NASA/TM— 20220007246

Total Ionizing Dose Test Report for the AD581 Precision Voltage Reference

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June 2022

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Report Date: 11/30/2012

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June 2022

Acknowledgments (optional)

This work was sponsored by the NASA GSFC Radiation Effects and Analysis Group and supported by the Joint Polar Satellite System (JPSS) Program.

Level of Review: This material has been technically reviewed by technical management.

Available from

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I. Introduction

The purpose of this test was to determine the low dose rate total ionizing dose susceptibility of the AD581 precision voltage reference, for the Joint Polar Satellite System (JPSS) Program.

II. Device Description

The AD581 is a temperature compensated, monolithic, band gap voltage reference manufactured by Analog Devices, Inc. The part provides a 10 V output from an unregulated input ranging from 12 to 30 V. Table I shows the part and test information. Detailed device parameters can be found in the datasheet [1]. Figure 1 shows schematic diagrams of the package outline and pin configuration.

Table I.
Test and part information

Manufacturer Part Number	AD581TH/883
SMD Part Number	5962-8688202XA
Manufacturer	Analog Devices, Inc.
Lot Date Code (LDC)	0020B
REAG ID Number	12-074
Quantity tested	20
Part Function	Precision voltage reference
Package Style	TO-5 metal can
Test Equipment	Keithley 2430 1kW pulse meter, Keithley 2425 100W source meter, oscilloscope, power supply
Dose Levels	2.5, 4.5, 9, 13.5, 18, and 27 krad(Si)
Dose Rate	0.010 rad(Si)/s

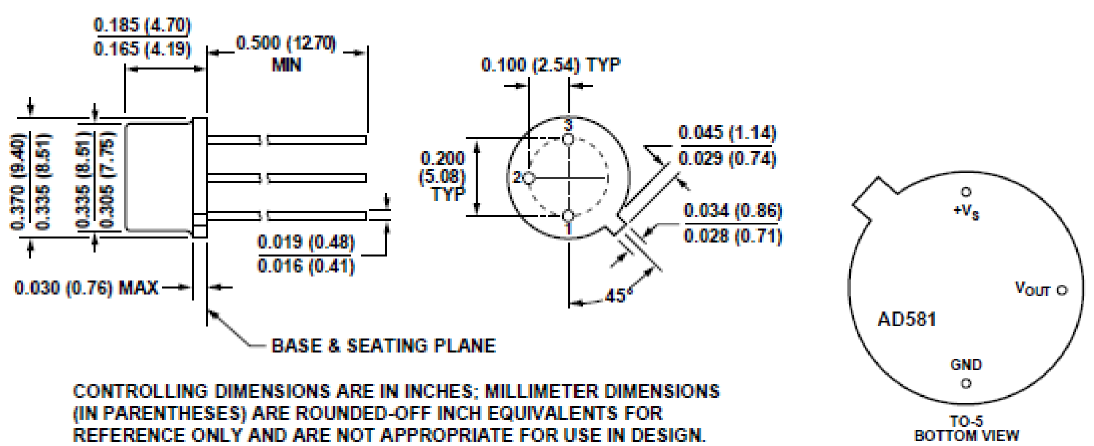

Figure 1. Package Outline and pin configuration.

III. Test Method

The test procedures, including the radiation dosimetry details, were in accordance with the latest version of MIL-STD-883 Method 1019 [2].

A. Parametric characterization

The electrical parameters of interest for this test are shown in Table II. The table also shows the desired measurement conditions and measurement precision levels.

The electrical performance measurements were arranged so that the lowest power dissipation in the device occurs in the earliest measurements, and the highest power dissipation occurs in the latest measurements, to avoid influences from device heating effects.

The devices were characterized in the following sequence: first the control sample, then the test samples, and finally the control sample again. The devices were tested in the same order throughout testing. The measurements were in accordance with the manufacturer's datasheet.

Table II.
Electrical parameters

Parameter	Measurement Conditions[†]	Measurement Resolution
Quiescent Current (ICC1)	VIN = +15V	≤ 0.01mA
Quiescent Current (ICC2)	VIN = +13.1V	≤ 0.01mA
Output Voltage (VOUT)	VIN = +15V	≤ 0.1mV
Line Regulation (VRLINE)	$13V \le V_{IN} \le 15V$	≤ 0.01mV
Load Regulation (VRLOAD1)	VIN = +15V $0 \le I_{OUT} \le 5$ mA	≤ 5µV/mA
Load Regulation (VRLOAD2)	VIN = +13.1V $0 \le I_{OUT} \le 5$ mA	≤ 5µV/mA

[†]All measurements at T = +25°C.

B. Irradiation bias configuration

Ten (10) devices were irradiated under bias. The bias configuration is shown in Figure 2. Ten (10) devices were irradiated unbiased (all pins grounded).

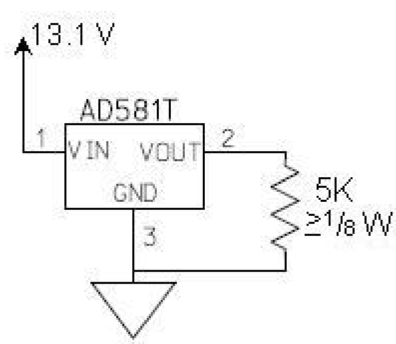

Figure 2. Bias configuration during irradiation.

C. Irradiation procedures

The devices were irradiated with 1.1 MeV gamma rays in air at room temperature. The devices were placed inside Al/Pb shielding boxes to minimize dose enhancement effects. The dose rate was 0.010 rad(Si)/s. The dose rate was within ±10% for each irradiation interval.

The irradiation steps were 2.5, 4.5, 9, 13.5, 18, and 27 krad(Si). Ball Aerospace has performed radiation transport analysis, and determined that the worst case 1× total ionizing dose level for this part is approximately 4.5 krad(Si). The dose levels specified in this test satisfies the JPSS program radiation design margin requirements.

The down time during each irradiation step were kept to a minimum, and did not exceed 72 hours. No annealing characterization was required due to the low dose rate nature of the test.

IV. Results

The parts showed parametric degradation from total dose irradiation. All parts were functional through the completion of the test, with an accumulated dose of 27 krad(Si). The parts irradiated with pins grounded showed higher degradation levels relative to the parts irradiated with biased configuration, for all measured electrical parameters.

The output voltage was the most radiation sensitive parameter. One part irradiated with pins grounded exceeded specification following 8.8 krad(Si). The remaining 9 parts irradiated with pins grounded exceeded specification following 13.5 krad(Si). All 10 parts irradiated with biased configuration exceeded specifications after 18 krad(Si). Figures 3 and 4 show the output voltage as a function of total dose, with output at 0 mA and 5 mA, respectively.

The parts also exhibited parametric failure to the line regulation following 13.5 krad(Si). Figure 5 shows the line regulation as a function of total dose. The load regulation remained within specification limits until 27 krad(Si), where 4 parts irradiated with pins grounded exhibited parametric failure. Figures 6 and 7 show the load regulation as a function total dose, with input voltage at 13 and 15 V, respectively. The quiescent current did not degrade throughout the irradiation, and remained within specification up to 27 krad(Si).

We note that following the 8.5 krad(Si) step, a power outage at the facility from Hurricane Sandy resulted in 80 hours of down time. During that time the parts remained biased in their respective configurations, without radiation. We took another measurement immediately following the interruption at 8.8 krad(Si). The measurements at 8.8 krad(Si), which includes the 80 hours of biased annealing, revealed slight parametric drifts. However, the effects are insignificant relative to the magnitude of the radiation-induced parametric degradation for each dose step.

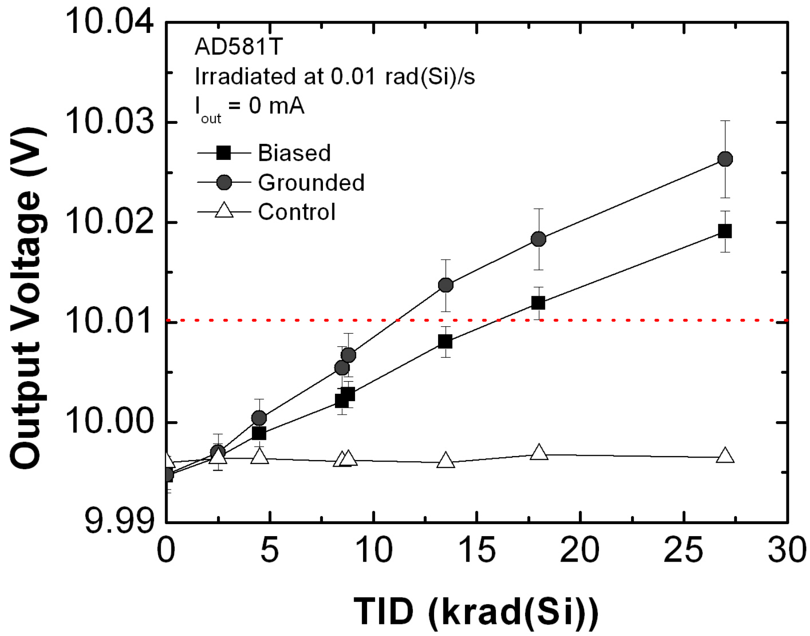

Figure 3. Output voltage vs. TID, with I_{out} = 0 mA, for parts irradiated at 0.01 rad(Si)/s with biased configuration and with all pins grounded. The error bars indicate standard deviation from part-to-part variability. The red dotted line indicates maximum specification limit.

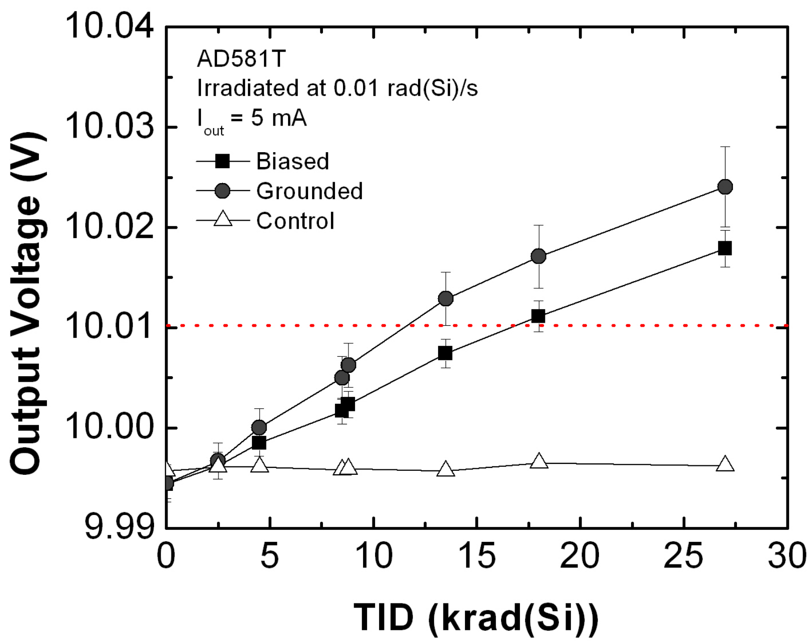

Figure 4. Output voltage vs. TID, with I_{out} = 5 mA, for parts irradiated at 0.01 rad(Si)/s with biased configuration and with all pins grounded. The error bars indicate standard deviation from part-to-part variability. The red dotted line indicates maximum specification limit.

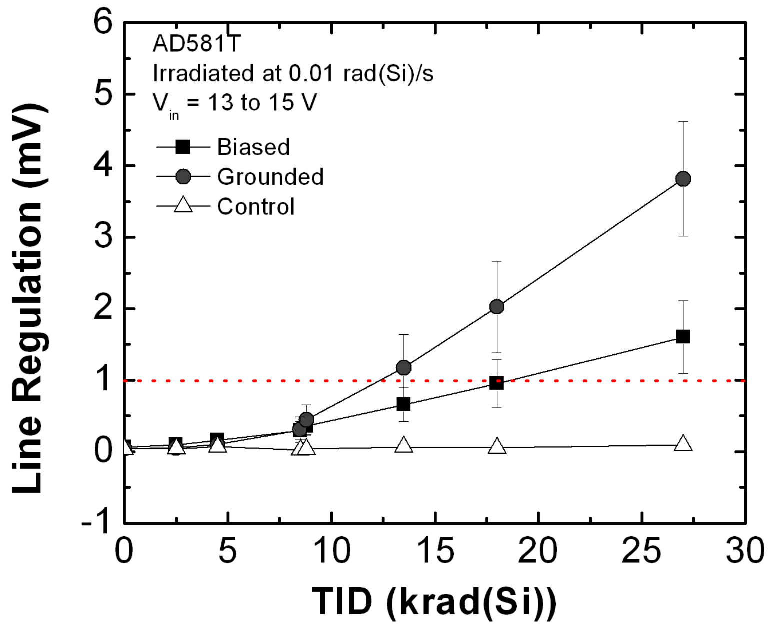

Figure 5. Line regulation vs. TID, with V_{in} = 13 to 15 V, for parts irradiated at 0.01 rad(Si)/s with biased configuration and with all pins grounded. The error bars indicate standard deviation from part-to-part variability. The red dotted line indicates maximum specification limit.

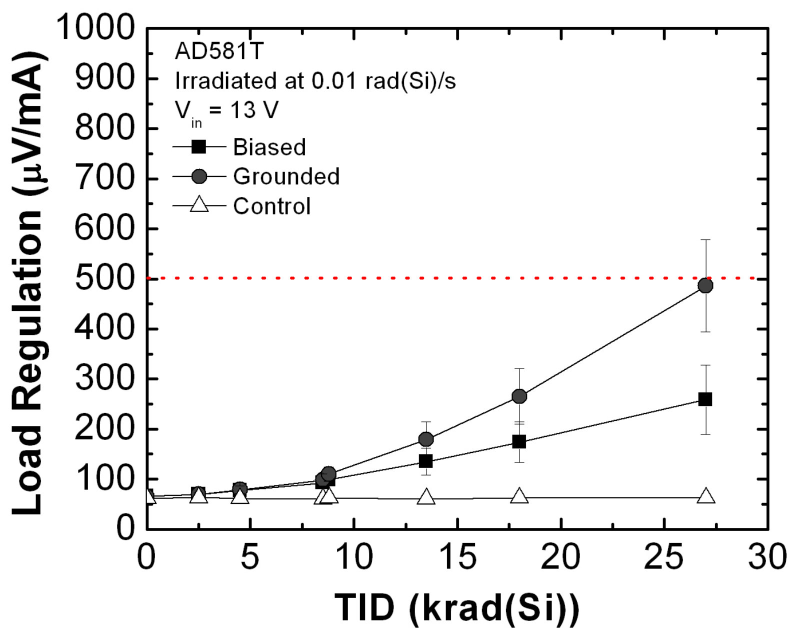

Figure 6. Load regulation vs. TID, with V_{in} = 13 V, for parts irradiated at 0.01 rad(Si)/s with biased configuration and with all pins grounded. The error bars indicate standard deviation from part-to-part variability. The red dotted line indicates maximum specification limit.

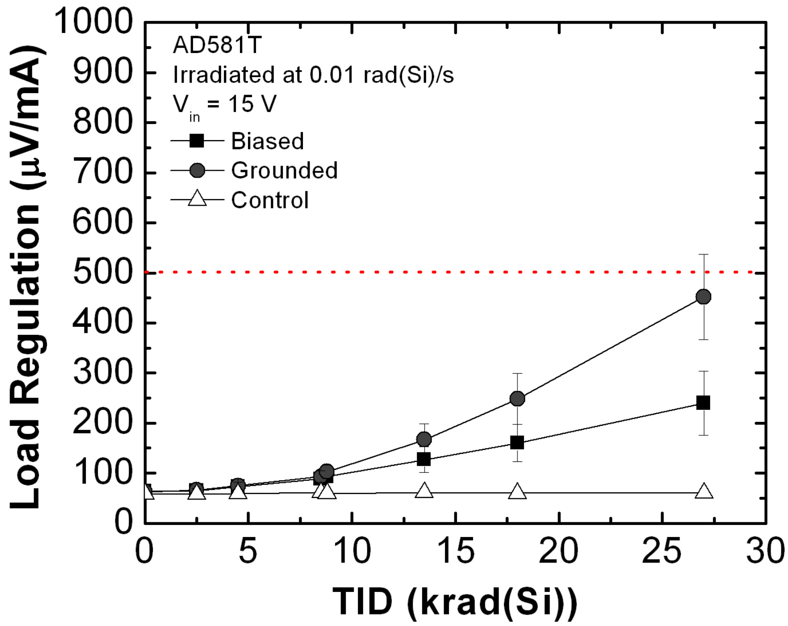

Figure 7. Load regulation vs. TID, with V_{in} = 15 V, for parts irradiated at 0.01 rad(Si)/s with biased configuration and with all pins grounded. The error bars indicate standard deviation from part-to-part variability. The red dotted line indicates maximum specification limit.

V. Conclusion

The AD581 voltage reference is susceptible to TID-induced parametric degradation. We observed that the parts irradiated with pins grounded showed higher degradation levels relative to the parts irradiated with the application bias configuration. We also observed that the output voltage was the most radiation sensitive parameter, where initial parametric failure occurred following 8.8 krad(Si) for parts irradiated with pins grounded.

The parts do not meet the JPSS total dose requirement of 9 krad(Si) (2× radiation design margin). However, since the parametric degradation is monotonic and predictable, the parts may still be acceptable for the specific application, given that the degradation levels are within the application limits.

VI. Reference

[1] Manufacturer's datasheet for the AD581 available on-line, see https://www.analog.com/media/en/technical-documentation/data-sheets/AD581.pdf

[2] MIL-STD-883, Test Method 1019 Condition D, Ionizing Radiation (Total Dose) Test Procedure.