Unisys

DATE: November 03, 1998 PPM-99-003
TO: S Hull/562
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SUBJECT: Radiation Report on **OP400 (Analog Devices) (LDC 9814A)**
PROJECT: IRAC

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A radiation evaluation was performed on **OP400 (M5962/8777101MCA) Quad Low Offset, Low Power Operational Amplifier (Analog Devices)** to determine the total ionizing dose (TID) tolerance of these parts. The TID testing was performed using a Co^{60} gamma ray source. During the radiation testing, eight parts were irradiated under bias (see Figure 1 for bias configuration) and two parts were used as control samples. The total dose radiation levels were 2.5, 5.0, 10.0, 15.0, 20.0, 30.0, and 50.0kRads.[1] The effective dose rate was 0.149kRads/hour (0.04 Rads/s). See Table II for the radiation schedule and effective dose rate calculation. After the 50.0kRad irradiation, the parts were annealed under bias at 25°C for 168 hours.[2] After each radiation exposure and annealing treatment, parts were electrically tested according to the test conditions and the specification limits[3] listed in Table III.

An executive summary of the test results is provided below in bold, followed by a detailed summary of the test results after each radiation level and annealing step. For detailed information, refer to Tables I through IV and Figures 1 through 3.

All parts passed all tests up to 5kRads with no significant degradation observed in any parameter. All parts showed significant degradation in all +Ib, -Ib, Gain_2k, and Slew Rate measurements from 10 to 50kRads. All parts showed significant degradation in Slew Rate from 15 to 50kRads. All parts showed some degradation in all Gain_2k measurements after 50kRads. After annealing the parts for 168 hours at 25°C, the parts showed marginal recovery in the Gain_2k measurements. No significant recovery was observed in any other parameter. Figures 2 and 3 show the degradation in Ib and Slew Rate with increasing TID and annealing.

Initial electrical measurements were made on 10 samples. Eight samples (SN's 13, 14, 15, 16, 17, 18, 19, and 20) were used as radiation samples while SN's 11 and 12 were used as control samples. All parts passed all tests during initial electrical measurements.

After the 10.0kRad irradiation, most parts marginally exceeded the specification limit of 3.0nA for all eight of the +Ib and -Ib tests with readings in the range of 3.1 to 3.6nA for all. **All parts passed all other tests.**

After the 15.0kRad irradiation, all parts exceeded the specification limit of all of the +Ib and -Ib tests with readings in the range of 5.4 to 7.0nA for all. Two parts fell marginally below the specification limit of 120dB for CMRR_A with readings of 109dBand 106dB. Four parts fell marginally below the specification limit of 0.100V/µs for one or two Slew Rate measurements with readings in the range of 0.001 to 0.007V/µs. **All parts passed all other tests.**

After the 20.0kRad irradiation, all parts exceeded the specification limit of all of the +Ib and -Ib tests with readings in the range of 8.4 to 10.1nA for all. Two parts fell marginally below the specification limit of 120dB for CMRR_D with readings of 107dBand 108dB. Most parts fell below the specification limit for all Slew Rate measurements with readings in the range of 0.001 to 0.098V/µs. **All parts passed all other tests.**

[1] The term Rads, as used in this document, means Rads (silicon). All radiation levels cited are cumulative.
[2] The temperature 25°C as used in this document implies room temperature.
[3] These are manufacturer's pre-irradiation data specification limits. The manufacturer provided no post-irradiation limits at the time these tests were performed.

After the 30.0kRad irradiation, all parts exceeded the specification limit of all of the +Ib and -Ib tests with readings in the range of 13 to 16nA for all. One part fell marginally below the specification limit for CMRR_D with reading of 111dB. Most parts fell marginally below the specification limit of 126dB for two or more Gain_2k_A measurements with readings in the range of 124 to 125dB. All parts fell below the specification limit for all Slew Rate measurements with readings in the range of 0.001 to 0.056V/μs. **All parts passed all other tests.**

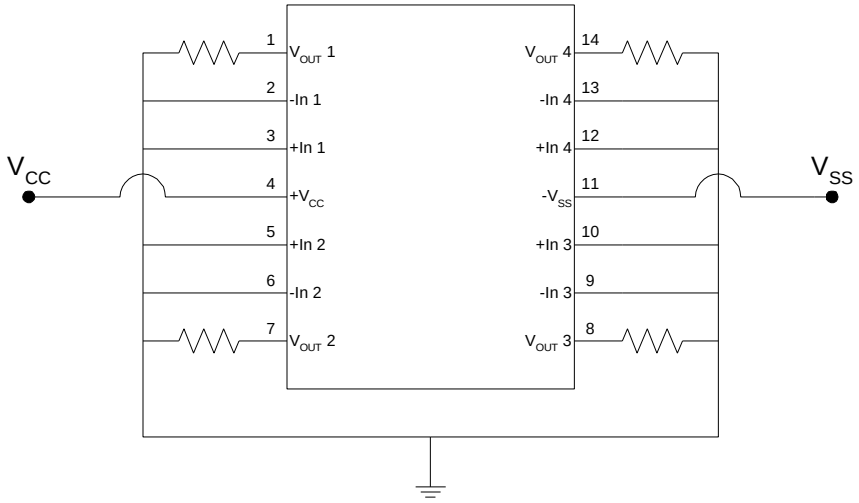
After the 50.0kRad irradiation, all parts exceeded the specification limit of all of the +Ib and -Ib tests with readings in the range of 21 to 26nA for all. All parts fell below the specification limit for all Gain_2k measurements with readings in the range of 120 to 124dB. All parts fell below the specification limit for all Slew Rate measurements with readings in the range of 0.001 to 0.024V/μs. **All parts passed all other tests.**

After annealing the parts for 168 hours at 25°C, the parts showed marginal recovery in Gain_2k with most parts passing. No significant recovery was noted in any other parameter.

Table IV provides a summary of the test results with the mean and standard deviation values for each parameter after each irradiation exposure and annealing step.

Any further details about this evaluation can be obtained upon request. If you have any questions, please call us at (301) 731-8954.

Figure 1. Radiation Bias Circuit for OP400



Notes:
1. V_{CC} = +15V ±0.5V, V_{SS} = -15V ±0.5V.
2. R = 15kΩ ±10%, ½W.

TABLE I. Part Information

Generic Part Number:	OP400
IRAC Part Number:	M5962/8777101MCA
Charge Number:	M88542
Manufacturer:	Analog Devices
Lot Date Code (LDC):	9814A
Quantity Tested:	10
Serial Number of Control Samples:	11, 12
Serial Numbers of Radiation Samples:	13, 14, 15, 16, 17, 18, 19, and 20
Part Function:	Quad Low Offset, Low Power Op Amp
Part Technology:	Bipolar
Package Style:	14 Pin Dip
Test Equipment:	A540
Test Engineer:	A. Duvalsaint

- The manufacturer for this part guaranteed no radiation tolerance/hardness.

TABLE II. Radiation Schedule for OP400

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	09/22/98
2) 2.5 KRAD IRRADIATION (0.038 KRADS/HOUR)	10/05/98
POST-2.5 KRAD ELECTRICAL MEASUREMENT	10/06/98
3) 5.0 KRAD IRRADIATION (0.147 KRADS/HOUR)	10/06/98
POST-5.0 KRAD ELECTRICAL MEASUREMENT	10/07/98
4) 10.0 KRAD IRRADIATION (0.121 KRADS/HOUR)	10/07/98
POST-10.0 KRAD ELECTRICAL MEASUREMENT	10/09/98
5) 15.0 KRAD IRRADIATION (0.121 KRADS/HOUR)	10/09/98
POST-15.0 KRAD ELECTRICAL MEASUREMENT	10/13/98
6) 20.0 KRAD IRRADIATION (0.077 KRADS/HOUR)	10/13/98
POST-20.0 KRAD ELECTRICAL MEASUREMENT	10/15/98
7) 30.0 KRAD IRRADIATION (0.244 KRADS/HOUR)	10/15/98
POST-30.0 KRAD ELECTRICAL MEASUREMENT	10/19/98
8) 50.0 KRAD IRRADIATION (0.488 KRADS/HOUR)	10/19/98
POST-50.0 KRAD ELECTRICAL MEASUREMENT	10/21/98
9) 168 HOUR ANNEALING @25°C	10/21/98
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	10/28/98

Effective Dose Rate = 50,000 RADS/14 DAYS=148.8 RADS/HOUR=0.04 RADS/SEC
The effective dose rate is lower than that of the individual radiation steps as it takes into account the time needed to test the parts.

PARTS WERE IRRADIATED AND ANNEALED UNDER BIAS, SEE FIGURE 1.

Table III. Electrical Characteristics of OP400 /1

Test #	Parameter	Units	Test Conditions /2	Spec. Lim. min	Spec. Lim. max
1	Icc	mA			2.90
2	Out_A	mV		-150	150
3	Out_B	mV		-150	150
4	Out_C	mV		-150	150
5	Out_D	mV		-150	150
6	+Ib_A	nA	V_{CM} = 0V	-3.0	3.0
7	-Ib_A	nA	V_{CM} = 0V	-3.0	3.0
8	Ios_A	nA	V_{CM} = 0V	-1.0	1.0
9	+Ib_B	nA	V_{CM} = 0V	-3.0	3.0
10	-Ib_B	nA	V_{CM} = 0V	-3.0	3.0
11	Ios_B	nA	V_{CM} = 0V	-1.0	1.0
12	+Ib_C	nA	V_{CM} = 0V	-3.0	3.0
13	-Ib_C	nA	V_{CM} = 0V	-3.0	3.0
14	Ios_C	nA	V_{CM} = 0V	-1.0	1.0
15	+Ib_D	nA	V_{CM} = 0V	-3.0	3.0
16	-Ib_D	nA	V_{CM} = 0V	-3.0	3.0
17	Ios_D	nA	V_{CM} = 0V	-1.0	1.0
18	P_PSRR_A	dB	V_S = ±3V to ±18V	114	
19	P_PSRR_B	dB	V_S = ±3V to ±18V	114	
20	N_PSRR_C	dB	V_S = ±3V to ±18V	114	
21	N_PSRR_D	dB	V_S = ±3V to ±18V	114	
22	CMRR_A	dB	V_{CM} = ±12V	120	
23	CMRR_B	dB	V_{CM} = ±12V	120	
24	CMRR_C	dB	V_{CM} = ±12V	120	
25	CMRR_D	dB	V_{CM} = ±12V	120	
26	Gain_2k_A	dB	V_O = ±10V, R_L = 2kW	126	
27	Gain_2k_B	dB	V_O = ±10V, R_L = 2kW	126	
28	Gain_2k_C	dB	V_O = ±10V, R_L = 2kW	126	
29	Gain_2k_D	dB	V_O = ±10V, R_L = 2kW	126	
30	Voh_2k_A	V	R_L = 2kW	11.0	
31	Voh_2k_A	V	R_L = 2kW		-11.0
32	Voh_2k_B	V	R_L = 2kW	11.0	
33	Voh_2k_B	V	R_L = 2kW		-11.0
34	Voh_2k_C	V	R_L = 2kW	11.0	
35	Voh_2k_C	V	R_L = 2kW		-11.0
36	Voh_2k_D	V	R_L = 2kW	11.0	
37	Voh_2k_D	V	R_L = 2kW		-11.0
38	Slew Rate A	V/ms	V_{OUT} = ±0.25V	0.100	
39	Slew Rate B	V/ms	V_{OUT} = ±0.25V	0.100	
40	Slew Rate C	V/ms	V_{OUT} = ±0.25V	0.100	
41	Slew Rate D	V/ms	V_{OUT} = ±0.25V	0.100	

Notes:

1/ These are the manufacturer's non-irradiated data sheet specification limits. The manufacturer provided no post-irradiation limits at the time the tests were performed.

2/ V_S = ±15V unless otherwise specified.

TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for OP400 /1

					Total Dose Exposure (kRads Si)																Annealing	
					Initial		2.5		5.0		10.0		15.0		20.0		30.0		50.0		168 hours @25°C	
Test #	Parameters	Units	Spec. Lim. /2 min	Spec. Lim. /2 max	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1	Icc	mA		2.90	2.24	0.02	1.73	0.02	1.51	0.09	1.36	0.06	1.16	0.03	1.38	0.04	0.98	0.12	0.60	0.03	1.48	0.04
2	Out_A	?V	-150	150	9	30	16	26	15	34	20	31	33	32	67	44	51	43	50	55	37	51
3	Out_B	?V	-150	150	8	28	15	31	15	30	23	27	33	29	61	38	46	43	51	55	39	38
4	Out_C	?V	-150	150	16	24	13	31	11	30	20	30	33	33	64	37	51	49	52	55	-4	52
5	Out_D	?V	-150	150	16	24	13	31	17	30	22	36	35	32	66	39	52	44	50	54	5	65
6	+Ib_A	nA	-3.0	3.0	0.2	0	1.1	0.1	2.0	0.1	3.2	0.2	6.4	0.5	9.4	0.6	15	0.9	24	1.7	22	1.6
7	-Ib_A	nA	-3.0	3.0	0.2	0	1.1	0.1	1.9	0.1	3.2	0.2	6.5	0.6	9.4	0.6	15	0.8	24	1.8	22	1.6
8	Ios_A	nA	-1.0	1.0	0	0	0.03	0.1	0.04	0.06	0.01	0.08	-0.02	0.08	-0.02	0.13	0.03	0.10	-0.04	0.09	-0.07	0.06
9	+Ib_B	nA	-3.0	3.0	0.2	0	1.1	0.1	1.9	0.2	3.2	0.2	6.4	0.5	9.4	0.6	15	0.9	24	1.9	22	1.7
10	-Ib_B	nA	-3.0	3.0	0.2	0	1.1	0.1	1.9	0.1	3.2	0.2	6.5	0.5	9.4	0.6	15	0.9	24	1.8	22	1.6
11	Ios_B	nA	-1.0	1.0	0	0	0.04	0.1	0.04	0.08	0.02	0.04	-0.02	0.06	-0.01	0.09	-0.01	0.11	-0.13	0.24	-0.08	0.21
12	+Ib_C	nA	-3.0	3.0	0.2	0	1.1	0.1	1.9	0.1	3.2	0.2	6.4	0.6	9.4	0.6	15	0.9	24	1.7	22	1.6
13	-Ib_C	nA	-3.0	3.0	0.2	0	1.1	0.1	1.9	0.1	3.2	0.2	6.4	0.5	9.4	0.6	15	0.8	24	1.8	22	1.6
14	Ios_C	nA	-1.0	1.0	0	0	-0.01	0.1	0.04	0.10	0.04	0.13	-0.01	0.06	-0.04	0.10	0.01	0.10	-0.04	0.10	-0.00	0.09
15	+Ib_D	nA	-3.0	3.0	0.2	0	1.1	0.1	1.9	0.1	3.2	0.2	6.5	0.6	9.4	0.6	14	0.9	24	1.8	22	1.6
16	-Ib_D	nA	-3.0	3.0	0.2	0	1.1	0.1	1.9	0.1	3.2	0.2	6.4	0.6	9.4	0.6	15	0.8	24	1.8	22	1.6
17	Ios_D	nA	-1.0	1.0	0	0	0.03	0.1	0.03	0.05	0.00	0.05	0.03	0.12	0.01	0.07	-0.04	0.23	-0.10	0.13	-0.04	0.06
18	P_PSRR_A	dB	114		144	0.4	143	0.4	144	0.3	143	0.4	144	0.4	143	0.4	143	0.4	144	0.4	183	14
19	P_PSRR_B	dB	114		144	0.4	143	0.2	143	0.5	144	0.4	144	0.4	144	0.6	143	0.5	143	0.6	178	11
20	N_PSRR_C	dB	114		144	0.3	144	0.3	144	0.4	144	0.4	144	0.4	143	0.5	143	0.6	144	0.5	174	13
21	N_PSRR_D	dB	114		143	0.3	143	0.3	143	0.3	143	0.3	144	0.4	144	0.6	144	0.6	143	0.5	111	6
22	CMRR_A	dB	120		139	11	138	12	134	7	132	10	125	12	135	8	140	11	136	10	135	15
23	CMRR_B	dB	120		128	6	138	9	133	5	137	6	135	10	140	13	133	9	132	22	115	12
24	CMRR_C	dB	120		137	14	138	6	134	6	139	11	137	10	136	7	137	11	132	13	137	5
25	CMRR_D	dB	120		131	7	136	5	133	6	134	9	140	9	129	14	132	15	130	7	134	5
26	Gain_2k_A	dB	126		136	2	135	2	133	1	132	2	130	2	128	2	128	4	122	1	129	3
27	Gain_2k_B	dB	126		135	1	136	2	135	2	134	2	130	1	129	2	126	2	122	1	128	2
28	Gain_2k_C	dB	126		136	2	137	3	136	4	133	2	129	1	128	2	127	4	123	2	127	4
29	Gain_2k_D	dB	126		134	2	135	1	136	2	133	3	130	2	129	1	128	4	122	1	127	3
30	Voh_2k_A	V	11.0		12.3	0	12.8	0	12.8	0	12.8	0	12.8	0	12.8	0	12.8	0	12.7	0	12.2	0
31	Voh_2k_A	V		-11.0	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.0	0	-13.0	0	-13.0	0	-12.9	0.1	-12.9	0.1
32	Voh_2k_B	V	11.0		12.3	0	12.8	0	12.8	0	12.8	0	12.8	0	12.8	0	12.8	0	12.6	0	12.2	0
33	Voh_2k_B	V		-11.0	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.0	0	-13.0	0	-13.0	0	-12.9	0.1	-12.9	0.1
34	Voh_2k_C	V	11.0		12.3	0	12.8	0	12.8	0	12.8	0	12.8	0	12.8	0	12.8	0	12.6	0	12.2	0
35	Voh_2k_C	V		-11.0	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.0	0	-13.0	0	-13.0	0	-12.9	0.1	-12.9	0.1
36	Voh_2k_D	V	11.0		12.3	0	12.8	0	12.8	0	12.8	0	12.8	0	12.8	0	12.8	0	12.6	0	12.2	0
37	Voh_2k_D	V		-11.0	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.0	0	-13.0	0	-13.0	0	-12.9	0.1	-12.9	0.1
38	Slew Rate A	V/ms	0.100		0.184	0.010	0.255	0.008	0.243	0.009	0.179	0.070	0.079	0.070	0.067	0.048	0.025	0.025	-0.005	0.013	0.009	0.024
39	Slew Rate B	V/ms	0.100		0.174	0.008	0.250	0.008	0.239	0.010	0.199	0.009	0.107	0.047	0.067	0.044	0.008	0.023	0.018	0.003	0.024	0.012
40	Slew Rate C	V/ms	0.100		0.184	0.007	0.255	0.007	0.245	0.08	0.205	0.009	0.101	0.060	0.092	0.011	0.020	0.028	0.014	0.011	0.028	0.005
41	Slew Rate D	V/ms	0.100		0.171	0.005	0.245	0.007	0.235	0.007	0.196	0.008	0.111	0.044	0.075	0.029	0.040	0.005	0.008	0.012	0.025	0.003

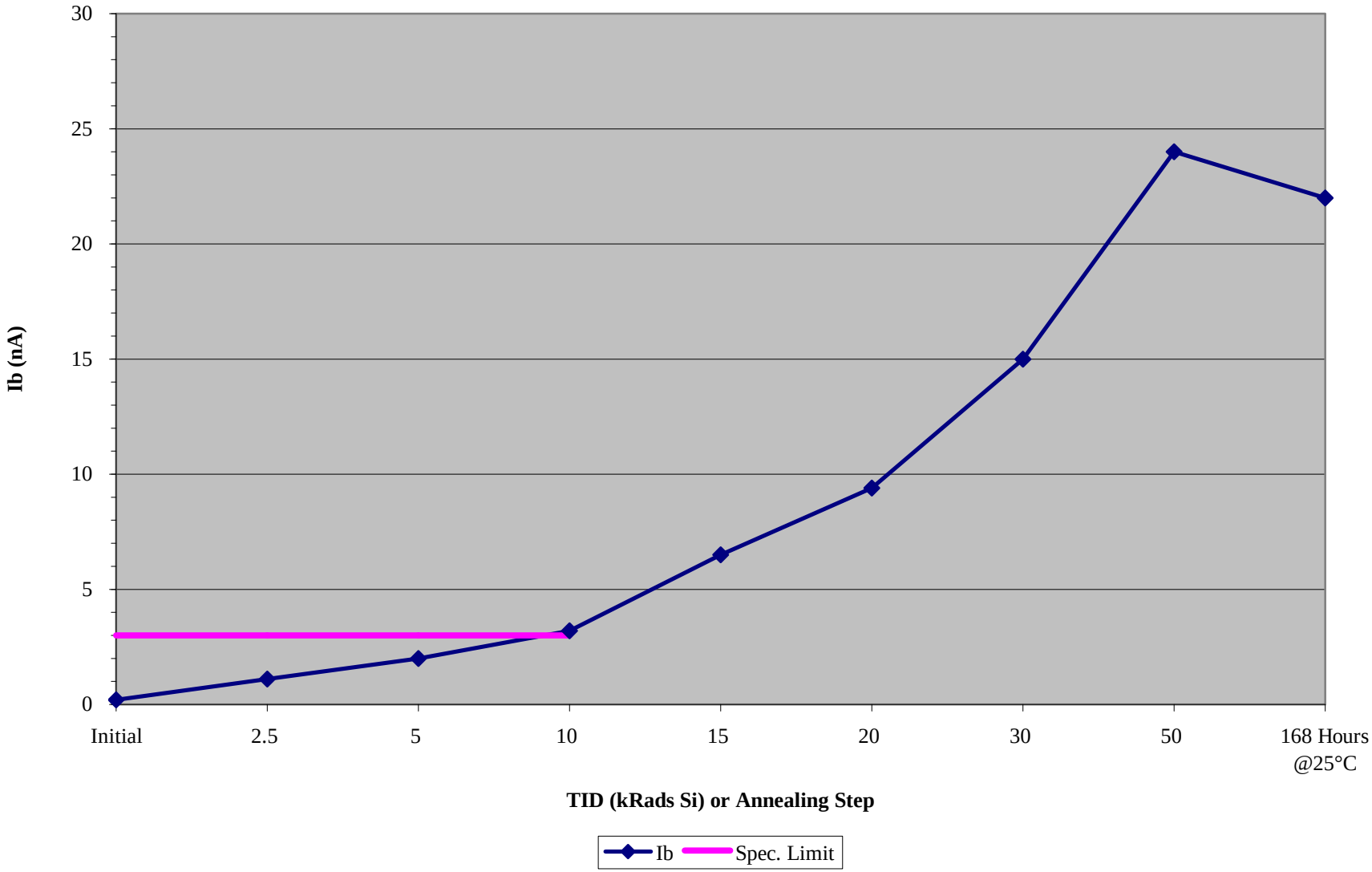
Notes:

1/ The mean and standard deviation values were calculated over the eight parts irradiated in this testing. The control samples remained constant throughout testing and are not included in this t

2/ These are manufacturer's pre-irradiation data sheet specification limits. No post-irradiation limits were provided by the manufacturer at the time the tests were perform

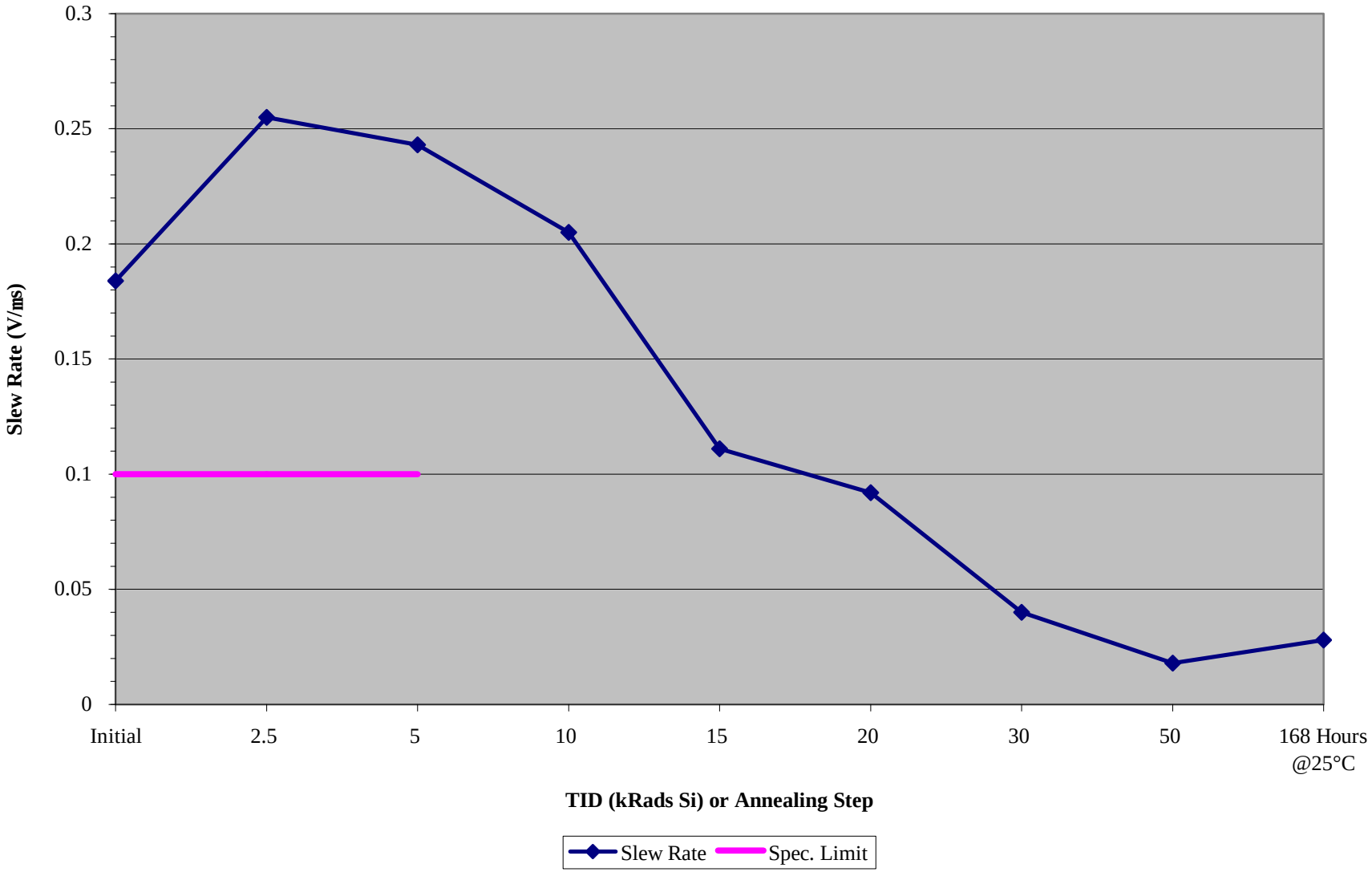
Radiation sensitive parameters: +Ib, -Ib, Gain_2k, Slew Rate.

Figure 2: Ib vs Total Ionizing Dose (kRads Si) for OP400



The values of Ib shown correspond to the one of the four OpAmps that had the most degradation at that TID or annealing step.

Figure 3: Slew Rate vs. Total Ionizing Dose (kRads Si) for OP400



The values of Slew Rate shown correspond to the one of the four OpAmps that had the most degradation at that TID or annealing step.