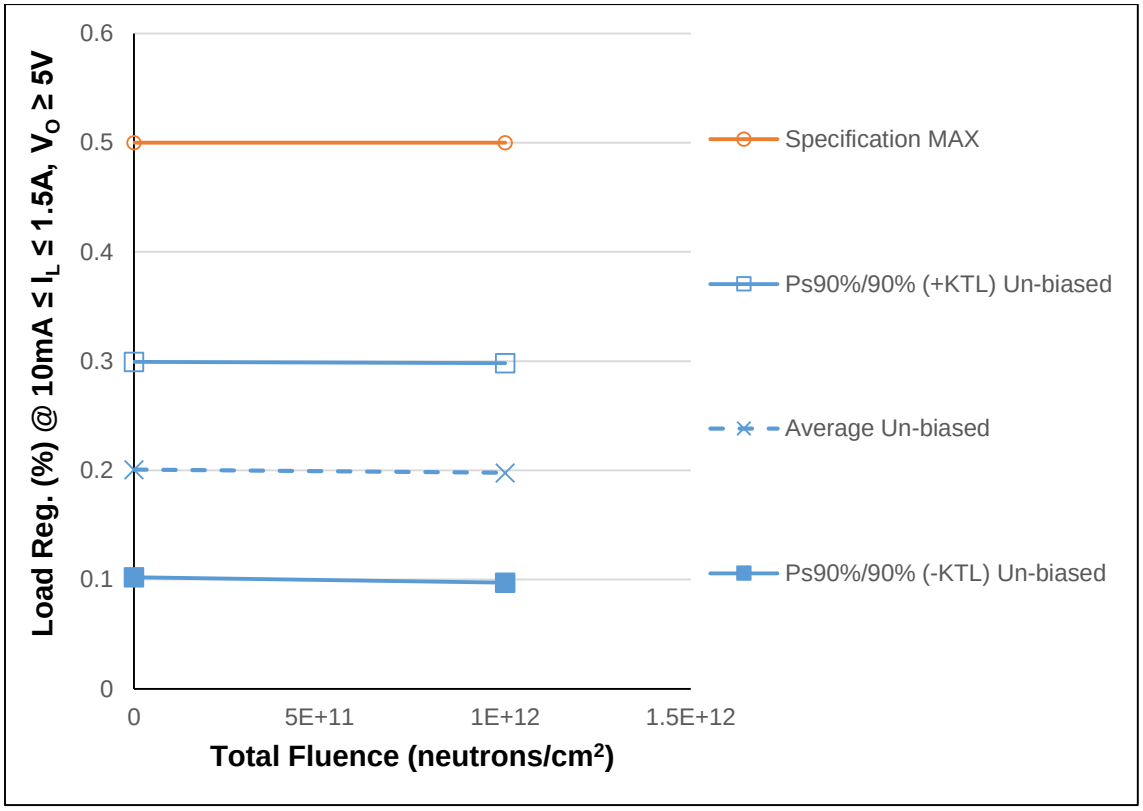

Figure 5.10: Plot of Load Regulation @ 10mA ≤ I_L ≤ 1.5A, V_O ≥ 5V *versus Total Fluence*

Table 5.10: Raw data table for Load Reg. @ 10mA ≤ I_L ≤ 1.5A, V_O ≥ 5V of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Load Reg. @ 10mA≤I_L≤1.5A,V_O≥5V	Total Fluence (neutrons/cm^2)	
Units	(%)	0	1.E+12
1	Un-biased Irradiation	0.24098	0.20935
2	Un-biased Irradiation	0.16950	0.25072
3	Un-biased Irradiation	0.15970	0.15839
4	Un-biased Irradiation	0.20296	0.20186
5	Un-biased Irradiation	0.23041	0.16840
6	Control Unit	0.21351	0.17850
12	Control Unit	0.16792	0.16792
	Un-biased Irradiation Statistics		
	Average Un-biased	0.20071	0.19774
	Std Dev Un-biased	0.03593	0.03663
	Ps90%/90% (+KTL) Un-biased	0.29924	0.29820
	Ps90%/90% (-KTL) Un-biased	0.10219	0.09729
	Specification MIN		
	Status (Measurements)		
	Specification MAX	0.5	0.5
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased		
	Status (+KTL) Un-biased	PASS	PASS

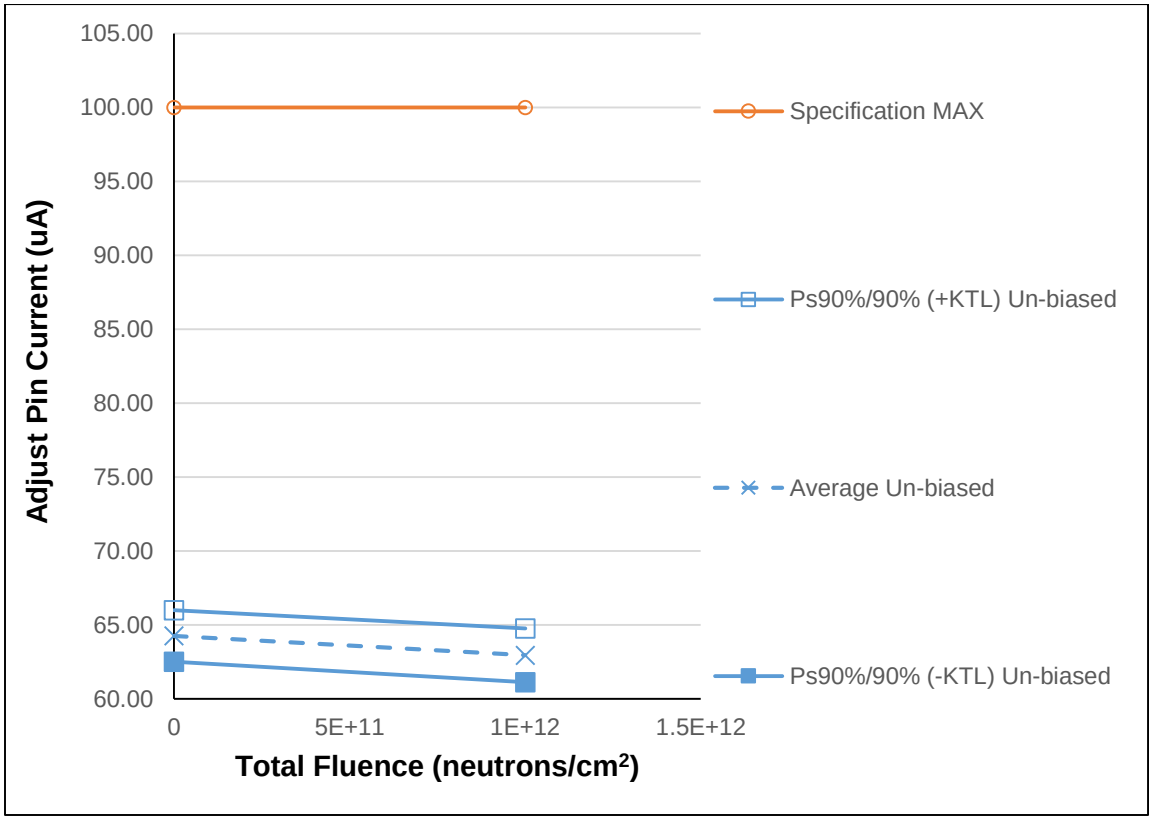

Figure 5.11: Plot of Adjust Pin Current versus Total Fluence

Table 5.11: Raw data table for Adjust Pin Current of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Adjust Pin Current	Total Fluence (neutron/cm$^{2)}$	
Units	(uA)	0	1.E+12
1	Un-biased Irradiation	64.71181	63.35652
2	Un-biased Irradiation	64.69150	63.52898
3	Un-biased Irradiation	63.87320	62.52822
4	Un-biased Irradiation	64.67717	63.32914
5	Un-biased Irradiation	63.30278	61.98551
6	Control Unit	64.22501	63.40881
12	Control Unit	63.16840	63.22433
	Un-biased Irradiation Statistics		
	Average Un-biased	64.25129	62.94567
	Std Dev Un-biased	0.63833	0.66187
	Ps90%/90% (+KTL) Un-biased	66.00159	64.76051
	Ps90%/90% (-KTL) Un-biased	62.50099	61.13084
	Specification MIN		
	Status (Measurements)		
	Specification MAX	100	100
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased		
	Status (+KTL) Un-biased	PASS	PASS

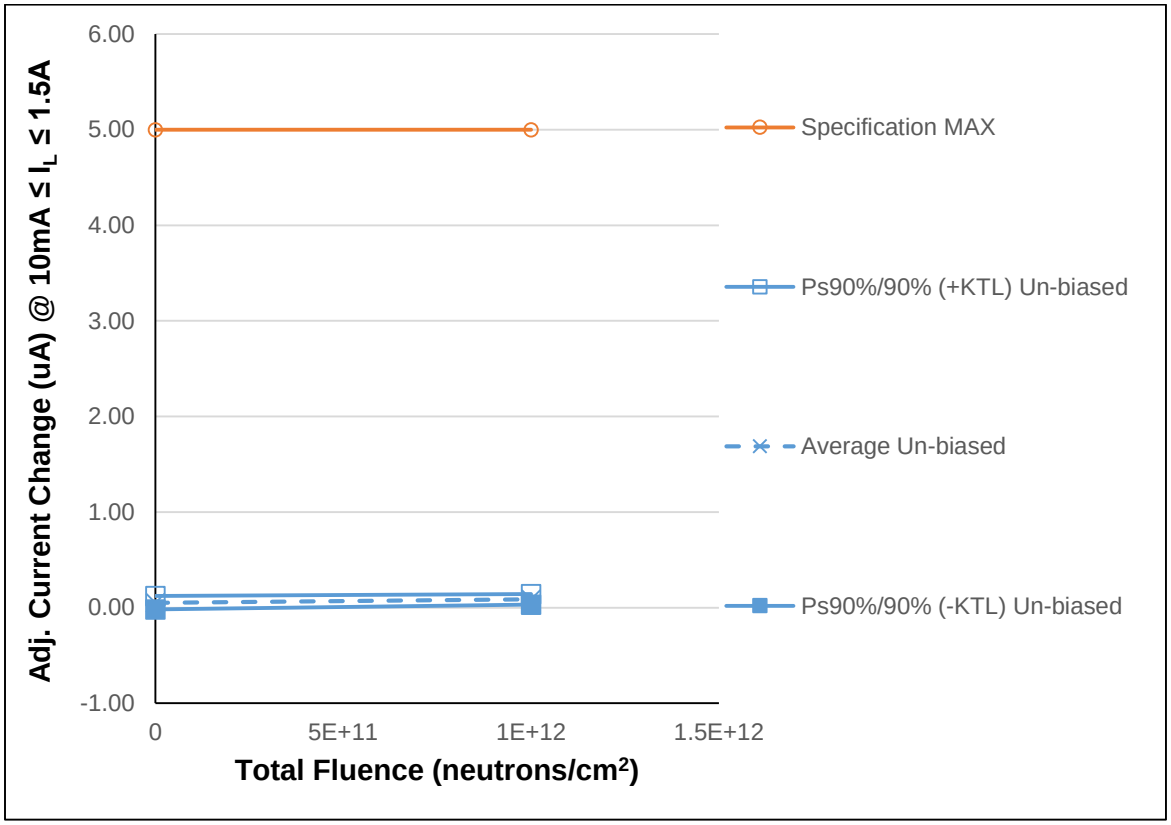

Figure 5.12: Plot of Adjust Pin Current Change @ 10mA ≤ I_L ≤ 1.5A *versus Total Fluence*

Table 5.12: Raw data table for Adjust Pin Current Change @ 10mA ≤ I_L ≤ 1.5A of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Adj Current Change @ 10mA≤I_L≤1.5A	Total Fluence (neutron/cm$^{2)}$	
Units	(uA)	0	1.E+12
1	Un-biased Irradiation	0.06749	0.06669
2	Un-biased Irradiation	0.01433	0.12017
3	Un-biased Irradiation	0.05614	0.08575
4	Un-biased Irradiation	0.08063	0.09171
5	Un-biased Irradiation	0.03942	0.07611
6	Control Unit	0.07015	0.09038
12	Control Unit	0.07586	0.03811
	Un-biased Irradiation Statistics		
	Average Un-biased	0.05160	0.08809
	Std Dev Un-biased	0.02575	0.02030
	Ps90%/90% (+KTL) Un-biased	0.12222	0.14376
	Ps90%/90% (-KTL) Un-biased	-0.01901	0.03241
	Specification MIN		
	Status (Measurements)		
	Specification MAX	5	5
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased		
	Status (+KTL) Un-biased	PASS	PASS

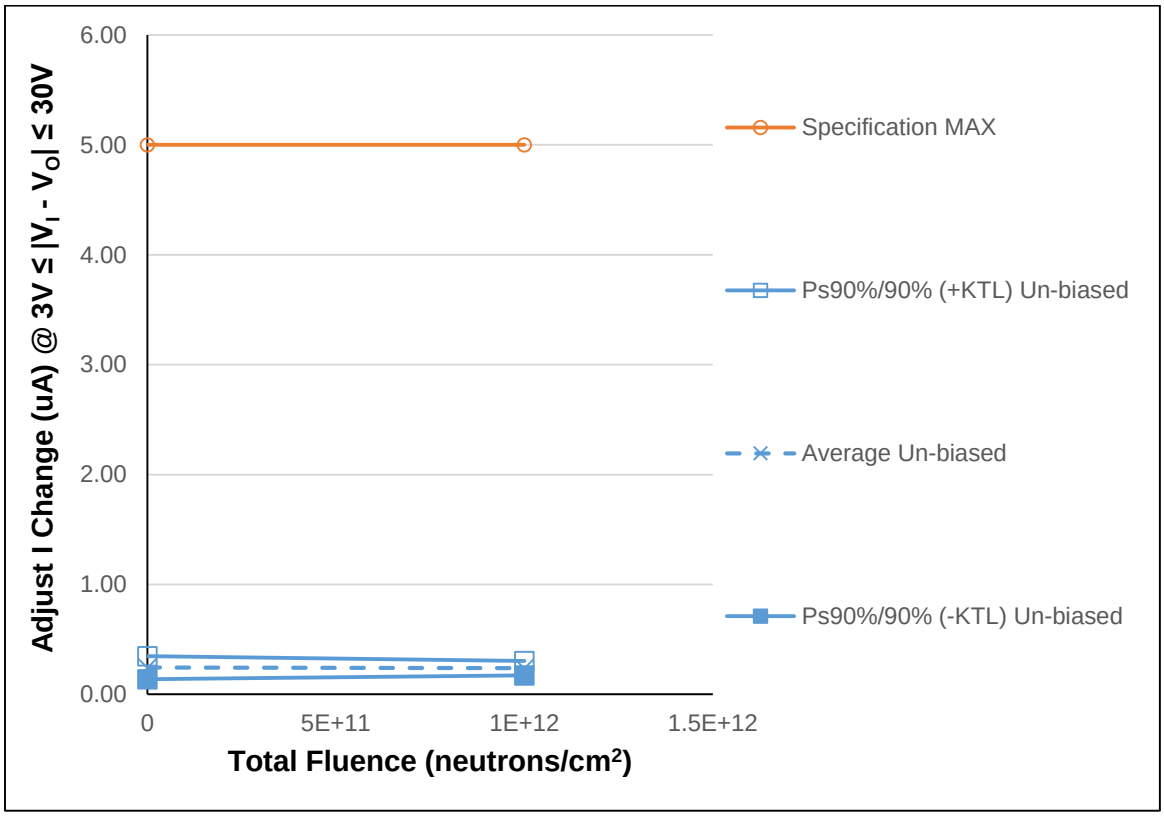

Figure 5.13: Plot of Adjust Pin Current Change @ $3V \le |V_I - V_O| \le 30V$ *versus Total Fluence*

Table 5.13: Raw data table for Adjust Pin Current Change @ 3V ≤ $|V_I - V_O|$ ≤ 30V of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Adj. I Change @ 3V ≤ $\|V_I - V_O\|$ ≤ 30V	Total Fluence (neutrons/cm^2)	
Units	(uA)	0	1.E+12
1	Un-biased Irradiation	0.27237	0.24165
2	Un-biased Irradiation	0.26281	0.25355
3	Un-biased Irradiation	0.25744	0.21663
4	Un-biased Irradiation	0.17681	0.26665
5	Un-biased Irradiation	0.24370	0.20949
6	Control Unit	0.20786	0.23319
12	Control Unit	0.18576	0.20949
	Un-biased Irradiation Statistics		
	Average Un-biased	0.24262	0.23759
	Std Dev Un-biased	0.03823	0.02421
	Ps90%/90% (+KTL) Un-biased	0.34744	0.30398
	Ps90%/90% (-KTL) Un-biased	0.13781	0.17121
	Specification MIN		
	Status (Measurements)		
	Specification MAX	5	5
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased		
	Status (+KTL) Un-biased	PASS	PASS

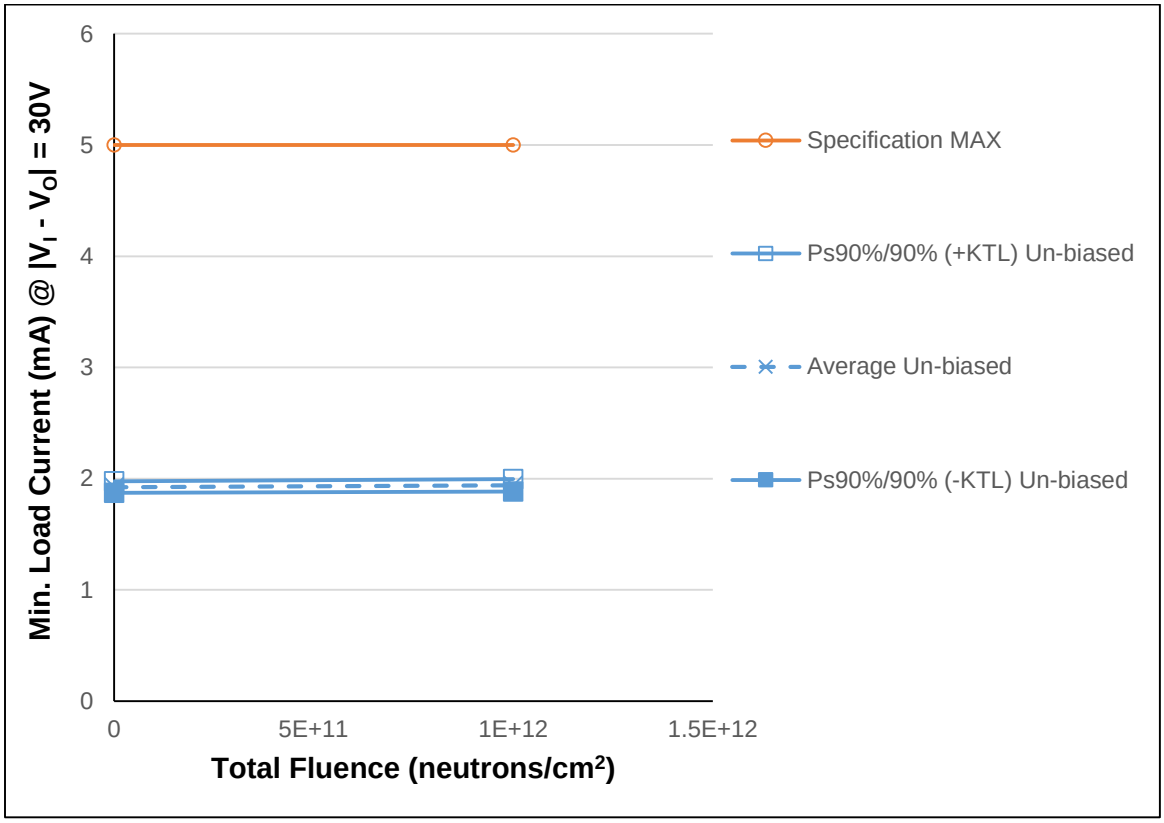

Figure 5.14: Plot of Minimum Load Current @ $|V_I - V_O| = 30V$ *versus Total Fluence*

Table 5.14: Raw data table for Minimum Load Current @ $|V_I – V_O|$ = 30V of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Min. Load Current @ $\|V_I - V_O\|$ = 30V	Total Fluence (neutrons/cm^2)	
Units	(mA)	0	1.E+12
1	Un-biased Irradiation	1.92897	1.94687
2	Un-biased Irradiation	1.95324	1.97151
3	Un-biased Irradiation	1.91229	1.92643
4	Un-biased Irradiation	1.91776	1.93246
5	Un-biased Irradiation	1.90612	1.92163
6	Control Unit	1.91822	1.88183
12	Control Unit	1.88354	1.88312
	Un-biased Irradiation Statistics		
	Average Un-biased	1.92368	1.93978
	Std Dev Un-biased	0.01854	0.02011
	Ps90%/90% (+KTL) Un-biased	1.97452	1.99492
	Ps90%/90% (-KTL) Un-biased	1.87284	1.88464
	Specification MIN		
	Status (Measurements)		
	Specification MAX	5	5
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased		
	Status (+KTL) Un-biased	PASS	PASS

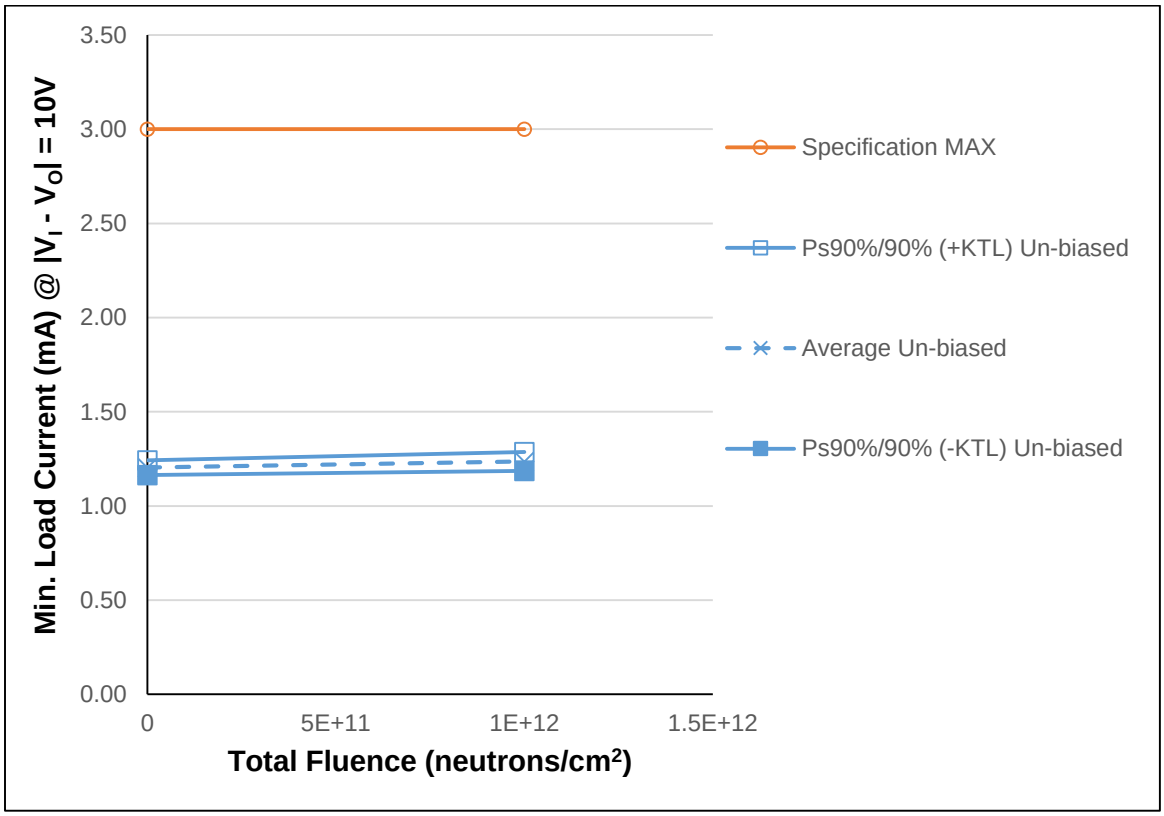

Figure 5.15: Plot of Minimum Load Current @ $|V_I - V_O| = 10V$ *versus Total Fluence*

Table 5.15: Raw data table for Minimum Load Current @ $|V_I - V_O|$ = 10V of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Min. Load Current @ $\|V_I - V_O\|$ = 10V	Total Fluence (neutrons/cm^2)	
Units	(mA)	0	1.E+12
1	Un-biased Irradiation	1.21297	1.24133
2	Un-biased Irradiation	1.22280	1.26627
3	Un-biased Irradiation	1.19321	1.22540
4	Un-biased Irradiation	1.20160	1.22540
5	Un-biased Irradiation	1.18812	1.22235
6	Control Unit	1.19789	1.18521
12	Control Unit	1.18345	1.18033
	Un-biased Irradiation Statistics		
	Average Un-biased	1.20374	1.23615
	Std Dev Un-biased	0.01421	0.01841
	Ps90%/90% (+KTL) Un-biased	1.24271	1.28663
	Ps90%/90% (-KTL) Un-biased	1.16477	1.18567
	Specification MIN		
	Status (Measurements)		
	Specification MAX	3	3
	Status (Measurements)	PASS	PASS
	Status (-KTL) Un-biased		
	Status (+KTL) Un-biased	PASS	PASS

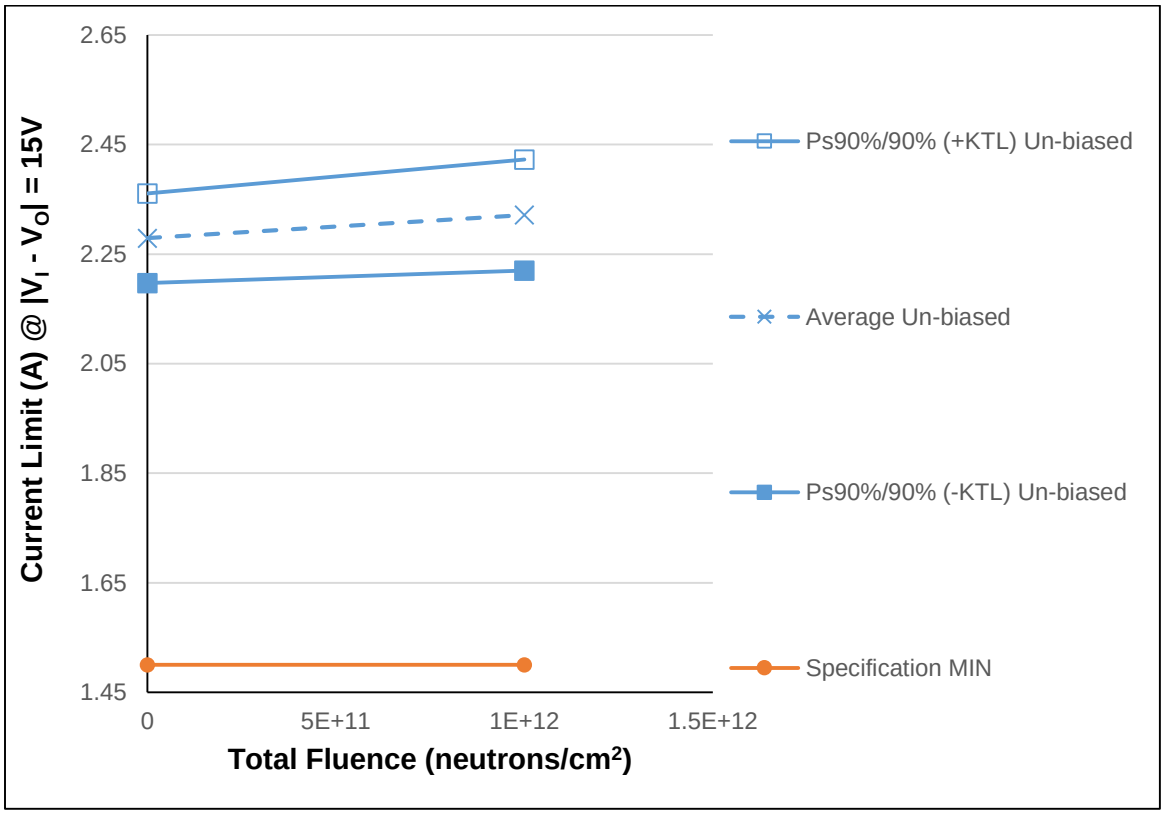

Figure 5.16: Plot of Current Limit @ $|V_I - V_O|$ = 15V versus Total Fluence

Table 5.16: Raw data table for Current Limit @ $|V_I – V_O| = 15V$ of pre- and post-irradiation (1E12 N/cm^2)

Parameter	Current Limit @ $\|V_I - V_O\| = 15V$	Total Fluence (neutrons/cm^2)	
Units	(A)	0	1.E+12
1	Un-biased Irradiation	2.24349	2.28103
2	Un-biased Irradiation	2.30183	2.36145
3	Un-biased Irradiation	2.30815	2.34491
4	Un-biased Irradiation	2.25112	2.28340
5	Un-biased Irradiation	2.29143	2.33687
6	Control Unit	2.25525	2.30383
12	Control Unit	2.30775	2.33690
	Un-biased Irradiation Statistics		
	Average Un-biased	2.27920	2.32153
	Std Dev Un-biased	0.02985	0.03698
	Ps90%/90% (+KTL) Un-biased	2.36104	2.42293
	Ps90%/90% (-KTL) Un-biased	2.19736	2.22014
	Specification MIN	1.5	1.5
	Status (Measurements)	PASS	PASS
	Specification MAX		
	Status (Measurements)		
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased		

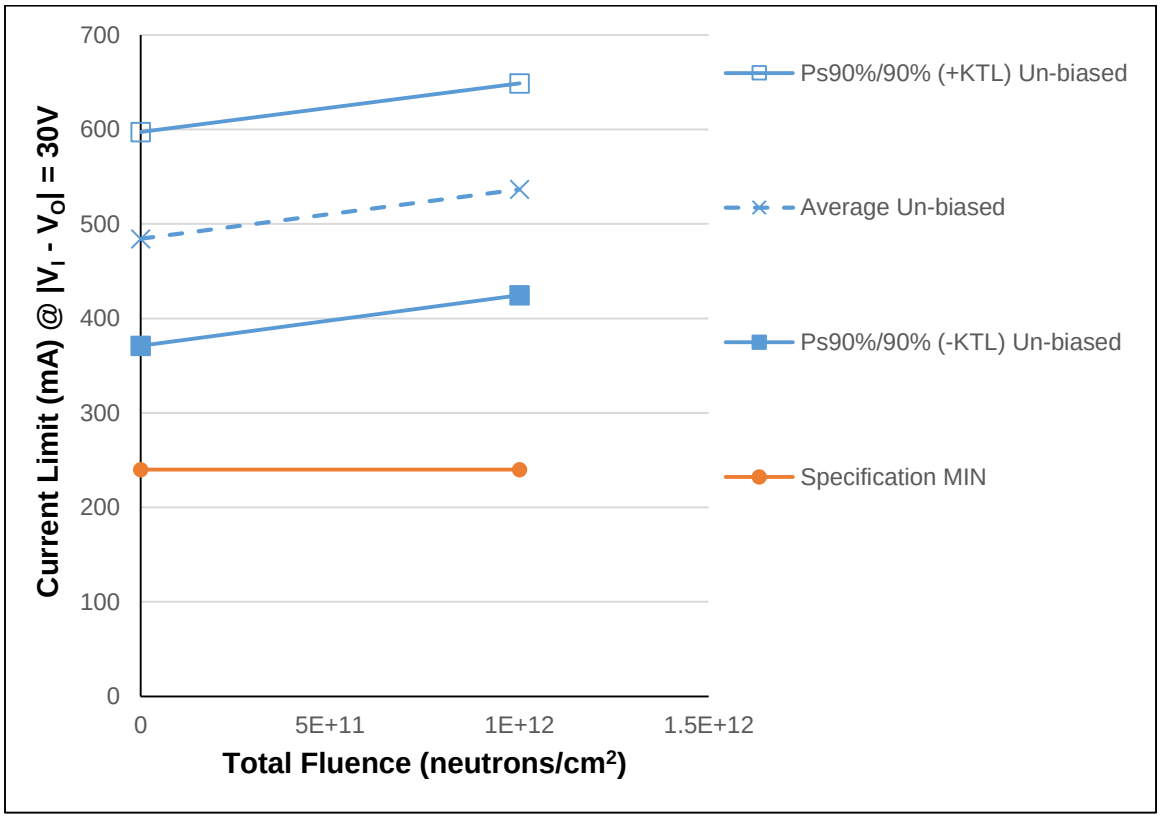

Figure 5.17: Plot of versus Current Limit @ $|V_I - V_O|$ = 30V Total Fluence

Table 5.17: Raw data table for Current Limit @ $|V_I - V_O| = 30V$ pre- and post-irradiation (1E12 N/cm^2)

Parameter	Current Limit @ $\|V_I - V_O\| = 30V$	Total Fluence (neutrons/cm^2)	
Units	(mA)	0	1.E+12
1	Un-biased Irradiation	443.53690	494.67060
2	Un-biased Irradiation	459.33330	516.25170
3	Un-biased Irradiation	549.61520	602.49260
4	Un-biased Irradiation	473.17630	525.58860
5	Un-biased Irradiation	495.88540	544.68380
6	Control Unit	474.76020	521.95490
12	Control Unit	518.17090	520.06770
	Un-biased Irradiation Statistics		
	Average Un-biased	484.30942	536.73746
	Std Dev Un-biased	41.25833	40.92819
	Ps90%/90% (+KTL) Un-biased	597.43976	648.96256
	Ps90%/90% (-KTL) Un-biased	371.17908	424.51236
	Specification MIN	240	240
	Status (Measurements)	PASS	PASS
	Specification MAX		
	Status (Measurements)		
	Status (-KTL) Un-biased	PASS	PASS
	Status (+KTL) Un-biased		

Appendix A

Pictures of one among five samples used in the test.

Figure A1: Top View showing date code, lot and wafer numbers

Appendix B

Radiation Bias Connection Table

Table B1: Unbiased condition

Pin	Function	Connection
1	Adjust	Float
2	V_{OUT}	Float
3	V_{IN} (CASE)	Float

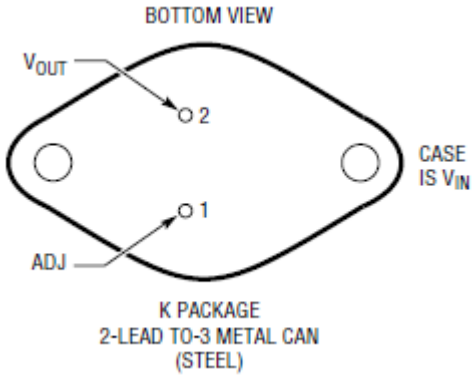

Figure B1: Pin-Out

Appendix C

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Thomas Regan
Reactor Engineering

University of Massachusetts
UMASS Lowell

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 D

Table D1: Electrical Characteristics of Device-Under-Test Pre-Irradiation

SYMBOL	PARAMETER	CONDITIONS	NOTES	$T_A = 25°C$ MIN	TYP	MAX	SUB-GROUP	$-55°C \le T_A \le 150°C$ MIN	TYP	MAX	SUB-GROUP	UNITS
V_{REF}	Reference Voltage	$\lvert V_{IN} - V_{OUT} \rvert = 5V$, $I_{OUT} = 10mA$		−1.225		−1.275	1					V
		$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 30V$, $10mA \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$		−1.200		−1.300	1	−1.200		−1.300	2, 3	V
$\frac{\Delta V_{OUT}}{\Delta V_{IN}}$	Line Regulation	$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 30V$	2			0.02	1			0.05	2, 3	%/V
$\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$	Load Regulation	$10mA \le I_{OUT} \le I_{MAX}$, $\lvert V_{OUT} \rvert \le 5V$	2			25	1			50	2, 3	mV
		$10mA \le I_{OUT} \le I_{MAX}$, $\lvert V_{OUT} \rvert \ge 5V$	2			0.5	1			1	2, 3	%
	Thermal Regulation	10ms Pulse				0.02	1					%/W
	Ripple Rejection	$V_{OUT} = -10V$, f = 120Hz, $C_{ADJ} = 0$			60							dB
		$V_{OUT} = -10V$, f = 120Hz, $C_{ADJ} = 10\mu F$	3	66				66				dB
I_{ADJ}	Adjust Pin Current					100	1			100	2, 3	µA
ΔI_{ADJ}	Adjust Pin Current Change	$10mA \le I_{OUT} \le I_{MAX}$				5	1			5	2, 3	µA
		$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 30V$				5	1			5	2, 3	µA
I_{MIN}	Minimum Load Current	$\lvert V_{IN} - V_{OUT} \rvert = 30V$				5	1			5	2, 3	mA
		$\lvert V_{IN} - V_{OUT} \rvert \le 10V$				3	1			3	2, 3	mA
	Current Limit	$\lvert V_{IN} - V_{OUT} \rvert \le 15V$ H Package	5	0.5			1	0.5			2, 3	A
		K Package	5	1.5			1	1.5			2, 3	A
		$\lvert V_{IN} - V_{OUT} \rvert = 30V$ H Package	5	0.15			1					A
		K Package	5	0.24			1					A
$\frac{\Delta V_{OUT}}{\Delta Temp}$	Temperature Stability	$-55°C \le T_J \le 125°C$	3						0.6			%
$\frac{\Delta V_{OUT}}{\Delta Time}$	Long Term Stability	$T_A = 125°C$	3							1		%
e_n	RMS Output Noise	$10Hz \le f \le 10kHz$			0.003							%
θ_{JC}	Thermal Resistance (Junction to Case)	H Package	3			15						°C/W
		K Package	3			3						°C/W

Table D2: Electrical Characteristics of Device-Under-Test Post-Irradiation

SYMBOL	PARAMETER	CONDITIONS	NOTES	10KRAD(Si) MIN	10KRAD(Si) MAX	20KRAD(Si) MIN	20KRAD(Si) MAX	50KRAD(Si) MIN	50KRAD(Si) MAX	100KRAD(Si) MIN	100KRAD(Si) MAX	200KRAD(Si) MIN	200KRAD(Si) MAX	UNITS
V_{REF}	Reference Voltage	$\lvert V_{IN} - V_{OUT} \rvert \le 5V$, $I_{OUT} = 10mA$		−1.225	−1.275	−1.225	−1.275	−1.225	−1.275	−1.225	−1.275	−1.22	−1.28	V
		$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 30V$, $10mA \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$		−1.2	−1.3	−1.2	−1.3	−1.2	−1.3	−1.2	−1.3	−1.2	−1.3	V
$\frac{\Delta V_{OUT}}{\Delta V_{IN}}$	Line Regulation	$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 30V$,	2		0.02		0.02		0.02		0.02		0.02	%/V
$\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$	Load Regulation	$10mA \le I_{OUT} \le I_{MAX}$, $\lvert V_{OUT} \rvert \le 5V$	2		25		25		25		25		25	mV
		$10mA \le I_{OUT} \le I_{MAX}$, $\lvert V_{OUT} \rvert \ge 5V$	2		0.5		0.5		0.5		0.5		0.5	%
I_{ADJ}	Adjust Pin Current				100		100		100		100		100	µA
ΔI_{ADJ}	Adjust Pin Current Change	$10mA \le I_{OUT} \le I_{MAX}$ $3V \le \lvert V_{IN} - V_{OUT} \rvert \le 30V$			5 5		5 5		5 5		5 5		5 5	µA µA
I_{MIN}	Minimum Load Current	$\lvert V_{IN} - V_{OUT} \rvert = 30V$ $\lvert V_{IN} - V_{OUT} \rvert \le 10V$			5 3		5 3		5 3		5 3		5 3	mA mA
	Current Limit H Package	$\lvert V_{IN} - V_{OUT} \rvert \le 15V$ $\lvert V_{IN} - V_{OUT} \rvert = 30V$		0.5 0.15		0.5 0.15		0.5 0.15		0.5 0.15		0.5 0.15		A A
	K Package	$\lvert V_{IN} - V_{OUT} \rvert \le 15V$ $\lvert V_{IN} - V_{OUT} \rvert = 30V$		1.5 0.24		1.5 0.24		1.5 0.24		1.5 0.24		1.5 0.24		A A

Note 1: Unless otherwise specified, these specifications apply for $\lvert V_{IN} - V_{OUT} \rvert = 5V$; and $I_{OUT} = 0.1A$ for the H package (TO-39) and $I_{OUT} = 0.5A$ for the K package (TO-3) package. Although power dissipation is internally limited, these specifications are applicable for power dissipations of 2W for the TO-39 and 20W for the TO-3. I_{MAX} is 0.2A for the TO-39 and 1.5A for the TO-3 package.

Note 2: Regulation is measured at a constant junction temperature using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

Note 3: Guaranteed by design, characterization or correlation to other tested parameters.

Note 4: $T_J = 25°C$ unless otherwise noted.

Note 5: I_{SC} is tested at the ambient temperatures of 25°C and –55°C. I_{SC} cannot be tested at the maximum ambient temperature of 150°C due to the high power level required. I_{SC} specification at 150°C ambient is guaranteed by characterization and correlation to 25°C testing.