Government Systems Group

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PPM-95-115

TO: B. Fafaul/311
FROM: K. Sahu/300.1 Ksahu
SUBJECT: Radiation Report on IIST/CAL
Part No. LM10
Control No. 11117A

cc: A. Sharma/311.0
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OFA Library/300.1

A radiation evaluation was performed on LM10 (Op Amp) to determine the total dose tolerance of these parts. A brief summary of the test results is provided below. For detailed information, refer to Tables I through IV and Figure 1.

The total dose testing was performed using a ^{60}Co 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, 10, 15, 20, 30 and 50 krads*. The dose rate was between 0.08 and 1.18 krads/hour, depending on the total dose level (see Table II for radiation schedule). After the 50 krad irradiation, parts were annealed at 25°C for 168 hours, after which the parts were annealed at 100°C for 168 hours. After each radiation exposure and annealing treatment, parts were electrically tested according to the test conditions and the specification limits** listed in Table III.

All parts passed initial electrical measurements. After the 2.5 krad irradiation, all eight irradiated parts exceeded the maximum specification limit of ±700 pA for IIOS@1.2V and IIOS@45V, with readings ranging from -747 to -1657 pA for IIOS@1.2V and -868 to -1774 pA for IIOS@45V. Four parts (S/N 42, 43, 46 and 49) exceeded the maximum specification limit of ±20 nA for P_IIB@1.2V, with readings ranging from -20 to -21 nA and two parts (S/N 43 and 49) marginally exceeded the maximum specification limit of ±20 nA for N_IIB@1.2V, with readings of -20.1 nA. Three parts (S/N 43, 46 and 49) marginally exceeded the maximum specification limit of ±20 nA for P_IIB@45V, with readings ranging from -20.6 to -21.1 nA. In addition, S/N 43 fell below the minimum specification limit of 5 V/mV for AOL_20mA, with a reading of 2.19 V/mV. No reliable reading could be obtained for S/N 49 for this parameter at this irradiation level.

At the 5 krad level, All eight irradiated parts fell outside the specification limits for P_IIB@1.2V, N_IIB@1.2V, and IIOS@1.2V and for P_IIB@45V, N_IIB@45V and IIOS@45V. Readings for both P_IIB@1.2V and P_IIB@45V, were similar, and ranged from -29 to -36 nA. Readings for N_IIB and IIOS for both 1.2 V and 45 V were also similar, and ranged from -27 to -34 nA for N_IIB and from -1526 to -3534 pA for IIOS. In addition, all irradiated parts except S/N 44 exceeded the maximum specification limit of ±3 mV for VOS@+20mA, with readings of -10.2 mV, and all irradiated parts fell below the minimum specification limit of 5 V/mV for AOL_20mA, with readings of 2.2 V/mV.

At the 10 krad level, all irradiated parts exceeded specification limits for P_IIB@1.2V, N_IIB@1.2V, and IIOS@1.2V and for P_IIB@45V, N_IIB@45V and IIOS@45V, with readings approximately three to four times the values at the 5 krad level. All irradiated parts also continued to exceed specification limits for VOS@+20mA, with readings of -10 mV, and also exceeded the maximum specification limit of ±3 mV for VOS@-20mA, with readings of 9.08 mV.

*The term rads, as used in this document, means rads(silicon). All radiation levels cited are cumulative.
**These are manufacturer's pre-irradiation data specification limits. No post-irradiation limits were provided by the manufacturer at the time these tests were performed.

At the 10 krad level, all irradiated parts also exceeded the maximum specification limit of 50 nA for both I_FB@45V and I_FB@1.2V, with readings ranging from 74 to 91 nA. All irradiated parts also fell below the minimum specification limit of 5 V/mV for AOL_20mA, with readings of 2.2 V/mV and all irradiated parts except S/N 44 fell below the minimum specification limit of 8 V/mV for ASH_15mA, with readings of 3.9 V/mV.

At the 15 krad level through the 50 krad level, all irradiated parts continued to exceed specification limits for additional parameters. At the 50 krad level, At least one, and in most cases more than one part exceeded specification limits for every electrical test parameter except Is@1.2V, V_FB@0V, 0mA and Load Reg @ 45V.

After annealing for 168 hours at 25°C, no recovery was observed.

After annealing for 168 hours at 100°C, no rebound effects were observed.

Table IV provides a summary of the mean and standard deviation values for each parameter after different irradiation exposures and annealing steps.

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

TABLE I. Part Information

TABLE I. Part Information

Generic Part Number:	LM10
HST/CAL Part Number:	5962-8760401GA
HST/CAL Control Number:	11117A
Charge Number:	EI56047
Manufacturer:	National Semiconductor
Lot Date Code:	9431
Quantity Tested:	10
Serial Number of Control Samples:	40, 41
Serial Numbers of Radiation Samples:	42, 43, 44, 45, 46, 47, 48, 49
Part Function:	Op Amp
Part Technology:	CMOS
Package Style:	8-pin Tox Can
Test Equipment:	A540
Test Engineer:	P. Srioudom

* No radiation tolerance/hardness was guaranteed by the manufacturer for this part.

TABLE II. Radiation Schedule for LM10

EVENTS	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	11/16/94
2) 2.5 KRAD IRRADIATION (0.15 KRADS/HOUR)	11/16/94
POST-2.5 KRAD ELECTRICAL MEASUREMENT	11/17/94
3) 5 KRAD IRRADIATION (0.15 KRADS/HOUR)	11/17/94
POST-5 KRAD ELECTRICAL MEASUREMENT	11/18/94
4) 10 KRAD IRRADIATION (0.08 KRADS/HOUR)	11/18/94
POST-10 KRAD ELECTRICAL MEASUREMENT	11/21/94
5) 15 KRAD IRRADIATION (0.29 KRADS/HOUR)	11/21/94
POST-15 KRAD ELECTRICAL MEASUREMENT	11/23/94
6) 20 KRAD IRRADIATION (0.29 KRADS/HOUR)	11/23/94
POST-20 KRAD ELECTRICAL MEASUREMENT	11/29/94
7) 30 KRAD IRRADIATION (0.59 KRADS/HOUR)	11/29/94
POST-30 KRAD ELECTRICAL MEASUREMENT	11/30/94
8) 50 KRAD IRRADIATION (1.18 KRADS/HOUR)	11/30/94
POST-50 KRAD ELECTRICAL MEASUREMENT	12/02/94
9) 168-HOUR ANNEALING @ 25°C	12/02/94
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	12/11/94
9) 168-HOUR ANNEALING @ 100°C*	12/11/94
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	12/19/94

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

*High temperature annealing is performed to accelerate long term time dependent effects (TDE), namely, the "rebound" effect due to the growth of interface states after the radiation exposure. For more information on the need to perform this test, refer to MIL-STD-883D, Method 1019, Para. 3.10.1.

Table III. Electrical Characteristics of LM10

Unless Otherwise Specified: T_A =25°C

TEST NAME	SYMBOL	CONDITIONS	LIMITS	
			MIN	MAX
Is @ 1.2V	Is	+Vcc = 1.2V, -Vcc= 0.0, V_{OUT} = 0.6V		400uA
Is @ 45V	Is	+Vcc = 45V, -Vcc= 0.0V, V_{OUT} = 0.6V		400uA
Delta Is	ΔIs	+Vcc = (1.2V,45V), -Vcc= 0.0V, V_{OUT} = 0.6V	-100uA	100uA
Delta Is	ΔIs	+Vcc = 5V, -Vcc= 0.0V, V_{OUT} = (4.5V, 5V)	-60uA	60uA
V_{OS} @ 1.2V	V_{IO}	+Vcc = 1.2V, -Vcc= 0, V_{OUT} = 0.6V, I_L = 0mA	2mV	-2mV
P_IIB @ 1.2V	$+I_{IB}$	+Vcc = 1.2V, -Vcc= 0.0, V_{OUT} = 0.6V		20nA
N_IIB @ 1.2V	$-I_{IB}$	+Vcc = 1.2V, -Vcc= 0.0, V_{OUT} = 0.6V		20nA
IIOS @ 1.2V	I_{IO}	+Vcc = 1.2V, -Vcc= 0.0, V_{OUT} = 0.6V	-700pA	700pA
V_{OS} @ 45V	V_{IO}	+Vcc = 45V, -Vcc= 0, V_{OUT} = 22.5V, I_L = 0mA	2mV	-2mV
P_IIB @ 45V	$+I_{IB}$	+Vcc = 45V, -Vcc= 0.0, V_{OUT} = 22.5V		20nA
N_IIB @ 45V	$-I_{IB}$	+Vcc = 45V, -Vcc= 0.0, V_{OUT} = 22.5V		20nA
IIOS @ 45V	I_{IO}	+Vcc = 45V, -Vcc= 0.0, V_{OUT} = 22.5V	-700pA	700pA
V_{os} @ 2mA	V_{IO}	+Vcc = 1.2V, -Vcc= 0, V_{OUT} = .6V, I_L = 2mA	-3mV	3mV
V_{os} @ -2mA	V_{IO}	+Vcc = 1.2V, -Vcc= 0, V_{OUT} = .6V, I_L = -2mA	-3mV	3mV
V_{os} @ 20mA	V_{IO}	+Vcc = 4.0V, -Vcc= 0, V_{OUT} = 2V, I_L = 20mA	-3mV	3mV
V_{os} @ -20mA	V_{IO}	+Vcc = 4.0V, -Vcc= 0, V_{OUT} = 2V, I_L = -20mA	-3mV	3mV
CMRR	CMRR	+Vcc = (25V, 5V) , -Vcc= (-20V, 0V), V_{OUT} = (22.5V,-21.7V) See Note	93dB	
-PSRR	PSRR	+Vcc = 0.85V , -Vcc= (-0.35V,-44.2V), V_{OUT} = 0.25V	90dB	
+PSRR	PSRR	+Vcc = (0.85V, 44.6V) , -Vcc= -0.35V, V_{OUT} = 0.25V	90dB	
AOL	A_V	+Vcc = 20V, -Vcc= -20V, V_{OUT} = ±19.95V, I_L = 0mA	120 V/mV	
AOL_20mA	A_V	+Vcc = 2V, -Vcc= -2V, V_{OUT} = ±1.4V, I_L = ±20mA	5 V/mV	
AOL_2mA	A_V	+Vcc = 0.85V, -Vcc= -0.35V, V_{OUT} = ±19.95V, I_L = ±2mA	1.5 V/mV	
ASH_2mA	A_{VSH}	V_{OUT} = +Vcc = (1.2V, 6.1V), -Vcc= 0V, I_L=2mA	14V/mV	
ASH .1mA	A_{VSH}	V_{OUT} = +Vcc = (1.2V, 6.1V), -Vcc= 0V, I_L=0.1mA	14 V/mV	

Table III (Cont'd.). Electrical Characteristics of LM10

Unless Otherwise Specified: T_A =25°C

TEST NAME	SYMBOL	CONDITIONS	LIMITS	
			MIN	MAX
ASH_15mA	A_{VSH}	V_{OUT} = +Vcc = (1.4V, 6.4V), -Vcc= 0V, I_L=15mA	8V/mV	
ASH_.1mA	A_{VSH}	V_{OUT} = +Vcc = (1.4V, 6.4V), -Vcc= 0V, I_L=0.1mA	8 V/mV	
REF_GAIN	A_V	+Vcc = 44.8V, -Vcc= -0.2V, V_{OUT} = (0V,35V) I_L = 1mA	50V/mV	
V_FB @ 35V, 1mA	V_{SENSE}	+Vcc = 44.8V, -Vcc= -0.2V, V_{OUT} = 35V I_L = 1mA	195mV	205mV
V_FB @ 0V, 1mA	V_{SENSE}	+Vcc = 44.8V, -Vcc= -0.2V, V_{OUT} = 0V I_L = 1mA	195mV	205mV
V_FB @ 35V, 0mA	V_{SENSE}	+Vcc = 44.8V, -Vcc= -0.2V, V_{OUT} = 35V I_L = 0mA	195mV	205mV
I_FB @ 45V	I_{SENSE}	+Vcc = 44.8V, -Vcc= -0.2V, V_{OUT} = 0V I_L = 0mA		50nA
I_FB @ 1.2V	I_{SENSE}	+Vcc = 1V, -Vcc= -0.2V, V_{OUT} = 0V I_L = 0mA		50nA
Line Reg.	V_{RLINE}	+Vcc = (1.2V, 45V), -Vcc= 0V, V_{OUT} = V_{REF} I_L = 1mA	91dB	
Load Reg @ 1.2V	V_{RLOAD}	+Vcc = 1.2V, -Vcc= 0V, V_{OUT} = V_{REF} I_L = (5uA, 1mA)	60dB	
Load Reg @ 45V	V_{RLOAD}	+Vcc = 45V, -Vcc= 0V, V_{OUT} = V_{REF} I_L = (5uA, 1mA)	60dB	

Note: The Common Mode Rejection Ratio Test was performed with ΔVcm = 44.2V

TABLE IV: Summary of electrical Measurements after Total Dose Exposures and Annealing for LM10 1/

Test #	Parameters	Units	Spec. Lim./2 min	Spec. Lim./2 max	Initial mean	Initial sd	2.5 mean	2.5 sd	5 mean	5 sd	10 mean	10 sd	15 mean	15 sd	20 mean	20 sd	30 mean	30 sd	50 mean	50 sd	168 hrs @25°C mean	168 hrs @25°C sd	168 hrs @100°C mean	168 hrs @100°C sd
1	Is@1.2V	µA	0.00	400.00	229	3.0	228	3.0	229	3.0	228	3.0	229	3.0	231	3.0	233	3.0	170	7.0	222	10	230	4.0
2	Is@45V	µA	0.00	400.00	256	5.0	252	0.5	254	5.0	251	5.0	252	5.0	252	4.0	253	4.0	657	352	248	5.0	251	5.0
101	Delta Is	µA	-100.00	100.00	-27	3.0	-26	2.0	-25	2.0	-23	2.0	-22	2.0	-21	2.0	-20	1.0	-487	354	-26	12	-21	2.0
102	Delta Is	µA	-60.00	60.00	-7.1	2.0	-5.0	2.0	-2.0	2.0	3.0	2.0	8.0	2.0	15	3.0	25	3.0	26	15	36	3.0	20	2.0
3	VOS@1.2V	mV	-2.000	2.000	0.21	0.22	0.35	0.22	0.51	0.23	0.95	0.26	1.61	0.3	2.38	0.34	4.80	0.54	9.05	0.0	9.27	1.05	2.25	0.34
4	P_IIB@1.2V	nA	-20.00	20.00	-7.79	0.43	-20	1.55	-30	2.84	-60	5.17	-100	8.22	-100	9.37	-200	9.08	-137	8.91	-200	8.19	-100	3.50
5	N_IIB@1.2V	nA	-20.00	20.00	-7.75	0.36	-18.7	1.35	-30	2.40	-60	4.15	-79.4	5.98	-100	8.27	-200	10.7	-100	8.18	-200	17.5	-100	4.32
6	IIOS@1.2V	pA	-700.0	700.0	-40.9	0.94	-992	319	-2194	575	-6731	1266	-20000	2552	-30000	1736	-39633	3.15	-13646	13892	-78031	10329	-20000	904
7	VOS@45V	mV	-2.000	2.000	0.05	0.23	0.18	0.23	0.33	0.23	0.73	0.26	1.29	0.29	1.91	0.32	3.81	0.48	9.51	0.79	6.75	1.01	1.69	0.32
8	P_IIB@45V	nA	-20.00	20.00	-7.53	0.42	-20	1.54	-30	2.89	-60	5.35	-100	9.26	-100	0.12	-200	2.81	-200	13.0	-209	0.10	-100	4.92
9	N_IIB@45V	nA	-20.00	20.00	-7.47	0.35	-20	1.33	-30	2.37	-60	4.17	-79.8	6.19	-100	8.76	-200	12.3	-198	16.7	-200	0.01	-100	4.86
10	IIOS@45V	pA	-700.0	700.0	-59	93	-1147	322	-2586	615	-7867	1351	-20000	3.15	-40000	3301	-40000	9.70	-2462	10.7	-2477	0.01	-30000	0.03
11	VOS@+2mA	mV	-3.000	3.000	0.14	0.22	0.26	0.22	0.41	0.22	0.81	0.26	1.41	0.29	2.09	0.32	4.34	0.50	10.2	0.02	7.98	1.08	1.96	0.33
12	VOS@-2mA	mV	-3.000	3.000	0.28	0.22	0.44	0.23	0.62	0.23	1.14	0.27	2.0	0.33	3.27	0.52	9.14	0.03	9.16	3.0	9.14	0.0	3.80	0.62
13	VOS@+20mA	mV	-3.000	3.000	-0.19	0.28	0.07	0.22	-8.97	3.61	-10.2	0.0	-10	0.0	-10.2	0.0	-10.2	0.0	-10.2	0.0	-10.2	0.0	-10.2	0.0
14	VOS@-20mA	mV	-3.000	3.000	0.28	0.28	0.45	0.23	0.65	0.23	9.08	0.0	9.07	0.0	9.08	0.0	9.08	743	9.09	0.0	9.08	0.0	9.09	0.0
15	CMRR	dB	93.0		128	8.4	133	9.06	131	6.05	120	5.98	111	0.91	106	0.57	99.9	0.54	3/	3/	97.9	5.59	103	1.18
16	-PSRR	dB	90.0		107	0.81	107	0.83	107	0.83	107	0.89	105	0.93	102	1.18	95.1	1.32	138.2	30.8	86.8	3.29	102	0.63
17	+PSRR	dB	96.0		109	0.73	109	0.67	108	0.57	106	0.43	102	0.59	98.6	0.83	91.1	0.96	96.03	5.13	84.6	3.68	97.1	0.73
18	AOL	V/mV	120.00		1670	101	1333	49.5	1226	37.8	954	51.3	651	42.2	469	40.7	242	33.9	3/	3/	89.4	17.9	421	32.6
19	AOL_20mA	V/mV	5.000		8.66	0.48	6.09	1.70	2.18	0.0	2.19	0.0	2.19	0.0	2.19	0.0	2.19	0.0	2.19	0.0	2.19	0.0	2.19	0.0
20	AOL_2mA	V/mV	1.500		5.19	0.18	4.25	0.09	3.51	0.10	2.24	0.13	1.31	0.09	1.21	0.01	1.12	0.02	0.62	0.0	0.94	0.0	1.21	0.01
21	ASH_2mA	V/mV	14.00		41.3	1.11	36.5	0.79	32.2	0.59	21.5	0.86	12.1	1.32	7.97	0.04	4.28	1.28	3/	0.0	3/	0.0	7.99	0.05
22	ASH_.1mA	V/mV	14.00		51.9	1.70	47.9	1.27	44.4	0.98	33.7	0.75	22.9	1.25	15.8	1.34	8.16	0.07	3/	0.0	5.59	2.44	13.6	1.05
23	ASH_15mA	V/mV	8.00		30.1	0.47	27.6	0.43	24.5	0.514	4.79	2.51	3/	0.0	3/	0.0	3/	0.0	3/	0.0	3/	0.0	3/	0.0
24	ASH_.1mA	V/mV	8.00		73.9	2.82	69.6	2.45	65.4	1.78	51.6	1.42	36.5	1.83	26.3	1.78	12.4	1.38	3/	0.0	7.57	2.21	21.8	1.24
25	REF GAIN	V/mV	50.00		171	1.60	161.7	2.81	152.1	3.24	132.6	3.96	114	5.62	97.5	6.15	73.1	5.46	40.1	11.6	57.3	4.37	99.4	2.68
26	V_FB@35V, 1m	mV	195.0	205.0	200	0.53	200	0.53	200	0.53	200	0.52	200	0.49	200	0.50	202	0.50	205	0.64	205	2.59	201	0.48
27	V_FB@0V, 1mA	mV	195.0	205.0	200	0.53	200	0.53	200	0.53	200	0.51	200	0.48	200	0.49	201	0.49	204	0.65	204	2.62	201	0.49
28	V_FB@35V, 0m	mV	195.0	205.0	200	0.53	200	0.53	200	0.53	200	0.52	200	0.48	200	0.50	201	0.49	205	0.64	205	2.58	201	0.49
29	V_FB@0V, 0mA	mV	195.0	205.0	200	0.53	200	0.53	200	0.53	200	0.51	200	0.49	200	0.49	201	0.49	204	0.66	204	2.64	201	0.49
30	I_FB@45V	nA		50.00	12.2	0.52	27.8	1.91	45.4	3.34	83.3	6.16	123	8.89	167	11.8	197	0.02	197	0.01	197	0.01	172	7.35
31	I_FB@1.2V	nA		50.00	1.21	0.52	27.7	1.90	45.2	3.32	82.6	6.08	122	8.69	164	11.3	197	0.02	189	1.26	197	0.01	169	7.06
32	Line Reg.	dB	91.0		122	5.21	117	1.85	122	8.61	116	3.22	113	1.77	112	2.91	107	1.13	72.6	0.0	93.6	12.9	110	1.62
33	Load Reg @ 1.2V	dB	60.0		76.4	3.21	71.7	1.84	72.5	2.73	69.4	2.69	69.6	3.01	67.6	1.07	65.6	2.48	42.9	3.70	60.1	6.32	69.2	3.6
34	Load Reg@45V	dB	60.0		90.9	14.3	83.6	4.59	82.4	4.57	82.1	7.39	80.2	6.06	76.9	4.21	75.2	3.08	66.7	1.30	71.6	3.67	78.1	4.75

Notes:

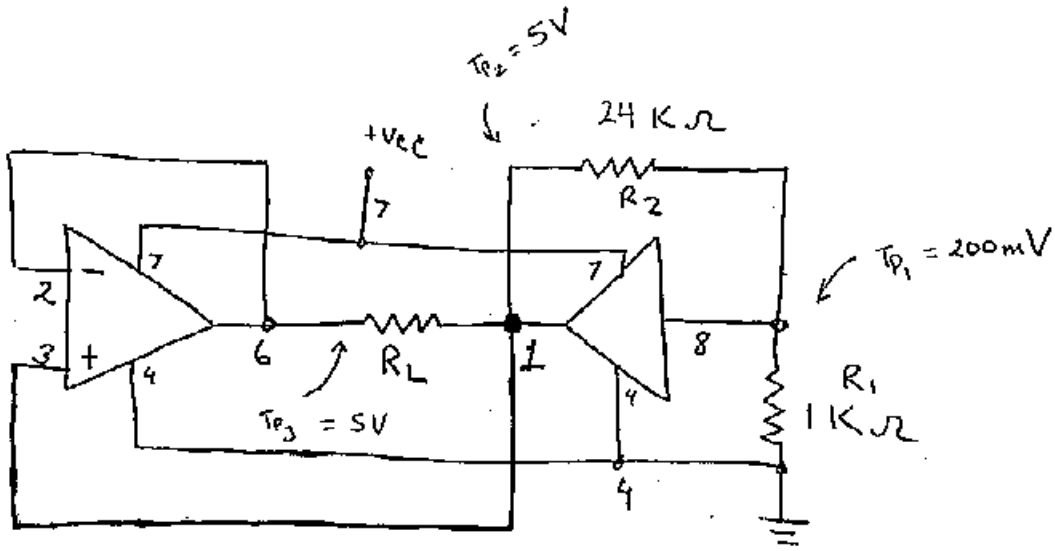
1/ The mean and standard deviation values were calculated over the eight parts irradiated in this testing. The control samples remained constant throughout the testing and are not included in this table.

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/ No reliable readings could be obtained at this level.

Radiation sensitive parameters: P_IIB, N_IIB, IIOS, VOS, CMRR, PSRR, AOL, ASH, REF GAIN, V_FB, I_FB, Line Reg, and Load Reg.

Figure 1. Radiation Bias Circuit for LM10



V_{CC} = 10.0 ± 0.05VDC
R_L = 500Ω, ½W
R_1 = 1KΩ, ¼W
R_2 = 24 KΩ, ¼W