Government Systems Group

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DATE: December 7, 1994

PPM-95-105

TO: B. Fafaul/311.1

FROM: K. Sahu/300.1 KS

SUBJECT: Radiation Report on HST/CAL
Part No. LM10
Control No. 11117

cc: A. Sharma/311
Library/300.1

A radiation evaluation was performed on LM10 (Operational Amplifier and Voltage Reference) 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 and 30 krads*. The dose rate was between 0.06 and 0.59 krads/hour, depending on the total dose level (see Table II for radiation schedule). After the 30 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. All irradiated parts passed all electrical and functional tests up to and including the 2.5 krad level. At the 5 krad level, all irradiated samples except SN/58 exceeded the maximum specification limit of ± 20.00 nA for all four P_IIB and N_IIB tests, with readings ranging from -21.70 nA to -28.94 nA. In addition, All irradiated samples exceeded the maximum specification limit of ± 700 pA for IIOS@1.2V and IIOS@45V, with readings ranging from -793 pA to -1756 pA.

In addition, at the 5 krad level, S/N 53, 56, 57 and 60 fell below the minimum specification limit of -3.000 mV for VOS@+20 mA, with readings of -10.246 mV, and S/N 53, 54, 56, 57 and 60 fell below the minimum specification limit of 5.000 V/mV for AOL_20mA, with readings of 2.186 V/mV.

At the 10 krad level, the same parts continued to exceed the maximum specification limit for P_IIB and N_IIB, with readings ranging from -30.54 to -55.78 nA, and all irradiated parts continued to exceed the maximum specification limit for IIOS@1.2V and IIOS@45V, with readings ranging from -2111 to -4747 pA. In addition, all exceeded the maximum specification limit of 50.00 nA for both I_FB@45V and I_FB@1.2V, with readings ranging from 50.31 to 76.93 nA. All irradiated parts except S/N 58 fell below the minimum specification limit for VOS@+20mA, with readings -10.246 mV, S/N 53, 54, 56, 57 and 59 exceeded the maximum specification limit of 3.000 mV for VOS@--20mA, with readings ranging from 4.329 to 9.093 mV and all irradiated parts fell below the minimum specification limit of 5.000 V/mV for AOL_20mA, with readings of 2.186 B/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 15 krad level, all parts continued to exceed specification limits for the P_IIB, N_IIB, IIOS and I_FB tests, with readings two to four times larger ,and all partsexceeded specification limits for VOS@120mA and AOL_20mA,, with readings approximately at the same level as at the 10 krad level.. In addition, all irradiated parts except S/N 58 fell below the minimum specification limit of 8.00 V/mV for ASH_15mA, with readings 2.186 to 3.900 V/mV. At this irradiation level, reliable data could not be obtained for ASH_15mA for some samples.

At the 20 and 30 krad levels, all parts exceeded specification limits for the same parameters at slightly higher levels. Some parts also exceeded specification limits for some additional AOL and ASH tests.

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.

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TABLE I. Part Information

Generic Part Number:	LM10
HST/CAL Part Number:	5962-8760401GA
HST/CAL Control Number:	11117
Charge Number:	EI44554
Manufacturer:	Linear Technology Corp.
Lot Date Code:	9330C
Quantity Tested:	10
Serial Number of Control Samples:	51, 52
Serial Numbers of Radiation Samples:	53, 54, 55, 56, 57, 58, 59, 60
Part Function:	Op Amp and Voltage Reference
Part Technology:	Bipolar
Package Style:	8-pin Tox can
Test Equipment:	A540
Test Engineer:	T. Mondy

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

TABLE II. Radiation Schedule for LM10

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	09/14/94
2) 2.5 KRAD IRRADIATION (0.15 KRADS/HOUR)	10/04/94
POST-2.5 KRAD ELECTRICAL MEASUREMENT	10/05/94
3) 5 KRAD IRRADIATION (0.15 KRADS/HOUR)	10/05/94
POST-5 KRAD ELECTRICAL MEASUREMENT	10/06/94
4) 10 KRAD IRRADIATION (0.15 KRADS/HOUR)	10/06/94
POST-10 KRAD ELECTRICAL MEASUREMENT	10/07/94
5) 15 KRAD IRRADIATION (0.56 KRADS/HOUR)	10/07/94
POST-15 KRAD ELECTRICAL MEASUREMENT	10/11/94
6) 20 KRAD IRRADIATION (0.29 KRADS/HOUR)	10/11/94
POST-20 KRAD ELECTRICAL MEASUREMENT	10/12/94
7) 30 KRAD IRRADIATION (0.59 KRADS/HOUR)	10/12/94
POST-30 KRAD ELECTRICAL MEASUREMENT	10/13/94
8) 168-HOUR ANNEALING @25°C	10/14/94
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	10/21/94
9) 168-HOUR ANNEALING @100°C**	10/21/94
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	10/28/94

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	Initials mean	Initials sd	Total Dose Exposure (krads) 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	Annealing 168 hrs @25°C mean	Annealing 168 hrs @25°C sd	Annealing 168 hrs @100°C mean	Annealing 168 hrs @100°C sd
1	Is@1.2V	µA	0	400	236	9.0	233	9.0	233	9.0	232	9.0	226	8.0	226	8.0	223	7.0	225	7.0	230	8.0
2	Is@45V	µA	0	400	252	13	258	10	257	10	255	10	248	9.0	247	9.0	245	7.0	246	7.0	249	8.0
3	VOS@1.2V	mV	-2	2	0.25	.24	0.26	.24	0.33	.24	0.33	.26	0.43	.28	0.44	.28	0.77	.23	0.88	.24	1.25	.19
4	P_IIB@1.2V	nA	-20	20	-9.57	.92	-14.6	1.6	-20.0	3.0	-45.6	6.3	-90.0	15	-100	24	-200	12	-200	13	-200	18
5	N_IIB@1.2V	nA	-20	20	-9.46	.96	-10.0	1.6	-20.0	2.8	-40.0	5.6	-80.0	12	-100	19	-200	18	-200	20	-200	17
6	IIOS@1.2V	pA	-700	700	-114	107	-450	128	-1224	251	-3678	766	-12610	2836	-20000	4738	-4823	6594	-7897	7230	-3000	4.1
7	VOS@45V	mV	-2	2	0.12	.23	0.15	.23	0.17	.24	0.14	.25	0.18	.28	0.12	.30	0.12	.28	0.35	.29	0.89	.20
8	P_IIB@45V	nA	-20	20	-9.30	.92	-10.0	1.6	-20.0	3.0	-50.0	6.3	-90.0	15	-100	24	-196	11	-200	13	-200	18
9	N_IIB@45V	nA	-20	20	-9.18	.94	-10.0	1.6	-20.0	2.8	-40.0	5.6	-80.0	12	-100	19	-191	19	-200	20	-154	18
10	IIOS@45V	pA	-700	700	-113	104	-517	137	-1420	297	-3982	862	-14139	3194	-20000	5371	-5143	7535	-7955	8083	-30000	5299
11	VOS@+2mA	mV	-3	3	0.19	.24	0.22	.24	0.25	.24	0.23	.26	0.28	.28	0.22	.29	0.30	.26	0.46	.27	1.02	.18
12	VOS@-2mA	mV	-3	3	0.32	.24	0.37	.24	0.41	.24	0.45	.25	0.68	.25	1.20	.31	8.37	2.2	8.25	2.5	4.08	2.6
13	VOS@+20mA	mV	-3	3	0.08	.24	0.07	.24	-5.02	5.6	-8.96	3.6	-10.2	0	-10.2	0	-10.2	0	-10.2	0	10.2	0
14	VOS@-20mA	mV	-3	3	0.42	.24	0.48	.23	0.53	.23	5.33	4.2	9.09	0	9.09	0	9.09	0	9.08	0	9.08	.99
15	CMRR	dB	93	-	114	1.9	114	1.9	113	1.7	111	1.4	109	1.3	107	1.3	103	1.5	103	1.5	105	1.5
16	-PSRR	dB	90	-	122	12	119	6.2	117	4.9	114	2.9	890	2.0	108	1.9	103	4.1	103	3.2	108	2.8
17	+PSRR	dB	96	-	112	1.4	111	1.1	110	.87	108	.55	105	.76	103	1.2	98.1	2.8	97.9	2.3	101	1.9
18	AOL	V/mV	120	-	1686	248	1407	212	1320	207	989	184	573	146	345	139	62.2	.26	104	61	358	112
19	AOL_20mA	V/mV	5	-	7.56	.94	6.15	1.7	5.71	2.1	2.19	0	2.19	0	2.19	0	2.19	0	2.19	0	2.19	0
20	AOL_2mA	V/mV	1.5	-	5.82	.67	5.15	.61	4.84	.56	3.36	.52	1.86	.44	1.32	.19	1.24	.01	1.24	.01	1.23	.01
21	ASH_2mA	V/mV	14	-	48.9	5.5	45.0	4.5	40.0	3.8	30.4	3.4	17.6	3.3	10.2	3.4	/3		/3		8.10	2.1
22	ASH_.1mA	V/mV	14	-	62.5	7.1	57.5	6.1	51.2	5.0	42.2	3.9	29.8	3.5	22.3	3.7	10.3	3.7	11.0	3.6	19.8	4.0
23	ASH_15mA	V/mV	8	-	31.4	2.6	29.4	2.2	27.4	2.0	21.4	2.8	/3		/3		/3		/3		/3	
24	ASH_.1mA	V/mV	8	-	84.7	9.7	77.4	8.1	71.0	6.4	58.6	4.1	45.4	4.1	38.4	4.6	28.0	6.5	22.5	5.8	30.2	5.7
25	REF GAIN	V/mV	50	-	195	7.1	180	4.6	167	5.7	142	6.6	113	9.1	90.3	9.6	56.2	8.4	61.7	8.9	86.6	8.0
26	V_FB@35V,1mA	mV	195	205	199	.87	199	.78	199	.81	199	.85	199	.84	199	1.0	199	1.3	200	1.3	201	1.0
27	V_FB@0V,1mA	mV	195	205	199	.87	199	.78	199	.81	199	.85	199	.83	199	1.0	198	1.3	199	1.3	201	.99
28	V_FB@35V,0mA	mV	195	205	199	.87	199	.79	199	.81	199	.86	199	.84	199	1.0	199	1.4	199	1.3	201	1.0
29	V_FB@0V,0mA	mV	195	205	199	.87	199	.79	199	.81	199	.86	199	.83	199	1.0	198	1.4	199	1.3	201	.99
30	I_FB@45V	nA	-	50	13.9	1.3	21.5	2.2	35.9	3.9	64.9	7.5	117	15	164	22	196	.01	197	.01	193	8.7
31	I_FB@1.2V	nA	-	50	13.9	1.3	21.4	2.2	35.8	3.9	64.6	7.4	116	14	163	22	196	.01	196	.90	193	9.6
32	Line Reg.	dB	91	-	118	4.3	116	3.7	115	2.0	115	1.9	115	2.8	112	1.8	109	2.9	108	2.1	108	1.5
33	Load Reg. @ 1.2V	dB	60	-	77.8	5.9	79.0	6.1	78.6	5.7	74.7	4.8	68.4	2.8	67.5	2.6	62.1	2.8	62.8	2.5	69.2	3.7
34	Load Reg. @ 45V	dB	60	-	85.5	8	90.9	12	88.0	7.5	86.3	12	81.0	9.4	90.4	9.8	76.4	5.1	80.5	4.8	93.5	15
35	101 Delta Is	µA	-100	100	-16.0	10	-24.0	3.0	-24.0	3.0	-23.0	3.0	-22.0	2.0	-21.0	2.0	-22.0	1.0	-21.0	1.0	-20.0	1.0
36	102 Delta Is	µA	-60	60	-6.00	3.0	-4.00	3.0	-2.00	3.0	2.00	3.0	13.0	4.0	22.0	5.0	43.0	7.0	40.0	7.0	25.0	5.0

Notes:

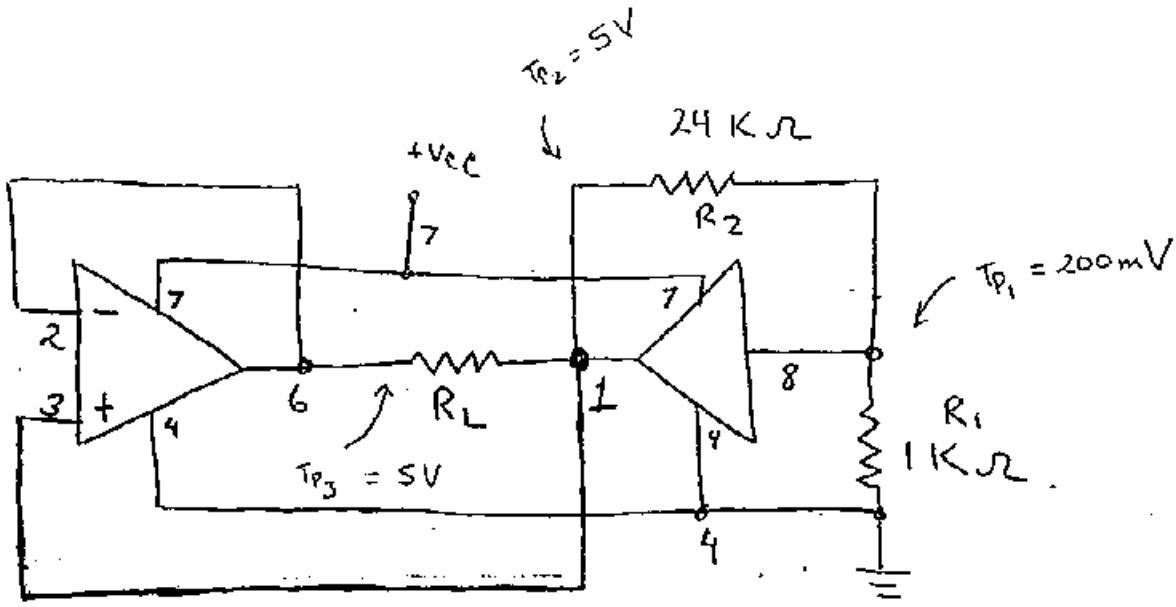
1/ The mean and standard deviation values were calculated over the eight parts irradiated in this testing. The control samples remained constant throughout the testing and are not included in this table.

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

3/ No reliable reading could be obtained at this point.

Radiation-sensitive parameters: P_IIB, N_IIB, IIOS, VOS, AOL and I_FB.

Figure 1. Radiation Bias Circuit for LM10



Bias Conditions:

V_{CC} = 10.0 VDC ± 0.05 VDC

R_L = 500 Ω, ½W

R_1 = 1 kΩ, ¼W

R_2 = 24 kΩ, ¼W