TID Test Results
AD654 Voltage-to-Frequency Converter (Analog Devices)

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1. Introduction

This plan describes the radiation testing and characterization of the AD654 voltage-to- frequency converter for the Solar Dynamic Observatory project.

2. Device Description

Table I contains the device information. Fig. 1 shows the pin connections for the device. Fig. 2 shows the electrical circuit used for testing the AD654.

Table I.
Test and Part Information

Generic Part Number:	AD654
Full Part Number	AD654JR
Manufacturer:	Analog Devices
Lot Date Code (LDC):	0451
Quantity Tested:	10
Serial Numbers of Control Sample:	1,2
Serial Numbers of Radiation Samples:	3,4,5,6,7,8,9,10
Part Function:	Voltage-to-frequency converter
Part Technology:	Linear Bipolar
Package Style:	8-Lead SOIC
Test Equipment:	Power Supply, frequency meter, multimeter, oscilloscope.
Test Engineer:	TBD
Dose Levels (krad (Si))	0, 5, 10, 15, 20, 25, 30
Target dose rate (rad (Si)/min)	0.02 krad(Si)/s

FUNCTIONAL BLOCK DIAGRAM

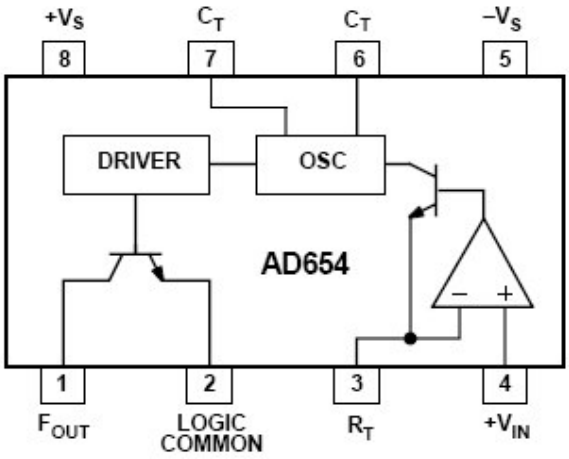

Fig. 1. Pin Connections for the AD654.

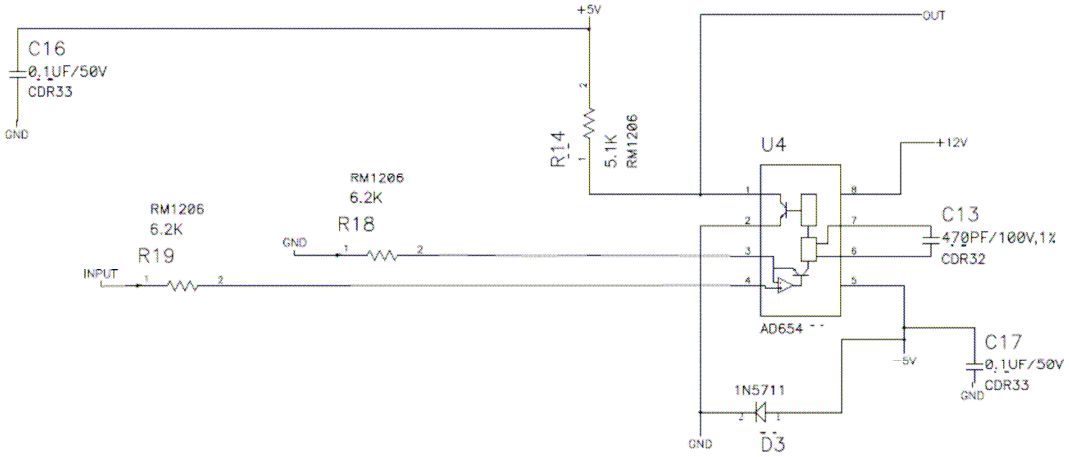

Fig. 2. Circuit required for testing the AD654.

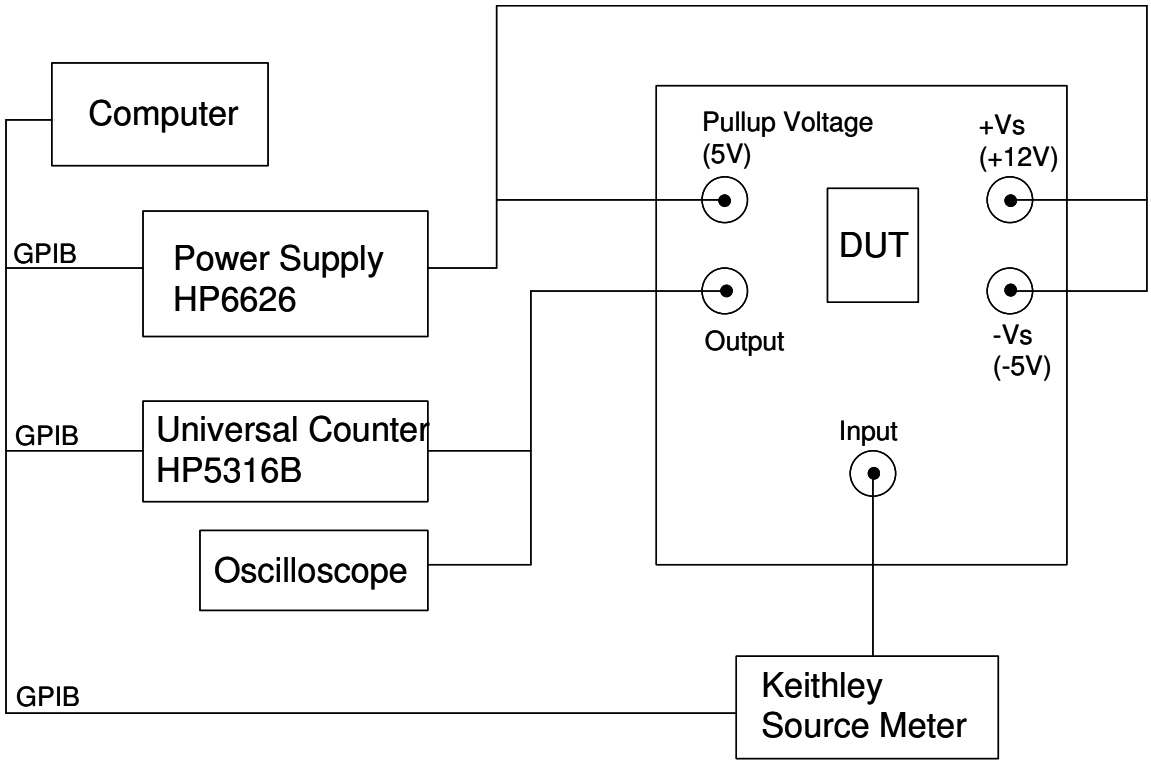

Fig. 3. Block diagram showing the equipment used for doing the electrical characterization.

3. Test Method

Ten devices were tested. Eight devices were exposed to gamma rays using the GSFC Co^{60} source; two devices were used as controls. During radiation exposure, the devices were electrically biased with Vs(+) = 12V, Vs(-) = -5V, and Fout = 5V. The other connections were grounded and the parts were at room temperature. The dose levels were 0, 5, 10, 15, 20, 25, & 35 krad(Si). The parts being linear bipolar, the dose rate was 0.02 rad(Si)/s to check for ELDRS. The dose rate is higher than 0.01 rad(Si)/s recommended in Military Standard 883, Test Method 1019.6 due to time constraints. At each dose level the devices were characterized for functionality and various electrical parameters were measured. No post-irradiation annealing was done.

The following test procedure was used:

1. Apply voltage (+12, +5 and –5 Volts) to the setup.
2. Measure output rise time and fall time for input at 7.5 Volts using an oscilloscope.
3. Measure 12 V and –5 V current for input at 0 and 7.5 V.
4. Measure output frequency for input at 0 V, 0.1 V 1.0 V, 3.0 V and 7.5 V to 1%.
5. Measure input voltage for which output is 1 Hz.

4. Results

Tables II through XIII summarize the test results. We note that some of the parameters, such as rise and fall times, cannot be compared with those specified in the data sheet because the test setup was specific to the application and was, therefore, not

the same as that suggested in the data sheet. Overall, the parameters showed very little change with total ionizing dose, except for the input voltage required for an output frequency of 1 Hz and the output frequency for Vin = 0V.

Table II
Rise Time (μs)

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	1.41	1.42	1.42	1.44	1.46	1.46	1.36	1.47	1.41	1.47	1.43	0.04
5	1.46	1.47	1.42	1.45	1.44	1.50	1.39	1.49	1.40	1.44	1.45	0.04
10	1.47	1.50	1.47	1.47	1.52	1.53	1.42	1.54	1.47	1.45	1.49	0.04
15	1.47	1.55	1.48	1.47	1.52	1.56	1.47	1.55	1.42	1.42	1.51	0.04
20	1.46	1.53	1.48	1.47	1.55	1.57	1.48	1.55	1.44	1.45	1.51	0.04
25	1.52	1.57	1.52	1.48	1.54	1.58	1.47	1.56	1.44	1.46	1.53	0.04
35	1.54	1.55	1.56	1.52	1.58	1.58	1.54	1.58	1.45	1.48	1.56	0.02

Table III
Fall Time (ns)

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	163	179	172	175	185	186	170	175	185	184	176	8
5	186	183	188	180	194	185	174	184	185	176	184	6
10	186	189	184	188	194	192	182	194	181	160	189	5
15	193	195	194	192	205	197	193	195	185	185	195	4
20	190	195	196	193	205	200	191	202	179	172	196	5
25	196	197	193	194	212	207	193	206	187	178	197	7
35	206	212	204	213	215	214	196	215	183	178	198	7

Table IV
V_{in} required for Output Frequency of 1 Hz.

0 krad		5 krad		10 krad		15 krad		20 krad		25 krad		35 krad	
Vin for	Freq. (Hz)	Vin for	Freq. (Hz)	Vin for	Freq. (Hz)	Vin for	Freq. (Hz)	Vin for	Freq. (Hz)	Vin for	Freq. (Hz)	Vin for	Freq. (Hz)
0.01	(@1Hz)	9.00E-05	(@2.00Hz)	6.00E-05	(@6Hz)	-3.00E-05	(@5.63Hz)	3.00E-05	(@8Hz)	4.50E-05	(@11.86)	-7.00E-05	(@29.8)
2.20E-04	(@1Hz)	3.10E-04	(@2.00Hz)	1.85E-04	(@2.6Hz)	1.55E-04	(@5.57Hz)	2.20E-04	(@7.2Hz)	1.60E-04	(@10.72)	1.40E-04	(@29.9)
4.00E-04	(@1Hz)	3.85E-04	(@2.00Hz)	3.90E-04	(@2.69Hz)	3.20E-04	(@4.29Hz)	3.85E-04	(@5.7Hz)	3.40E-04	(@8.24)	2.85E-04	(@16.8)
7.50E-05	(@1Hz)	9.50E-05	(@2.00Hz)	9.00E-05	(@5Hz)	2.00E-05	(@5.47Hz)	7.00E-05	(@7.5Hz)	4.50E-05	(@10.75)	5.00E-05	(@29.9)
-1.90E-04	(@1Hz)	-2.10E-04	(@2.00Hz)	-2.35E-04	(@5Hz)	-3.35E-04	(@5.44Hz)	-3.25E-04	(@7.5Hz)	-3.40E-04	(@11.63)	-4.50E-04	(@20.94)
3.80E-04	(@1Hz)	3.30E-04	(@2.00Hz)	3.55E-04	(@2.8Hz)	2.25E-04	(@5.64Hz)	3.20E-04	(@7.2Hz)	3.40E-04	(@10.95)	2.90E-04	(@21.4)
-1.00E-04	(@1Hz)	-1.10E-04	(@2.00Hz)	-1.60E-04	(@2.8Hz)	-2.50E-04	(@5.85Hz)	-2.70E-04	(@6.6Hz)	-2.90E-04	(@9.47)	-3.70E-04	(@17.9)
-1.50E-04	(@1Hz)	-1.45E-04	(@2.75Hz)	-1.30E-04	(@5.7Hz)	-2.80E-04	(@8.97Hz)	-1.60E-04	(@13.7Hz)	-1.55E-04	(@20.56)	-6.00E-05	(@40.28)
-1.75E-04	(@1Hz)	-2.30E-04	(@2.00Hz)	-1.80E-04	(@2Hz)	-1.80E-04	(@9.67Hz)	-1.85E-04	(@1.03Hz)	-1.70E-04	(@1.15)	-1.50E-04	(@4.74)
-1.10E-04	(@1Hz)	-8.50E-05	(@2.00Hz)	-1.20E-04	(@2Hz)	-1.80E-04	(@9.67Hz)	-1.20E-04	(@1.15Hz)	-1.50E-04	(@1.19)	-1.40E-04	(@2.31)

(At higher doses the noise was so great that nothing could be measured at 1 Hz. Instead the minimum voltage, which produced a frequency that was not dominated by noise, was measured. The Table contains both the minimum stable frequency and the corresponding input voltage.)

Table V
I(+Vs) for Input =7.5V (mA)

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	5.37	5.37	5.36	5.32	5.34	5.34	5.33	5.36	5.32	5.33	5.35	0.02
5	5.36	5.39	5.37	5.32	5.37	5.36	5.33	5.37	5.32	5.36	5.36	0.02
10	5.37	5.40	5.39	5.37	5.39	5.39	5.36	5.37	5.34	5.34	5.38	0.01
15	5.40	5.41	5.37	5.37	5.39	5.40	5.36	5.36	5.32	5.32	5.38	0.02
20	5.39	5.41	5.41	5.37	5.36	5.40	5.34	5.37	5.30	5.34	5.38	0.03
25	5.39	5.41	5.40	5.36	5.39	5.37	5.34	5.37	5.32	5.36	5.38	0.02
35	5.4	5.37	5.37	5.33	5.34	5.34	5.32	5.34	5.33	5.34	5.35	0.03

Table VI
I(-Vs) for Input =7.5V (mA)

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	3.72	3.76	3.74	3.69	3.71	3.71	3.69	3.72	3.69	3.71	3.72	0.02
5	3.75	3.76	3.76	3.69	3.75	3.74	3.71	3.72	3.68	3.71	3.74	0.03
10	3.79	3.76	3.76	3.69	3.75	3.75	3.74	3.76	3.69	3.72	3.75	0.03
15	3.78	3.80	3.76	3.74	3.75	3.74	3.74	3.75	3.65	3.65	3.76	0.02
20	3.76	3.8	3.79	3.75	3.79	3.75	3.74	3.76	3.69	3.71	3.77	0.02
25	3.78	3.78	3.78	3.75	3.76	3.76	3.76	3.76	3.68	3.75	3.77	0.01
35	3.76	3.75	3.76	3.72	3.74	3.75	3.74	3.72	3.69	3.72	3.74	0.02

Table VII
I(+Vs) for Input =0V (mA)

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	1.83	1.94	1.92	1.93	1.85	1.94	1.82	1.88	1.85	1.85	1.89	0.05
5	1.93	1.96	1.90	1.93	1.85	1.94	1.83	1.85	1.85	1.85	1.90	0.05
10	1.92	2.18	2.14	2.14	2.14	2.16	2.08	2.12	2.07	2.15	2.11	0.08
15	2.23	2.23	2.16	2.29	2.08	1.94	2.08	2.12	2.08	2.08	2.14	0.11
20	2.12	2.12	2.15	2.29	1.83	2.24	1.85	2.14	2.07	2.14	2.09	0.17
25	2.12	2.18	2.37	1.85	2.33	2.22	2.08	2.16	2.09	2.16	2.16	0.16
35	1.92	2.55	2.48	2.27	2.24	2.26	2.2	2.27	2.03	2.3	2.27	0.19

Table VIII
I(-Vs) for Input =0V (mA)

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	1.54	1.53	1.47	1.50	1.53	1.51	1.53	1.55	1.54	1.61	1.52	0.03
5	1.49	1.53	1.49	1.53	1.54	1.50	1.57	1.57	1.54	1.54	1.53	0.03
10	1.50	1.53	1.47	1.55	1.54	1.53	1.55	1.54	1.54	1.61	1.53	0.03
15	1.51	1.53	1.49	1.54	1.55	1.50	1.54	1.58	1.61	1.61	1.53	0.03
20	1.53	1.57	1.47	1.54	1.57	1.5	1.54	1.55	1.54	1.58	1.53	0.03
25	1.53	1.54	1.47	1.57	1.55	1.51	1.53	1.54	1.57	1.57	1.53	0.03
35	1.49	1.54	1.49	1.53	1.51	1.51	1.5	1.53	1.58	1.55	1.51	0.02

Table IX
Output Frequency for Input = 0.0V

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	3.7	No signal	No signal	No signal	8	No signal	4	8	12	No signal	5.93	2.40
5	No signal	No signal	No signal	No signal	11	No signal	8	10	12	7	9.67	1.53
10	3.55	0	0	4.055	15.12	0	12.62	14.03	8.926	11.67	6.17	6.64
15	12.11	169.3	0	9.369	20.76	0	17.27	22.29	11.02	11.02	31.39	56.37
20	16.6	9.88	5.978	14.5	27.9	75.29	24.5	28.02	17.2	15.6	25.33	21.77
25	19.01	14.52	102.7	17.34	31.52	23.99	26.05	33.12	17.01	16.2	33.53	28.71
35	0	152	10.88	84.83	136.1	104.3	22.5	59.59	4.004	17.2	71.28	57.61

Table X
Output Frequency for Input = 0.1V

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	3270	3217	3253	3259	3259	3243	3252	3253	3274	32494	3251	16
5	3264	3244	3255	3258	3259	3248	3244	3251	3275	3245	3253	7
10	3264	3244	3254	3257	3258	3239	3244	3247	3271	3249	3251	9
15	3267	3242	3253	3256	3258	3240	3243	3247	3272	3272	3251	9
20	3260	3240	3252	3255	3260	3236	3250	3242	3280	3250	3249	9
25	3258	3236	3247	3251	3255	3228	3240	3234	3278	3253	3244	11
35	3230	3210	3220	3224	3232	3205	3220	3202	3260	3240	3218	11

Table XI
Output Frequency for Input = 1.0V

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	32732	32292	32681	32647	32550	32547	32435	32495	32672	32428	32547	143
5	32709	32547	32667	32629	32537	32529	32418	32469	32669	32422	32563	99
10	32690	32530	32650	32600	32510	32510	32400	32430	32660	32420	32540	101
15	32660	32490	32630	32580	32490	32470	32370	32380	32660	32660	32509	107
20	32600	32500	32600	32550	32500	32430	32400	32330	32700	32400	32489	97
25	32580	32410	32570	32510	32420	32380	32310	32270	32670	32420	32431	114
35	32500	32300	32460	32400	32310	32260	32200	32110	32650	32400	32318	131

Table XII
Output Frequency for Input = 3.0V

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	98315	97035	98158	98062	97734	97774	97417	97566	98095	97376	97758	421
5	98260	97782	98136	98007	97705	97706	97365	97502	98084	97364	97808	308
10	98200	97730	98100	97950	97650	97660	97310	97390	98080	97360	97749	318
15	98130	97620	98030	97880	97580	97560	97250	97260	98060	98060	97664	328
20	98000	97500	97970	97800	97500	97440	97200	97120	98100	97400	97566	330
25	97920	97390	97880	97700	97400	97310	97080	96960	98080	97360	97455	353
35	97600	97100	97620	97430	97120	97030	96800	96580	98060	97300	97160	372

Table XIII
Output Frequency for Input = 7.0V

TID	DUT1	DUT2	DUT3	DUT4	DUT5	DUT6	DUT7	DUT8	Control1	Control2	Average	St. Dev.
0	246000	243099	245771	245241	244526	244517	243767	244084	245381	243625	244626	997
5	245905	244704	245585	245206	244415	244505	243647	243898	245341	243572	244733	789
10	245800	244600	245500	245100	244300	244400	243500	243600	245400	243600	244600	832
15	245600	244300	245300	244900	244100	244100	243400	243300	245300	245300	244375	836
20	245000	244000	245100	244700	244000	243700	243000	242900	245000	244000	244050	843
25	245000	243700	244900	244400	243600	243400	242900	242500	245400	243600	243800	904
35	244000	243000	244300	243800	243000	242800	242000	241600	245300	244000	243063	949