Unisys

DATE: May 07, 1998 PPM-98-011
TO: J. Dafnis/303
FROM: K. Sahu/S. Kniffin/300.1
SUBJECT: Radiation Report on **OP07 (Analog Devices) (LDC 9723B)**
PROJECT: GOES (ITT)

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A radiation evaluation was performed on **OP07 Low Power, High Precision Operational Amplifier (Analog Devices)** to determine the total dose tolerance of these parts. The total dose 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 20.0, 40.0, 60.0, 80.0, 100.0, 150.0, and 200.0 kRads.[1] The dose rate was 1.200 kRads/hour (0.33 Rads/s). 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 24, 48 and 360 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 5.

The parts in this lot showed significant variation in the radiation response of the VOS test parameter. While SN136 gave a readings of 1124µV for VOS after 20 kRads, the remaining seven parts remained below 85µV up to 200kRads. Figure 2 shows this variation in radiation response of VOS for SN136 versus the mean of the other seven parts. Figure 3 shows the response of VOS for the other seven parts individually. Figure 3 also shows that there was a wide variation in the response of the seven parts, although SN136 was the outlier. The parts also showed significant degradation in IIB and AOL after the 40 to 200kRad exposures. Figures 4 and 5 demonstrate the degradation in these parameters. After the 100 to 200kRad exposures, the parts also showed degradation in IIOS, CMRR and Slew Rate. No significant change was observed in most parameters after annealing under bias at 25°C for 24, 48 and 360 hours.

Initial electrical measurements were made on 10 samples. Eight samples (SN's 99, 109, 110, 124, 133, 134, 136, and 155) were used as radiation samples while SN's 96 and 98 were used as control samples. All parts passed all tests during initial electrical measurements.

After the 20.0 kRad irradiation, SN 136 exceeded the specification limit of 25µV for VOS with a reading of 1124µV. All parts exceeded the specification limit of 2.0nA for P_IIB and N_IIB with readings in the range of 2.1 to 5.3 for both parameters. All parts fell below the specification limit of 300V/mV for N_AOL_2k with readings in the range of 254 to 273V/mV. **All parts passed all other tests.**

After the 40.0 kRad irradiation, four parts exceeded the specification limit for VOS with readings in the range of 26 to 3249µV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 10.5 to 14.9 for both. All parts fell below the specification limit of 110dB for CMRR with readings in the range of 94 to 107dB. SN 136 fell below the specification limit of 100dB for PSRR with a reading of 86dB. All parts exceeded the specification limit of 300V/mV for P_AOL_2k and N_AOL_2k with readings in the range of 107 to 269V/mV for both. **All parts passed all other tests.**

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[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 60.0 kRad irradiation, six parts exceeded the specification limit for VOS with readings in the range of 30 to 4486µV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 18 to 39 for both. SN's 99 and 124 marginally exceeded the specification limit of 2.0nA for IIOS with readings of 2.1 and 2.2nA respectively. All parts fell below the specification limit of for CMRR with readings in the range of 91 to 102dB. SN 136 fell below the specification limit for PSRR with a reading of 84dB. All parts exceeded the specification limit for P_AOL_2k and N_AOL_2k with readings in the range of 69 to 184V/mV for both. All parts fell below the specification limit of 0.10V for Slew Rate with readings in the range of 0.005 to 0.098V. **All parts passed all other tests.**

After the 80.0 kRad irradiation, most parts exceeded the specification limit for VOS with readings in the range of 28 to 5555µV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 32 to 66 for both. SN's 133 and 136 marginally exceeded the specification limit of 2.0nA for IIOS with readings of 2.1 and 3.4nA respectively. All parts fell below the specification limit of for CMRR with readings in the range of 88 to 98dB. SN 136 fell below the specification limit for PSRR with a reading of 82dB. All parts exceeded the specification limit for P_AOL_2k and N_AOL_2k with readings in the range of 50 to 145V/mV for both. SN 136 fell below the specification limit of 150V/mV for N_AOL_600 with a reading of 135V/mV. All parts fell below the specification limit for Slew Rate with readings in the range of 0.086 to 0.095V. **All parts passed all other tests.**

After annealing the parts for 72 hours at 25°C, parts showed only a marginal improvement in several parameters with all parts reading much the same as at 60kRads.

After the 100.0 kRad irradiation, most parts exceeded the specification limit for VOS with readings in the range of 35 to 1097µV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 37 to 57 for both. SN 133 marginally exceeded the specification limit of 2.0nA for IIOS with a reading of 2.2nA. All parts fell below the specification limit of for CMRR with readings in the range of 96 to 99dB. SN 136 fell below the specification limit for PSRR with a reading of 99dB. All parts exceeded the specification limit for P_AOL_2k and N_AOL_2k with readings in the range of 94 to 163V/mV for both. SN's 109 and 133 fell below the specification limit of 150V/mV for P_AOL_600 with readings of 48 and 30V/mV respectively. All parts fell below the specification limit for Slew Rate with readings in the range of 0.088 to 0.095V. **All parts passed all other tests.**

After the 150.0 kRad irradiation, the automatic test equipment suffered an internal malfunction rendering the data at this step unreliable. The data following the 200kRad step is acceptable.

After the 200.0 kRad irradiation, most parts exceeded the specification limit for VOS with readings in the range of 36 to 359µV. All parts exceeded the specification limit for P_IIB and N_IIB with readings in the range of 98 to 127 for both. Four parts marginally exceeded the specification limit of 2.0nA for IIOS with readings in the range of 2.1 to 7.1nA. All parts fell below the specification limit of for CMRR with readings in the range of 97 to 100dB. All parts exceeded the specification limit for P_AOL_2k and N_AOL_2k with readings in the range of 97 to 148V/mV for both. SN's 109 and 133 fell below the specification limit for P_AOL_600 with readings of 49 and 41V/mV respectively. All parts fell below the specification limit for Slew Rate with readings in the range of 0.005 to 0.095V. **All parts passed all other tests.**

After annealing the parts for 24 hours at 25°C, parts showed no significant change in any parameter with readings much the same as at 200kRads.

After annealing the parts for 48 hours at 25°C, parts showed modest recovery in VOS, IIB, CMRR, P_AOL_2k, and N_AOL_2k; however, not enough for any parts that were failing to pass. Most parts recovered and passed Slew Rate after 48 hours.

After annealing the parts for 360 hours at 25°C, parts showed no significant additional recovery with readings similar to those after 48 hours of annealing.

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.

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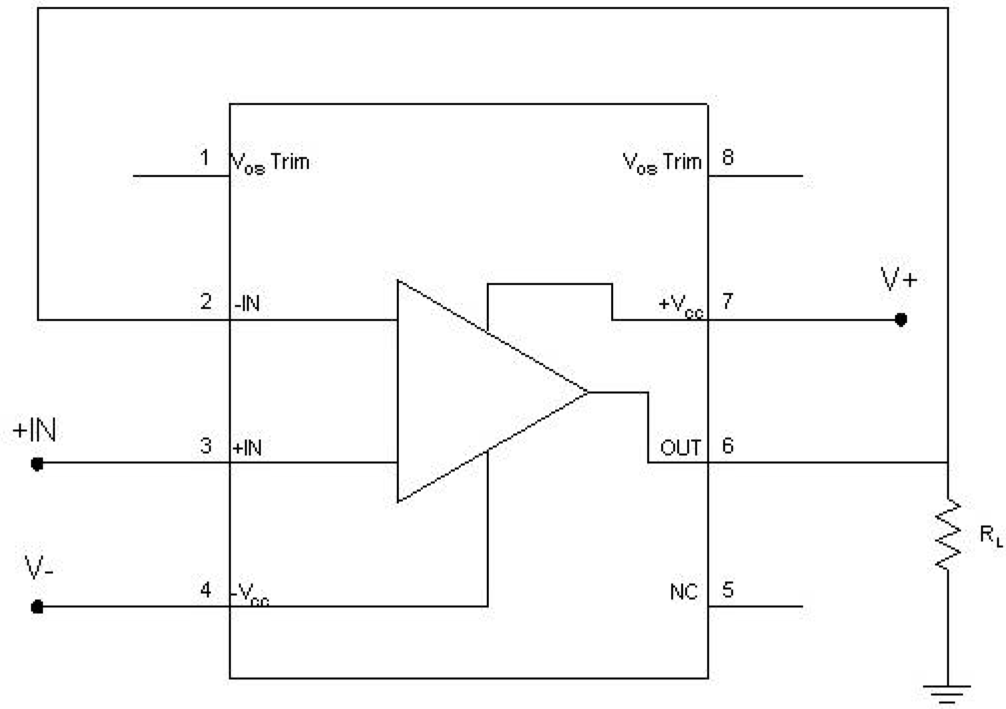
Figure 1. Radiation Bias Circuit for OP07



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:	C80709
Manufacturer:	Analog Devices
Lot Date Code (LDC):	9723B
Quantity Tested:	10
Serial Number of Control Samples:	96, 98
Serial Numbers of Radiation Samples:	99, 109, 110, 124, 133, 134, 136, and 155
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 II. Radiation Schedule for OP07

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	03/23/98
2) 20.0 KRAD IRRADIATION (1.200 KRADS/HOUR)	04/06/98
POST-20.0 KRAD ELECTRICAL MEASUREMENT	04/07/98
3) 40.0 KRAD IRRADIATION (1.200 KRADS/HOUR)	04/07/98
POST-40.0 KRAD ELECTRICAL MEASUREMENT	04/08/98
4) 60.0 KRAD IRRADIATION (1.200 KRADS/HOUR)	04/08/98
POST-60.0 KRAD ELECTRICAL MEASUREMENT	04/09/98
5) 80.0 KRAD IRRADIATION (1.200 KRADS/HOUR)	04/09/98
POST-80.0 KRAD ELECTRICAL MEASUREMENT	04/10/98
6) 72 HOUR ANNEALING @25°C *	04/10/98
POST-72 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/13/98
7) 100.0 KRAD IRRADIATION (1.200 KRADS/HOUR)	04/13/98
POST-100.0 KRAD ELECTRICAL MEASUREMENT	04/14/98
8) 150.0 KRAD IRRADIATION (1.200 KRADS/HOUR)	04/14/98
POST-150.0 KRAD ELECTRICAL MEASUREMENT	04/16/98
9) 200.0 KRAD IRRADIATION (0.450 KRADS/HOUR) **	04/16/98
POST-200.0 KRAD ELECTRICAL MEASUREMENT	04/20/98
10) 24 HOUR ANNEALING @25°C	04/20/98
POST-24 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/21/98
11) 48 HOUR ANNEALING @25°C	04/20/98
POST-48 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/22/98
12) 360 HOUR ANNEALING @25°C ***	04/20/98
POST-360 HOUR ANNEAL ELECTRICAL MEASUREMENT	05/05/98

Effective Dose Rate = 200,000 RADS/14 DAYS=595.2 RADS/HOUR=0.17 RADS/SEC
The effective dose rate is lower than that of the individual radiation steps as it takes into account the interim-annealing step.

* This 72 hour annealing step was added to maintain the prescribed dose rate due to the weekend.
** The dose rate was adjusted to allow the parts to receive radiation dose over the weekend.
*** The length of the final annealing step was extended due to a malfunction in the automatic test equipment.

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	$V_{CC} = \pm 15V$, $V_O = 0V$		120
4	VOS	μV	$V_{CM} = 0V$	-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	$V_{CM} = \pm 13V$	110	
9	PSRR	dB	$\pm V_{CC} = \pm 3V$ to $\pm 18V$, $V_{CC} =$ 15V	100	
10	P_VOUT_10k	V	$R_L = 10k\Omega$	12.5	
11	N_VOUT_10k	V	$R_L = 10k\Omega$		-12.5
12	P_VOUT_2k	V	$R_L = 2k\Omega$	12.0	
13	N_VOUT_2k	V	$R_L = 2k\Omega$		-12.0
14	P_AOL_2k	V/mV	$R_L = 2k\Omega$, $V_O = +10V$	300	
15	N_AOL_2k	V/mV	$R_L = 2k\Omega$, $V_O = -10V$	300	
16	P_AOL_600	V/mV	$R_L = 600\Omega$, $V_O = +10V$	150	
17	N_AOL_600	V/mV	$R_L = 600\Omega$, $V_O = -10V$	150	
18	Slew Rate	V/μs	$C_L = 50pF$, $R_L = 2k\Omega$	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 IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for OI

							Total Dose Exposure (kRads Si)								Annealing		otal Dose Exposure (kRads S				Annealing					
					Initial		20.0		40.0		60.0		80.0		72 hours		100.0		200.0		24 hours		48 hours		360 hours	
Test			Spec. Lim. /2												@25°C			3/			@25°C		@25°C		@25°C	
#	Parameters	Units	min	max	mean	sd	mean	sd	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	2.2	0.1	2.0	0	1.9	0	1.9	0	1.9	0	1.9	0	1.9	0	1.9	0	1.9	0	1.9	0	1.9	0
2	-Icc	mA	-4.0	0.0	-2.2	0.1	-2.0	0	-1.9	0	-1.9	0	-1.8	0	-1.9	0	-1.9	0	-1.9	0	-1.9	0	-1.9	0	-1.9	0
3	Power_Diss	mW		120	32	0	30	0.1	29	0.3	28	0.4	28	0.4	29	0.4	28	0.4	28	0.4	28	0.4	28	0.4	28	0.4
4	VOS	? V	-25	25	11.5	6.9	151	367	427	1067	591	1472	730	1824	667	1712	168	351	84	100	85	110	66	89	73	70
5	P_IIB	nA	-2.0	2.0	-0.1	0.3	4.5	0.5	14	0.9	25	5.8	39	11	30	7.4	46	5.3	108	7.9	107	8.1	91	8.4	67	6.0
6	N_IIB	nA	-2.0	2.0	-1.2	0.5	3.1	0.8	13	0.9	23	5.8	38	10	28	7.0	44	5.3	108	10.1	106	9.9	90	11.3	68	7.3
7	IIOS	nA	-2.0	2.0	1.1	0.2	1.4	0.3	1.4	0.2	1.6	0.4	1.8	0.8	1.5	0.6	1.5	0.4	2.5	1.8	1.9	1.4	3.0	2.7	16	2.4
8	CMRR	dB	110		126	1.1	114	1.7	105	1.6	99	3.3	96	3.2	105	1.4	98	1.3	99	1.2	99	1.5	104	1.6	110	5.0
9	PSRR	dB	100		112	0.7	114	1.5	124	5.1	124	17	120	16	120	15	126	18	128	9.4	128	9.7	122	5.9	122	4.9
10	P_VOUT_10k	V	12.5		14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	0	14.2	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	-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	13.7	0	13.7	0	13.7	0	13.7	0	13.7	0	13.7	0	13.7	0
13	N_VOUT_2k	V		-12.0	-12.9	0	-12.9	0	-12.9	0	-12.9	0	-12.8	0	-12.9	0	-12.8	0	-12.8	0	-12.8	0	-12.8	0	-12.8	0
14	P_AOL_2k	V/mV	300		1184	36	480	75	253	13	156	37	119	30	219	56	133	18	126	14	127	14	175	20	244	29
15	N_AOL_2k	V/mV	300		375	5	258	17	172	6	121	19	98	17	158	25	108	9	105	8	106	8	134	8	173	12
16	P_AOL_600	V/mV	150		148000	58000	4997	888	1923	108	1040	251	745	195	1533	419	617	374	483	330	565	319	1090	153	1675	240
17	N_AOL_600	V/mV	150		1480	14	795	51	435	16	281	40	217	36	373	60	233	16	207	14	214	15	286	20	385	25
18	Slew Rate	V/? s	0.100		0.22	0.33	0.18	0.01	0.15	0.01	0.09	0.05	0.09	0.01	0.09	0.03	0.09	0.01	0.08	0.03	0.09	0.05	0.10	0.01	0.11	0.01

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 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/ Due to an error in the Automaic Test Equipment, the data at 150kRads was completely unreliable and is not included in this summary.

Radiation sensitive parameters: VOS, P_IIB, N_IIB, CMRR, PSRR, P_AOL_2k, N_AOL_2k, P_AOL_600, Slew Rate.

Figure 2: VOS vs TID for OP07

SN 136 and Mean of All Other Parts

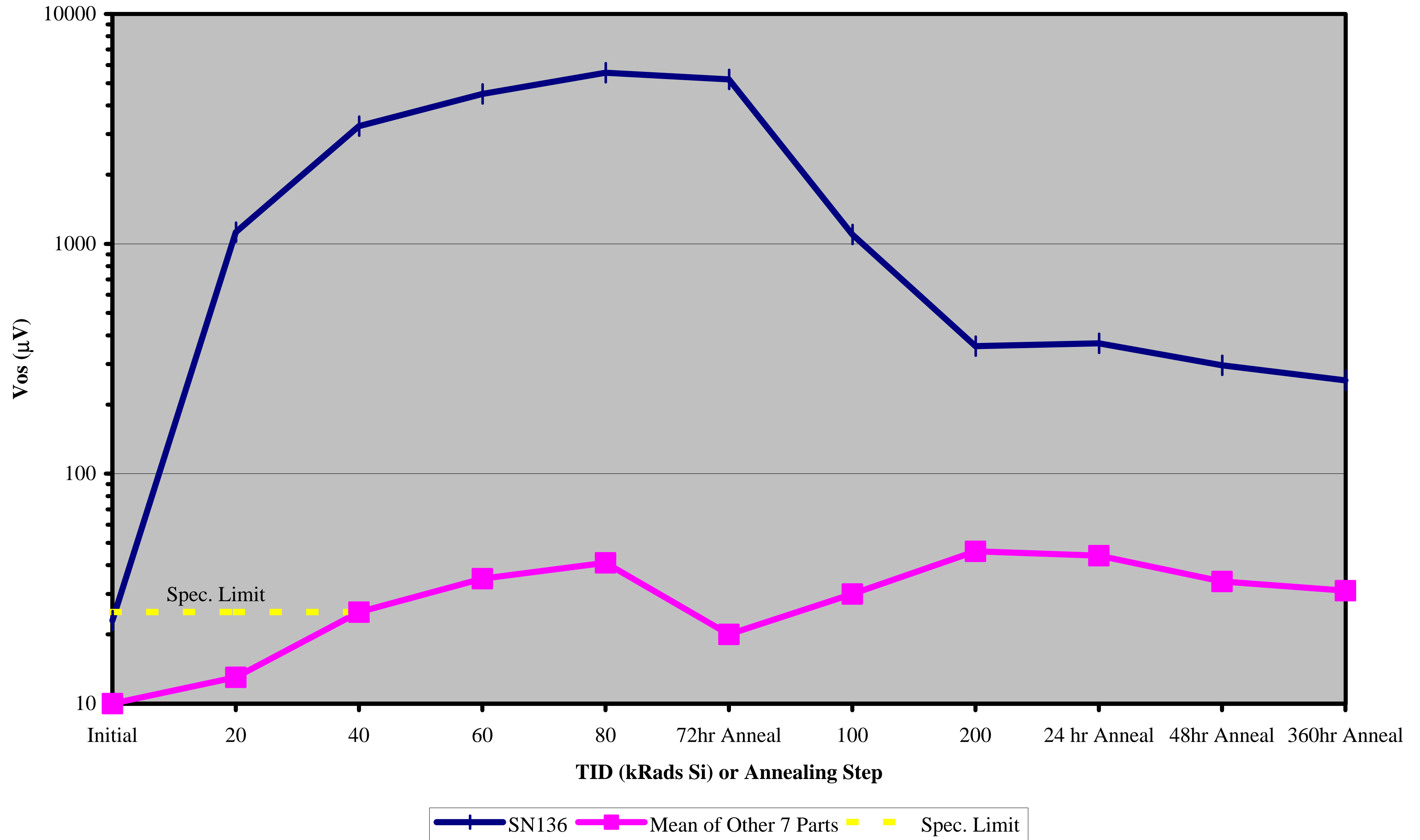
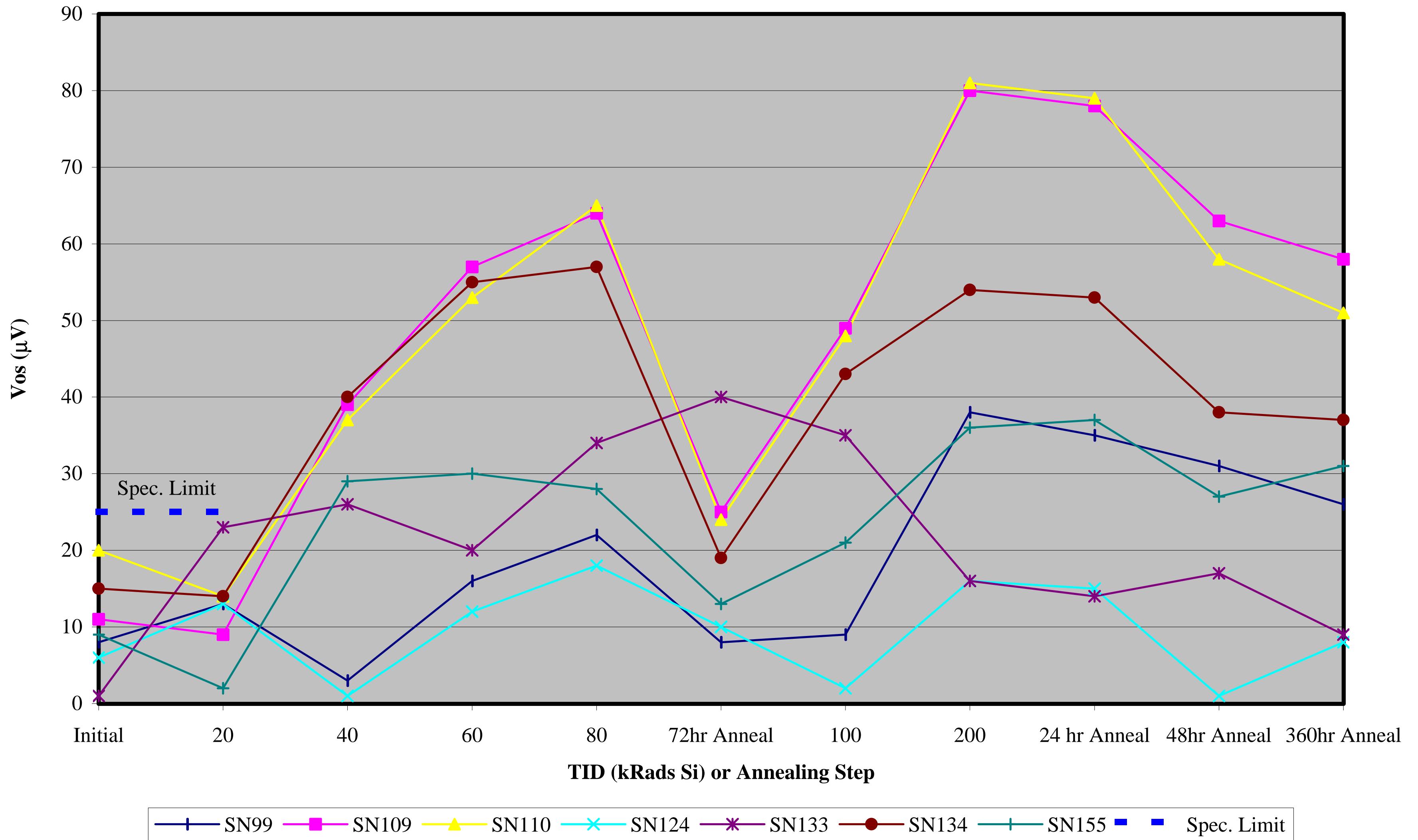


Figure 3: VOS vs TID for OP07
Without SN136



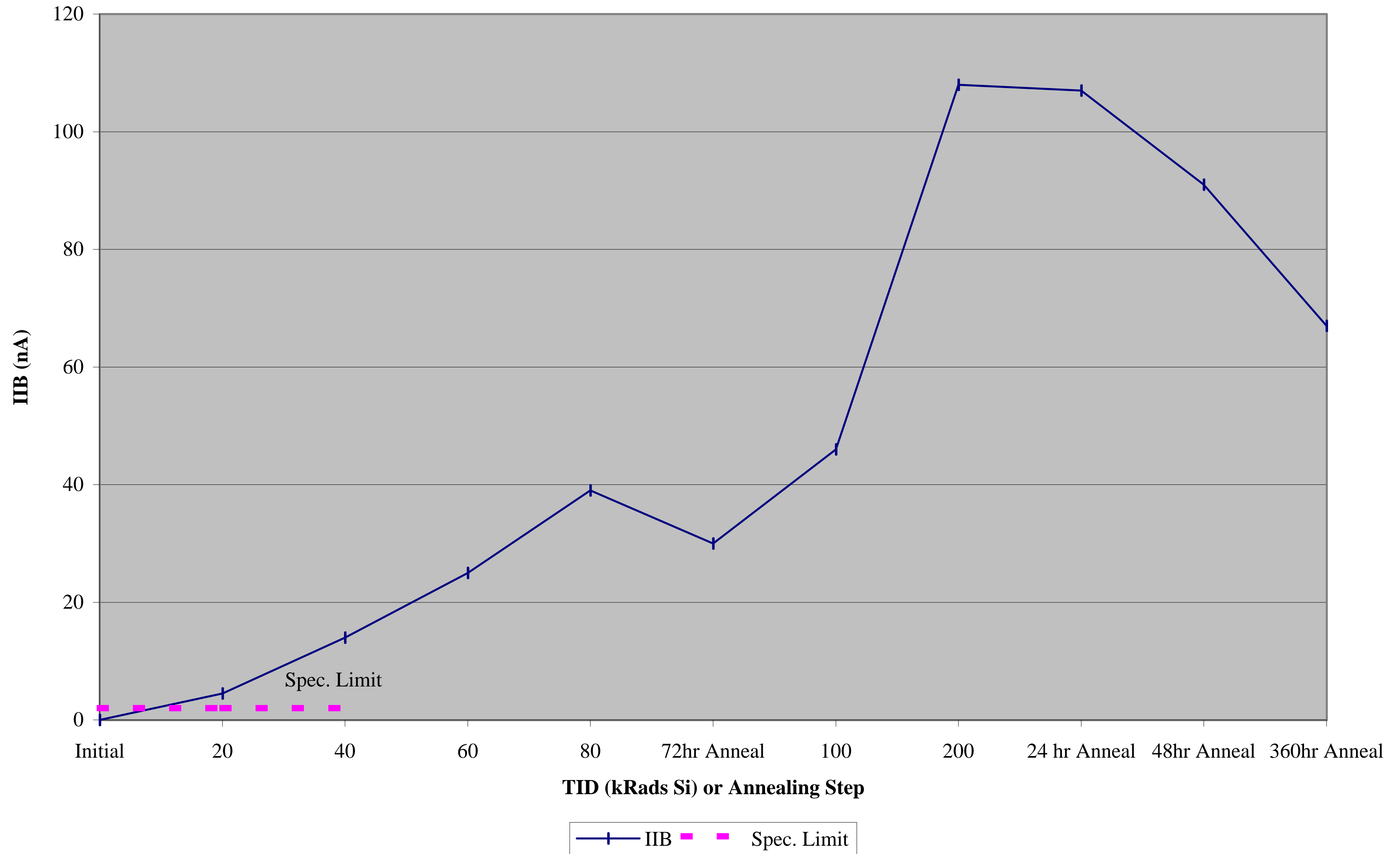


Figure 4: IIB vs TID for OP07
IIB (nA)
120
100
80
60
40
20
0
Spec. Limit
Initial
20
40
60
80
72hr Anneal
100
200
24 hr Anneal
48hr Anneal
360hr Anneal
TID (kRads Si) or Annealing Step
IIB
Spec. Limit

Figure 5: AOL vs TID for OP07