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DATE: October 10, 1997 PPM-97-043
TO: P. Huber/400
FROM: K. Sahu/300.1
SUBJECT: Radiation Report on: LM137
Project: GOES Sounder/Imager
Job #: M78297
Project part #: LM137

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A radiation evaluation was performed on LM137 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 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 10.0, 20.0, 30.0, 50.0, 75.0, 100.0, 150.0, and 200.0 kRads.* The dose rate was between 0.250 and 1.250 kRads/hour (0.069 to 0.347 Rads/s). After the 30.0 kRad irradiation, the parts were annealed for 48 hours at 25°C. After the 200.0 kRad exposure, the parts were annealed for 168 hours at 25°C. See Table II for the radiation schedule and effective dose rate calculation. The effective dose rate over all testing was 0.049Rads/sec. After each radiation exposure and annealing treatment, parts were electrically tested according to the test conditions and the specification limits** listed in Table III.

Initial electrical measurements were made on 10 samples. Eight samples (SN's 78, 85, 94, 103, 106, 114, 119, and 121) were used as radiation samples while SN's 72 and 76 were used as a control samples. All parts passed all tests during initial electrical measurements. Parts showed no significant degradation on exposure to 50kRads followed by 192 hours of annealing at 25°C. The table below provides a brief summary of radiation sensitive parameters after the 75 to 200kRad exposures and annealing steps. A detailed summary is provided following the table.

Summary Table of Radiation Sensitive Parameters

			Exposure/ Annealing Level				
Parameter	Units	Specification Limits	75.0 kRads	100 kRads + 264hr anneal	150 kRads	200 kRads	168hr anneal
IQ_-41.25V	mA	1.0 – 5.0	Pass	Pass	>9.8	>9.8	1.69 – 9.8
IADJ_-41.25	µA	25 – 100	Pass	Pass	167 – 274	245 – 333	195 – 285
Delta_IADJ_1	µA	-5.0 – 5.0	-17.7 – -40.5	-7.9 – -19.2	-117 – -122	-190 – -283	-140 – -241
V_Out_3	V	-1.275 – -1.225	-1.19 – -1.22	-1.20 – -1.22	-1.55 – -2.04	<-2.049	-1.30 – -1.91
V_Line1	mV	-9.0 – 9.0	9.3 – 20.5	1.7 – 20.5	<-20.5	<-20.5	<-51.2
V_Load2	mV	-12.0 – 12.0	13.2 – 16.9	18.6 – 20.0	<-20.5	<-20.5	-49.6 – -51.0
V_Out_4	V	-1.275 – -1.225	-1.20 – -1.51	-1.16 – -1.21	<-2.049	<-2.049	-1.85 – -2.64

Detailed Summary:

* 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. The manufacturer provided no post-irradiation limits at the time these tests were performed.

All parts passed all tests to 20.0 kRads. No significant degradation was noted in any parameter.

After the 30.0 kRad irradiation, all parts fell marginally below the specification limit of –5.00µA for Delta_IADJ_1 with readings in the range of –5.31 to –5.62µA. Several parts exceeded the specification limit of 12mV for V_Load2 with readings in the range of 13.0 to 47.7mV. SN's 78 and 94 marginally exceeded the specification limit of –1.225V for V_Out_4 with readings of -1.220 and –1.218V. **All parts passed all other tests.**

After the annealing the parts for 48 hours at 25°C, parts showed significant recovery. Most parts fell only marginally below the specification limit for Delta_IADJ_1 with readings in the range of –5.16 to –5.47µA. SN 94 marginally exceeded the specification limit for V_Out_4 with a reading of –1.223V. **All parts passed all other tests.**

After the 50.0 kRad irradiation, all parts fell below the specification limit for Delta_IADJ_1 with readings in the range of –7.66 to –12.5µA. SN's 78 marginally exceeded the specification limit of –1.225V for V_Out_3 with a reading of –1.222V. SN's 119 and 121 exceeded the specification limit of 9.0mV for V_Line1 with readings of 11.9 and 15.7mV. All parts exceeded the specification limit for V_Load2 with readings in the range of 16.2 to 19.4mV. All parts exceeded the specification limit for V_Out_4 with readings in the range of –1.219 to –1.179V. **All parts passed all other tests.**

After the annealing the parts for 192 hours at 25°C, parts showed some recovery. All parts continued to marginally exceed the specification limit for Delta_IADJ_1 with readings in the range of –5.31 to –5.62µA. Some parts continued to exceed the specification limit for V_Load2 with readings in the range of 12.2 to 14.0mV. Only SN's 78 and 94 marginally exceed the specification limit for V_Out_4 with readings of –1.221 and –1.219V. **All parts passed all other tests.**

After the 75.0 kRad irradiation, all parts fell below the specification limit for Delta_IADJ_1 with readings in the range of –17.7 to –40.5µA. Most parts marginally exceeded the specification limit for V_Out_3 with readings in the range of –1.223 to –1.186V. All parts exceeded the specification limit for V_Line1 with readings in the range of 9.3 to 20.5mV. Several parts exceeded the specification limit for V_Load2 with readings in the range of 13.2 to 16.9mV. All parts exceeded or fell below the specification limit for V_Out_4 with readings in the range of –1.509 to –1.200V. **All parts passed all other tests.**

After the 100.0 kRad irradiation and 264 hour annealing, the parts showed some recovery with the following results. All parts fell below the specification limit for Delta_IADJ_1 with readings in the range of –7.9 to –19.2µA. Four parts marginally exceeded the specification limit for V_Out_3 with readings in the range of –1.204 to –1.218V. Most parts exceeded the specification limit for V_Line1 with readings of 20.5mV. All parts exceeded the specification limit for V_Load2 with readings in the range of 18.6 to 20.0mV. All parts exceeded or fell below the specification limit for V_Out_4 with readings in the range of –1.160 to –1.205V. **All parts passed all other tests.**

After the 150.0 kRad irradiation, all parts exceeded the specification limit of 5.0mA for IQ_-41.25V with readings greater than 9.8mA. All parts exceeded the specification limit of 100µA for IADJ_-41.25V with readings in the range of 167 to 274µA. All parts continued to fall below the specification limit for Delta_IADJ_1 with readings in the range of –117 to –222µA. Two parts marginally exceeded the specification limit of –1.225V for V_Out_1 with readings of –1.216 and –1.222V. Four parts marginally exceeded the specification limit of –1.225V for V_Out_2 with readings in the range of –1.222 to –1.214V. All parts fell below the specification limit of –1.275V for V_Out_3 with readings in the range of –1.547 to –2.039V. All parts exceeded the specification limit for V_Line1 with readings greater than 20.5mV. All parts fell below the specification limit of –12.0V for V_Load2 with all parts reading less than –20.5V. All parts fell below the specification limit of –1.275V for V_Out_4 with readings less than –2.049V. All parts marginally exceeded the specification limit of –1.225V for V_Out_5 with readings in the range of –1.222 to –1.193V. **All parts passed all other tests.**

After the 200.0 kRad irradiation, all parts exceeded the specification limit for IQ_-41.25V with readings greater than 9.8mA. All parts exceeded the specification limit for IADJ_-41.25V with readings in the range of 245 to 333µA.

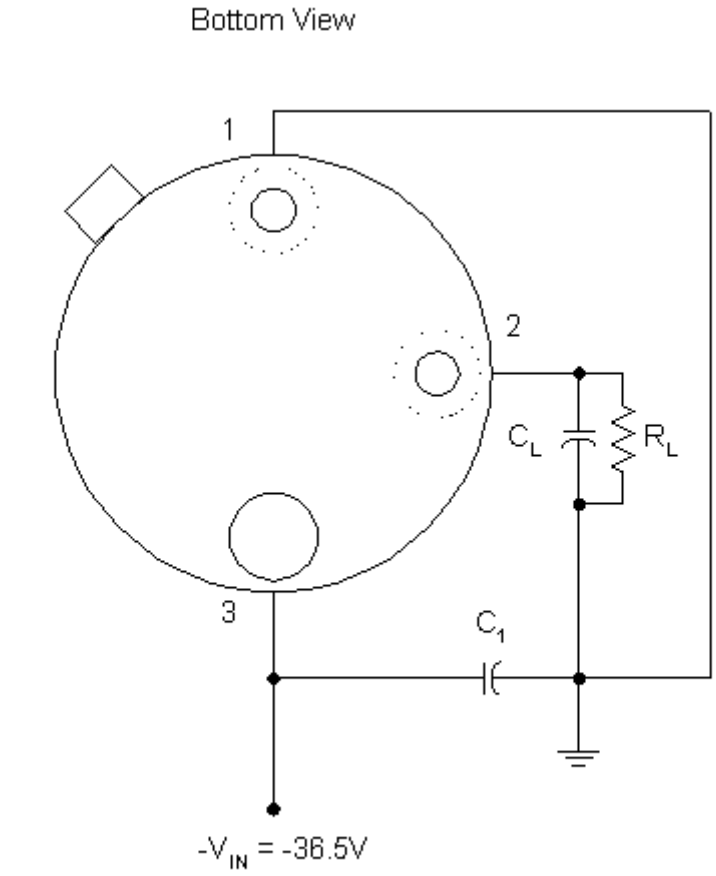
All parts fell below the specification limit for Delta_IADJ_1 with readings in the range of −190 to −283μA. Two parts marginally exceeded the specification limit for V_Out_1 with readings of −1.222 and −1.221V. Three parts marginally exceeded the specification limit for V_Out_2 with readings in the range of −1.224 to −1.220V. All parts fell below the specification limit for V_Out_3 with readings less than −2.049V. All parts fell below the specification limit for V_Line1 with readings less than −20.5mV. All parts fell below the specification limit for V_Load2 with readings less than −20.5V. All parts fell below the specification limit for V_Out_4 with readings less than −2.049V. All parts continued to marginally exceed the specification limit for V_Out_5 with readings in the range of −1.224 to −1.221V. **All parts passed all other tests.**

After annealing the parts for 168 hours at 25°C, parts showed modest recovery in IQ_-41.25V with three parts passing and slight recovery in V_Out_3 with all parts continuing to fail however. Only one part marginally exceeded the specification limit for V_Out_5. No significant recovery was noted in any other parameter. A modification of the test program revealed higher readings for several parameters. V_Line1 now has all parts reading less than −51.2mV, V_Load2 had readings in the range of −49.6 to −51.0mV, and V_Out_4 had readings in the range of −1.848 to −2.635V.

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 me at (301) 731-8954.

Figure 1. Radiation Bias Circuit for LM137



Notes:
1. Capacitors are 1µf, 50V and are only required if the parts oscillate.
2. R_L is 250Ω ± 5%, ½ W.

TABLE I. Part Information

Generic Part Number:	LM137
GOES Sounder/Imager Part Number	LM137
Charge Number:	M78297
Manufacturer:	National Semiconductor
Lot Date Code (LDC):	9328
Quantity Tested:	10
Serial Number of Control Sample:	72, 76
Serial Numbers of Radiation Samples:	78, 85, 94, 103, 106, 114, 119, and 121
Part Function:	Voltage Regulator
Part Technology:	Bipolar
Package Style:	TO-39
Test Equipment:	A540
Test Engineer:	D. Davis

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

TABLE II. Radiation Schedule for LM137

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	09/12/97
2) 10.0 KRAD IRRADIATION (0.250 KRADS/HOUR)	09/12/97
POST-10.0 KRAD ELECTRICAL MEASUREMENT	09/15/97
3) 20.0 KRAD IRRADIATION (0.250 KRADS/HOUR)	09/15/97
POST-20.0 KRAD ELECTRICAL MEASUREMENT	09/18/97
4) 30.0 KRAD IRRADIATION (0.250 KRADS/HOUR)	09/19/97
POST-30.0 KRAD ELECTRICAL MEASUREMENT	09/22/97
5) 48 HOUR ANNEALING @25°C	09/23/97
POST-48 HOUR ANNEAL ELECTRICAL MEASUREMENT	09/25/97
6) 50.0 KRAD IRRADIATION (0.250 KRADS/HOUR)	09/25/97
POST-50.0 KRAD ELECTRICAL MEASUREMENT	09/27/97
7) 192 HOUR ANNEALING @25°C	09/27/97
POST-192 HOUR ANNEAL ELECTRICAL MEASUREMENT	10/04/97
8) 75.0 KRAD IRRADIATION (0.625 KRADS/HOUR)	10/04/97
POST-75.0 KRAD ELECTRICAL MEASUREMENT	10/07/97
9) 100.0 KRAD IRRADIATION (0.625 KRADS/HOUR) + 264 HOUR ANNEALING @25°C	10/07/97
POST-100.0 KRAD + 264 HOUR ANNEAL ELECTRICAL MEASUREMENT	10/22/97
10) 150.0 KRAD IRRADIATION (1.250 KRADS/HOUR)	10/22/97
POST-150.0 KRAD ELECTRICAL MEASUREMENT	10/24/97
11) 200.0 KRAD IRRADIATION (1.250 KRADS/HOUR)	10/27/97
POST-200.0 KRAD ELECTRICAL MEASUREMENT	10/29/97
12) 168 HOUR ANNEALING @25°C	10/29/97
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	11/04/97

Effective Dose Rate = 200,000 RADS/47 DAYS=177.3 RADS/HOUR=0.049 RADS/SEC
The effective dose rate is lower than that of the individual radiation steps as it takes into account the interim-annealing step.

The interim annealing following the 30.0 and 50.0 kRad steps were added due to degradation in the parts. The addition of an interim annealing step better simulates the space environment's lower dose rate for very sensitive devices. This may allow the parts to show satisfactory performance at higher doses or indicate that the part can not be used beyond the previous dose level.

The annealing after the 100 kRad step was the result of test equipment repair.

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

Table III. Electrical Characteristics of LM137 /1

Test #	Parameter	Units	Test Conditions /2	Spec. min	Lim. max
1	IQ_-4.25V	mA		0.2	3.0
2	IQ_-14.25V	mA		0.2	3.0
3	IQ_-41.25	mA		1.0	5.0
4	IADJ_-4.25V	mA	I_L = 5mA	25	100
5	IADJ_-41.25V	mA	I_L = 5mA	25	100
6	Delta_IADJ_1	mA	I_L = 5mA	-5.0	5.0
7	V_Out_1	V	V_{IN} = -4.25V, I_L = 5mA	-1.275	-1.225
8	V_Out_2	V	V_{IN} = -41.25V, I_L = 5mA	-1.275	-1.225
9	V_Out_3	V	V_{IN} = -6.25V, I_L = 5mA	-1.275	-1.225
10	V_Line1	mV		-9.0	9.0
11	V_Load1	mV	V_{IN} = -6.25V, 5mA<I_L<400mA	-6.0	6.0
12	V_Load2	mV	V_{IN} = -4.25V, 5mA<I_L<400mA	-12.0	12.0
13	V_Out_4	V	V_{IN} = -41.25V, 5mA<I_L<400mA	-1.275	-1.225
14	V_Out_5	V	V_{IN} = -6.25V, 5mA<I_L<400mA	-1.275	-1.225

Note:

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

2/ -41.25V < V_{IN} < -4.25V unless otherwise noted.

TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for LM137H /1

					Total Dose Exposure (kRads)																						Annealing	
					Initial		10.0		20.0		30.0		72 hours @25°C		50.0		192 hours @25°C		75.0		100.0 + 264 hr Annealing /4		150.0		200.0		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	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1	IQ_-4.25V	mA	0.2	3.0	0.50	0.02	0.46	0.01	0.41	0.01	0.38	0.01	0.40	0.01	/5		0.38	0.01	/5		/5		0.38	0.01	0.41	0.01	0.43	0.02
2	IQ_-14.25V	mA	0.2	3.0	0.57	0.02	0.53	0.02	0.49	0.02	0.47	0.02	0.49	0.02	0.44	0.02	0.47	0.02	0.45	0.02	0.47	0.02	0.47	0.01	0.50	0.01	0.51	0.01
3	IQ_-41.25V	mA	1.0	5.0	1.71	0.06	1.67	0.06	1.64	0.06	1.60	0.06	1.58	0.06	1.58	0.06	1.60	0.06	1.59	0.05	1.59	0.06	>9.8		>9.8		3P/5F	
4	IADJ_-4.25V	mA	25	100	62.4	2.2	59.7	2.0	56.7	2.8	53.2	2.0	54.5	2.0	50.4	2.0	51.9	1.9	48.9	1.5	52.1	1.5	52.1	1.1	55.8	1.4	55.0	1.7
5	IADJ_-41.25V	mA	25	100	66.6	2.4	64.2	2.0	61.2	2.5	58.8	2.1	59.7	2.0	60.5	1.1	57.5	2.0	78.2	6.9	65.0	3.0	233.5	42.2	305.5	33.1	243.5	37.5
6	Delta_IADJ_1	mA	-5.0	5.0	-4.2	0.2	-4.5	0.2	-4.6	0.5	-5.4	0.1	-5.2	0.1	-10.1	1.8	-5.5	0.2	-29.3	7.7	-13.5	4.1	-181.5	42.2	-245.9	33.9	-188.4	38.2
7	V_Out_1	V	-1.275	-1.225	-1.254	0.004	-1.251	0.006	-1.249	0.006	-1.252	0.006	-1.250	0.006	-1.245	0.006	-1.244	0.006	-1.241	0.006	-1.245	0.006	-1.226	0.005	-1.230	0.007	-1.234	0.007
8	V_Out_2	V	-1.275	-1.225	-1.254	0.005	-1.251	0.006	-1.246	0.006	-1.252	0.006	-1.250	0.006	-1.245	0.006	-1.244	0.006	-1.242	0.006	-1.245	0.006	-1.224	0.005	-1.228	0.007	-1.234	0.007
9	V_Out_3	V	-1.275	-1.225	-1.255	0.005	-1.253	0.005	-1.250	0.006	-1.253	0.006	-1.251	0.006	-1.239	0.008	-1.247	0.006	-1.211	0.014	-1.224	0.014	-1.845	0.227	<-2.049		-1.619	0.238
10	V_Line1 /6 /7	mV	-9.0	9.0	-1.77	0.09	-2.09	0.19	-2.78	0.20	-2.64	0.57	-2.76	0.41	-7.40	6.4	-3.30	0.50	18.3	3.7	14.7	7.6	<-20.5		<-20.5		<-51.2	/7
11	V_Load1	mV	-6.0	6.0	3.35	0.14	3.35	0.16	3.45	0.13	3.4	0.21	3.6	0.2	3.4	0.2	3.4	0.2	3.6	0.2	3.7	0.2	4.1	0.4	4.1	0.2	4.2	0.6
12	V_Load2 /7	mV	-12.0	12.0	9.18	0.66	9.32	0.66	9.90	0.68	11.9	1.6	11.2	1.3	18.2	1.3	11.7	1.2	10.3	5.5	19.6	0.4	<-20.5		<-20.5		-50.3	0.5
13	V_Out_4 /7	V	-1.275	-1.225	-1.242	0.005	-1.241	0.006	-1.240	0.007	-1.238	0.008	-1.231	0.008	-1.202	0.014	-1.203	0.077	-1.315	0.105	-1.184	0.016	<-2.049		<-2.049		-2.300	0.329
14	V_Out_5	V	-1.275	-1.225	-1.254	0.005	-1.251	0.006	-1.248	0.007	-1.248	0.007	-1.248	0.007	-1.245	0.005	-1.241	0.007	-1.237	0.007	-1.241	0.007	-1.205	0.007	-1.211	0.008	-1.234	0.008

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/ "P" ("F") indicates that all parts passed (failed) this test at this irradiation level or annealing step. "nPmF" means that n parts passed and m parts failed this test at this irradiation level or annealing step. The failing parts had degraded so much that no measurements could be made for these parameters.

4/ Measurements were not possible immediately after the 100 kRad irradiation due to a repair of the test equipment. The parts remained under bias until measurements were possible.

5/ No reliable readings were taken for this test at this level.

6/ The readings at 75 and 100 kRads may not be reliable, the sign change does not follow the pattern of degradation for these parts.

7/ The test program was modified after the 200kRad step in an attempt to achieve reliable readings. The new readings after the final annealing are indicitive of the actual value for this parameter.

Radiation sensitive parameters: IQ_-41.25V, Delta_IADJ_1, V_Out_1, V_Out_2, V_Out_3, V_Line1, V_Load2, V_Out_4, V_Out_5.