Unisys

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SUBJECT: Radiation Report on **MN5295 (Micro Networks) (LDC 9540 & LDC 9549)**
PROJECT: Ball Aerospace (GOES)

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A radiation evaluation was performed on **MN5295 16-Bit Analog to Digital Converter (Micro Networks)** to determine the total dose tolerance of these parts. The total dose testing was performed using a Co^{60} gamma ray source. During the radiation testing, ten 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 5.0, 10.0, 15.0, 20.0, 25.0, and 35.0kRads.[1] The dose rate was 0.069 kRads/hour (0.019 Rads/s). See Table II for the radiation schedule and effective dose rate calculation. After the 25.0kRad irradiation, the parts were annealed at 25°C for 96 and 264 hours under bias. After the 35kRad irradiation, the parts were annealed at 25°C for 168 hours and at 100°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.

It was noted during the development of the test program for these parts that they were very sensitive to the minimal noise generated by the A540 ATE. These noise problems were significant for Missing Codes and Integral Linearity (INL). These noise problems resulted in ATE driver oscillations, which appeared as noise to the device inputs. In testing the devices, it was observed that these devices were affected by this noise, which sometimes falsely indicated one or two random missing codes. Also, the INL measurements for most parts ranged from 0.5-1.5lsb against the specification limit of 0.5 lsb by the manufacturer. These higher INL values were again attributed to the noise oscillations in the ATE, which could not be further minimized. Because of this limitation of the ATE, the specification limit for INL was increased to 1 lsb so that the tester would not flag these parts as failing.

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.

All parts passed the Missing Codes test (i.e. showing 0 Missing Codes) up to 15kRads and showed very marginal degradation in INL and DNL. After the 20kRad irradiation, one part had a Missing Code and following the 25kRad irradiation, several parts had Missing Codes. Most parts showed significant degradation in INL and DNL. The parts showed significant recovery in Missing Codes, INL and DNL after annealing under bias at 25°C for 246 hours.

After the 35kRad irradiation, several parts showed a significant increase in Missing Codes and significant degradation INL, DNL, Voh, and Vol. Several parts also showed minor degradation in Idd, start_conv_Iih, and short_cyc_Iih. After annealing the parts under bias at 25°C for 96 and 168 hours, all parts showed significant recovery in all radiation sensitive parameters with only two parts having Missing Codes and the readings for INL and DNL significantly decreased. After annealing the parts under bias at 100°C for 96 and 168 hours, the parts showed no rebound effects.

Initial electrical measurements were made on 11 samples. Ten samples (SN's 58, 59, 60, 61, 66 (LDC9540) and 57, 62, 63, 64, 65 (LDC9549)) were used as radiation samples while SN 56 (LDC9549) was used as a control sample.

[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.

All parts passed all tests during initial electrical measurements (except for one part marginally exceeding the specification limit for INL).

After the 5.0kRad irradiation, four parts exceeded the specification limit of 1.00lsb for INL with readings in the range of 1.06 to 1.29lsb. **All parts passed all other tests.**

After the 10.0kRad irradiation, four parts exceeded the specification limit for INL with readings in the range of 1.01 to 1.18lsb. **All parts passed all other tests.**

After the 15.0kRad irradiation, eight parts exceeded the specification limit for INL with readings in the range of 1.03 to 1.27lsb. **All parts passed all other tests.**

After the 20.0kRad irradiation, one part had a Missing Code. Five parts exceeded the specification limit for INL with readings in the range of 1.06 to 1.22lsb. Four parts exceeded the specification limit of 1.00lsb for DNL with readings in the range of 1.01 to 1.38lsb. **All parts passed all other tests.**

After the 25.0kRad irradiation, four parts had one missing code and one part had two missing codes. Five parts exceeded the specification limit for INL with readings in the range of 1.12 to 2.53lsb. Four parts exceeded the specification limit for DNL with readings in the range of 1.19 to 2.01lsb. **All parts passed all other tests.**

After annealing the parts for 96 and 264 hours at 25°C, all parts showed modest recovery in all radiation sensitive parameters. Two parts had two missing codes, the readings for INL were in the range of 1.01 to 2.50lsb and readings for DNL were in the range of 1.07 to 2.07lsb.

After the 35.0kRad irradiation, two parts had two missing codes, one part had thirteen missing codes and one part had 147 missing codes. All parts exceeded the specification limit for INL with readings in the range of 1.05 to 19.68lsb. All parts exceeded the specification limit for DNL with readings in the range of 1.13 to 14.21lsb. Four parts marginally exceeded the specification limit of 18mA for Idd with readings of 19 or 20mA. Four parts exceeded the specification limit of 40µA for start_conv_Iih with readings in the range of 52 to 236µA. Four parts exceeded the specification limit of 40µA for short_cyc_Iih with readings in the range of 64 to 1000µA. Two parts fell below the specification limit of 2.4V for Voh with readings of 0.3V. Two parts exceeded the specification limit of 400mV for Vol with readings of >3700mV.

After annealing the parts for 168 hours at 25°C, all parts showed significant recovery in all radiation sensitive parameters. One part had one missing code and one part had two missing codes. Nine parts exceeded the specification limits for INL and DNL with readings in the range of 1.13 to 3.91lsb. All parts passed Idd, start_conv_Iih, short_cyc_Iih, Voh, and Vol.

After annealing the parts for 96 and 168 hours at 100°C, the parts showed no rebound effects.

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.

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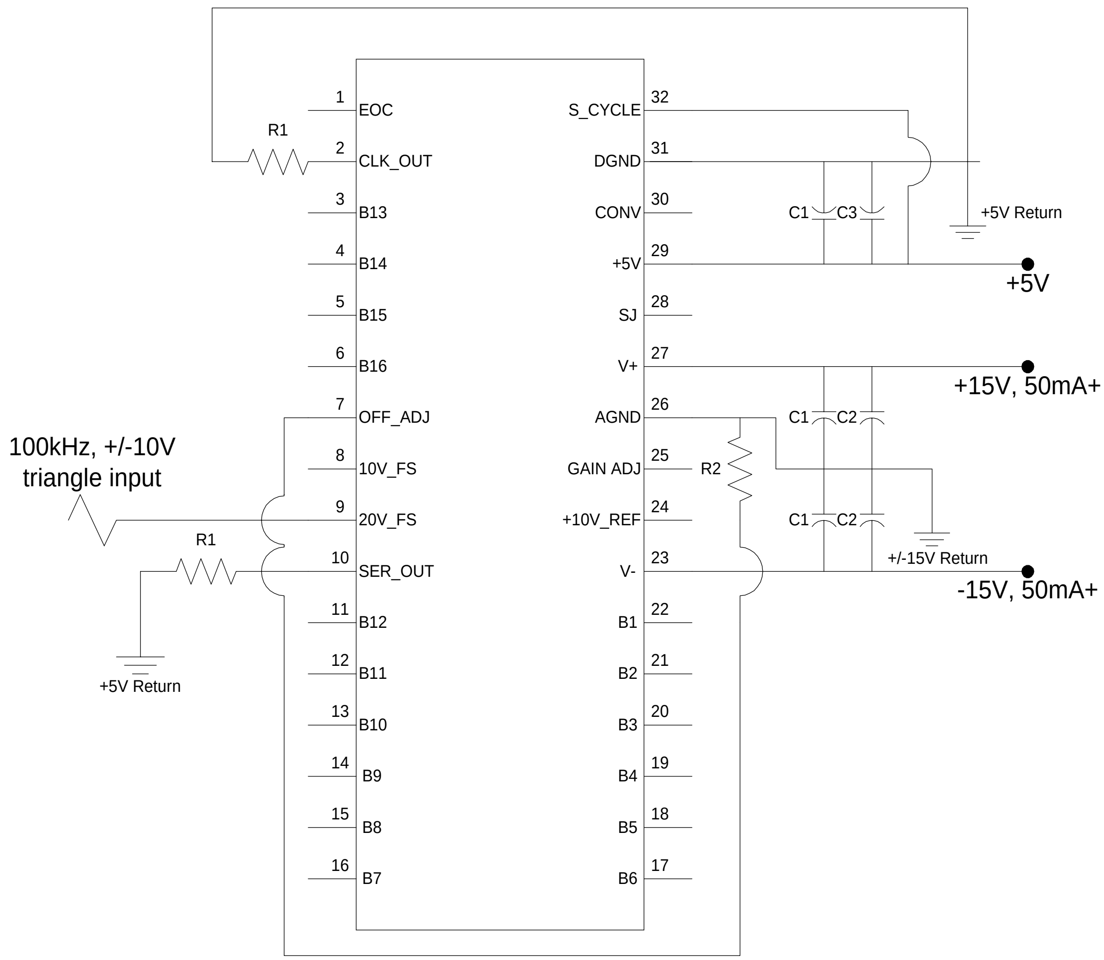
Figure 1. Radiation Bias Circuit for MN5295



Notes:

1. $R_1 = 10k\Omega \pm 5\%$, ¼W.
2. $R_2 = 20k\Omega \pm 5\%$, ¼W.
3. $C_1 = 0.1\mu F$, 10%, 100V.
4. $C_2 = 6.8\mu F$, 10%, 34V.
5. $C_3 = 4.7\mu F$, 10%, 10V.

TABLE I. Part Information

Generic Part Number:	MN5295
GOES Part Number	MN5295
Charge Number:	D-0326-0014-0000-002-0
Manufacturer:	Micro Networks
Lot Date Code (LDC):	9540, 9549
Quantity Tested:	11
Serial Number of Control Samples:	56
Serial Numbers of Radiation Samples:	58, 59, 60, 61, 66; 57, 62, 63, 64, 65
Part Function:	16-Bit Extended Temperature A/D Converter
Part Technology:	Bipolar
Package Style:	32-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 MN5295

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	03/02/98
2) 5.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/11/98
POST-5.0 KRAD ELECTRICAL MEASUREMENT	03/12/99
3) 10.0 KRAD IRRADIATION (0.121 KRADS/HOUR)	03/12/98
POST-10.0 KRAD ELECTRICAL MEASUREMENT	03/15/99
4) 15.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/15/98
POST-15.0 KRAD ELECTRICAL MEASUREMENT	03/16/99
5) 20.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/16/98
POST-20.0 KRAD ELECTRICAL MEASUREMENT	03/17/99
6) 25.0 KRAD IRRADIATION (0.294 KRADS/HOUR)	03/17/98
POST-25.0 KRAD ELECTRICAL MEASUREMENT	03/18/99
7) 96 HOUR ANNEALING @25°C	03/18/99
POST-96 HOUR ANNEAL ELECTRICAL MEASUREMENT	03/22/99
8) 264 HOUR ANNEALING @25°C	03/18/99
POST-264 HOUR ANNEAL ELECTRICAL MEASUREMENT	03/29/99
9) 35.0 KRAD IRRADIATION (0.062 KRADS/HOUR)	03/30/98
POST-35.0 KRAD ELECTRICAL MEASUREMENT	04/01/99
10) 168 HOUR ANNEALING @25°C	04/01/99
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/08/99
11) 96 HOUR ANNEALING @100°C	04/08/99
POST-96 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/12/99
12) 168 HOUR ANNEALING @100°C	04/08/99
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	04/15/99

Effective Dose Rate = 35,000 RADS/21 DAYS=69.4 RADS/HOUR=0.019 RADS/SEC

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

Table III. Electrical Characteristics of MN5295 /1

Test #	Parameter	Units	Spec. min	Lim. max	Test Conditions
100	**Missing Codes**			**0**	**Parallel Mode**
110	**INL**	**lsb**	**0**	**1.00**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V**
120	**DNL**	**lsb**	**0**	**1.00**	**AIN = ramp -10V to +10V See note 2 and 3 below.**
200	**-Vcc**	**mA**	**-32**	**0**	**$-V_{CC}$ = -15V**
201	**+Vcc**	**mA**	**0**	**42**	**$+V_{CC}$ = +15V**
202	**Idd**	**mA**	**0**	**18**	**V_{DD} = 5V**
203	**Pwr_Cnsmptn**	**W**	**0**	**1.20**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V**
300	**start_conv_Iil**	**mA**	**-1.6**	**1.6**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V, V_{IN} = 0V**
301	**short_cyc_Iil**	**mA**	**-1.6**	**1.6**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V, V_{IN} = 0V**
302	**start_conv_Iih**	**µA**	**-40**	**40**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V, V_{IN} = 5V**
303	**short_cyc_Iih**	**µA**	**-40**	**40**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V, V_{IN} = 5V**
400	**Vref**	**V**	**9.990**	**10.010**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V**
500-516	**Voh**	**V**	**2.40**		**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V, I_{OH} = 320µA**
600-616	**Vol**	**mV**	**0**	**400**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V, I_{OH} = 3.2mA**
700	**bipolar_0_error**	**mV**	**-12**	**12**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V**
710	**fs_abs_acc_-1**	**mV**	**-20**	**20**	**V_{IN} = -10V, $+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V**
720	**fs_abs_acc_+1**	**mV**	**-20**	**20**	**V_{IN} = 10V, $+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V**
730	**gain error**	**%**	**-0.100**	**0.100**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V**
800	**Conv. Time**	**µs**	**0.0**	**15.0**	**$+V_{CC}$ = +15V, $-V_{CC}$ = -15V, V_{DD} = 5V**

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.

2/ Missing Codes is a go/no-go test and the number of missing codes is calculated. If it is greater than 0 an "F" appears after the number of missing codes. There are 16,384 possible codes (0-16,383) when the device is tested at 14 bits. A series of triangular wave pulses is applied to the analog input. 262,144 samples are captured at the output at the rate of 40kSPS. The samples are analyzed for "code hits" and INL and DNL are calculated.
In order to gain more information on the missing codes, the output waveform was captured for all parts, including the control samples initially and after the total dose steps of 25 and 35kRads to evaluate the impact of any missing code on the output waveform. These waveforms were provided to the requestor for further analysis.

3/ The limit used for INL increased from 0.5lsb to 1lsb because of the differences in its calculation. The vendor used the best-fit definition, the ATE (A-540) uses the end-point definition.

TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for MN5295 /1

Test			Spec. Lim. /2				Total Dose Exposure (kRads Si)										Annealing				TDE (kRads Si		Annealing					
					Initial		5.0		10.0		15.0		20.0		25.0		96 hours @25°C		264 hours @25°C		35.0		168 hours @25°C		96 hours @100°C		168 hours @100°C	
#	Parameters	Units	min	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
100	Missing Codes /3			0	10P		10P		10P		10P		9P/1F		5P/5F		7P/3F		8P/2F		6P/4F		8P/2F		10P		10P	
110	INL	lsb	0	1.00	0.84	0.09	0.98	0.16	0.95	0.13	1.11	0.15	1.01	0.17	1.64	0.57	1.44	0.57	1.37	0.60	4.87	5.57	1.84	0.92	1.13	0.34	1.11	0.31
120	DNL	lsb	0	1.00	0.81	0.08	0.89	0.07	0.89	0.06	0.88	0.05	0.96	0.18	1.67	0.33	1.66	0.36	1.51	0.44	3.77	3.76	2.25	0.94	1.40	0.40	1.21	0.45
200	-Vcc	mA	-32	0	-21	0.5	-21	0.3	-21	0.03	-21	0.4	-21	0.3	-20	0.4	-21	0.3	-21	0.3	-21	0.3	-21	0.3	-20	0.3	-20	0.3
201	+Vcc	mA	0	42	31	0.3	31	0.4	31	0.4	31	0.4	31	0.4	31	0.4	31	0.4	31	0.4	31	0.4	31	0.4	31	0.4	31	0.4
202	Idd	mA	0	18	10	1.2	10	1.3	10	1.2	9	1.2	9	1.2	11	3.0	10	2.6	9	2.1	12	6.4	11	4.6	7	0.9	7	0.9
203	Pwr_Consumpti	W	0	1.2	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8	0
300	start_conv_Iil	mA	-1.6	1.6	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0
301	short_cyc_Iil	mA	-1.6	1.6	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0	-0.2	0
302	start_conv_Iih	mA	-40	40	3	0.5	3	0.3	3	0.4	3	0.6	3	1.3	12	9.5	9	9.3	7	5.9	59	86	16	17	2	0.2	2	0.2
303	short_cyc_Iih	mA	-40	40	8	0.5	6	1.3	6	1.2	5	1.2	5	1.2	7	3.3	6	3.0	5	2.3	237	411	7	4.9	3	0.8	3	0.8
400	Vref	V	9.990	10.010	9.997	0.002	9.998	0.003	9.998	0.003	9.999	0.001	10.000	0.002	10.000	0.004	10.000	0.003	10.000	0.005	10.001	0.003	10.000	0.002	9.999	0.004	9.998	0.002
500-516	Voh	V	2.40		4.95	0	4.95	0	4.95	0	4.95	0	4.95	0	4.95	0	4.95	0	4.95	0	3.89	2.05	4.45	1.56	4.95	0	4.95	0
600-616	Vol	mV	0	400	141	28	113	4	111	4	109	5	110	6	116	9	116	7	111	6	941	1753	116	11	107	5	107	7
700	bipolar_0_error	mV	-12	12	-1	1.1	-2	1.1	-2	1.1	-2	1.2	-2	1.3	-3	1.3	-2	1.0	-2	1.0	-3	1.2	-2	1.1	-1	0.5	-1	0.4
710	fs_abs_acc_-1	mV	-20	20	-4	1.8	-3	2.3	-3	2.4	-2	2.5	-2	2.6	-2	2.6	0	2.6	1	2.5	-1	2.5	0	2.7	2	2.5	2	2.5
720	fs_abs_acc_+1	mV	-20	20	0	3.0	-1	1.8	-1	1.8	-1	1.6	-2	2.4	-5	2.9	-5	2.2	-4	2.0	-7	2.5	-6	2.1	-5	1.8	-5	1.8
730	gain error	%	-0.100	0.100	0.044	0.019	-0.034	0.017	-0.033	0.018	-0.030	0.016	-0.020	0.020	-0.009	0.022	-0.003	0.020	0.002	0.019	0.007	0.019	0.006	0.019	0.009	0.020	0.012	0.020
800	Conv. Time	ms	0.0	15.0	13.7	0.4	13.1	0.5	12.8	0.5	12.4	0.4	11.8	0.5	11.3	0.4	11.3	0.4	11.4	0.4	8.2	4.3	10.3	0.4	11.3	0.2	11.6	0.2

Notes:

1/ The mean and standard deviation values were calculated over the ten 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. Note that vendor INL spec. limit is 0.5 lsb. The spec. limit was increased to 1.0 lsb because the inherent noise in the ATE made it difficult to measure INL to an accuracy of 0.5 lsb. No post-irradiation limits were provided by the manufacturer at the time the tests were performed.

3/ 10P implies all parts passed this test at this level. nP/mF implies that n parts passed and m parts failed this test at this level. See pages 1 and 2 for the number of mising codes for each part after each radiation exposure.

Radiation sensitive parameters: Missing Codes, INL, DNL, start_conv_Iih, short_cyc_Iih, Voh, Vol.