Synopsis V1.0
Co-60 Total Ionizing Dose (TID) Testing of the Analog Devices AD5334 Digital to Analog Converter (DAC)

Jim Howard and Hak Kim
Jackson and Tull Chartered Engineers, Washington DC 20018

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I. Introduction
This study was undertaken to determine the total ionizing dose susceptibility of the Analog Devices AD5334 Digital to Analog Converter. The device was biased and operating when exposed to a Cobalt-60 environment at the Goddard Space Flight Center (GSFC) Co-60 Radiation Effects Facility.

II. Devices Tested
Five parts were exposed for this testing. These devices were manufactured by Analog Devices and were characterized prior to exposure. The devices were from date code 0011.

III. Test Facility
Facility: GSFC Co-60 Radiation Effects Facility
Source: Cobalt 60
Dose Rate: approximately 400 rads(Si)/hour

IV. Test Methods

Five AD5334 devices (DUT69, DUT70, DUT71, DUT72 and DUT74) were exposed to the Co-60 radiation environment while under bias. The bias circuit diagram is shown in Figure 1, with V_{dd} = 5 volts and V_{ref} = 1.23 volts. The dose rate for the exposure was approximately 400 rads(Si)/hour.

The devices were characterized prior to entering the radiation chamber and at nine times during the exposure, the devices were removed to the Cobalt cell and characterized. The nine post exposure characterizations were done at approximately 2.5, 5, 7.5, 10, 15, 20, 30, 40 and 50 krads(Si). Finally, after the 50 krad(Si) exposure, the devices were placed in a 100°C oven for approximately 1 week and were then characterized a final time.

A block diagram showing the characterization methodology is given in Figure 2. A computer running LabView™ (LV) software (with an in-house application for the AD5334) controlled power supplies, a switch matrix and a digital multimeter (via a General Purpose Interface Bus (GPIB)). The LV application sequentially generated the input code for the DAC from 0 to 255. Utilizing the switch matrix, all four channels of each device had their output voltage read via the multimeter. The LV application recorded the input code, the ideal output voltage, the measured output voltages on the four channels (A-D), the supply current and the current on two input lines (6 and 7).

This data was used to calculate the maximum differential and integral non-linearity, the maximum gain and offset errors and the maximum supply and input current draw.

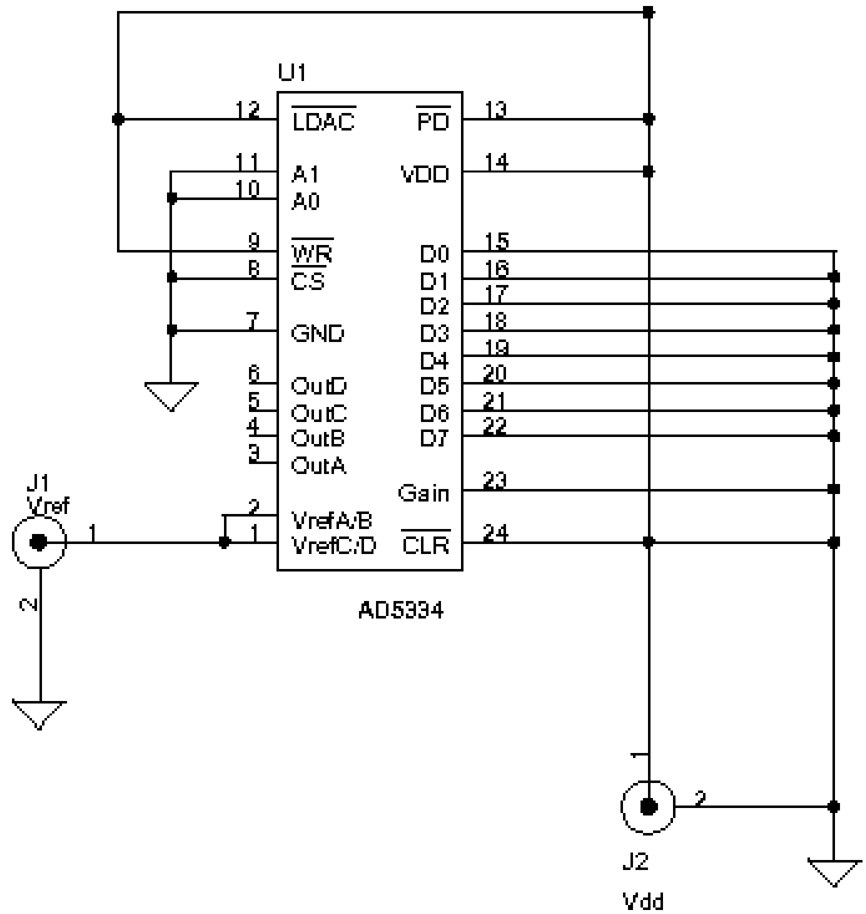

Figure 1. Bias circuit for the Analog Devices AD5334 Digital to Analog Converter.

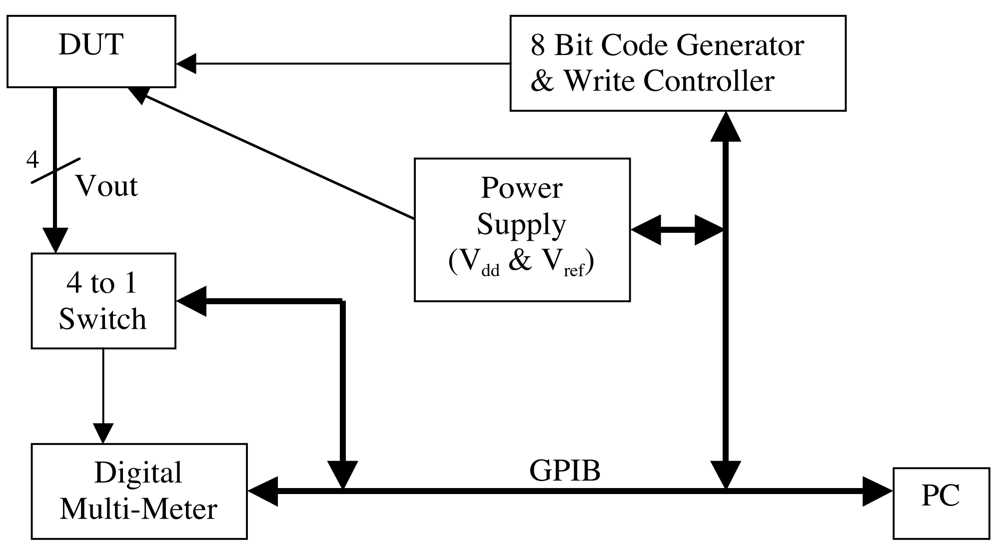

Figure 2. Block Diagram of Test System for the Analog Devices AD5334 Digital to Analog Converter.

V. Results

As stated above, the Differential Non-Linearity (DNL), Integral Non-Linearity (INL), Gain Error and Offset Error were calculated based on the collected output voltages. These values, as well as the supply and input currents, were collected and calculated as a function of the input code and the output channel. In each of the four channels of the five devices tested, the maximum value for each of these characteristics was determined. These twenty values for each of the characteristics were averaged and the characteristics plotted as a function of the dose. The results are shown in Figure 3 (DNL), Figure 4 (INL), Figure 5 (Gain Error), Figure 6 (Offset Error), Figure 7 (Supply Current), and Figure 8 (Input Current).

Due to noise in the test setup and the laboratory, some of the six parameters calculated were out of data sheet specification during the pre-radiation testing. This does not effect the overall testing, it just places a minimum "floor" for each of the parameters. This "floor" in the minimum sensitivity this testing will have for each of those parameters. The table of average and one-sigma values, for the six parameters, is given in Table I.

TABLE I

Parameter	Pre-radiation laboratory measurements
DNL	0.72 ± 0.42 LSBs
INL	2.3 ± 1.9 LSBs
Gain Error	-0.07 ± 0.2 % Full Scale
Offset Error	-0.6 ± 1.0 % Full Scale
Supply Current	415 ± 31 μAmps
Input Current	0.5 ± 0.01 μAmps

From the data plotted in Figure 3 through Figure 8 it can be seen that the parameters begin to deviate from the nominal values in Table I at approximately 15 krads(Si). By 20 krads(Si), all the parameters (except the input current) have begun to degrade significantly. In fact the DNL and INL have degraded beyond the 8-bit performance of the DAC. Even after the 100 °C, 1 week anneal, recovery of all the parameters is minimal.

Plotted in Figure 9 through Figure 14 is the raw data of output voltage versus input code for one channel of one test device (DUT69, channel A). Figure 9 (Pre-rad) and Figure 10 (15 krads(Si)) shown nominal output. However, once 20 krads(Si) is reached (Figure 11), the device has lost montonicity over the majority of the range of the input. By 30 krads(Si) (Figure 12), The oscillatory nature extends over the entire range and has increased. At 50 krads(Si) (Figure 13), the "linear" curve is now almost exponential in shape with large oscillations. After the 100 °C 1 week anneal, the curve is still basically the same as the 50 krads(Si) curve, indicating no recovery is expected due to lower dose rates in space.

Based on this data, the AD5334 parametrically changes between 15 and 20 krads(Si) to the point of non-performance. Therefore, the AD5334 is qualified to 15 krads(Si) under the bias conditions used in this testing.

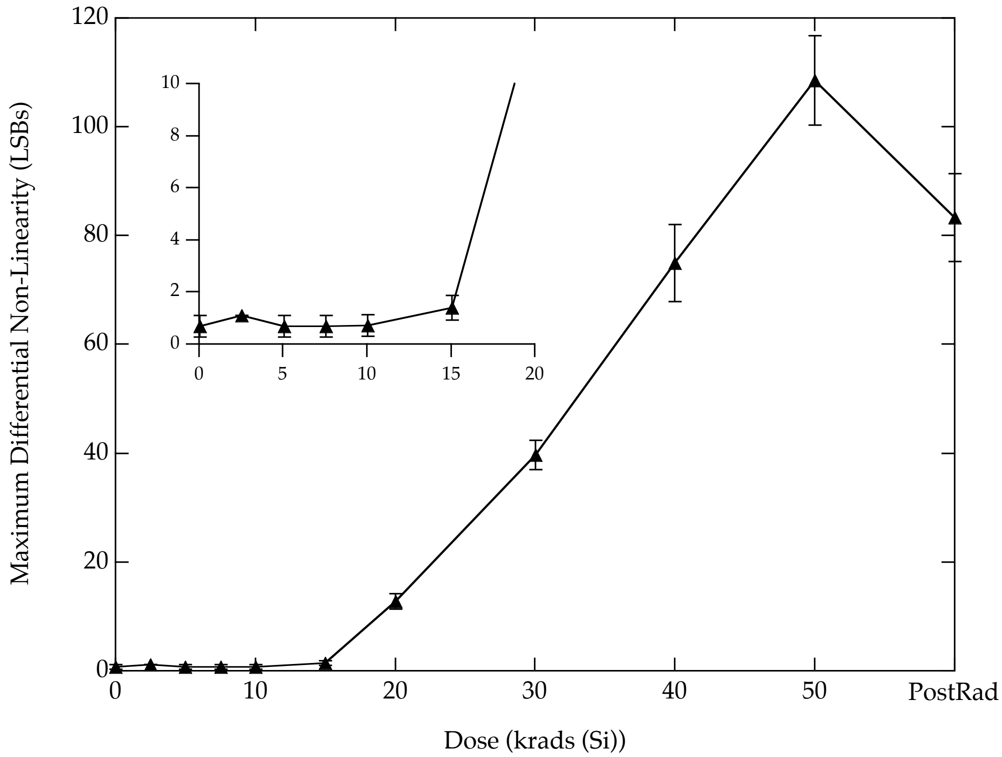

Figure 3. Maximum Differential Non-Linearity as a function of dose.

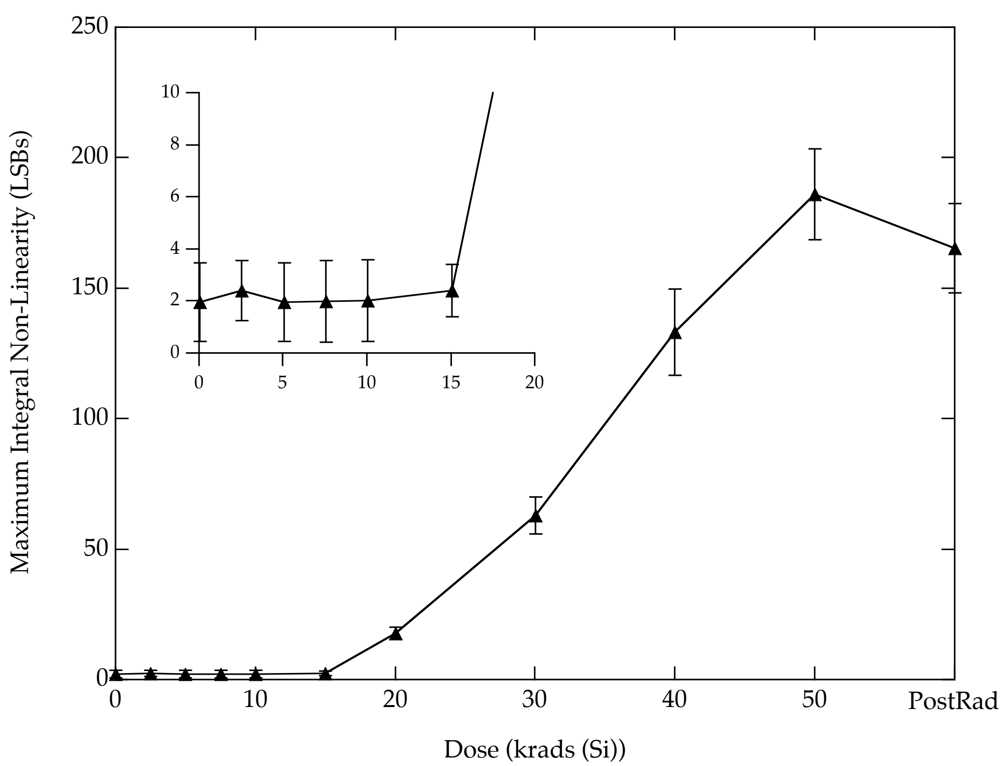

Figure 4. Maximum Integral Non-Linearity as a function of dose.

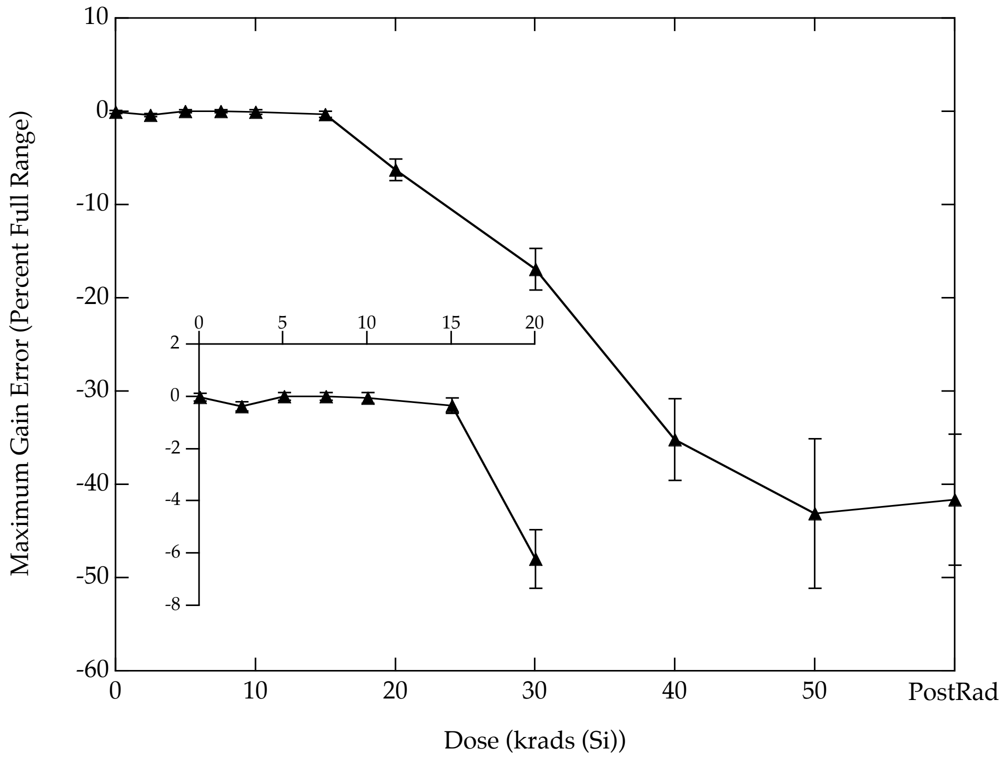

Figure 5. Maximum Gain Error as a function of dose.

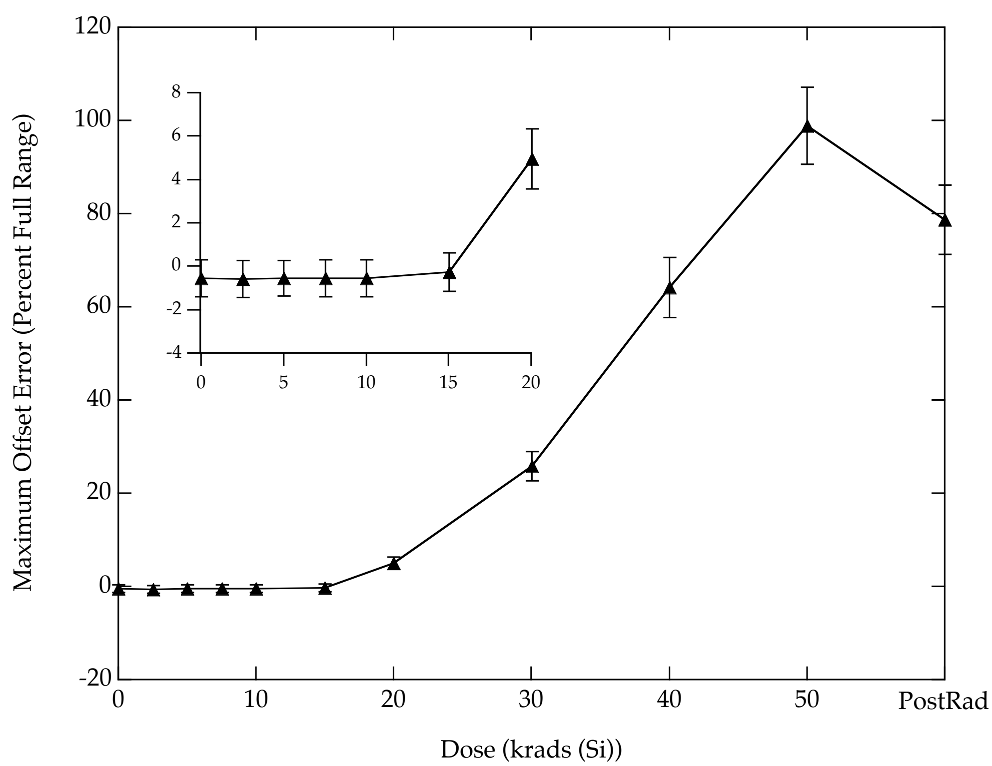

Figure 6. Maximum Offset Error as a function of dose.

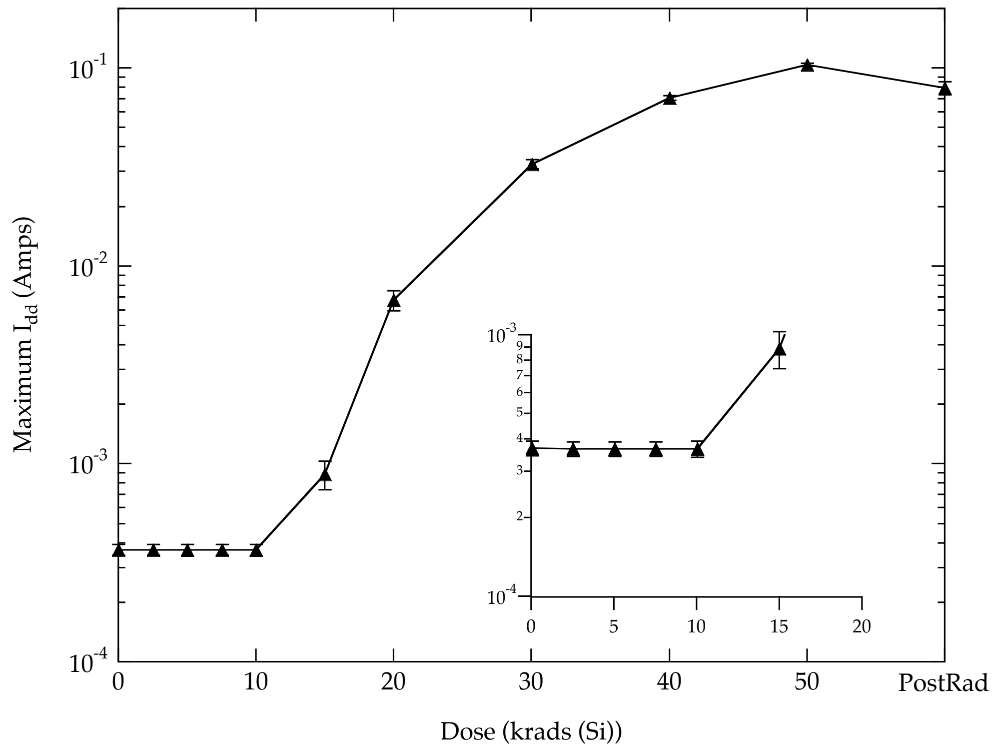

Figure 7. Maximum Supply Current as a function of dose.

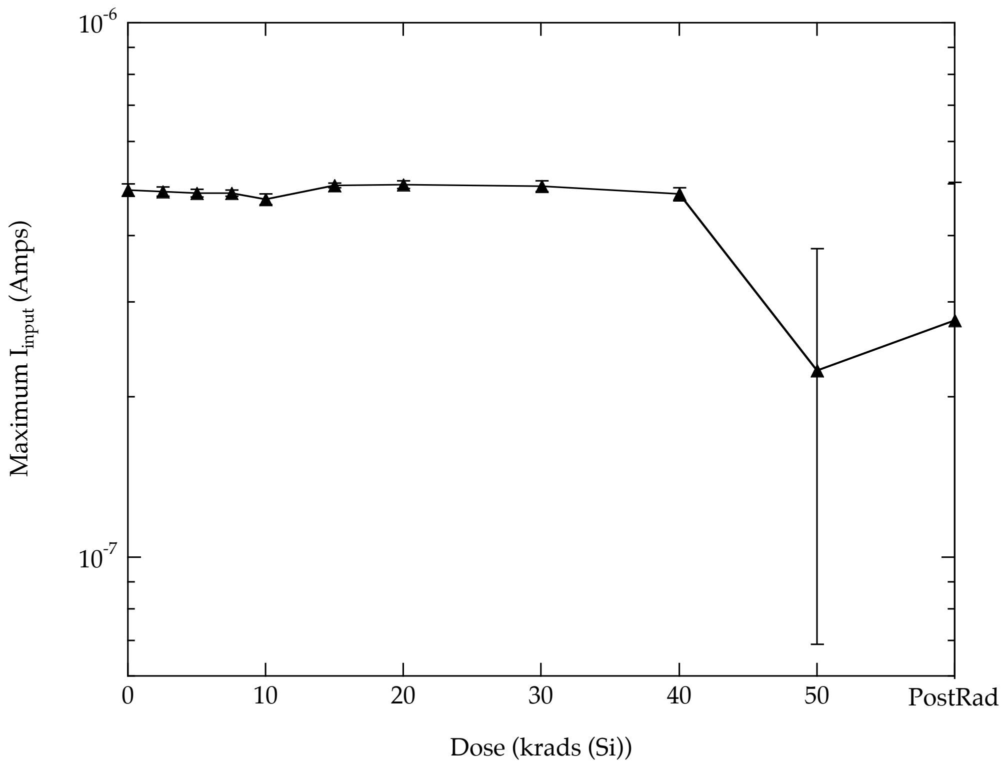

Figure 8. Maximum Input Current as a function of dose.

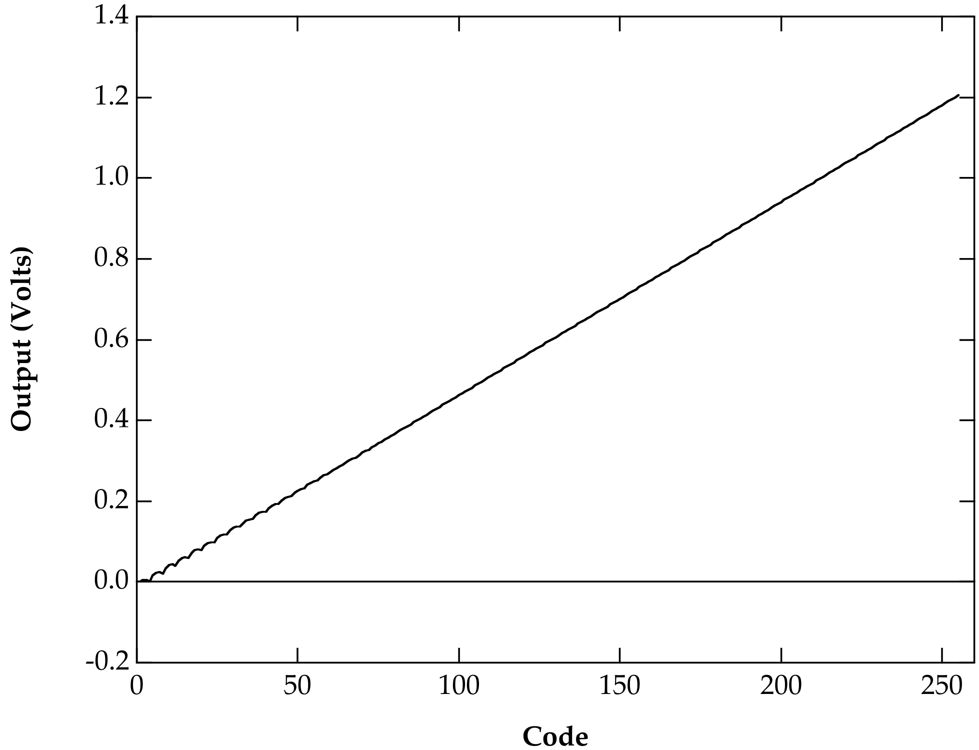

Figure 9. Output voltage for DUT69 (Channel A) as a function of the input code at 0 krads(Si).

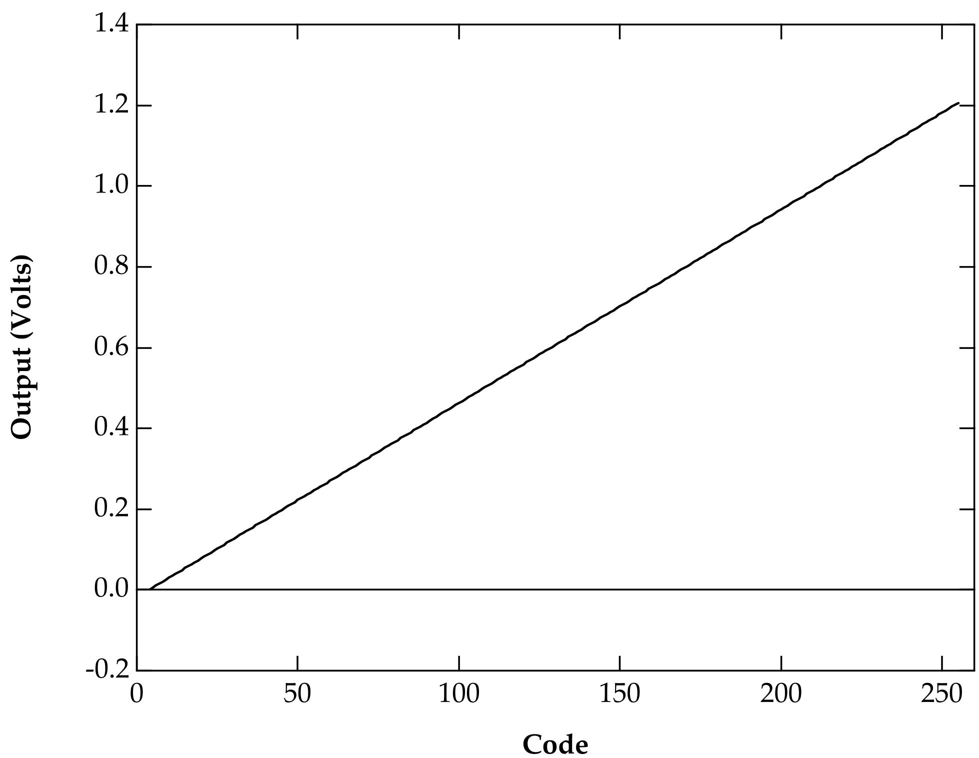

Figure 10. Output voltage for DUT69 (Channel A) as a function of the input code at 15 krads(Si).

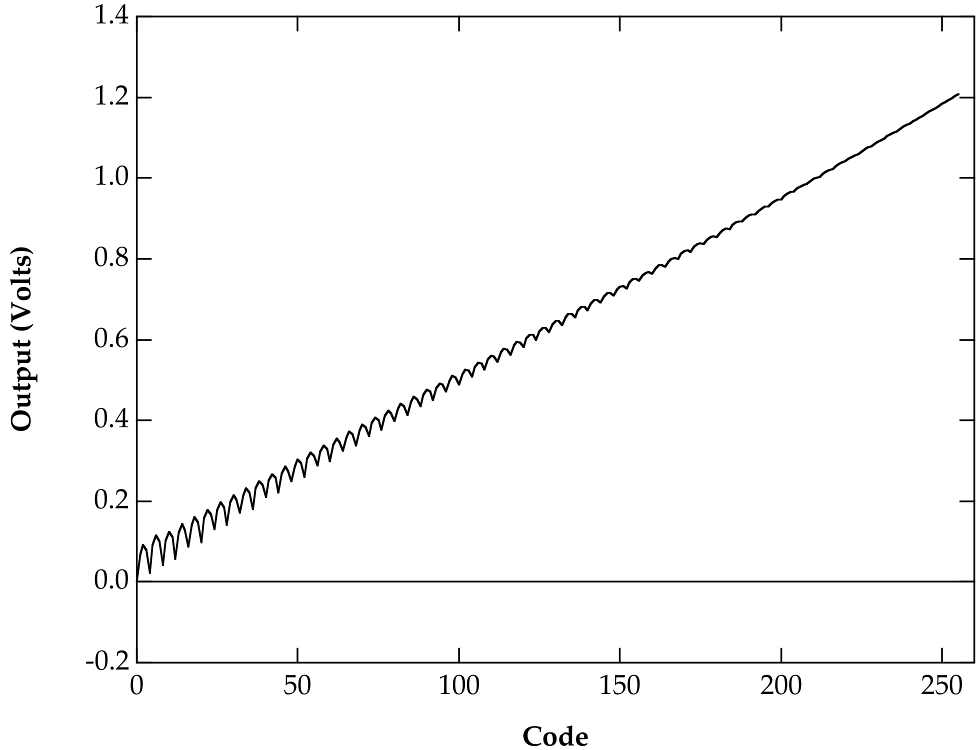

Figure 11. Output voltage for DUT69 (Channel A) as a function of the input code at 20 krads(Si).

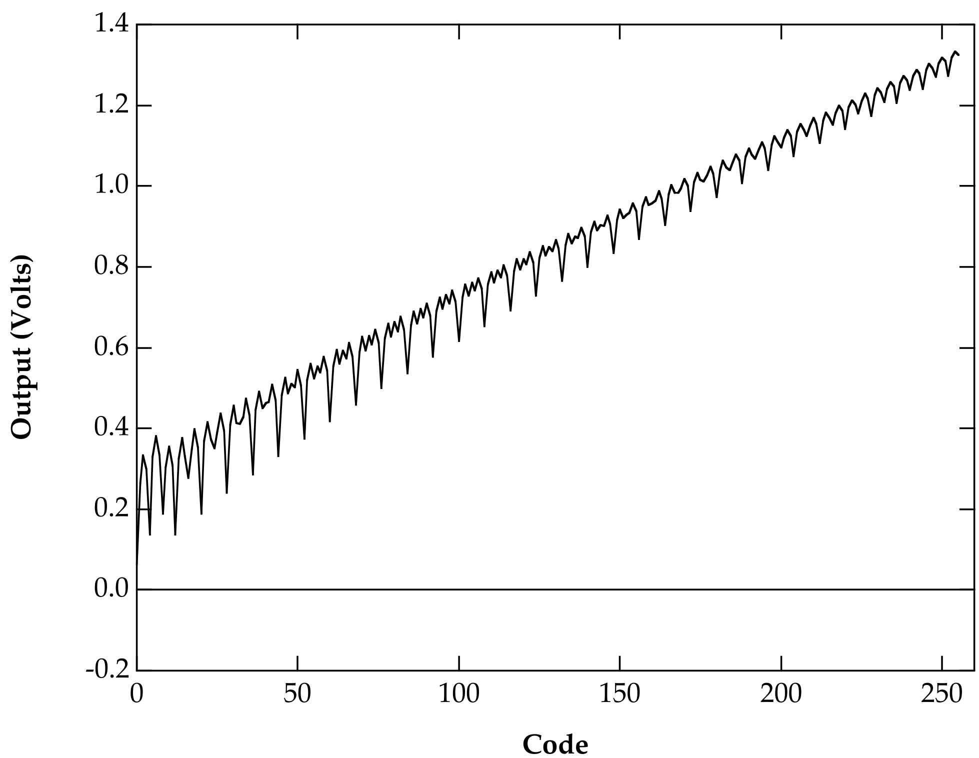

Figure 12. Output voltage for DUT69 (Channel A) as a function of the input code at 30 krads(Si).

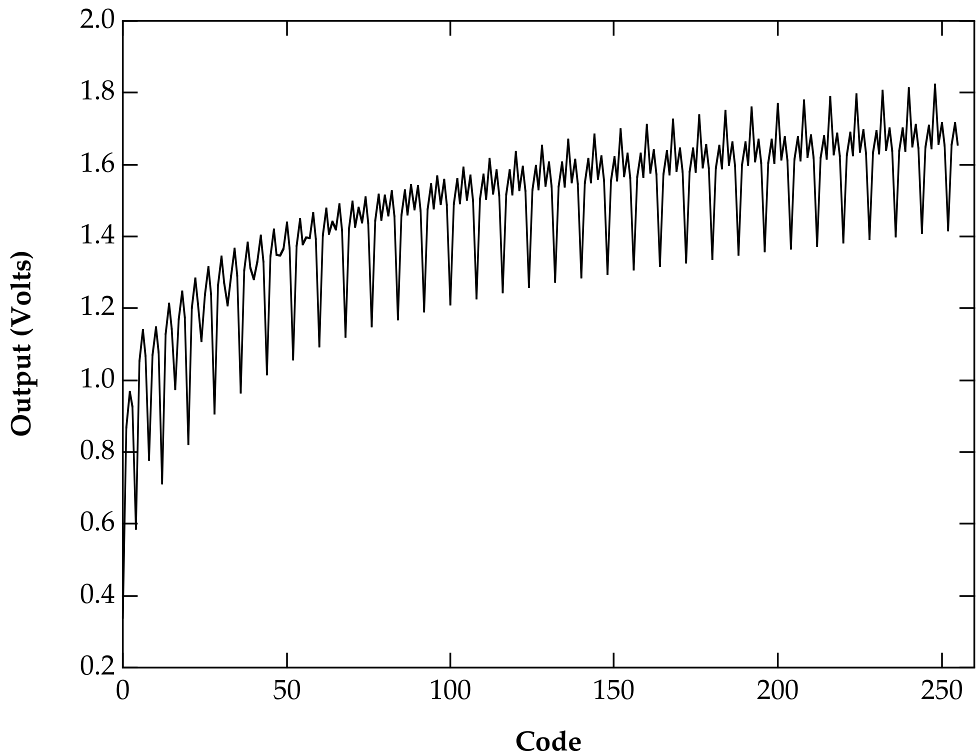

Figure 13. Output voltage for DUT69 (Channel A) as a function of the input code at 50 krads(Si).

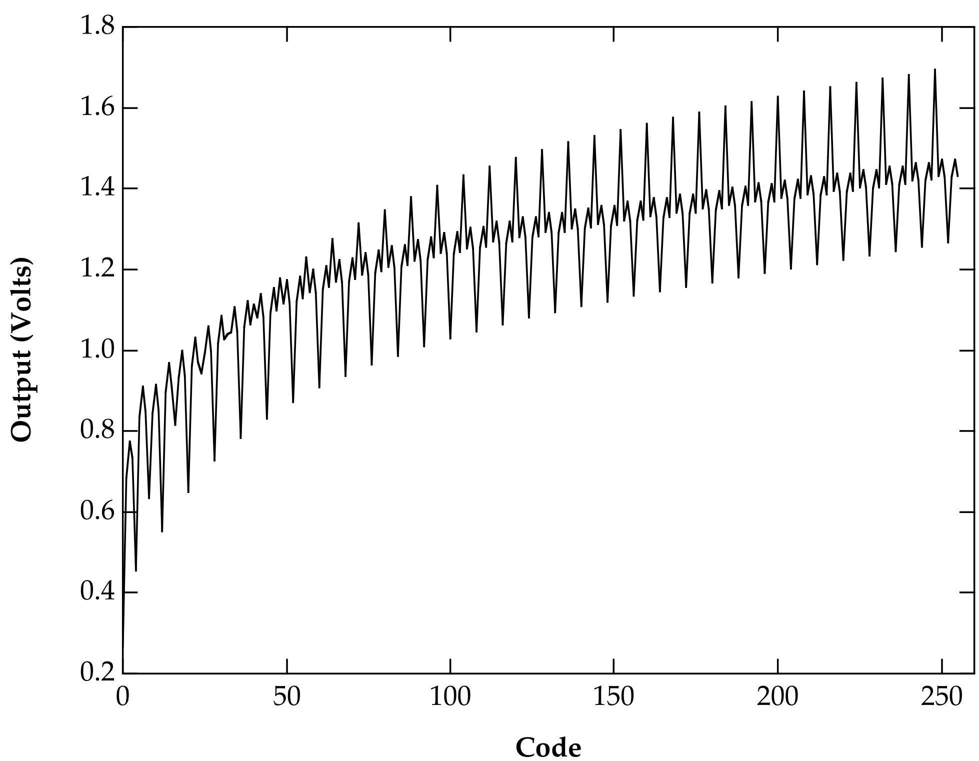

Figure 14. Output voltage for DUT69 (Channel A) as a function of the input code after 100 °C 1 week anneal.