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PPM-94-013

DATE: July 18 1994
TO: J. Lohr/311
FROM: K. Sahu/300.1
SUBJECT: Radiation Report on CASSINI/INMS
Part No. LM139
Control No. 11023

cc: G. Kramer/311.0
R. Katz/743.0
Library/300.1

A radiation evaluation was performed on LM139 (Quad Voltage Comparator) 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 V and Figure 1.

The total dose testing was performed using a cobalt-60 gamma ray source. During the radiation testing, ten parts were irradiated under bias (see Table V for bias configuration), ten parts were irradiated unbiased and three parts were used as control samples. The total dose radiation levels were 5, 10, 15, 20, 30, 50, 75 and 100 krads*. The dose rates were between 0.24 and 1.25 krads/hour (see Table II for radiation schedule). After the 15 krad irradiation, the parts annealed for 140 hours at 25°C, after which they were irradiated to the 20 krad level. After the 100 krad irradiation, the parts were annealed for 168 hours at 25°C, after which the parts were annealed for 168 hours at 100°C. After each radiation exposure and annealing step, the 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 the 10 krad level. After the 15 krad irradiation, two parts (S/N 954 and 956) from the unbiased group exceeded the maximum specification limit of -100 nA for P_IIB_5V, N_IIB_5V, P_IIB_30V and N_IIB_30V in at least one section, and one part (S/N 957) from the unbiased group exceeded the maximum specification limit for P_IIB_30V and N_IIB_30V in at least one section. In the biased group, one part (S/N 968) exceeded the maximum specification limit of -100 nA for P_IIB_5V, N_IIB_5V, P_IIB_30V and N_IIB_30V in at least one section, one part (S/N 967) exceeded the maximum specification limit for P_IIB_30V and N_IIB_30V in at least one section, two parts (S/N 966 and 969) exceeded the maximum specification limit for P_IIB_30V in at least one section and one part (S/N 975) exceeded the maximum specification limit for N_IIB_30V in at least one section. Readings ranged from -101 to -137 nA.

After the 15 krad irradiation, the parts were held under bias at room temperature (25°C) for 140 hours, due to difficulties with test equipment. After this annealing, six parts from the unbiased group (S/N 954, 956, 957, 958, 960 and 961) exceeded the maximum specification limits for P_IIB_5V, N_IIB_5V, P_IIB_30V and N_IIB_30V, with readings ranging from -100.15 to -135 nA. S/N 965 in the unbiased group exceeded the maximum specification limit for P_IIB_30V, with a maximum reading of -104.55 nA. In the biased group, nine parts (S/N 966, 967, 968, 969, 971, 972, 973, 974 and 975) exceeded the maximum specification limits for P_IIB_5V, N_IIB_5V, P_IIB_30V and N_IIB_30V, with readings ranging from -100.14 to -144 nA and one part (S/N 970) exceeded the maximum specification limit for P_IIB_30V, with a maximum reading of -104.3 nA.

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

After the 20 krad irradiation, all 20 irradiated parts exceeded the maximum specification limits for P_IIB_5V, N_IIB_5V, P_IIB_30V and N_IIB_30V, with readings ranging from -104 to -198 nA. After the 30 krad irradiation, the same failures continued, with readings ranging from -152 to -298 nA. In addition, one part in the unbiased group (S/N 956) exceeded the maximum specification limit of 25 nA for IIOS_5V and IIOS_30V, with readings of 26.24 and 29.34 nA, respectively.

After the 50 krad irradiation, the P_IIB and N_IIB failures continued, with readings ranging from -255 to -557 nA. In the unbiased group, nine parts (S/N 954, 956, 958, 959, 960, 961, 963, 964 and 965) exceeded the maximum specification limit for IIOS_5V and IIOS_30V, with readings ranging from -29.46 to 45.72 nA. In the biased group, five parts (S/N 966, 967, 968, 969, and 975) exceeded the maximum specification limit for IIOS_5V and IIOS_30V, with readings ranging from 26.11 to 36.56 nA and one part (S/N 973) exceeded the maximum specification limit for IIOS_30V, with a maximum reading of 27.68 nA. In addition, after the 50 krad irradiation, eight parts in the unbiased group (S/N 954, 956, 957, 958, 960, 961, 963 and 965) fell below the lower specification limit of 50 V/mV for AOL, with readings ranging from 41.10 to 48.47 and six parts (S/N 954, 956, 957, 960, 961 and 965) fell below the lower specification limit of 6.00 mA for I_SINK, with readings ranging from 5.48 to 5.96 mA.

After the 50 krad irradiation, five parts from the unbiased group and five parts from the biased group were removed from further testing. The statistical data in Table IV for the 75 krad irradiation step and all subsequent steps are therefore for five samples instead of ten.

After the 75 krad irradiation, the P_IIB and N_IIB failures continued, with readings ranging from -413 to -804 nA. All irradiated parts exceeded the maximum specification limit for IIOS_5V and IIOS_30V, with readings ranging from 29.30 to 61.53 nA. All five parts in the unbiased group fell below the minimum specification limit for AOL, with readings rangiang from 24.87 to 37.91 V/mV and four parts (S/N 972, 973, 974 and 975) in the biased group fell below the minimum specification limit for AOL, with readings rangiang from 42.83 to 46.00 V/mV. All five parts in the unbiased group fell below the minimum specification limit for I_SINK, with readings ranging from 3.82 to 4.72 mA and four parts (S/N 972, 973, 974 and 975) in the biased group fell below the minimum specification limit for I_SINK, with readings ranging from 5.63 to 6.00 mA. Four parts (S/N 960, 961, 962 and 965) in the unbiased group also exceeded the maximum specification limit of 400 mV for V_SAT, with readings beyond the measuring capability of the test equipment.

After the 100 krad irradiation, all but one part (S/N 971) failed all of the above tests. S/N 971 passed V_SAT. The ranges of readings were as follows: P_IIB and N_IIB: -634 to -1033 nA, IIOS_5V and IIOS_30V: 28.30 to 79.12 nA, AOL: 15.31 to 38.04 V/mV, I_SINK: 2.91 to 4.89 mA and V_SAT: 954.5 to 955.6 mV (some V_SAT readings were beyond the capability of the test equipment).

After annealing for 168 hours at 25°C, all irradiated parts continued to fail all of the above tests, with the exception that all five parts in the biased group passed V_SAT and S/N 974 passed IIOS_5V. The ranges of readings were as follows: P_IIB and N_IIB: -589 to -1044 nA, IIOS_5V and IIOS_30V: 26.23 to 60.82 nA, AOL: 14.12 to 40.63 V/mV, I_SINK: 2.68 to 5.42 mA. All V_SAT readings were beyond the capability of the test equipment. In most cases, failures were more frequent and worse in the unbiased group, as opposed to the biased group, and readings for P_IIB and N_IIB tended to be greater after room-temperature annealing.

After annealing for 168 hours at 100°C, no rebound effects were observed. Table IV provides 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:	LM139
CASSINI/INMS Part Number:	LM139
CASSINI/INMS Control Number:	8990
Charge Number:	C44429
Manufacturer:	National
Lot Date Code:	unknown
Quantity Tested:	23
Serial Numbers of Control Samples:	951, 952, 953
Serial Numbers of Radiation Samples:**	
Unbiased (Initial - 50 krads):	954, 956, 957, 958, 959, 960, 961, 963, 964, 965
Biased (Initial - 50 krads):	966, 967, 968, 969, 970, 971, 972, 973, 974, 975
Unbiased (75 krads - 100°C Anneal):	960, 961, 963, 964, 965
Biased (75 krads - 100°C Anneal):	971, 972, 973, 974, 975
Part Function:	Quad Voltage Comparator
Part Technology:	Bipolar
Package Style:	14-pin DIP
Test Equipment:	A540
Test Engineer:	C. Nguyen

* No radiation tolerance/hardness was guaranteed by the manufacturer for this part.
** After the 50 krad irradiation, five (5) samples from both the unbiased and biased groups were shipped to the requestor.

TABLE II. Radiation Schedule for LM139

EVENTS	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	05/25/94
2) 5 KRAD IRRADIATION (0.24 KRADS/HOUR)	05/31/94
POST-5 KRAD ELECTRICAL MEASUREMENTS	06/01/94
3) 10 KRAD IRRADIATION (0.24 KRADS/HOUR)	06/01/94
POST-10 KRAD ELECTRICAL MEASUREMENTS	06/06/94
4) 15 KRAD IRRADIATION (0.27 KRADS/HOUR)	06/06/94
POST-15 KRAD ELECTRICAL MEASUREMENTS	06/07/94
5) 140-HOUR ANNEALING @25°C	06/08/94
POST-48 HOUR ANNEAL ELECTRICAL MEASUREMENTS	06/13/94
6) 20 KRAD IRRADIATION (0.25 KRADS/HOUR)	06/13/94
POST-20 KRAD ELECTRICAL MEASUREMENTS	06/14/94
7) 30 KRAD IRRADIATION (0.25 KRADS/HOUR)	06/14/94
POST-30 KRAD ELECTRICAL MEASUREMENTS	06/15/94
8) 50 KRAD IRRADIATION (0.45 KRADS/HOUR)	06/15/94
POST-50 KRAD ELECTRICAL MEASUREMENTS	06/17/94
9) 75 KRAD IRRADIATION (0.36 KRADS/HOUR)	06/17/94
POST-75 KRAD ELECTRICAL MEASUREMENTS	06/20/94
10) 100 KRAD IRRADIATION (1.25 KRADS/HOUR)	06/20/94
POST-100 KRAD ELECTRICAL MEASUREMENTS	06/21/94
11) 168-HOUR ANNEALING @25°C	06/21/94
POST-336 HOUR ANNEAL ELECTRICAL MEASUREMENTS	06/28/94
8) 168-HOUR ANNEALING @100°C*	06/28/94
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENTS	07/05/94

*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-8830, Method 1019, Para. 3.10.1.

Table III. Electrical Characteristics of LM139

Unless Otherwise Specified: T_A =25°C

TEST NAME	SYMBOL	CONDITIONS	LIMITS	
			MIN	MAX
		SUPPLY CURRENT		
5V	Icc	+Vcc = 5V, V_{OUT} = 0V	0.000mA	3.000mA
30V	Icc	+Vcc = 30V, V_{OUT} = 0V	0.000mA	3.000mA
		INPUT OFFSET TESTS		
VOS_5V	V_{IO}	+Vcc = 5V, V_{OUT} = 1.4V	-5.00mV	5.00mV
VOS_30V	V_{IO}	+Vcc = 30V, V_{OUT} = 15V (Note: 1)	-5.00mV	5.00mV
PSRR	PSRR	+Vcc = (5V, 30V), V_{OUT} = 1.4V	70dB	
P_IIB_5V	$+I_{IB}$	+Vcc = 5V, V_{OUT} = 1.4V (Note: 1)	-100.00nA	-1.000nA
N_IIB_5V	$-I_{IB}$	+Vcc = 5V, V_{OUT} = 1.4V (Note: 1)	-100.00nA	-1.000nA
IIOS_5V	I_{IO}	+Vcc = 5V, V_{OUT} = 1.4V (Note: 1)	-25.00nA	25.00nA
P_IIB_30V	$+I_{IB}$	+Vcc = 30V, V_{OUT} = 15V (Note: 1)	-100.00nA	-1.000nA
N_IIB_30V	$-I_{IB}$	+Vcc = 30V, V_{OUT} = 15V (Note: 1)	-100.00nA	-1.000nA
IIOS_30V	I_{IO}	+Vcc = 30V, V_{OUT} = 15V (Note: 1)	-25.00nA	25.00nA
AOL		+Vcc = 5V, V_{OUT} = (11V, 1V)	50 V/mV	
I_SINK		+Vcc = 5V, V_{OUT} = 1.5V (Note: 2)	6.00mA	
V_SAT		+Vcc = 5V, I_{OUT} = 4.0mA (Note: 2)		400.0mV
I_LEAK		+Vcc = 30V, V_{OUT} = 30V		0.500uA

TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for LM139 (Unbiased) /1

Parameters /2		Spec. Lim. /3 min	max	Initial mean	sd	TDE 5 krads mean	sd	10 krads mean	sd	15 krads mean	sd	Annealing 140 hrs @25°C mean	sd	TDE 20 krads mean	sd	30 krads mean	sd	50 krads/4 mean	sd	75 krads mean	sd	100 krads mean	sd	Annealing 168 hrs @25°C mean	sd	168 hrs @100°C mean	sd
Icc_5V	mA	0	3.0	0.69	.01	0.66	.01	0.61	.01	0.58	.01	0.57	.01	0.64	.01	0.55	.01	0.44	.01	0.46	.01	0.39	.01	0.37	.01	0.38	.01
Icc_30V	mA	0	3.0	0.82	.02	0.71	.02	0.73	.02	0.69	.02	0.58	.02	0.65	.02	0.61	.02	0.53	.02	0.49	.02	0.42	.02	0.40	.02	0.45	.02
VOS_5V	mV	-5.0	5.0	0.67	.45	2.62	.47	0.94	.51	2.12	.53	1.11	.53	1.24	.52	1.14	.53	2.79	.59	2.01	.61	2.56	.72	2.46	.70	1.68	.67
VOS_30V	mV	-5.0	5.0	0.70	.49	2.66	.51	2.87	.54	2.43	.59	1.13	.58	1.30	.58	1.43	.58	2.49	.60	1.99	.69	2.82	.72	2.59	.71	1.40	.71
PSRR	dB	70		114.4	7.1	122	18	114	4.3	115	5.0	114	4.9	116	10	115	11	112	7.1	106	7.0	56.0	1.4	61.2	1.2	53.9	1.1
P_IIB_5V	nA	-100	-1.0	-13.9	.24	-31.0	2.4	-61.0	7.3	-87.7	12	-97.6	14	-125	21	-244	31	-556	61	-502	51	-668	47	-492	42	-533	16
N_IIB_5V	nA	-100	-1.0	-14.0	.29	-32.7	2.5	-65.5	7.5	-88.6	12	-98.1	15	-130	22	-279	39	-379	67	-357	49	-720	43	-737	38	-568	17
IIOS_5V	nA	-25	25	0.73	1.3	1.55	.50	2.57	1.0	4.95	1.9	4.47	1.9	3.51	2.9	14.8	5.3	29.4	6.0	16.6	3.6	51.8	47	45.0	3.6	14.5	1.7
P_IIB_30V	nA	-100	-1.0	-14.9	1.5	-34.4	4.0	-63.0	7.7	-93.5	13	-93.6	15	-137	23	-263	44	-398	69	-585	65	-790	60	-821	54	-617	19
N_IIB_30V	nA	-100	-1.0	-14.6	.29	-33.9	2.6	-56.7	7.9	-94.1	13	-105	16	-140	24	-276	33	-433	72	-581	45	-866	54	-885	49	-678	20
IIOS_30V	nA	-25	25	0.31	.17	1.88	.57	3.69	1.0	5.36	2.0	3.06	2.0	8.89	3.1	17.0	5.7	31.2	6.8	41.1	11	66.0	5.4	56.4	3	24.7	2.3
AOL	V/mV	50		2406	1285	902	400	306	34	278	17	223	15	182	19	107	9.5	56.9	5.5	29.3	3.2	17.9	2.2	16.4	1.9	52.9	4.0
I_SINK	mA	6.0		14.3	.63	13.1	.57	12.3	.53	10.9	.51	11.4	.51	5.50	.50	8.34	.48	4.39	.43	4.24	.35	5.24	.20	2.59	.26	5.23	.34
V_SAT	mV		400	208	3.5	215	3.6	222	3.6	225	3.8	221	4.0	239	4.3	245	5.1	268	8.0	402	365	133	0	183	0	398	13
I_LEAK	µA		0.5	0.05	0	0.20	.04	0.28	0	0.22	.02	0.09	.03	0	0	0.39	.03	.052	0	.126	.01	.552	0	0	0	0	0

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

2/ Values for all parameters except Icc_5V and Icc_30V are given only for section 3, which was usually the worst case. Values for other sections are available on request. Mean and standard deviation values for VOS and IIOS are computed from absolute values.

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

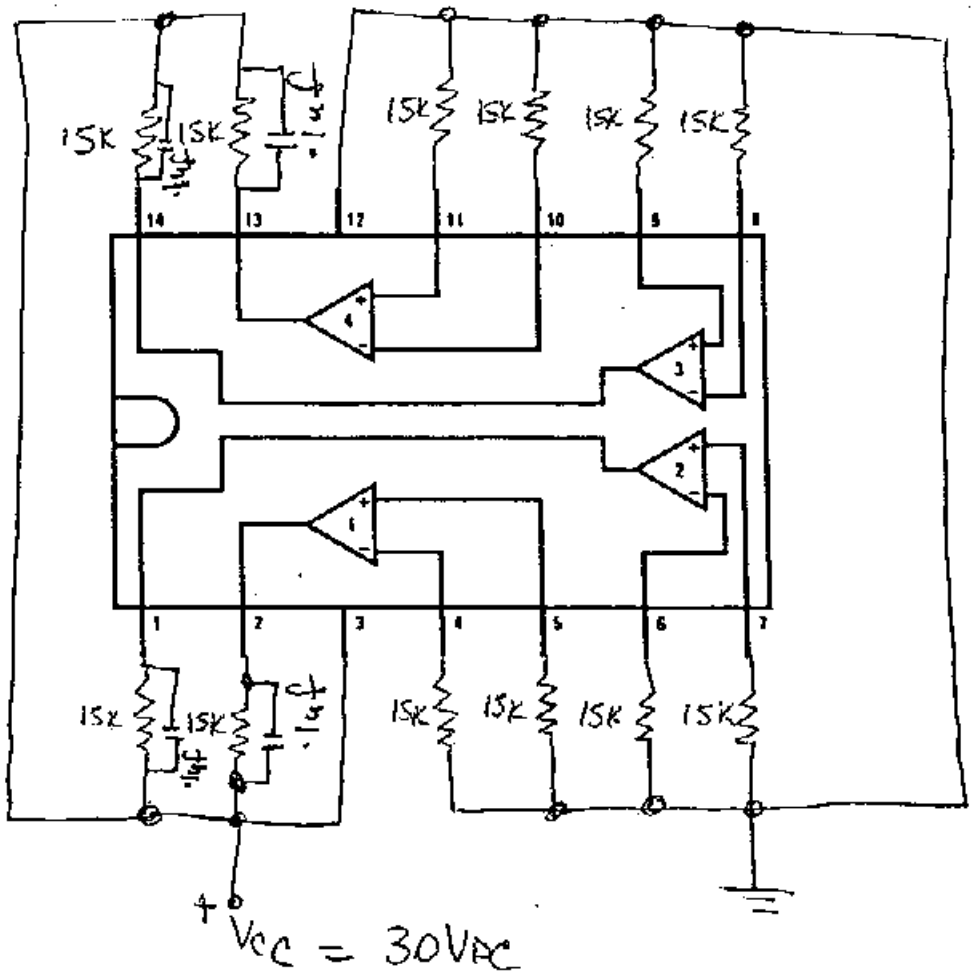
4/ After the 50 Krad(Si) irradiation, half (5) of each of the unbiased and unbiased parts were removed from testing. Therefore, for the 75 Krad(Si) and 100 Krad(Si) irradiations and the subsequent annealing steps, statistical data are for only five (5) samples.
Radiation-sensitive parameters were: P_IIB, N_IIB, IIOS, AOL, I_SINK and V_SAT.

TABLE IV (cont'd.): Summary of Electrical Measurements after Total Dose Exposures and Annealing for LM139 (Biased) /1

Parameters /2		Spec. Lim. /3 min	Spec. Lim. /3 max	Initial mean	Initial sd	TDE 5 krads mean	5 krads sd	TDE 10 krads mean	10 krads sd	TDE 15 krads mean	15 krads sd	Annealing 143 hrs @25°C mean	143 hrs sd	TDE 20 krads mean	20 krads sd	TDE 30 krads mean	30 krads sd	TDE 50 krads/4 mean	50 krads/4 sd	75 krads mean	75 krads sd	100 krads mean	100 krads sd	Annealing 168 hrs @25°C mean	168 hrs @25°C sd	168 hrs @100°C mean	168 hrs @100°C sd
Icc_5V	mA	0	3.0	0.69	.02	0.65	.02	0.62	.01	0.60	.01	0.59	.01	[illegible]	.01	[illegible]	.01	0.48	.01	0.43	.02	0.37	.02	0.39	.01	0.43	.01
Icc_30V	mA	0	3.0	0.82	.03	0.77	.03	0.74	.02	0.72	.02	0.70	.02	[illegible]	.02	0.65	.02	0.50	.02	0.51	.03	0.45	.03	0.49	.02	0.55	.02
VOS_5V	mV	-5.0	5.0	0.69	.49	0.81	.49	0.91	.51	0.98	.54	0.97	.55	1.04	.57	1.12	.48	1.85	.35	2.02	.31	2.48	.29	1.95	.26	0.84	.27
VOS_30V	mV	-5.0	5.0	0.70	.54	0.81	.52	0.90	.53	0.98	.56	0.97	.57	1.02	.58	1.25	.50	2.02	.47	2.35	.30	2.44	.26	1.86	.23	0.72	.27
PSRR	dB	70		123	14	126	7.2	119	6.5	119	6.9	112	9.0	112	9.6	112	9.8	110	9.0	102	7.5	85.1	2.8	95.9	2.0	101	1.4
P_IIB_5V	nA	-100	-1.0	-15	1.5	-33.3	3.7	-68.2	7.2	-90.9	11	-193	11	-125	15	-211	21	-294	35	-517	28	-715	17	-606	12	-412	2.9
N_IIB_5V	nA	-100	-1.0	-13.9	.37	-34.2	3.3	-69.9	6.9	-91.4	10	-195	11	-111	14	-224	27	-317	25	-529	28	-752	.20	-633	14	-419	3.5
IIOS_5V	nA	-25	25	0.27	.15	4.75	9.6	1.92	.82	3.80	1.1	3.16	1.3	5.31	1.4	10.3	1.9	21.2	2.6	27.8	5.2	47.9	7.8	25.3	5.7	7.21	3.1
P_IIB_30V	nA	-100	-1.0	-14.3	.26	-32.9	2.6	-71.2	7.9	-95.3	12	-198	12	-122	17	-227	21	-314	42	-540	37	-824	20	-595	13	-459	2.9
N_IIB_30V	nA	-100	-1.0	-14.3	.40	-35.4	3.5	-75.1	7.5	-99.6	12	-211	12	-139	16	-251	18	-347	41	-609	35	-851	25	-725	16	-467	3.3
IIOS_30V	nA	-25	25	0.65	1.3	3.44	.48	2.11	.82	3.35	1.1	3.59	1.3	5.94	1.4	10.0	1.5	24.5	2.9	7.62	15	56.6	6.9	33.8	6.1	7.76	3.3
AOL	V/mV	50		1547	1055	2789	2700	401	56	344	35	324	50	252	33	135	25	95.2	12	53.6	8.4	26.3	4.4	33.7	4.4	93.3	9.0
I_SINK	mA	6.0		14.3	.40	13.5	.41	12.5	.42	11.5	.41	11.3	.42	10.6	.41	9.43	.41	7.2	.40	6.30	.41	4.23	.35	4.84	.33	7.56	.34
V_SAT	mV		400	209	2.0	212	2.2	214	2.4	221	2.5	224	2.6	223	2.8	235	4.1	218	5.5	252	7.2	659	323	299	15	245	4.3
I_LEAK	µA		0.5	-0.99	.02	-0.01	.03	0.21	0	0.21	0	-0.06	0	0	0	-0.00	0	.092	0	.112	0	.072	0	0	0	-0.10	0

1/ The mean and standard deviation values were calculated over the ten parts irradiated in this testing. The control samples remained constant throughout the testing and is not included in this table.
2/ Values for all parameters except Icc_5V and Icc_30V are given only for section 3, which was usually the worst case. Values for other sections are available on request.
Mean and standard deviation values for VOS and IIOS are computed from absolute values.
3/ These are manufacturers' non-irradiated data sheet specification limits. No post-irradiation limits were provided by the manufacturer at the time the tests were performed.
4/ After the 50 Krad(Si) irradiation, half (5) of each of the unbiased and unbiased parts were removed from testing. Therefore, for the 75 Krad(Si) and 100 Krad(Si) irradiations and the subsequent annealing steps, statistical data are for only five (5) samples.
Radiation-sensitive parameters were: P_IIB, N_IIB, IIOS, AOL, I_SINK and V_SAT.

Table V. Radiation Bias Circuit for LM139



Conditions:

Vcc = 30.0V+0.5VDC
R = 15kOhms, 1/2W
Ta = 25°C