Unisys

DATE: November 18, 1998 PPM-99-001
TO: J. Dafnis/303
FROM: K. Sahu/S. Kniffin/300.1
SUBJECT: Radiation Report on **OP07 (Analog Devices) (LDC 9724A)**
PROJECT: GOES (ITT)

cc: R. Reed/562, D. Maus/ITT, C. Chiming/ITT, L. Deemer/300.1, A. Sharma/562, OFA Library/300.1

A radiation evaluation was performed on **OP07 Low Power, High Precision 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, four at 0.14R(Si)/s and four at 0.58R(Si)/s (see Figure 1 for bias configuration). Two parts were used as control samples. The total dose radiation levels were 20.0, 40.0, 60.0, 80.0, 100.0, 150.0, and 200.0 kRads for the lower dose rate and 50.0, 150.0 and 200.0 for the higher dose rate.[1] See Table II for the radiation schedule and effective dose rate calculation. After the 200.0 kRad irradiation, the parts were annealed under bias at 25°C and tested after 144 hours for the lower dose rate and after 96 and 168 hours for the higher dose rate.[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 6.

When irradiated at 0.14R/s, the parts in this lot showed significant variation in the radiation response of the VOS tests parameter. While SN 122 showed exceedingly large degradation in VOS (readings were 3148mV against the specification limit of 25mV), two parts fell below the specification limit from 40 to 200kRads and one part stayed within specification limits through 150kRads. See Figures 2 and 3 for details. The parts also showed significant degradation in IIB and AOL from 20 to 200kRads, CMRR from 40 to 200kRads, Slew Rate from 60 to 200kRads, and IIOS from 150 to 200kRads. After annealing under bias at 25°C for 144 hours, some recovery was observed in VOS, IIB, CMRR, AOL, and Slew Rate; however all parts remained outside of specification limits for these parameters.
When irradiated at 0.58R/s, the parts showed significant degradation in VOS, IIB, CMRR, PSRR, VOUT, AOL, and Slew Rate from 50 to 200kRads. The rate of degradation was dramatically higher than at the lower dose rate. After annealing the parts for 96 and 168 hours at 25°C, there was some recovery, however all parts remained significantly outside of specification limits for those tests listed above. See Figures 4 through 6 for additional details.

Initial electrical measurements were made on 10 samples. Four samples (SN's 119, 121, 122, and 123) were used as radiation samples at lower dose, four samples (SN's 130, 131, 138, and 139) were used as radiation samples at higher dose rate and SN's 95 and 106 were used as control samples. All parts passed all tests during initial electrical measurements.

Lower Dose Rate (0.14R/s) Test Results

After the 20.0 kRad irradiation, SN119 fell below the specification limit of -25µV for VOS with a reading of -35µV. All parts exceeded the specification limit of 2.0nA for P_IIB and N_IIB with readings in the range of 4.2 to 6.8nA for both. All parts fell below the specification limit of 300V/mV for N_AOL_2k with readings in the range of 256 to 266V/mV.

[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 40.0 kRad irradiation, three parts fell outside the specification limit for VOS with readings of -31, -26 and 3148µV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 12.3 to 15.2nA for both. Three parts fell below the specification limit of 110dB for CMRR with readings of 107dB. All parts fell below the specification limit of 300V/mV for P_AOL_2k with readings in the range of 169 to 283V/mV. All parts fell below the specification limit for N_AOL_2k with readings in the range of 149 to 182V/mV.

After the 60.0, 80.0 and 100.0kRad irradiations, three parts fell outside the specification limit for VOS with readings in the range of -40µV to 385µV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 22.0 to 44.1nA for both. All parts fell below the specification limit for CMRR with readings in the range of 98 to 102dB. All parts fell below the specification limit for P_AOL_2k with readings in the range of 174 to 199V/mV. All parts fell below the specification limit for N_AOL_2k with readings in the range of 134 to 148V/mV. All parts fell marginally below the specification limit of 0.100V/µs for Slew Rate with readings in the range of 0.096 to 0.094V/µs.

After the 150.0 and 200.0kRad irradiations, three parts fell outside the specification limit for VOS with readings in the range of -98µV to 100µV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 80 to 119nA for both. Three parts exceeded the specification limit of 2.0nA for IIOS with readings in the range of 2.2 to 3.1nA. All parts fell below the specification limit for CMRR with readings in the range of 96 to 102dB. All parts fell below the specification limit for P_AOL_2k with readings in the range of 96 to 132V/mV. All parts fell below the specification limit for N_AOL_2k with readings in the range of 94 to 111V/mV. All parts fell marginally below the specification limit of 0.100V/µs for Slew Rate with readings in the range of 0.087 to 0.093V/µs.

After annealing the parts for 144 hours at 25°C, the parts showed some recovery in VOS with readings within double the specification limit for all parts. Some recovery was noted in P_IIB and N_IIB with readings in the range of 57 to 67nA. Significant recovery was observed in CMRR with only one part falling below the specification limit with a reading of 108dB. Modest recovery was also observed in P_AOL_2k and N_AOL_2k with readings similar to those after 40kRads. All parts passed the Slew Rate test with readings comparable to those prior to irradiation. See Figure 2 for the VOS readings of SN 122.

Higher Dose Rate (0.58R/s) Test Results

After the 50kRad irradiation, all parts exceeded the specification limit of 25µV for VOS with readings in the range of 154 to 697µV. All parts exceeded the specification limit of 2.0nA for P_IIB and N_IIB with readings in the range of 16.1 to 19.5nA for both. All parts fell below the specification limit of 110dB for CMRR with readings in the range of 59 to 76dB. All parts fell below the specification limit of 300V/mV for P_AOL_2k and N_AOL_2k with readings in the range of 24 to 71V/mV. Three parts fell below the specification limit of 150V/mV for N_AOL_600 with readings in the range of 55 to 83V/mV. All parts fell below the specification limit of 0.100V/µs for Slew Rate with readings in the range of 0.009 to 0.045V/µs.

After the 150kRad irradiation, all parts exceeded the specification limit for VOS with readings in the range of 21780 to >25600µV. (Note that the ATE is limited in the testing of VOS to a maximum of 25600µV.) If the parts measure more than that, the ATE goes into an over range condition and stops testing VOS. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 33 to 64nA for both. All parts exceeded the specification limit of 2.0nA for Iios with readings in the range of 2.3 to 4.7nA. All parts fell below the specification limit for CMRR with readings of 59dB and fell below the specification limit of 100dB for PSRR with readings in the range of 67 to 72dB. Two parts exceeded the specification limit of -12.5V for N_VOUT_10k with readings of 11.8V and 6.5V. Two parts exceeded the specification limit of -12.0V for N_VOUT_2k with readings of 11.2V and 5.9V. Three parts could not be measured reliably beyond this point due to excessive degradation. See Table IVb for more details. SN 138 failed all four AOL tests with readings less than 4V/mV and fell below the specification limit for Slew Rate with a reading of 0.021V/µs.

After the 200kRad irradiation, all parts exceeded the specification limit for VOS with readings greater than 25600μV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 35 to 46nA for both. All parts exceeded the specification limit for Iios with readings in the range of 2.6 to 3.4nA. All parts fell below the specification limit for CMRR with readings of 59dB and failed all Vout, AOL and Slew Rate tests.

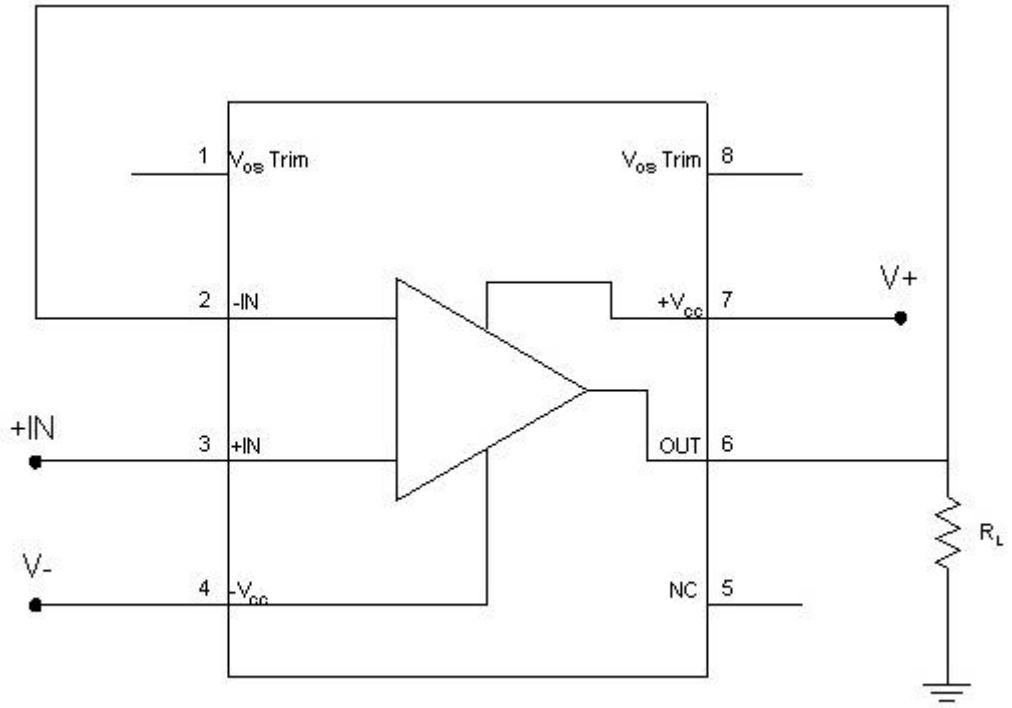
After annealing the parts for 96 hours at 25°C, the parts showed significant recovery in VOS, CMRR, PSRR, VOUT_10k, VOUT_2k, AOL_2k, AOL_600, and Slew Rate. The parts showed increased degradation in P_IIB, N_IIB and Iios.

After annealing the parts for 168 hours at 25°C, the parts showed no significant additional recovery or change.

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 OP07



Notes:
1. R_L = 402Ω ±5%, ½W.
2. +IN = 3.0V, V+ = +15V, V- = -15V.

TABLE I. Part Information

Generic Part Number:	OP07
GOES ITT Part Number	OP07
Charge Number:	M90402
Manufacturer:	Analog Devices
Lot Date Code (LDC):	9724A
Quantity Tested:	10
Serial Number of Control Samples:	95, 106
Serial Numbers of Radiation Samples:	119, 121, 122, 123 (LDR); 130, 131, 138, 139 (HDR)
Part Function:	Low Power, High Precision Operational Amplifier
Part Technology:	Bipolar
Package Style:	8-Pin DIP
Test Equipment:	A540
Test Engineer:	S. Archer-Davies

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

TABLE IIA. Radiation Schedule for OP07 (Low Dose Rate)

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	09/23/98
2) 20.0 KRAD IRRADIATION (0.488 KRADS/HOUR)	09/23/98
POST-20.0 KRAD ELECTRICAL MEASUREMENT	09/25/98
3) 40.0 KRAD IRRADIATION (0.308 KRADS/HOUR)	09/25/98
POST-40.0 KRAD ELECTRICAL MEASUREMENT	09/28/98
4) 60.0 KRAD IRRADIATION (0.488 KRADS/HOUR)	09/28/98
POST-60.0 KRAD ELECTRICAL MEASUREMENT	09/30/98
5) 80.0 KRAD IRRADIATION (0.488 KRADS/HOUR)	09/30/98
POST-80.0 KRAD ELECTRICAL MEASUREMENT	10/02/98
6) 100.0 KRAD IRRADIATION (0.308 KRADS/HOUR)	10/02/98
POST-100.0 KRAD ELECTRICAL MEASUREMENT	10/05/98
7) 150.0 KRAD IRRADIATION (1.220 KRADS/HOUR)	10/05/98
POST-150.0 KRAD ELECTRICAL MEASUREMENT	10/07/98
8) 200.0 KRAD IRRADIATION (1.220 KRADS/HOUR)	10/07/98
POST-200.0 KRAD ELECTRICAL MEASUREMENT	10/09/98
9) 144 HOUR ANNEALING @25°C	10/09/98
POST-144 HOUR ANNEAL ELECTRICAL MEASUREMENT	10/15/98

Effective Dose Rate = 200,000 RADS/16 DAYS=520.8 RADS/HOUR=0.14 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 IIB. Radiation Schedule for OP07 (High Dose Rate)

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	09/23/98
2) 50.0 KRAD IRRADIATION (2.790 KRADS/HOUR)	11/02/98
POST-50.0 KRAD ELECTRICAL MEASUREMENT	11/03/98
3) 150.0 KRAD IRRADIATION (3.703 KRADS/HOUR) *	11/03/98
POST-150.0 KRAD ELECTRICAL MEASUREMENT	11/05/98
4) 200.0 KRAD IRRADIATION (2.777 KRADS/HOUR)	11/05/98
POST-200.0 KRAD ELECTRICAL MEASUREMENT	11/06/98
5) 96 HOUR ANNEALING @25°C	11/06/98
POST-96 HOUR ANNEAL ELECTRICAL MEASUREMENT	11/10/98
5) 168 HOUR ANNEALING @25°C	11/06/98
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	11/13/98

Effective Dose Rate = 200,000 RADS/4 DAYS=2083 RADS/HOUR=0.579 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.

* Due to an electrical failure at the REF, the parts were partially irradiated during the planned 100kRad exposure and were pushed to 150kRads to maintain the dose rate and schedule.

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

Table III. Electrical Characteristics of OP07 /1

Test #	Parameter	Units	Test Conditions	Spec. min	Lim. max
1	+Icc	mA	$+V_S$ = +15V, V_O = 0V	0.0	4.0
2	-Icc	mA	$-V_S$ = -15V, V_O = 0V	-4.0	0.0
3	Power_Diss	mW	V_{CC} = ±15V, V_O = 0V		120
4	VOS	mV	V_{CM} = 0V	-25	25
5	P_IIB	nA	V_{CM} = 0V	-2.0	2.0
6	N_IIB	nA	V_{CM} = 0V	-2.0	2.0
7	IIOS	nA	V_{CM} = 0V	-2.0	2.0
8	CMRR	dB	V_{CM} = ±13V	110	
9	PSRR	dB	$\pm V_{CC}$ = ±3V to ±18V, $\pm V_{CC}$ = ±15V	100	
10	P_VOUT_10k	V	R_L = 10kW	12.5	
11	N_VOUT_10k	V	R_L = 10kW		-12.5
12	P_VOUT_2k	V	R_L = 2kW	12.0	
13	N_VOUT_2k	V	R_L = 2kW		-12.0
14	P_AOL_2k	V/mV	R_L = 2kW, V_O = +10V	300	
15	N_AOL_2k	V/mV	R_L = 2kW, V_O = -10V	300	
16	P_AOL_600	V/mV	R_L = 600W, V_O = +10V	150	
17	N_AOL_600	V/mV	R_L = 600W, V_O = -10V	150	
18	Slew Rate	V/ms	C_L = 50pF, R_L = 2kW	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.

TABLE IVa: Summary of Electrical Measurements after Total Dose Exposures and Annealing for OP07 /1
Dose Rate = 0.14R(Si)/s

							Total Dose Exposure (kRads Si)														Annealing	
					Initial		20.0		40.0		60.0		80.0		100.0		150.0		200.0		144 hours @25°C	
Test #	Parameters	Units	Spec. Lim. /2 min	max	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1	+Icc	mA	0.0	4.0	2.1	0	2.0	0	1.9	0	1.9	0	1.9	0	1.9	0	1.9	0	1.9	0	2.0	0
2	-Icc	mA	-4.0	0.0	-2.1	0	-2.0	0	-1.9	0	-1.9	0	-1.9	0	-1.9	0	-1.9	0	-1.9	0	-2.0	0
3	Power_Diss	mW		120	32	0.2	30	0.2	29	0.2	28	0.2	29	0.2	29	0.3	29	0.2	29	0.2	29	0.3
4	VOS	?V	-25	25	-6	6	-19	15	771	1584	86	187	47	134	21	95	-10	76	-48	55	-17	30
5	P_IIB	nA	-2.0	2.0	0.5	0.3	6.0	0.6	14.4	0.7	24.6	1.2	36.2	2.1	42.4	2.8	88.4	4.9	113	7.3	64	4.1
6	N_IIB	nA	-2.0	2.0	-0.2	0.5	5.0	0.6	13.4	0.8	23.3	1.1	34.9	1.8	41.1	2.5	86.1	4.4	110	6.8	62	3.8
7	IIOS	nA	-2.0	2.0	0.7	0.2	1.0	0.1	1.0	0.4	1.2	0.4	1.2	0.4	1.3	0.4	2.3	0.6	2.7	0.4	2.0	0.4
8	CMRR	dB	110		125	2	114	2	108	2	101	1.7	100	1.5	102	1.3	98	1.4	100	1.3	110	1.7
9	PSRR	dB	100		112	1	115	4	110	15	120	11	120	8	119	5	124	10	119	3.9	120	10
10	P_VOUT_10k	V	12.5		14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.4	0	14.3	0	14.4	0	14.5	0
11	N_VOUT_10k	V		-12.5	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.1	0	-13.1	0
12	P_VOUT_2k	V	12.0		13.9	0	13.8	0	13.8	0	13.7	0	14.2	0	14.3	0	14.2	0	14.2	0	14.3	0
13	N_VOUT_2k	V		-12.0	-12.9	0	-12.9	0	-12.9	0	-12.9	0	-12.9	0	-12.9	0	-12.8	0	-12.8	0	-12.8	0
14	P_AOL_2k	V/mV	300		1221	31	499	23	246	52	183	7	165	9	185	13	120	9	127	12	246	21
15	N_AOL_2k	V/mV	300		376	5	260	4	172	15	137	4	127	7	142	5	99	4	104	5	179	13
16	P_AOL_600 /3	V/mV	150		>10000		5324	933	1941	547	1285	205	1321	194	1545	242	875	133	934	163	2378	452
17	N_AOL_600	V/mV	150		1500	28	786	23	439	42	317	18	280	19	309	22	202	14	210	17	397	31
18	Slew Rate	V/?s	0.100		0.220	0	0.121	0	0.105	0	0.095	0	0.071	0.041	0.095	0.001	0.088	0.002	0.091	0.001	0.106	0.002

Notes:

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

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 performed.

3/ The initial gain was greater than 10000, the maximum gain that the ATE is capable of measuring.

Radiation sensitive parameters: VOS, P_IIB, N_IIB, IIOS, CMRR, P_AOL_2k, N_AOL_2k, Slew Rate.

TABLE IVb: Summary of Electrical Measurements after Total Dose Exposures and Annealing for OP07 /1
Dose Rate = 0.58R(Si)/s

					Total Dose Exposure (kRads Si)								Annealing			
					Initial		50.0		150.0		200.0		96 hours @25°C		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
1	+Icc	mA	0.0	4.0	2.2	0	1.9	0	1.1	0.5	0.8	0	2.0	0	2.0	0
2	-Icc	mA	-4.0	0.0	-2.2	0	-1.9	0	-1.1	0.5	-0.9	0	-1.9	0	-2.0	0
3	Power_Diss	mW		120	32	0.2	29	0.5	17	7	13	0.4	29	0.2	29	0.2
4	VOS	?V	-25	25	8	6	370	231	24653	1915	>25600		893	2117	897	2064
5	P_IIB	nA	-2.0	2.0	0.5	0.5	18.3	1.0	45	13	41	4	82	23	69	20
6	N_IIB	nA	-2.0	2.0	-0.2	0.9	17.1	0.9	42	12	38	4	77	22	65	19
7	IIOS	nA	-2.0	2.0	0.7	0.4	1.2	0.2	3.2	1.1	3.0	0.4	5.0	1.8	4.2	1.4
8	CMRR	dB	110		127	4	63	9	59	0.2	60	0.6	103	3	103	4
9	PSRR	dB	100		111	1	112	4	70	3	5/		105	11	105	11
10	P_VOUT_10k	V	12.5		14.2	0	14.2	0	14.2	0	5/		14.2	0	14.2	0
11	N_VOUT_10k	V		-12.5	-13.1	0	-13.1	0	1.8	13.0	5/		-13.1	0	-13.1	0
12	P_VOUT_2k	V	12.0		13.9	0	13.8	0	13.5	0.1	5/		13.7	0	13.7	0
13	N_VOUT_2k	V		-12.0	-12.9	0	-12.8	0	1.5	12.5	5/		-12.8	0	-12.8	0
14	P_AOL_2k	V/mV	300		1219	48	43	20	1.4	4/	5/		160	31	193	37
15	N_AOL_2k	V/mV	300		377	5	39	17	1.6	4/	5/		125	15	146	16
16	P_AOL_600 /3	V/mV	150		>10000		288	138	3.9	4/	5/		955	180	1228	251
17	N_AOL_600	V/mV	150		1482	34	92	44	3.9	4/	5/		243	35	298	43
18	Slew Rate	V/?s	0.100		0.220	0	0.035	0.017	0.021	4/	5/		0.092	0.003	0.097	0.002

Notes:

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

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 performed.

3/ The initial gain was greater than 10000, the maximum gain that the ATE is capable of measuring.

4/ The parts had degraded so severly, that only one part could be tested on these parameters at this level.

5/ The parts had degraded so severly, that no reliable measurements could be obtained at at this level.

Radiation sensitive parameters: VOS, P_IIB, N_IIB, IIOS, CMRR, PSRR, VOUT, AOL, Slew Rate.

Figure 2: VOS vs TID (kRads Si) for OP 07 (SN 122) at 0.14R(Si)/s

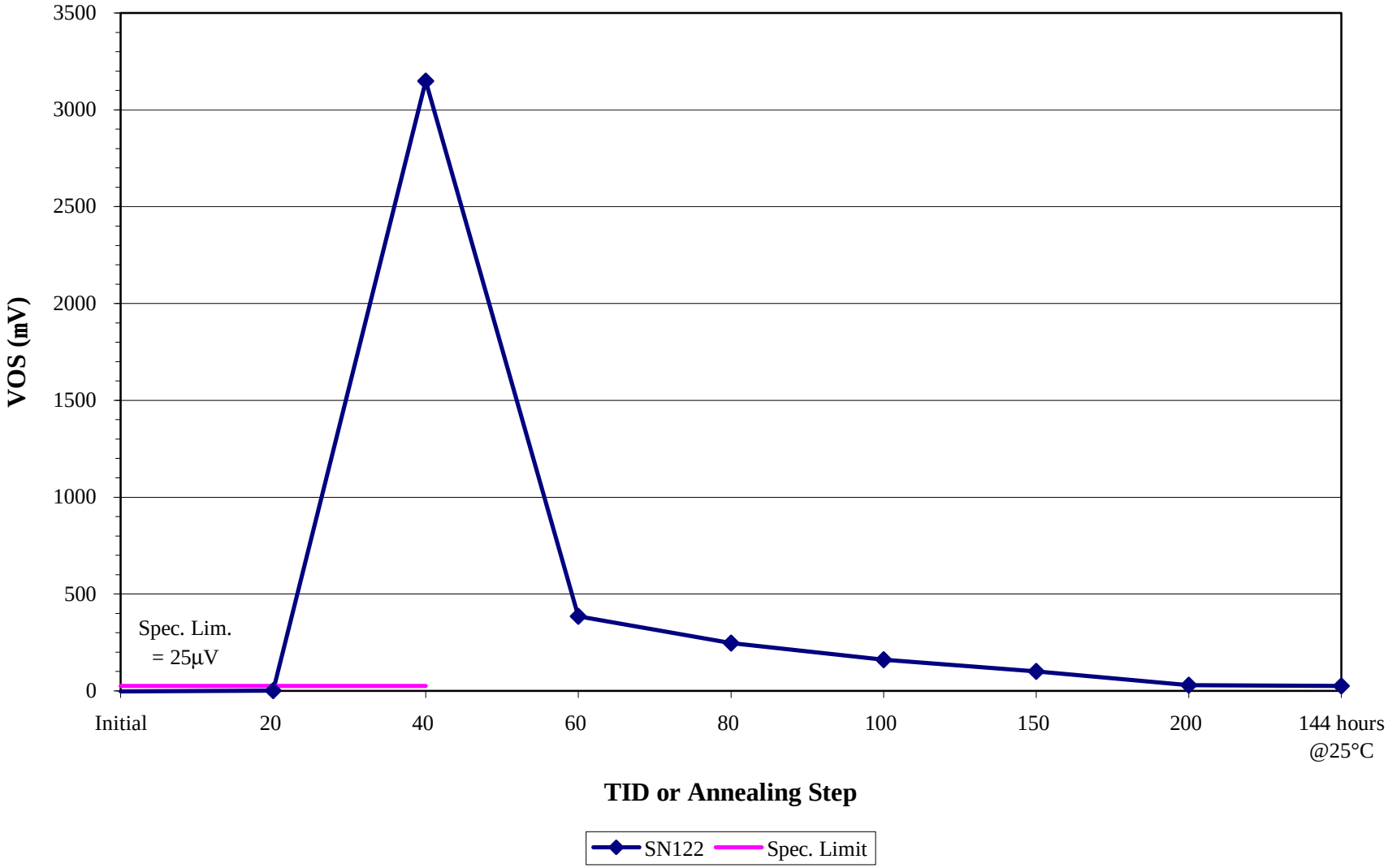


Figure 3: Vos vs. TID (kRads Si) for Remaining OP07 Parts at 0.14R(Si)/s

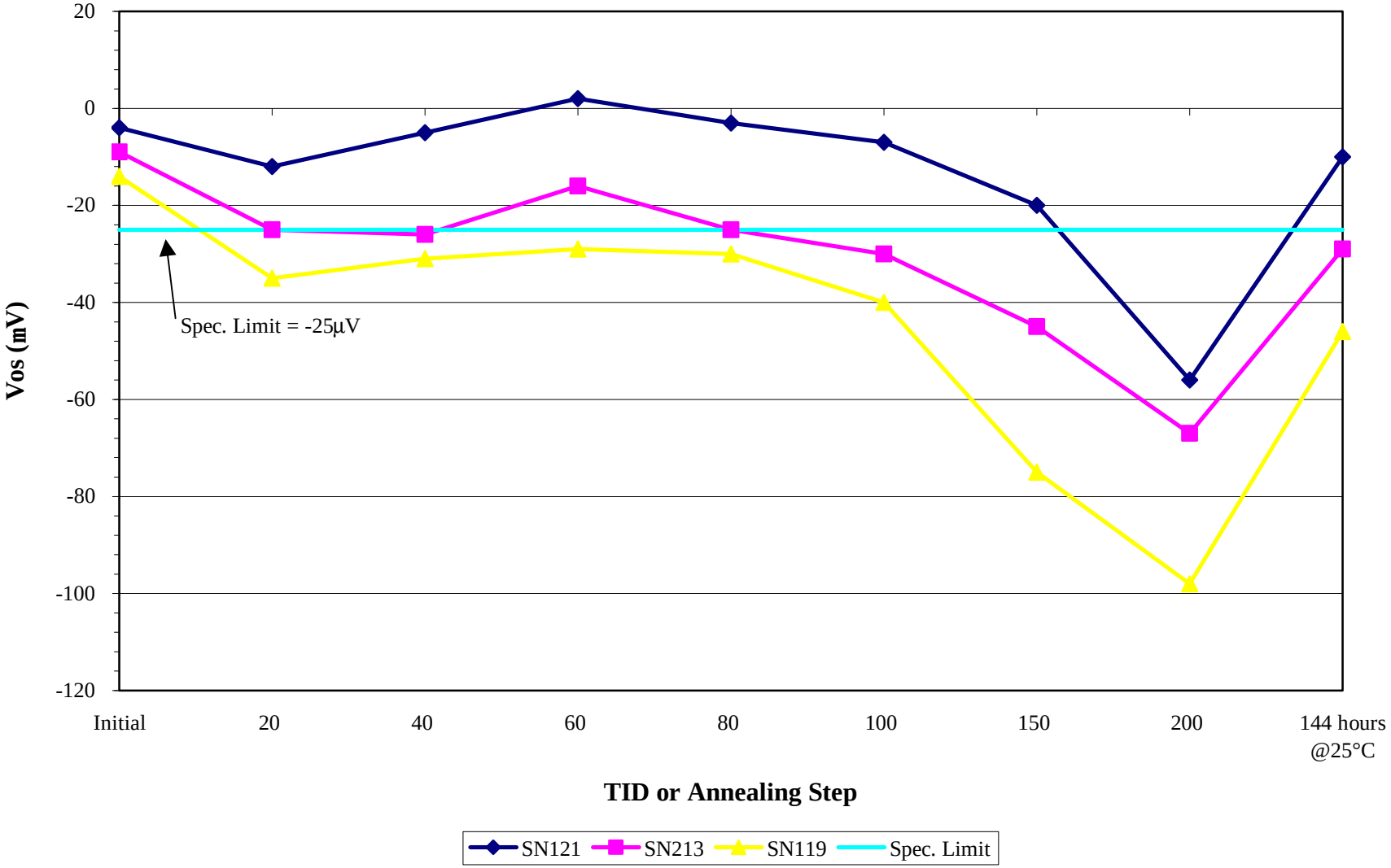
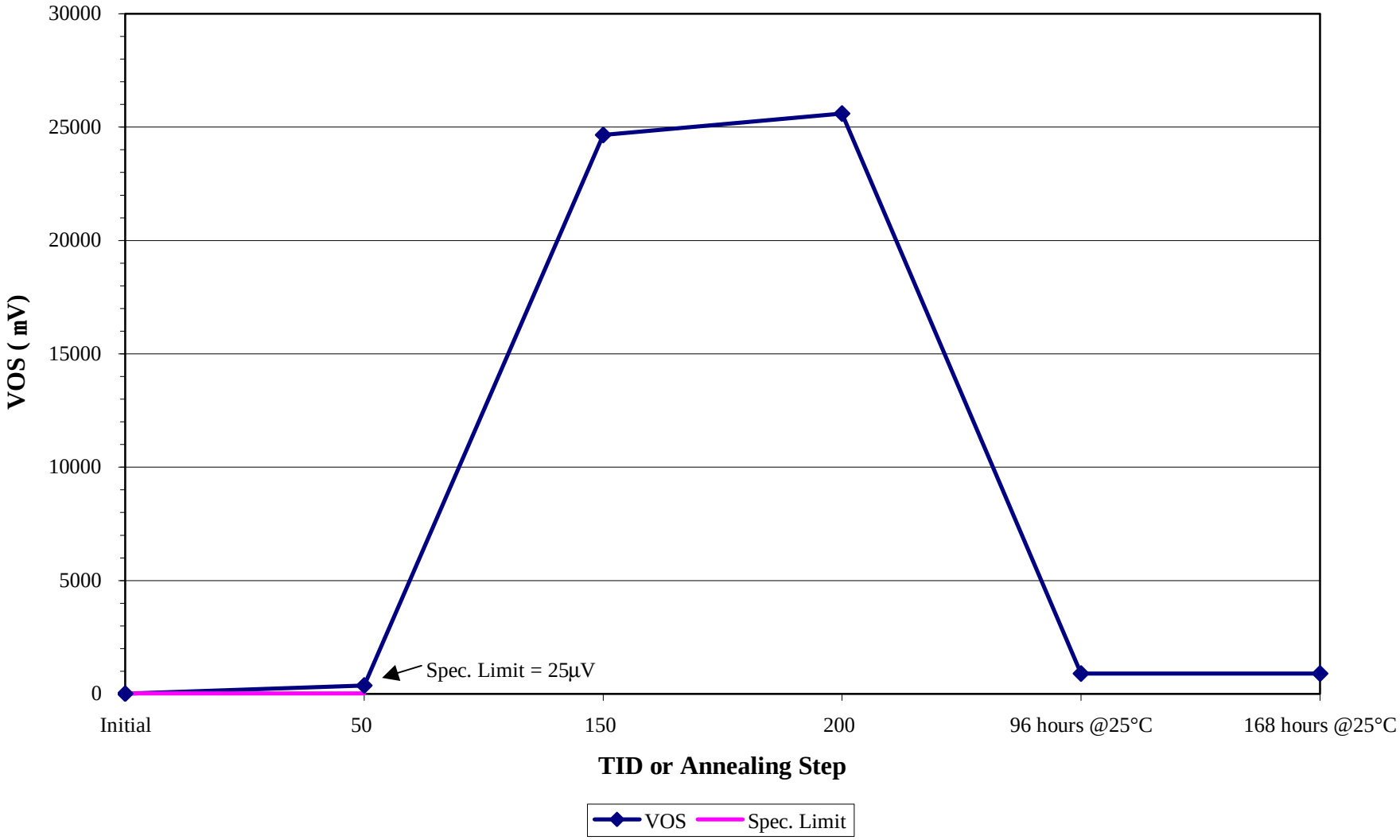


Figure 4: VOS vs. TID (kRads Si) for OP07 at 0.58R(Si)/s



The data shown represents the mean of the 4 samples as no significant spread was observed in the radiation response of the parts at this dose rate.

Figure 5: P_IIB vs. TID (kRads Si) for OP07 at 0.14 and 0.58R(Si)/s

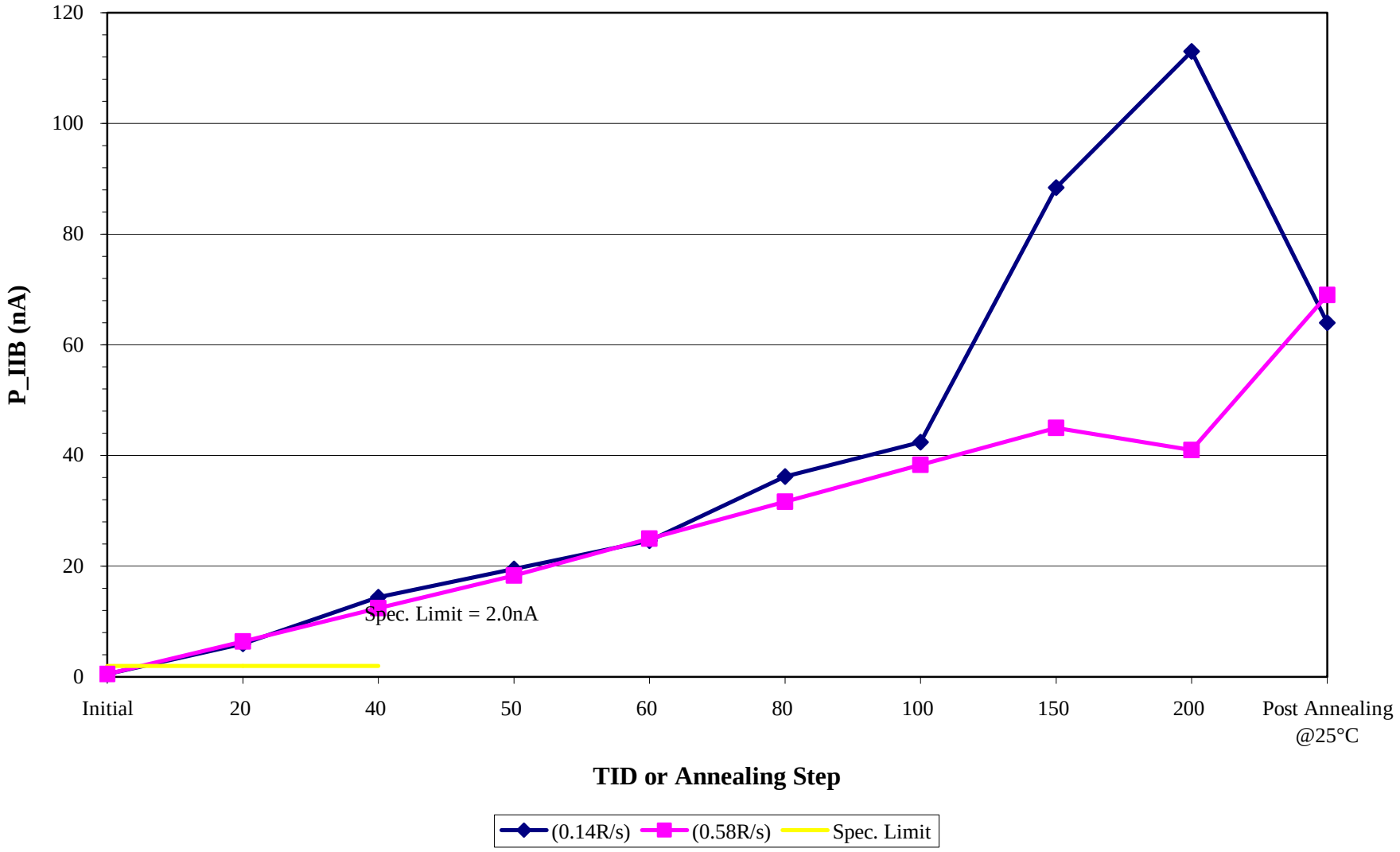


Figure 6: P_AOL_2kW vs. TID (kRads Si) for OP07 at Both Dose Rates