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TO: F. Duttweiler/UCSD
FROM: K. Sahu/300.1
SUBJECT: Radiation Report on: AD9050
Project: Univ. of CA, San Diego
Job #: F10066/F30347
Project part #: AD9050BR

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OFA Library/300.1

A radiation evaluation was performed on AD9050BR (10 bit A/D Converter) 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 5.0, 10.0, 15.0, 20.0, 30.0, 50.0, 75.0, and 100.0 kRads. [*] The dose rate was between 0.250 and 0.650 kRads/hour (0.069 to 0.181 Rads/sec.). (See Table II for radiation schedule.) The parts were annealed three times at 25°C: after the 20.0 kRad exposure for 144 hours, after the 50.0 kRad exposure for 168 hours, and after the 100.0 kRad exposure 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. Table V shows the performance of critical parameters.

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 particularly significant for two of the tests; namely, Missing Code and Integral Linearity (INL). In order to meet the minimum guaranteed conversion rate of 3MSPS for the AD9050, ATE frequencies of greater than 16 MHz were used. This 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, producing results that falsely indicated one or two random missing codes. Also, the INL measurements for most parts ranged from 2-3 lsb against the specification limit of 2.0 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 3 lsb so that the tester would not flag these parts as failing. In order to gain more information on the missing codes, the output waveform was captured for all parts, including the control samples, after the total dose steps of 20, 30 and 50 kRads to evaluate the impact of any missing code on the output waveform. Appendix 1 provides the details of the captured waveforms and their interpretations. The following provides a brief summary of the test measurements initially, and after different radiation and annealing steps.

Initial electrical measurements were made on 10 samples. SN 56 failed initial electrical testing and was removed from further testing. Seven samples (SN's 51, 52, 53, 54, 55, 57, and 58) were used as radiation samples while SN's 250 and 50 were used as control samples. All parts except SN 56 passed all tests during initial electrical measurements.

After the 5.0 kRad irradiation, SN 54 had a missing code. **All parts passed all other tests**.

After the 10.0 kRad irradiation, SN's 51, 54 and 57 had missing codes. SN 51 exceeded the specification limits of 1.75 lsb for DNL and 3.00 lsb for INL with readings of 1.97 and 4.38 lsb respectively. **All parts passed all other tests**.

[**] These are manufacturer's pre-irradiation data specification limits. The manufacturer provided no post-irradiation limits at the time these tests were performed.

After the 15.0 kRad irradiation, SN's 54 and 57 had missing codes. SN 57 exceeded the specification limit for DNL with a reading of 2.02 lsb. **All parts passed all other tests**.

After the 20.0 kRad irradiation, SN's 51, 54 and 57 had missing codes. SN's 51 and 57 exceeded the specification limit for DNL with readings of 3.00 and 1.83 lsb. SN's 51 and 58 exceeded the specification limit for INL with readings of 5.56 and 3.03 lsb. **All parts passed all other tests**.

After annealing the parts for 144 hours at 25°C, the parts showed significant recovery in Missing Codes, and some recovery in DNL and INL. The only part with Missing code was SN 51 with a DNL reading of 2.98 lsb. SN's 51 and 58 had INL readings of 5.38 and 3.26 lsb respectively. **All parts passed all other tests**.

After the 30.0 kRad irradiation, all parts except SN 53 degraded significantly. All parts except SN 53 had missing codes, failed DNL and INL. Readings for DNL were in the range of 2.59 to 56.8 lsb and readings for INL were in the range of 5.23 to 43.0 lsb. All parts catastrophically failed Encode_iil. **All parts passed all other tests**.

After the 50.0 kRad irradiation, all parts had missing codes, failed DNL, INL, and Encode_Iil. Readings for DNL were in the range of 37.2 to 55.7 lsb and readings for INL were all 43.0 lsb. All parts continued to catastrophically fail Encode_iil. **All parts passed all other tests**.

After annealing the parts for 168 hours at 25°C, the parts showed little to no recovery in any parameter.

After the 75.0 and 100 kRad irradiations, all parts continued to degrade in missing codes, DNL, INL, and Encode_Iil, with readings much the same as at 50 kRads. **All parts passed all other tests**.

After annealing the parts for 168 hours at 25°C, the parts showed little to no recovery in any parameter.

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. Table V provides details of performance of the three critical parameters; namely, Missing Codes, DNL and INL. This table shows how these parameters varied for each radiation and control sample through out the radiation testing. **The data in this table clearly indicates that up to 20 kRads and after annealing for 144 hours at 25°C, there was very little change from the initial electrical measurements for all parts. However, after 30, 50 and 100 kRads, the radiation-induced degradation in these parts increased significantly.**

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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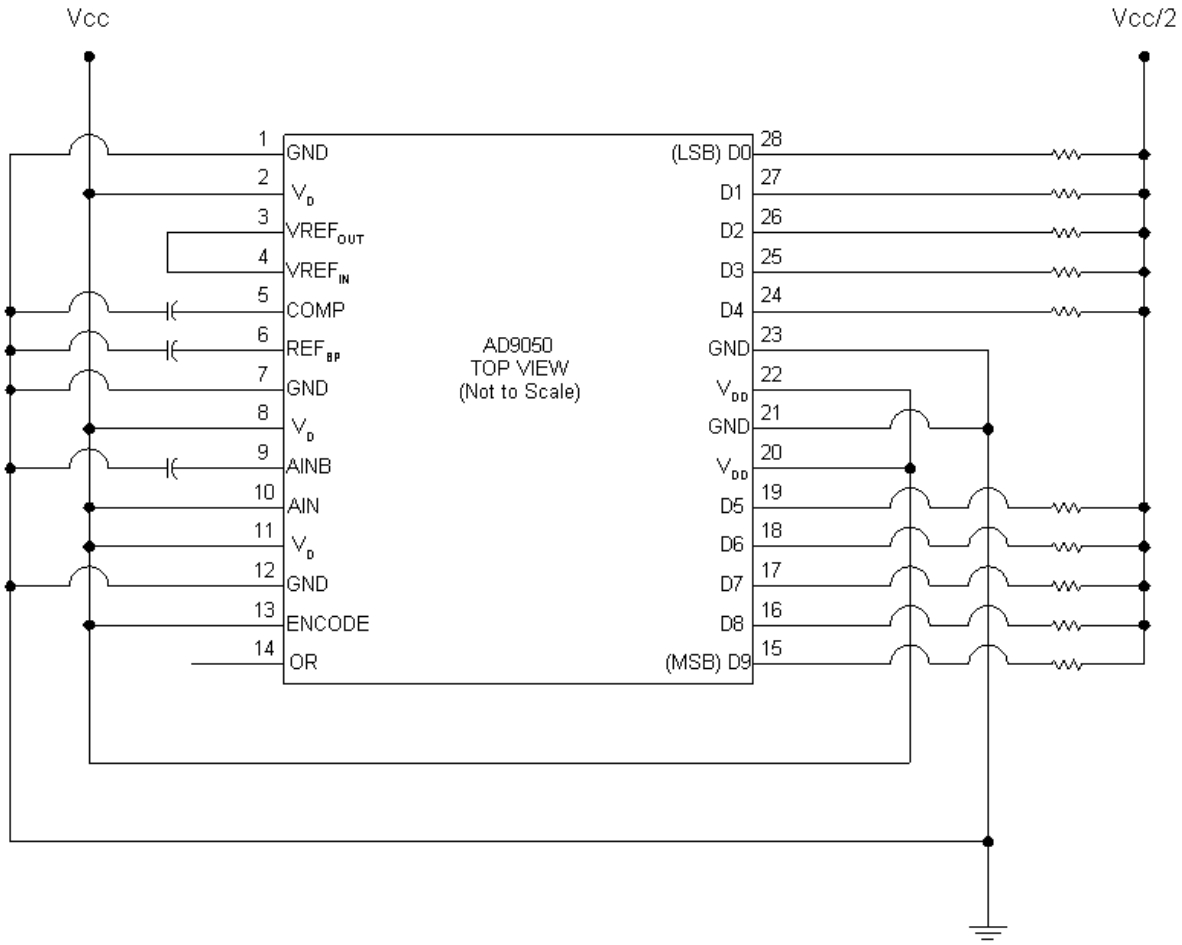
Figure 1. Radiation Bias Circuit for AD9050BR



Notes:

1. V_{CC} = +5VDC, $V_{CC}/2$ = +2.5VDC.
2. Resistors are 2kΩ ±5%, ¼ W.
3. Capacitors are 0.1µf 10V.

TABLE I. Part Information

Generic Part Number:	AD9050
Univ. of CA Part Number	AD9050BR
Charge Number:	F10066
Manufacturer:	Analog Devices
Lot Date Code (LDC):	9615
Quantity Tested:	10*
Serial Numbers of Control Samples:	250, 50
Serial Numbers of Radiation Samples:	51, 52, 53, 54, 55, 57, 58
Part Function:	10-bit A/D Converter
Part Technology:	Bipolar
Package Style:	28 Pin DIP
Test Equipment:	A540
Test Engineer:	D. Davis

* SN 56 failed initial testing and was removed initially.

- The manufacturer for this part guaranteed no radiation tolerance/hardness.

TABLE II. Radiation Schedule for AD9050BR

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	07/18/97
2) 5.0 KRAD IRRADIATION (0.125 KRADS/HOUR)	07/21/97
POST-5.0 KRAD ELECTRICAL MEASUREMENT	07/23/97
3) 10.0 KRAD IRRADIATION (0.125 KRADS/HOUR)	07/23/97
POST-10.0 KRAD ELECTRICAL MEASUREMENT	07/25/97
4) 15.0 KRAD IRRADIATION (0.125 KRADS/HOUR)	07/25/97
POST-15.0 KRAD ELECTRICAL MEASUREMENT	07/30/97
5) 20.0 KRAD IRRADIATION (0.125 KRADS/HOUR)	07/30/97
POST-20.0 KRAD ELECTRICAL MEASUREMENT	08/01/97
6) 144 HOUR ANNEALING @25°C	08/01/97
POST-144 HOUR ANNEAL ELECTRICAL MEASUREMENT	08/06/97
7) 30.0 KRAD IRRADIATION (0.250 KRADS/HOUR)	08/06/97
POST-30.0 KRAD ELECTRICAL MEASUREMENT	08/08/97
8) 50.0 KRAD IRRADIATION (0.500 KRADS/HOUR)	08/11/97
POST-50.0 KRAD ELECTRICAL MEASUREMENT	08/13/97
9) 168 HOUR ANNEALING @25°C	08/13/97
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	08/20/97
10) 75.0 KRAD IRRADIATION (0.625 KRADS/HOUR)	08/20/97
POST-75.0 KRAD ELECTRICAL MEASUREMENT	08/22/97
11) 100.0 KRAD IRRADIATION (0.625 KRADS/HOUR)	08/22/97
POST-100.0 KRAD ELECTRICAL MEASUREMENT	08/25/97
12) 168 HOUR ANNEALING @25°C	08/25/97
POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT	09/08/97

Effective Dose Rate = 100,000 RADS/35 DAYS = 119.0 RADS/HOUR=0.033 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 20.0 and 50.0 kRad steps were added due to significant 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.

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

Table III. Electrical Characteristics of AD9050BR /1

Test # /2	Parameter	Units	Test Conditions	Spec. Lim. min	Spec. Lim. max
48	Missing Codes /3	P/F	V_D = 5V, V_{DD} = 5V, AIN = ramp 2.65V to 3.95V		
49	DNL	lsb	V_D = 5V, V_{DD} = 5V, AIN = ramp 2.65V to 3.95V		1.75
50	INL /4	lsb	V_D = 5V, V_{DD} = 5V, AIN = ramp 2.65V to 3.95V		3.00
1	I_{DD}	mA	V_D = 5V, V_{DD} = 5V		80
2	PD	mW	PD = I_{DD} * 5V		400
3	Encode_I_{IL}	nA	V_D = 5V, V_{DD} = 5V, V_{IN} = 0V	-1000	1000
4	Encode_I_{IH}	nA	V_D = 5V, V_{DD} = 5V, V_{IN} = 5V	-1000	1000
5-14	Voh_5V	V	V_D = 5V, V_{DD} = 5V, Ioh = -100µA, DB9-DB0	4.95	
15-24	Vol_5V	mV	V_D = 5V, V_{DD} = 5V, Iol = 100µA, DB9-DB0		50
25-34	Voh_3V	V	V_D = 5V, V_{DD} = 3.0V, Ioh = -100µA, DB9-DB0	2.95	
35-44	Vol_3V	mV	V_D = 5V, V_{DD} = 3.0V, Iol = 100µA, DB9-DB0		50
46	Input Resistance /5	kΩ	V_D = 5V, V_{DD} = 5V, V_{AIN} = 5V, R = V/I	3.5	100

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/ There are no tests #45 or #47.

3/ Missing Codes is a go/no-go test and an "F" appears after the code number displayed when it fails. There are 1024 codes (0-1023) associated with this device. A series of triangular eave pulses are applied to the analog input. 64k digital samples are captured at the output at the rate of 4MSPS. The samples are statistically analyzed for "code hits", INL and DNL. For a passing part, the code that is hit the lease is displayed. For a failing part, the first code that is missing is displayed.

4/ The limit used for INL was increased to 3 lsb due to tester limitations (noise and oscillations). The actual specification limit is 1.75 lsb.

5/ The limit used for Input Resistance is >3.5 kΩ to <100 kΩ because the actual test performed is Impedance not Resistance. The actual specification limits are >3.5 kΩ to <6.5 kΩ.

TABLE IV: Summary of Electrical Measurements After Total Dose Exposures and Annelaing for AD9050BR /1

							Total Dose Exposure (kRads)								Annealing /5		Total Dose Exposure (kRads)				Annealing /5		Total Dose Exposure (kRads)			
Test			Spec. Lim. /2		Initial		5.0		10.0		15.0		20.0		144 hours @25°C		30.0 /6		50.0 /7		168 hours @25°C		75.0		100	
#	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
48	Missing Codes /3 /4	P/F			P		6P/1F		4P/3F		5P/2F		4P/3F		6P/1F		1P/6F		F		F		F		F	
49	DNL	lsb		1.75	1.00	0.13	1.05	0.24	1.20	0.36	1.12	0.37	1.38	0.73	1.32	0.70	18.8	19.4	50.1	5.6	41.1	5.4	37.0	2.1	35.9	1.8
50	INL	lsb		3.00	2.41	0.33	2.45	0.32	2.66	0.73	2.51	0.32	2.94	1.10	2.94	1.06	16.8	13.6	43.0	0	41.8	3.0	41.8	3.0	42.5	9.2
1	Idd	mA		80	50	1.9	50	1.8	50	1.8	50	1.8	50	1.7	50	1.7	50	1.7	55	1.2	52	1.1	59	1.4	62	2.6
2	PD	mW		400	249	9.0	249	8.9	248	8.8	248	9.2	248	9.3	248	9.0	251	8.5	276	6.2	260	5.4	296	7.6	312	11.9
3	Encode_Iil	nA	-1000	1000	-173	47	-156	22	-144	25	-168	33	-153	30	-163	33	<-2E4		<-2E4		<-2E4		<-2E4		<-2E4	
4	Encode_Iih	nA	-1000	1000	39	7	32	7	33	5	31	6	32	4	29	5	34	7	50	4	92	21	54	4.2	51	5.6
5-14	Voh_5V	V	4.95		4.99	0	4.99	0	4.99	0	4.99	0	4.99	0	4.99	0	4.99	0	4.99	0	4.99	0	4.99	0	4.99	0
15-24	Vol_5V	mV		50	10	0.3	10	0.5	10	0.5	10	0.5	10	0.5	10	0.5	11	0.5	12	0.5	8	0.5	12	0.5	13	0.5
25-34	Voh_3V	V	2.95		2.97	0	2.97	0	2.97	0	2.97	0	2.97	0	2.97	0	2.97	0	2.97	0	2.97	0	2.97	0	2.97	0
35-44	Vol_3V	mV		50	13	0.5	13	0.5	13	0.5	14	0.5	14	0.5	13	0.6	13	0.9	15	0.8	15	0.5	15	0.5	15	1.0
46	Input_Resistance	kW	3.5	100	16.1	0.7	16.2	0.7	16.1	0.7	16.1	0.7	16.1	0.7	16.1	0.7	16.1	0.6	16.1	0.6	16.1	0.6	16.1	0.6	16.2	0.6

Notes:

1/ The mean and standard deviation values were calculated over the seven 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/ "P" ("F") means that all parts passed (failed) this test at this step, nPmF means that n parts passed and m parts failed this test at this step.

4/ Missing Codes is a very sensitive test and occasionally the noise associated with the ATE may lead to a missing code. The details of this test are provided in tabel 3. For more information in Missing Codes, the ouput waveforms were captured after 20, 30 and 50 kRads. The captured waveforms and their interpretations are included in Appendix 1.

5/ The interim annealing step was added due to significant degradation in the parts at this level. The addition of this interim annealing step better simulates the space environment's lower dose rate for very sensitive devices. This may allow parts to show satisfactory performance at higher doses or indicate that the part can not be used beyond the previous dose level.

6/ All parts from this point read -20,000nA, the minimum value the the test equimpment can measure for Encode_iil.

7/ At 50 kRads, SN 54 output pin DB5 produced anomalous readings for several tests. The mean and standard deviation are calculated without this part for this step only.

Radiation sensitive parameter: Missing Codes, DNL, INL Encode_Iil, Voh, Vol.

Table V: Performance of Critical Parameters for Each Part after Total Dose Expsoures and Annealing 1/ 2/ 3/

				Total Ionizing Dose (kRads)				Anneal	TID (kRads)		Anneal	TID (kRads)		Anneal
SN	Parameter	Units	Initial	5	10	15	20	144 hrs	30	50	168 hrs	75	100	168 hrs
250	Missing Codes	address	P	P	P	P	P	P	P	P		P	P	P
	DNL	lsb	0.98	0.98	0.98	0.98	0.98	0.98	0.96	0.98		0.96	0.98	0.96
	INL	lsb	2.08	2.18	2.07	2.04	2.04	2.01	2.08	2.00		2.01	2.11	2.18
50	Missing Codes	address	P	P	P	P	P	P	P	P		P	P	P
	DNL	lsb	0.96	0.98	0.96	0.98	0.98	0.96	0.96	0.98		0.94	0.96	0.98
	INL	lsb	2.48	2.53	2.40	2.22	2.47	2.47	2.29	2.47		2.56	2.38	2.00
51	Missing Codes	address	P	P	45 F	P	45 F	45 F	1 F	1 F	1 F	1 F	1 F	1 F
	DNL	lsb	0.98	0.94	1.97 F	0.98	3.00 F	2.98 F	56.8 F	51.7 F	42.2 F	34.5 F		35.3 F
	INL	lsb	2.73	2.70	4.38 F	2.91	5.56 F	5.38 F	43.0 F	43.0 F	43.0 F	43.0 F		76.6 F
52	Missing Codes	address	P	P	P	P	P	P	1 F	1 F	1 F	1 F	1 F	1 F
	DNL	lsb	0.94	0.96	0.92	0.96	0.96	0.98	7.42 F	37.2 F	34.7 F	35.5 F	37.8 F	40.4 F
	INL	lsb	2.39	2.44	2.54	2.39	2.54	2.49	11.3 F	43.0 F	43.0 F	43.0 F	34.1 F	91.4 F
53	Missing Codes	address	P	P	P	P	P	P	P	1 F	1 F	1 F	1 F	1 F
	DNL	lsb	0.98	0.98	0.98	0.98	0.98	0.98	0.94	50.2 F	45.5 F	38.5 F	36.7 F	35.1 F
	INL	lsb	2.15	2.18	2.25	2.19	2.36	2.26	1.98	43.0 F	43.0 F	43.0 F	33.0 F	58.2 F
54	Missing Codes	address	P	519 F	519 F	519 F	909 F	P	1 F	1 F	1 F	1 F	1 F	1 F
	DNL	lsb	0.98	1.00	1.00	1.00	1.00	0.98	34.7 F	49.7 F	42.0 F	37.5 F	38.4 F	36.2 F
	INL	lsb	1.89	1.86	1.98	1.96	2.02	1.98	26.3 F	43.0 F	43.0 F	34.3 F	33.0 F	61.6 F
55	Missing Codes	address	P	P	P	P	P	P	45 F	1 F	1 F	1 F	1 F	1 F
	DNL	lsb	0.87	0.87	0.87	0.89	0.89	0.92	5.03 F	51.4 F	31.4 F	34.2 F	34.0 F	13.9 F
	INL	lsb	2.47	2.57	2.57	2.63	2.56	2.53	6.69 F	43.0 F	34.4 F	43.0 F	54.4 F	58.3 F
56	Missing Codes	address	231 F											
	DNL	lsb	1.00											
	INL	lsb	3.28 F											
57	Missing Codes	address	P	P	845 F	845 F	845 F	P	45 F	1 F	1 F	1 F	1 F	1 F
	DNL	lsb	1.32	1.64	1.24	2.02 F	1.83 F	1.41	24.3 F	55.7 F	46.8 F	40.3 F	34.6 F	35.5 F
	INL	lsb	2.26	2.52	2.42	2.61	2.54	2.68	22.8 F	43.0 F	43.0 F	43.0 F	48.8 F	67.7 F
58	Missing Codes	address	P	P	P	P	P	P	45 F	1 F	1 F	1 F	1 F	1 F
	DNL	lsb	0.98	0.98	1.41	0.98	0.98	0.96	2.59 F	54.5 F	45.4 F	38.3 F	34.1 F	1.00
	INL	lsb	2.97	2.89	2.50	2.90	3.03 F	3.26 F	5.23 F	43.0 F	43.0 F	43.0 F	51.4 F	57.1 F

Notes:

1. SN's 250 and 50 are control samples
2. P (F) means the part passed (failed) this test at this level. The number for MC is the code block. The number for DNL and INL is in lsb.
3. SN 56 failed initially and was removed from further tseting.