Unisys

DATE: March 24, 1999 PPM-99-017
TO: J. Dafnis/303
FROM: K. Sahu/S. Kniffin/300.1
SUBJECT: Radiation Report on **OP07 (Analog Devices) (LDC 9723B)**
PROJECT: GOES (ITT)

cc: R. Ross/562, R. Reed/562, D. Maus/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 dose tolerance of these parts. This testing was a follow-up to the earlier testing of OP-07 LDC9724A. The earlier testing indicated some outlier parts with very high VOS degradation. (Refer to Appendix 1 in this report, PPM-99-001 and PPM-98-011.) The total dose testing was performed using a Co^{60} gamma ray source. During the radiation testing, eighteen 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 10.0, 20.0, 30.0, and 40.0kRads.[1] The dose rate was 0.049 kRads/hour (0.014 Rads/s). See Table II for the radiation schedule and effective dose rate calculation. After the 40.0kRad irradiation, the parts were annealed at 25°C for 96 and 168 hours under bias.[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 and 2.

All parts stayed within the specification limits for VOS up to 10kRads. Most parts showed some degradation in VOS beginning at 20kRads, however, no signs of excessive degradation were seen and there was no VOS outlier problem throughout this testing (See Appendix 1). All parts showed marginal degradation in P_IIB and N_IIB from 10 to 40kRads. All parts showed some degradation in N_AOL_2k from 20 to 40kRads. Most parts showed some degradation in N_AOL_2k from 20 to 40kRads. Most parts showed some degradation in CMRR from 30 to 40kRads. A few parts showed some degradation in P_AOL_2k at 40kRads. A few parts showed degradation in Slew Rate at 40kRads. After annealing the parts under bias at 25°C for 96 and 168 hours, all parts showed some recovery in all radiation sensitive parameters. (See Figure 2 for VOS data.)

Initial electrical measurements were made on 20 samples. Eighteen samples (SN's 376, 380, 384, 385, 386, 391, 393, 394, 395, 398, 399, 400, 408, 409, 410, 414, 415, and 467) were used as radiation samples while SN's 373 and 375 were used as control samples. All parts passed all tests during initial electrical measurements.

After the 10.0kRad irradiation, all parts were within the specification limits for VOS. Four parts marginally exceeded the specification limit of 2.0nA for P_IIB with readings in the range of 2.1 to 2.6nA. One part marginally exceeded the specification limit of 2.0nA for N_IIB with a reading of 2.2nA. **All parts passed all other tests.**

After the 20.0kRad irradiation, two parts exceeded the specification limit of 25µV for VOS with readings of 40.4 and 33.5µV. All parts exceeded the specification limits for P_IIB and N_IIB with readings in the range of 2.1 to 7.9nA for both. Eighteen parts fell below the specification limit of 30V/mV for N_AOL_2k with readings in the range of 264 to 292V/mV. **All parts passed all other tests.**

After the 30.0kRad irradiation, twelve parts exceeded the specification limit for VOS with readings in the range of 25.8 to 58.1µV. All parts exceeded the specification limits for P_IIB and N_IIB with readings in the range of 5.9 to

[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.

12.0nA for both. Sixteen parts fell below the specification limit of 110dB for CMRR with readings in the range of 106 to 109dB. All parts fell below the specification limit for N_AOL_2k with readings in the range of 227 to 282V/mV. **All parts passed all other tests.**

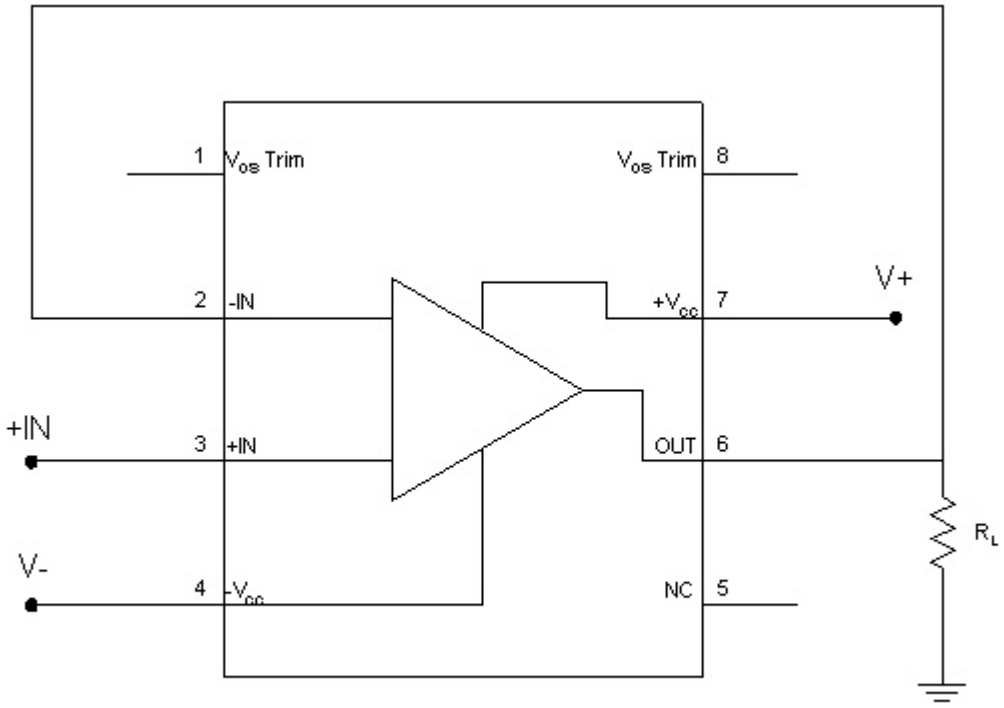
After the 40.0kRad irradiation including 72 hours annealing at 25°C, all parts exceeded the specification limit for VOS with readings in the range of 30.3 to 396µV. All parts exceeded the specification limits for P_IIB and N_IIB with readings in the range of 8.5 to 15.3nA for both. Seventeen parts fell below the specification limit for CMRR with readings in the range of 59 to 109dB. Nine parts fell below the specification limit of 300V/mV for P_AOL_2k with readings in the range of 76 to 101V/mV. All parts fell below the specification limit for N_AOL_2k with readings in the range of 227 to 282V/mV. Seven parts fell below the specification limit of 0.100V/µs for Slew Rate with readings in the range of 0.059 to 0.068V/µs. **All parts passed all other tests.**

After annealing the parts for 96 and 168 hours at 25°C, all parts showed some recovery in all radiation sensitive parameters.

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:	M90415
Manufacturer:	Analog Devices
Lot Date Code (LDC):	9723B
Quantity Tested:	20
Serial Number of Control Samples:	373, 375
Serial Numbers of Radiation Samples:	376, 380, 384, 385, 386, 391, 393, 394, 395, 398, 399, 400, 408, 409, 410, 414, 415, and 467
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	02/12/98
2) 10.0 KRAD IRRADIATION (0.062 KRADS/HOUR)	02/12/98
POST-10.0 KRAD ELECTRICAL MEASUREMENT	02/19/99
3) 20.0 KRAD IRRADIATION (0.062 KRADS/HOUR)	02/19/99
POST-20.0 KRAD ELECTRICAL MEASUREMENT	02/26/99
4) 30.0 KRAD IRRADIATION (0.062 KRADS/HOUR)	02/26/99
POST-30.0 KRAD ELECTRICAL MEASUREMENT	03/05/99
5) 40.0 KRAD IRRADIATION (0.062 KRADS/HOUR) + 72 HOUR ANNEALING @25°C	03/05/99
POST-40.0 KRAD + 72 HOUR ANNEAL ELECTRICAL MEASUREMENT	03/15/99
6) 96 HOUR ANNEALING @25°C	03/12/99
POST-96 HOUR ANNEAL ELECTRICAL MEASUREMENT	03/16/99
7) 168 HOUR ANNEALING @25°C	03/12/99
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	03/19/99

Effective Dose Rate = 40,000 RADS/30 DAYS=55.6 RADS/HOUR=0.014 RADS/SEC

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	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} = ±13V	110	
9	PSRR	dB	$\pm V_{CC}$ = ±3V to ±18V, $\mp V_{CC}$ = ∓15V	100	
10	P_VOUT_10k	V	R_L = 10kΩ	12.5	
11	N_VOUT_10k	V	R_L = 10kΩ		-12.5
12	P_VOUT_2k	V	R_L = 2kΩ	12.0	
13	N_VOUT_2k	V	R_L = 2kΩ		-12.0
14	P_AOL_2k	V/mV	R_L = 2kΩ, V_O = +10V	300	
15	N_AOL_2k	V/mV	R_L = 2kΩ, V_O = -10V	300	
16	P_AOL_600	V/mV	R_L = 600Ω, V_O = +10V	150	
17	N_AOL_600	V/mV	R_L = 600Ω, V_O = -10V	150	
18	Slew Rate	V/µs	C_L = 50pF, R_L = 2kΩ	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.

BLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for OP0

Test			Spec. Lim. /2		Total Dose Exposure (kRads Si)										Annealing			
					Initial		10.0		20.0		30.0		40.0 + 72 hour Ann. @25°C /		96 hours @25°C		168 hours @25°C	
#	Parameters	Units	min	max	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1	+Icc	mA	0.0	4.0	2.3	0.1	2.3	0.1	2.2	0.1	2.2	0.1	2.1	0.1	2.1	0.1	2.1	0.1
2	-Icc	mA	-4.0	0.0	-2.3	0.1	-2.3	0.1	2.2	0.1	-2.2	0.1	-2.1	0.1	-2.1	0.1	-2.1	0.1
3	Power_Diss	mW		120	35	2	34	2	33	2	33	2	32	2	32	2	32	2
4	VOS	mV	-25	25	3.8	10.1	2.5	11.8	13.2	12.3	31.3	13.2	172	128	108	63	85.3	48
5	P_IIB	nA	-2.0	2.0	0.3	0.3	1.7	0.4	6.1	1.1	10.1	1.3	11.8	2.0	8.0	3.3	7.9	1.3
6	N_IIB	nA	-2.0	2.0	-0.4	0.5	0.9	0.7	5.4	1.2	9.6	1.2	11.3	2.0	7.6	3.7	7.7	1.3
7	IIOS	nA	-2.0	2.0	0.7	0.2	0.6	0.3	0.7	0.3	0.6	0.2	0.4	0.2	0.4	0.5	0.2	0.3
8	CMRR	dB	110		125	2	118	2	113	2	108	2	83	24	97	15	97	11
9	PSRR	dB	100		112	1	114	1	117	3	125	8	118	13	120	8	116	6
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
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
12	P_VOUT_2k	V	12.0		13.8	0	13.8	0	13.8	0	13.7	0	13.7	0	13.7	0	13.8	0
13	N_VOUT_2k	V		-12.0	-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		1169	222	2140	5083	629	329	453	140	228	152	718	2001	264	118
15	N_AOL_2k	V/mV	300		367	23	323	21	278	17	243	16	147	79	171	68	171	56
16	P_AOL_600	V/mV	150		174679	203905	11356	2641	6042	3709	3638	963	1677	1187	2016	1078	2052	1057
17	N_AOL_600	V/mV	150		1552	37	1225	49	958	63	774	58	443	263	487	239	538	201
18	Slew Rate	V/ms	0.100		0.181	0.009	0.160	0.009	0.144	0.009	0.134	0.009	0.093	0.033	0.104	0.028	0.107	0.026

Notes:

1/ The mean and standard deviation values were calculated over the eighteen parts irradiated in this testing. The control samples remained constant throu 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 te

3/ No electrical measurements could be made immediately after the 40kRad exposure due to problems with the ATE. The parts were kept under bias and for 72 hours before being measured.

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

Appendix 1

The following is the transcript of the email to Jim Dafnis, Code 303, describing the final results and recommendation for OP07 LDC9724A.

Jim,

We're summarizing below the TID radiation testing performed on OP-07 LDC9724A for the GOES project to determine the suitability of these parts from a TID aspect. The recommendation that you asked for this morning on these parts is provided at the bottom.

Kusum and Scott

Background:

We tested 4 parts of LDC 9724A in Nov 98 at 0.14R/s. One part in this lot showed significant degradation in the Vos test parameter at 40kRads. The readings were 3148μV with a spec limit of 25μV. The other three parts were within +/-10% of the spec limit at 40kRads.

We also tested 4 parts of this LDC at 0.58R/s. At 50kRads, the parts showed significant degradation in Vos. The mean was 370μV but there was no outlier. Note that the rate of degradation was dramatically higher than at the lower dose rate of 0.14R/s. Also note that the parts showed significant recovery on annealing at room temp after the final exposure. See PPM-99-001 for more details.

We had also tested 8 parts of LDC 9723B in May 98 at 0.33R/s. One part showed significant degradation in the Vos test parameter with a reading of 3249μV at 40kRads. The readings for the other 7 parts were within +/-60μV with a spec limit of 25uV. See PPM-98-011 for more details.

The results above raised the issue as to how significant the outlier problem was for the LDC9724A parts, of which many have been used in the GOES project. There was also a question regarding whether the outlier issue would couple with the Extremely Low Dose Rate Effect (ELDR) and make the problem worse in the space environment where the dose rate may be smaller by a factor of 10-100.

A test plan was designed to test a larger sample size of OP-07 parts from LDC9724A at a dose rate of about 0.004R/s. It was determined that these parts would be tested to 40kRads only, to see how significant the outlier problem is in this test group at the lower dose rate. The 40kRad level was chosen because the project determined that the radiation exposure at the part level was going to be less than 17kRads thereby giving an RDM of >2 at 40kRads. Although a RDM of 5 would have been better, that would have taken too long to resolve this issue at this dose rate.

New/Recent Test Results:

The testing of the 18 parts up to 40kRads was finished 2 days ago and the Vos results are summarized below.

All parts stayed within the specification limit of 25μV up to 10kRads. At 20kRads, all parts except 2 stayed within the specification limit. Only 2 parts marginally exceeded the limit with readings of 29.6 and 26.8μV.

After 30kRads, 8 parts exceeded (10 parts stayed within) the Vos spec limit with readings in the range of 25.7 to 45.7μV.

After 40kRads, 13 parts exceeded (5 stayed within) the Vos spec limit with readings in the range of 25 to 59μV.

See the attached figure for a graphical representation of the Vos degradation with increasing TID exposure up to 40kRads.

The new test data on a sample size of 18 at lower dose rate (0.004R/s) does not indicate any outlier problem as related to the Vos parameter up to 40kRads. It should be noted that in general, the OP-07 parts showed higher degradation at the higher dose rate of 0.58R/s. The dose rate of the space environment is much less than the dose rates at which the outlier problem was observed in our testing. Even if there is an outlier, it probably will not show as much degradation in space as it did in our testing at 0.14R/s.

(Please note that a number of other parameters such as P_IIB, N_IIB, CMRR, etc. showed marginal degradation from the specification limit. Those results will be included in the final report, but do not impact the primary issue of Vos outliers.)

Recommendation:

The lack of the outlier problem as well as any significant degradation in Vos up to 40kRads at the low dose rate of 0.004R/s in a sample size of 18, greatly reduces the risk associated with the use of these parts in the GOES project where the expected exposure on the parts is less than 17kRads. However, the project should determine that in the event of an outlier, the resulting Vos will not cause a critical functional failure in its intended application.