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Unisys

DATE: January 05, 1997 PPM-97-057
TO: S. Hull/562
FROM: K. Sahu/S. Kniffin/300.1
SUBJECT: Radiation Report on: AD652 (Analog Devices) (LDC 9434A)
Project: MAP INST.
Job #: M78276
Project Part #: AD652SE/883B

cc: M. Delmont/303
D. Bergman/783
A. Reyes/OSC
A. Sharma/311
OFA Library/300.1

A radiation evaluation was performed on **AD652SE/883B Synchronous Voltage-to-Frequency Converter (Analog Devices)** 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, and 100.0 kRads.[*] The dose rate was between 0.125 and 0.625 kRads/hour (0.035 to 0.174 Rads/s). After the 100.0 kRad exposure, the parts were annealed for 336 hours at 25°C. See Table II for the radiation schedule and effective dose rate calculation. The effective dose rate over all testing was 0.072 Rads/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 153, 154, 155, 156, 157, 158, 159, and 160) were used as radiation samples while SN's 151 and 152 were used as control samples. All parts passed all tests during initial electrical measurements.

After the 5.0 kRad irradiation, seven parts fell marginally below the specification limit of 4.950V for REF_OUT with readings in the range of 4.887 to 4.938V. **All parts passed all other tests.**

After the 10.0, 15.0, 20.0, 30.0, and 50.0 kRad irradiations, all parts continued to fall below the specification limit for REF_OUT with readings in the range of 4.738 to 4.865V at 10kRads and dropping to 4.465 to 4.650V at 50kRads. **All parts passed all other tests.**

After the 100.0 kRad irradiation, all parts fell below the specification limit for REF_OUT with readings in the range of 4.285 to 4.486V. All parts exceeded the specification limit of 50nA for I_BIAS_POS with readings in the range of 54 to 102nA. **All parts passed all other tests.**

No significant degradation was observed in the linearity of the frequency output with the input voltage varying from 0.5 to 10V up to 100kRads.

After annealing the parts for 336 hours at 25°C, parts showed modest recovery in I_BIAS_POS with several parts passing. There was some recovery in REF_OUT, however all parts continued to fall below the specification limit. **All parts passed all other tests.**

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[*] 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.

Tables IV and V provide a summary of the test results with the mean and standard deviation values for each parameter after each irradiation exposure and annealing step. Figure 2 provides the output frequency vs. voltage before and after irradiation.

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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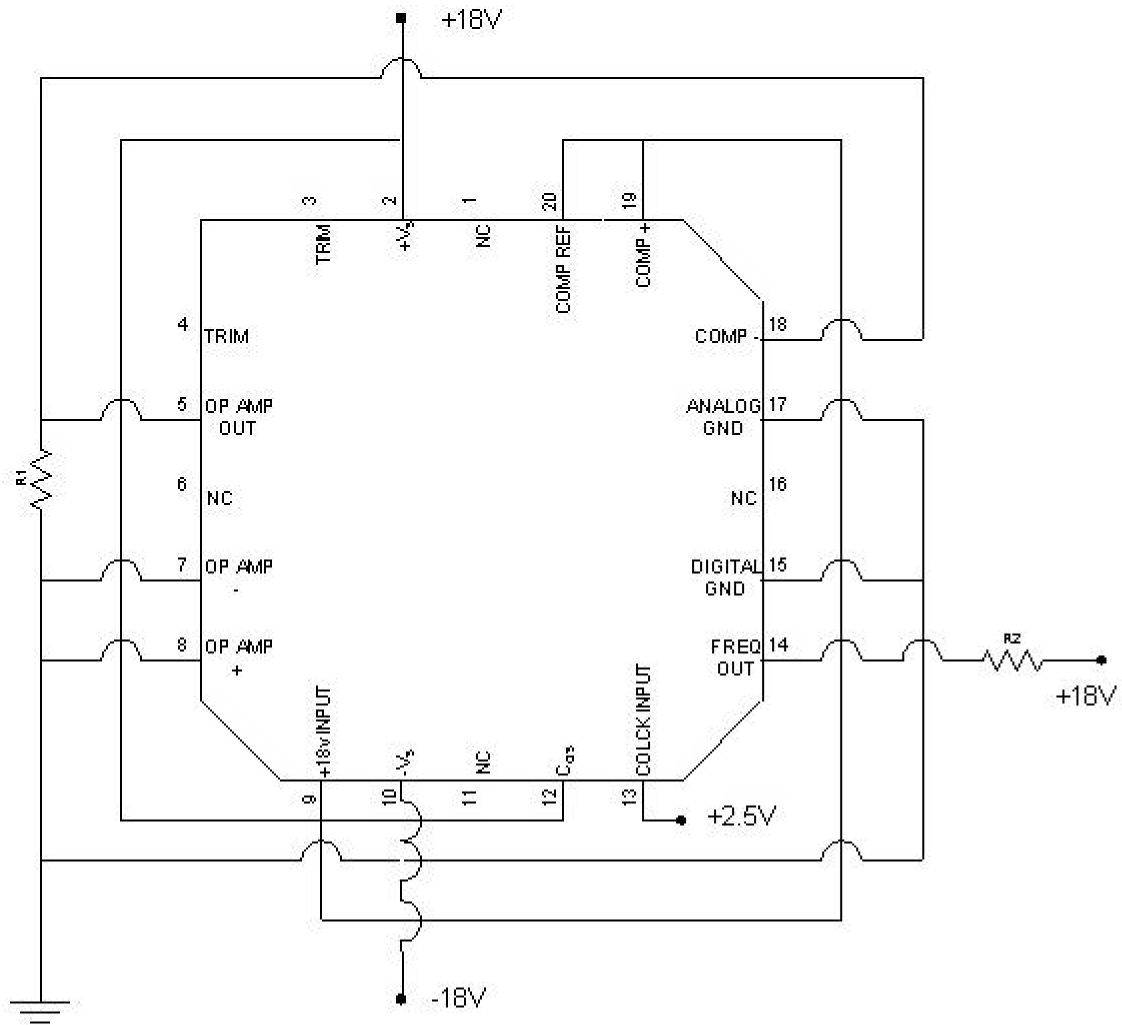
Figure 1. Radiation Bias Circuit for AD652



Notes:

1. R1 is 10kΩ ±5% ¼W, R2 is 2.05kΩ ±5% ¼W.
2. +18V = 2, 12, 14; GND = 5, 7, 8, 15, 17, 18; Linked = 9, 19, 20; -18V = 10; +2.5V = 13.

TABLE I. Part Information

Generic Part Number:	AD652
MAP INST. Part Number	AD652SE/883B
Charge Number:	M78276
Manufacturer:	Analog Devices
Lot Date Code (LDC):	9434A
Quantity Tested:	10
Serial Number of Control Samples:	151, 152
Serial Numbers of Radiation Samples:	153, 154, 155, 156, 157, 158, 159, and 160
Part Function:	Synchronous Voltage-to-Frequency Converter
Part Technology:	Bipolar
Package Style:	20 Pin LCC
Test Equipment:	A540
Test Engineer:	D. Davis

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

TABLE II. Radiation Schedule for AD652

EVENT	DATE
1) INITIAL ELECTRICAL MEASUREMENTS	11/26/97
2) 5.0 KRAD IRRADIATION (0.250 KRADS/HOUR)	12/01/97
POST-5.0 KRAD ELECTRICAL MEASUREMENT	12/02/97
3) 10.0 KRAD IRRADIATION (0.250 KRADS/HOUR)	12/03/97
POST-10.0 KRAD ELECTRICAL MEASUREMENT	12/04/97
4) 15.0 KRAD IRRADIATION (0.125 KRADS/HOUR)	12/05/97
POST-15.0 KRAD ELECTRICAL MEASUREMENT	12/08/97
5) 20.0 KRAD IRRADIATION (0.125 KRADS/HOUR)	12/09/97
POST-20.0 KRAD ELECTRICAL MEASUREMENT	12/10/97
6) 30.0 KRAD IRRADIATION (0.250 KRADS/HOUR)	12/10/97
POST-30.0 KRAD ELECTRICAL MEASUREMENT	12/12/97
7) 50.0 KRAD IRRADIATION (0.500 KRADS/HOUR)	12/12/97
POST-50.0 KRAD ELECTRICAL MEASUREMENT	12/15/97
8) 100.0 KRAD IRRADIATION (0.625 KRADS/HOUR)	12/15/97
POST-100.0 KRAD ELECTRICAL MEASUREMENT	12/17/97
9) 336 HOUR ANNEALING @25°C	12/17/97
POST-336 HOUR ANNEAL ELECTRICAL MEASUREMENT	01/02/98

Effective Dose Rate = 100,000 RADS/16 DAYS=260.4 RADS/HOUR=0.072 RADS/SEC
The effective dose rate is lower than that of the individual radiation steps as it takes into account the testing time.

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

http://flick.gsfc.nasa.gov/radhome/papers/tid/057_353.pdf

Table III. Electrical Characteristics of AD652 /1

Test #	Parameter	Units	Test Conditions /2 /3	Spec. min	Lim. max
1	**REF_OUT**	**V**	**I_{REF} = 0mA**	**4.950**	**5.050**
6	**freq_2.0V /4**		**V_{IN} = 2.0V**	**45**	**55**
12	**freq_5.0V /4**		**V_{IN} = 5.0V**	**112.5**	**137.5**
18	**freq_8.0V /4**		**V_{IN} = 8.0V**	**180**	**220**
22	**freq_10.0V /4**		**V_{IN} = 10.0V**	**225**	**275**
23	**Lin_ERROR_200kHz**	**%**		**-0.05**	**0.05**
24	**GAIN_ERROR_200kHz**	**%**	**V_{IN} = 0.01V & 9.4V, f_C = 200kHz**	**-1.00**	**1.00**
25	**Lin_ERROR_1MHz**	**%**		**-0.05**	**0.05**
26	**GAIN_ERROR_1MHz**	**%**	**V_{IN} = 0.01V & 9.4V, f_C = 1MHz**	**-1.00**	**1.00**
27	**Lin_ERROR_2MHz**	**%**		**-0.05**	**0.05**
28	**GAIN_ERROR_2MHz**	**%**	**V_{IN} = 0.01V & 9.4V, f_C = 2MHz**	**-1.00**	**1.00**
29	**PSRR**	**%**	**12V £V_S £18V, f_C = 4MHz**	**-0.05**	**0.05**
30	**Lin_ERROR_200kHz**	**%**		**-0.05**	**0.05**
31	**GAIN_ERROR_200kHz**	**%**	**V_{IN} = 0.01V & 9.4V, f_C = 200kHz**	**-1.00**	**1.00**
32	**Lin_ERROR_1MHz**	**%**		**-0.05**	**0.05**
33	**GAIN_ERROR_1MHz**	**%**	**V_{IN} = 0.01V & 9.4V, f_C = 1MHz**	**-1.00**	**1.00**
34	**Lin_ERROR_2MHz**	**%**		**-0.05**	**0.05**
35	**GAIN_ERROR_2MHz**	**%**	**V_{IN} = 0.01V & 9.4V, f_C = 2MHz**	**-1.00**	**1.00**
36	**PSRR**	**%**	**12V £V_S £18V, f_C = 4MHz**	**-0.05**	**0.05**
37	**I_BIAS_POS**	**nA**	**V_{IN} = 0V, noninverting input**	**-50**	**50**
38	**AOL**	**dB**		**50**	
39	**CMRR**	**dB**		**80**	
40	**COMP_BIAS_P**	**mA**		**-5.0**	**5.0**
41	**COMP_BIAS_N**	**mA**		**-5.0**	**5.0**
42	**IIL**	**mA**	**-V_S < V_C < -V_S**	**-20.0**	**20.0**
43	**IIH**	**mA**	**-V_S < V_C < -V_S**	**-20.0**	**20.0**
44	**IOL**	**mA**	**V_{OL} < 0.8V**	**0**	**15.0**
45	**I_SUPPLY_POS /5**	**mA**		**0**	**20.0**
46	**I_SUPPLY_NEG /5**	**mA**		**-20.0**	**0**

Notes:

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/ For all tests, $\pm V_S = \pm 15V$, $T_A = 25°C$ unless otherwise specified.

3/ For tests 30-36, an external voltage source was use to obtain these measurements. The results appear in Table V.

4/ These tests were selected to demonstrate linearity of response. The specification limits given represent ±10% of the expected value for the measurement. The tests for other voltages were performed, but were not included for brevity and clarity.

5/ The mfr's limits for these tests are 15mA. See Appendix 1 for the reason behind increasing this limit to 20mA

TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for AD652 /1

							Total Dose Exposure (kRads)														Annealing	
					Initial		5.0		10.0		15.0		20.0		30.0		50.0		100.0		336 hours	
Test			Spec. Lim. /2																		@25°C	
#	Parameters	Units	min	max	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
1	REF_OUT	V	4.950	5.050	5.007	0.001	4.920	0.021	4.801	0.040	4.718	0.057	4.644	0.068	4.550	0.071	4.543	0.057	4.370	0.069	4.553	0.027
6	freq_2.0V /3	kHz	45	55	52	0	52	0	52	0	52	0	52	0	52	1.0	52	1.0	51	1.5	52	1.0
12	freq_5.0V /3	kHz	112.5	137.5	128	0	128	0	128	1.3	127	1.5	126	1.6	126	1.7	126	1.7	127	0	126	1.5
18	freq_8.0V /3	kHz	180	220	204	1.4	203	1.9	203	2.0	205	1.3	204	1.7	204	1.9	204	1.7	204	1.7	203	2.0
22	freq_10.0V /3	kHz	225	275	250	0	250	0	250	0	250	0	250	0	250	0	250	0	250	0	250	0
23	Lin_ERROR_200kHz /4	%	-0.05	0.05	0.029	0.012	0.029	0.012	0.029	0.012	0.029	0.011	0.029	0.012	0.030	0.010	0.028	0.010	0.035	0.007	0.032	0.005
24	GAIN_ERROR_200kHz	%	-1.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Lin_ERROR_1MHz	%	-0.05	0.05	0.024	0.012	0.030	0.007	0.029	0.009	0.031	0.014	0.029	0.011	0.028	0.011	0.028	0.008	0.029	0.008	0.030	0.009
26	GAIN_ERROR_1MHz	%	-1.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Lin_ERROR_2MHz	%	-0.05	0.05	0.028	0.008	0.028	0.010	0.028	0.011	0.029	0.009	0.029	0.010	0.030	0.010	0.027	0.009	0.031	0.008	0.034	0.008
28	GAIN_ERROR_2MHz	%	-1.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	PSRR	%	-0.05	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	I_BIAS_POS	nA	-50	50	12	4.3	18	5.1	24	4.2	28	4.9	32	7.8	41	6.6	42	4.6	74	16	59	10
38	AOL	dB	50		52	0	52	0	52	0	52	0	52	0	52	0	52	0.5	52	0	52	0
39	CMRR	dB	80		108	10.1	115	16.1	85	2.0	97	3.4	93	4.2	99	3.7	207	40	200	12	218	17
40	COMP_BIAS_P	mA	-5.0	5.0	-0.005	0.005	-0.001	0.004	-0.003	0.004	-0.005	0.006	-0.008	0.006	-0.003	0.007	-0.004	0.005	0.000	0.006	0.003	0.005
41	COMP_BIAS_N	mA	-5.0	5.0	-0.003	0.008	-0.001	0.003	0.004	0.008	-0.003	0.009	-0.008	0.003	0.002	0.008	-0.001	0.014	0.000	0.005	-0.003	0.004
42	IIL	mA	-20.0	20.0	-6.9	0.2	-16.1	1.4	-19.9	0	-19.9	0	-19.9	0	-19.9	0	-19.9	0	-19.9	0	-19.9	0
43	IIH	mA	-20.0	20.0	0.004	0.007	0.002	0.005	0.008	0.006	0.009	0.007	0.010	0.009	0.011	0.007	0.011	0.011	0.014	0.008	0.008	0.006
44	IOL	mA	0	15.0	13.5	1.3	10.2	4.4	6.4	3.7	4.9	3.9	5.0	3.1	2.8	2.3	2.9	2.3	4.9	2.3	0.1	0.2
45	I_SUPPLY_POS	mA	0	20.0	15.2	0.2	14.2	1.4	13.7	1.2	12.9	1.5	12.6	1.4	12.5	0.9	12.7	0.7	12.0	0.6	12.3	0.6
46	I_SUPPLY_NEG	mA	-20.0	0	-14.2	0.2	-13.1	1.4	-12.6	1.2	-11.8	1.5	-11.6	1.4	-11.4	0.9	-11.6	0.7	-11.0	0.6	-11.3	0.6

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/ These tests demonstrate the linearity of the frequency response. The min/max represents +-10% of the expected value at this voltage. These tests were also performed at 0.5V steps from 0.5V to 10.0V. This data is available upon request.

4/ Tests 23 - 29 represent these measurements taken with the internal reference voltage associated with that chip. See Table V for results of the same tests using an external voltage reference.

Radiation sensitive parameters: REF_OUT, I_BIAS_POS.

TABLE V: Summary of Electrical Measurements after Total Dose Exposures and Annealing for AD652 /1 Using an External Voltage Reference /4

Test #	Parameters /3	Units	Spec. Lim. /2 min	Spec. Lim. /2 max	Initial mean	Initial sd	Total Dose Exposure (kRads) 5.0 mean	5.0 sd	10.0 mean	10.0 sd	15.0 mean	15.0 sd	20.0 mean	20.0 sd	30.0 mean	30.0 sd	50.0 mean	50.0 sd	100.0 mean	100.0 sd	Annealing 336 hours @25°C mean	Annealing sd
1	REF_OUT	V	4.950	5.050	5.007	0.001	4.920	0.021	4.801	0.040	4.718	0.057	4.644	0.068	4.550	0.071	4.543	0.057	4.370	0.069	4.553	0.027
30	Lin_ERROR_200kHz	%	-0.05	0.05	0.025	0.010	0.025	0.011	0.030	0.009	0.030	0.011	0.026	0.010	0.026	0.012	0.027	0.009	0.022	0.008	0.027	0.009
31	GAIN_ERROR_200kHz	%	-1.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	Lin_ERROR_1MHz	%	-0.05	0.05	0.026	0.005	0.036	0.010	0.024	0.010	0.024	0.010	0.026	0.011	0.024	0.013	0.027	0.010	0.029	0.009	0.026	0.007
33	GAIN_ERROR_1MHz	%	-1.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	Lin_ERROR_2MHz	%	-0.05	0.05	0.028	0.010	0.026	0.009	0.035	0.007	0.029	0.013	0.029	0.009	0.028	0.013	0.026	0.008	0.028	0.009	0.034	0.006
35	GAIN_ERROR_2MHz	%	-1.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	PSRR	%	-0.05	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

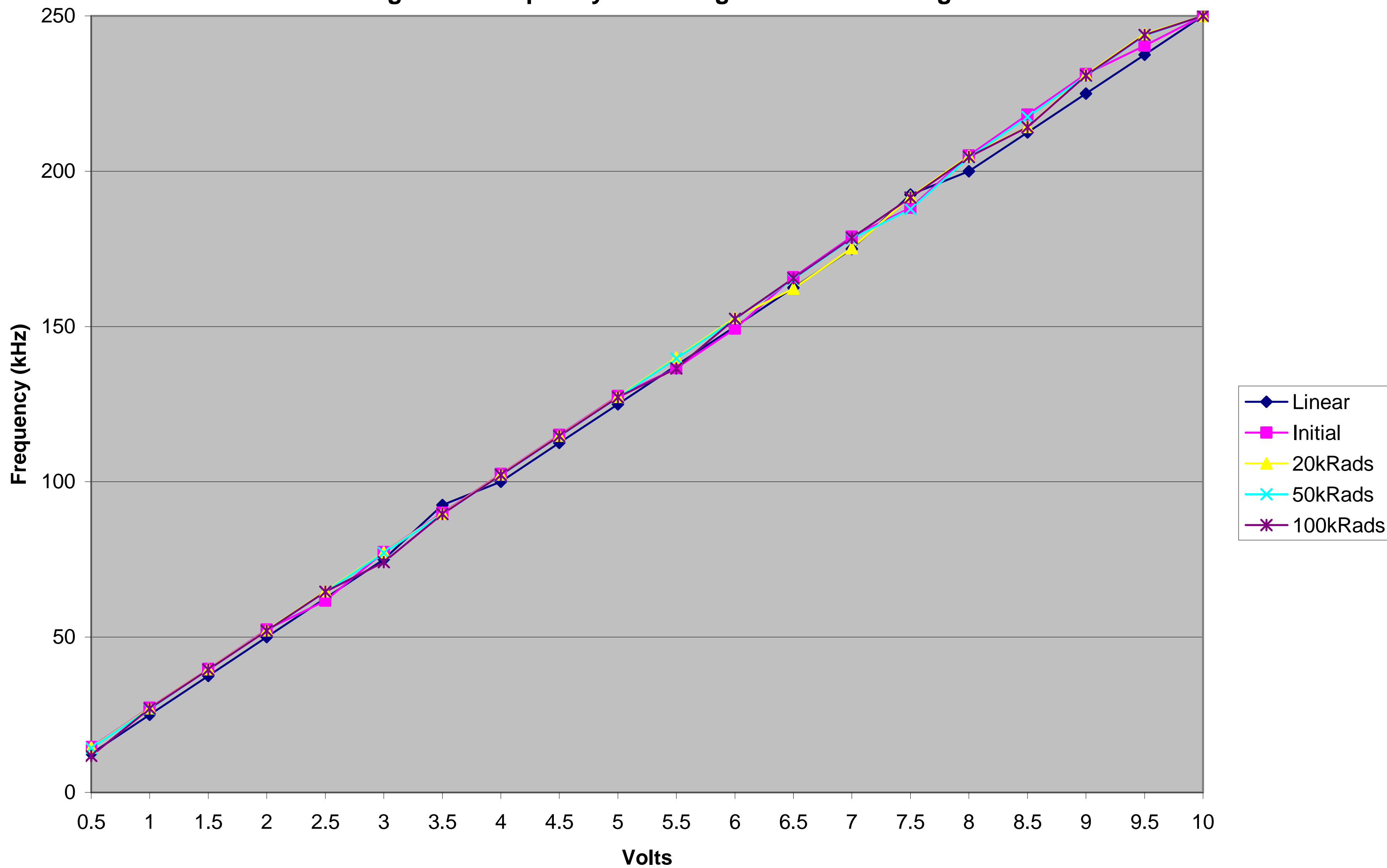
1/ The mean and standard deviation values were calculated over the eight parts irradiated in this testing. The control samples remained constant throughout testing and are not included in this table.

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/ Tests 30 - 36 were performed with an external reference voltage to give a comparison due to the degradation of REF_OUT.

4/ The REF_OUT parameter was expected to show degradation at low radiation levels. Therefore, tests 30 - 36 were performed with an external voltage reference as well. The results are reported in this table.

Radiation sensitive parameters: REF_OUT.



Note: The 'linear' line plots the ideal frequency response (25kHz/V). The A540 measurements are within 8% of the ideal frequency before and after irradiation exposures up to 100kRads. This data indicates that the frequency does not degrade with radiation exposure.

http://flick.gsfc.nasa.gov/radhome/papers/tid/057_353.pdf

Table VI: Frequency Data for SN160

Voltage	Linear	Initial	20kRads	50kRads	100kRads		Max deviation from linear
0.5	12.5	14.6	14.4	14.3	11.8		5.6%
1	25	27.3	27.1	26.9	27		8.0%
1.5	37.5	39.8	39.7	39.5	39.5		5.3%
2	50	52.4	52.2	52	52		4.0%
2.5	62.5	61.7	64.8	64.5	64.6		3.4%
3	75	77.4	77.3	77.1	74.1		1.2%
3.5	92.5	90	89.8	89.6	89.6		3.1%
4	100	102.5	102.4	102.1	102.2		2.2%
4.5	112.5	115.1	114.9	114.6	114.7		2.0%
5	125	127.6	127.4	127.1	127.2		1.8%
5.5	137.5	136.6	140	139.7	136.5		0.7%
6	150	149.3	152.8	152.4	152.5		1.6%
6.5	162.5	165.9	162.2	165.3	165.5		1.8%
7	175	178.9	175.2	178.3	178.5		2.0%
7.5	192.5	188.2	191.8	187.8	191.5		0.1%
8	200	205.1	204.9	204.4	204.6		2.3%
8.5	212.5	218.2	214.3	217.5	214.2		0.1%
9	225	231.3	231.1	230.6	230.8		2.6%
9.5	237.5	240.4	244.2	243.7	243.9		2.7%
10	250	250	250	250	250		0.0%

Appendix 1

AD652 – Voltage to Frequency Converter

The following provides information on the two tests, namely output frequency and power supply current. The ATE measurements made by UNISYS most likely differed from the bench measurements made by the requestor because different measurement techniques were used. The details of these measurement techniques are provided below. However the test results obtained by the ATE tests indicated no significant degradation in both tests up to 100 kRads exposure.

Frequency Measurement
In the Unisys Lab, these measurements were made using the Automatic Test Equipment, A540. The measurement technique used was the one recommended by Teradyne, the equipment mfr. This technique measures the output frequency as the average of multiple (>1000) instantaneous frequency measurements at the output of the device. The technique used by the requestor during bench testing measures frequency by counting pulses gated to a signal derived from the clock. This technique could not be easily implemented on the automatic tester used in the Unisys EEE lab given that the AD652 output is not a fixed stable frequency.
The ATE technique used was considered adequate for Radiation Evaluation as it has the capability to show whether the output frequency was changing with the radiation exposure or not. It was realized that the ATE technique might lead to about ±10% error in Absolute frequency measurements because of the way the part is designed by the mfr. The difference in the ATE measurement and the bench testing is due to the fact that the part is designed to drop pulses that can affect the ATE frequency measurement.
The attached Excel file provides the details of frequency measurement for SN 160 as a function of input voltage before irradiation and after radiation exposure to 20, 50 and 100 kRads. The test data shows that the output frequency is linear with the input voltage in the range from 0.5-10 volts and that the output frequency does not change with the radiation exposures.

Test Conditions Used for Testing Power Supply Current with A540:

1. No External Connections: This implies that
   Integrator capacitor not connected
   *One-shot pin (pin12) left open
   5v reference not connected to COMP+
   OP AMP OUT not connected to COMP-

2. COMP+ = 5v
   COMP- = 5v
   CLOCK_INPUT = 0v

3. VS+ = 15v
   VS- = -15v

4. ANALOG GND connected to ground plane
   DIGITAL GND connected to ground plane

5. All other pins left open

(*) One shot is not completely disabled and may be running during test. To completely disable one-shot, pin12 should be connected to VS+. This was not done due to fixturing constraints and is a possible source of excessive currents measured. We were aware of this and increased limit to 20mA to avoid unnecessary failure flags during Radiation Testing. This may be the reason for HIGHER CURRENT READINGS on the ATE 540 as compared to bench test measurements.