Total Ionizing Dose Report

Apogee AP54RHC Product Family

30 krad (Si)

This report covers the radiation characterization results for the devices in the AP54RHC product family. The report specifies the measured performance impact of TID (Total Ionizing Dosage) up to 30krad(Si). The results show that the devices passed all parametric measurements within the specified limits.

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1 Scope

The report covers the AP54RHC family, and it details the test procedures, the measurement and irradiation test setups, and the measured characteristics of the devices before and after being irradiated. The reported measurement results show that the devices have excellent performance for low-earth-orbiting (LEO) and other applications up to 30krad (Si).

2 Tested Devices

AP54RHC11 (Triple 3-input AND) and AP54RHC27 (Triple 3-input NOR) were tested. These parts were burned-in for 240 hours at 125°C in accordance with MIL-STD-883J, Test Method 1015.10 prior to TID exposure. The burn-in oven, located at Apogee's Plano based electronics lab is shown in Figure 1 and Figure 2.

Figure 1: Burn-in apparatus

Figure 2: Burn-in Oven Internal

Although the AP54RHC11 and AP54RHC27 were the only parts tested in the AP54RHC family, the remaining parts of the family are Qualified By Similarity given that all parts in the family use the same base silicon layers. A single top level metal layer is used to set the boolean functionality and is the only difference between die in the members family, as shown in Figure 6.

3 Irradiation and Testing Setups and Procedure

3.1 Irradiation Facility and Equipment

VPTrad, based in Chelmsford, Massachusetts, served as the irradiation facility and provided an exposure report dated August 20th, 2020 [2]. As specified there, the dosimetry equipment was based on the BioSpin e-scan from Bruker [3], and the source was a Gammacell GC220 Cobalt 60 irradiation unit [4], shown in Figure 3 below. The irradiation rate was 126 rad(Si)/s and the rate at calibration was 136 rad(Si)/s ±6%, as per a calibration performed on January 3rd, 2020. Figure 4 shows one of the biasing boards that was used to bias the devices during the irradiation. The jumpers shown in the photo were used to create the desired biasing conditions for each of the 2 different boards. The boards, referred to as "Board #2 and Board #3" in the VPTrad report, were irradiated at incremental TID levels, and the devices were removed at specific dosage levels as detailed in Table 1.The devices remained in these boards while being shipped to the testing

facility, such that the identity of the tested devices and the TID levels they were exposed to could be easily confirmed.

Figure 3: Cobalt 60 irradiation unit

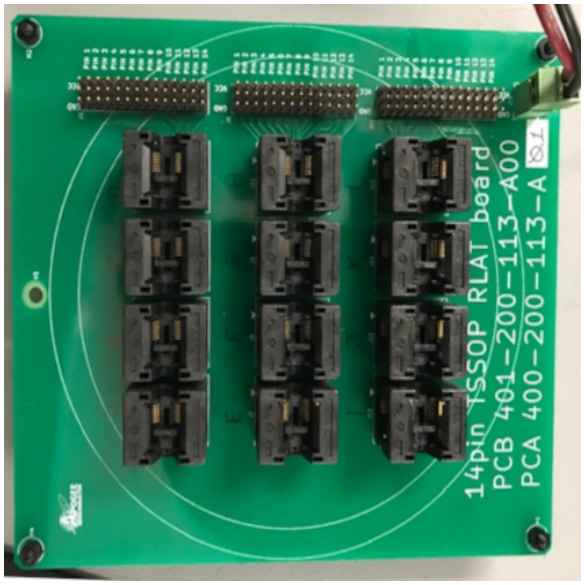

Figure 4: Biasing board used in irradiation

3.2 Measurement Setup

The devices went through pre-radiation and post-radiation DC parametric and functional testing at the facility of Apogee Semiconductor in Texas. The devices were tested in a semi-automatic benchtop screening board interfacing with Keithley 2400 SMUs (Source Measurement Unit) as shown in figure 5. The calibration certificates of all instruments used can be found in appendix A.

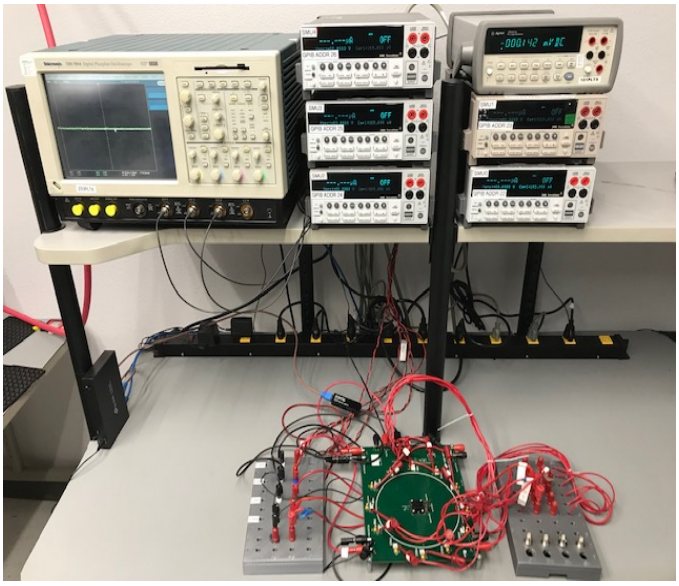

Figure 5: Apogee benchtop screening board

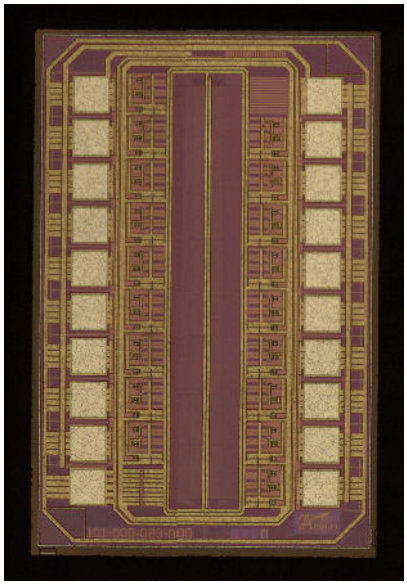

Figure 6: Apogee AP54RHC Family Die

3.3 Test Procedure

The TID irradiation test was done in accordance with the procedures outlined in MIL-STD-883-1 (Testing Method 1019.9) [5]. During the irradiation at the VPTrad facility, the tested devices were all biased such that their inputs were tied to either GND or to VDD (3.3V or 5V), to validate all possible bias conditions during the exposure for common VDD expected in most applications. The boards were exposed to increasing TID levels at VPTrad, Chelmsford, Massachusetts and the devices were then removed from the biasing boards at corresponding dosage levels, as specified in Table 1. They were then packed in a pillowstat box and shipped overnight in dry ice to the testing facility, Apogee Semiconductor's lab in Texas. Upon arrival, the devices were unpacked from the dry ice and allowed to warm to ambient/room temperature. These parts were then tested using the measurement setup described above. The characteristics recorded for each tested device were compared against what was recorded for it at the same setup prior to its irradiation, as shown in Figure 7 and Figure 8.

Table 1: List of tested devices and corresponding dosage levels

VDD (V)	Device Type	Device Serial Number	DUT #	Dosage (krad (Si))
5	AP54RHC11	819	1	10
	AP54RHC11	498	2	10
	AP54RHC11	839	3	20
	AP54RHC11	813	4	20
	AP54RHC11	808	5	30
	AP54RHC11	844	6	30
	AP54RHC11	810	7	35
	AP54RHC11	822	8	35
	AP54RHC11	824	9	45
	AP54RHC11	801	10	45
3.3	AP54RHC27	740	11	20
	AP54RHC27	717	12	20
	AP54RHC27	739	13	35
	AP54RHC27	712	14	35
	AP54RHC11	831	15	45
	AP54RHC11	807	16	45

4 Test Results

The parametric and functional results of both the AP54RHC11 and the AP54RHC27 devices pass for all biasing conditions and across all dosage levels.At TID levels below the specified 30krad(Si) rating for the AP54RHC Family, the maximum shift in I_{DD} (quiescent power supply current) observed was below 1%. At TID levels greater than the specified 30krad(Si) limit, the I_{DD} current was observed to exhibit a small increase in current, but still well within the product datasheet limits. These results are visualized in Figure 7 and Figure 8. There was no significant shift (<1%) observed in the other measured parameters accross all the radiation levels and biasing conditions. It was noted that DUT 8 and DUT 15 had input pins that were pulling excessive amount of current, which is indicative of electrical overstress on the gate oxides. Therefore, their results have been omitted from this report. At the time of publication of this report, the 2 units exhibiting electrical overstress had been submitted to the failure analysis lab. The results of this will be published in a separate report.

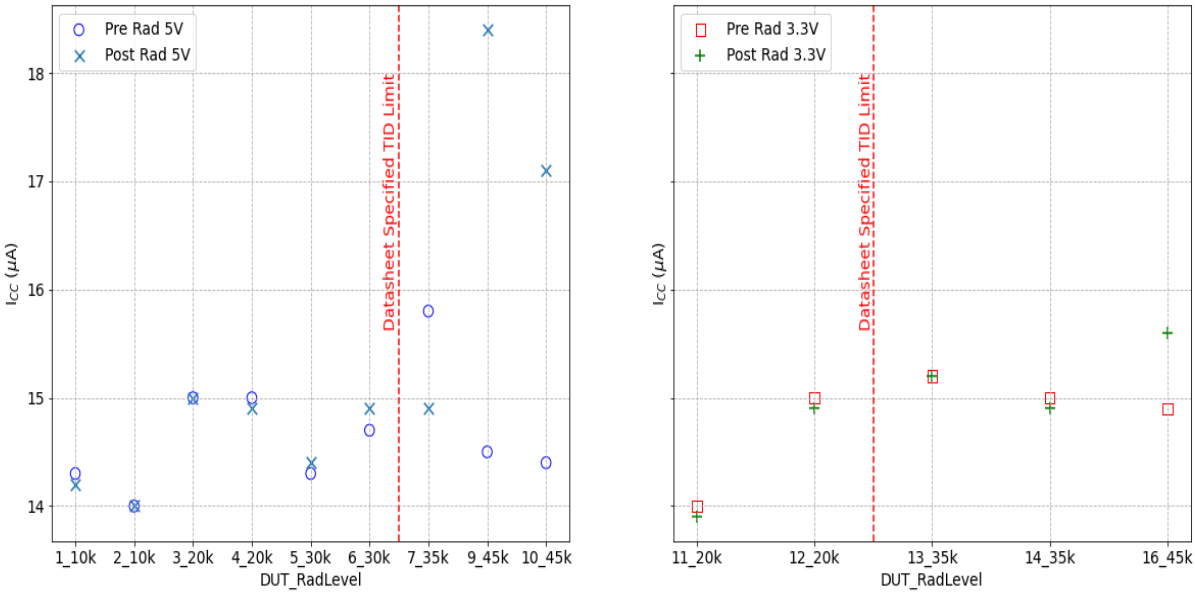

Figure 7: Pre radiation and post radiation power supply current all outputs HIGH

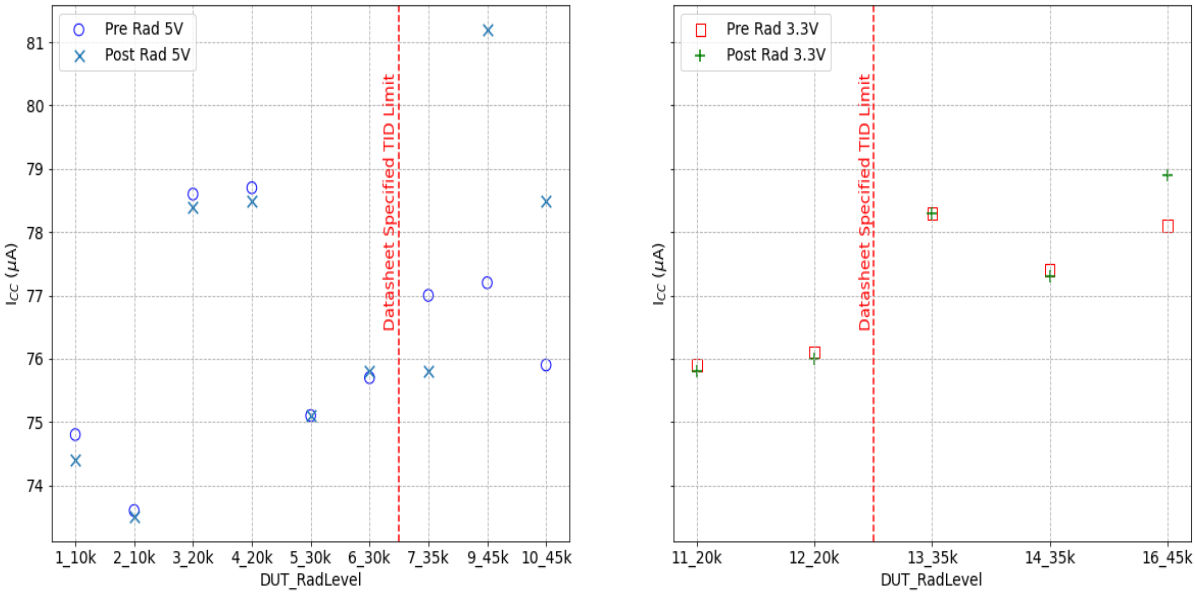

Figure 8: Pre radiation and post radiation power supply current all outputs LOW

5 Exposure Report from VPTrad

101 Brick Kiln Road
Chelmsford, MA 01824

Chelmsford, MA 01824
www.VPTRad.com

Radiation Lab & Test Services

Apogee Semiconductor
538 Haggard Street
Suite 406
Plano, TX 75074

August 20, 2020

Subject: Exposure Report

Job#:	20185
Product:	12 DUT Boards
Irradiation Date:	08/20/2020
Source Number:	GC220 #136R
Dosimetry Equipment:	Bruker Biospin escan # SC0424
Calibration Due:	(NIST) 06/21 (Batch # T030901)
Cal. Rate:	136 ±6% rad(Si)/s @ 01/03/2020
Start Rate:	126 rad(Si)/s

The Irradiation Schedule/Test Points are based on the dosimetry maps generated on 01/03/2020. The dose rate is corrected for radiological decay at the start of the irradiation.

Irradiation Schedule/Test Points

Operator:	Board #1	Run#	Rate rad(Si)/s	Dose rad(Si)	Duration Time	Measure Dose rad(Si) (+3%)	Cummulative Dose rad(Si)	Time on	(seconds)
GB		1	126	100,000	0:13:38	103,068	103,068	1021	818
		2	126	100,000	0:13:38	103,068	206,136	1038	818
		3	126	100,000	0:13:38	103,068	309,204	1056	818
		4	126	100,000	0:13:38	103,068	412,272	1113	818
Operator:	Board #2 & #3	Run#	Rate rad(Si)/s	Dose rad(Si)	Duration Time	Measure Dose rad(Si) (+3%)	Cummulative Dose rad(Si)	Time on	(seconds)
GB		1	126	10,000	0:01:22	10,332	10,332	1151	82
		2	126	10,000	0:01:22	10,332	20,664	1154	82
		3	126	10,000	0:01:22	10,332	30,996	1158	82
		4	126	5,000	0:00:41	5,166	36,162	1201	41
		5	126	10,000	0:01:22	10,332	46,494	1205	82

VPT Rad 101 Brick Kiln Road Building 2 Unit 3 Chelmsford MA, 01824	DLA Land and Maritime Lab Suitability VQH-14-028561 MIL-STD-750 & 883 - TM 1017/1019/1080	Cage Code:849M4

6 Revision History

REVISION	DESCRIPTION	DATE
A00	Initial internal release.	September 5, 2020

For the latest version of this document, please visit https://www.apogeesemi.com.

7 Legal

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References

[1] TSI 180nm CMOS Process (1.8V & 5V)-http://www.tsisemi.com/process/

[2] Exposure Report, VPTrad, February 6, 2020 (available upon request and appended here)

[3] Bruker BioSpin e-scan - https://www.bruker.com/products/mr/epr/e-scan.html

[4] Instruction Manual, Gammacell 220 Cobalt 60 Irradiation Unit
https://www.nrc.gov/docs/ML0216/ML021630449.pdf

[5] Department of Defense, Test Method Standard, Environmental Test Methods for Microcircuits,
MIL-STD-883-1, Part 1: Test Methods 1000-1999
https://quicksearch.dla.mil/Transient/57DC2ED445914404AE4805799B6BD99A.pdf

[6] Agilent 4156B Precision Semiconductor Parameter Analyzer,
User's Guide Volume 2, Measurement and Analysis
https://mntl.illinois.edu/facilities/device-characterization/
equipment/documents/Agilent4155Buserguide.pdf

A Calibration Certificates

SIMCO electronics

Certificate No. **8788829**

783 N. GROVE ROAD, STE. 106
RICHARDSON, TX 75081

ON SITE
CERTIFICATE OF CALIBRATION
FOR
APOGEE SEMICONDUCTOR
538 HAGGARD ST.
PLANO, TX 75074

Description: **KEITHLEY, 2400, Source Meter**

Serial No: **1192264** Asset No: **SMU1** SIMCO ID: **57647-325**

Dept: **NONE** PO No: **2002**

Calibration Date: **12/04/2019**	Calibration Interval: **12 Months**	Next Calibration Date: **12/04/2020**

Arrival Condition:	Service:
MEETS MANUFACTURER'S SPEC'S.	**CALIBRATED TO MFR SPEC, & CLEAN**

Procedure: **2400-902-01 REV D**
Temperature: **72°F** Relative Humidity: **29.2%**

Standards Used:

Manufacturer, Model	Description	SIMCO ID	Due Date	Certificate
FLUKE, 5450A	**Resistance Calibrator**	**15940-812**	**11/16/2020**	**8664094**
AGILENT, 34410A	**Digital Multimeter**	**15940-748**	**09/10/2020**	**8694770**
OMEGA ENGINEERING, RH82	**Thermo Hygrometer W/Dew Point**	**15940-421**	**10/24/2020**	**8734655**

There are 2 Supplementary Data Sheet(s) attached.

Work performed by:
Gregory Bender

Reviewed by:
Daniel Beights

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PLANO, TX 75074

Description: **KEITHLEY, 2400, Source Meter**

Serial No: **4076934** Asset No: **SMU0** SIMCO ID: **57647-324**

Dept: **NONE** PO No: **2002**

Calibration Date: **12/04/2019**	Calibration Interval: **12 Months**	Next Calibration Date: **12/04/2020**
Arrival Condition: **MEETS MANUFACTURER'S SPEC'S.**	Service: **CALIBRATED TO MFR SPEC, & CLEAN**	

Procedure: **2400-902-01 REV D**
Temperature: **72°F** Relative Humidity: **29.2%**

Standards Used:

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FLUKE, 5450A	**Resistance Calibrator**	**15940-812**	**11/16/2020**	**8664094**
AGILENT, 34410A	**Digital Multimeter**	**15940-748**	**09/10/2020**	**8694770**
OMEGA ENGINEERING, RH82	**Thermo Hygrometer W/Dew Point**	**15940-421**	**10/24/2020**	**8734655**

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Work performed by:
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538 HAGGARD ST.
PLANO, TX 75074

Description: **KEITHLEY, 2400, Source Meter**

Serial No: **4300766** Asset No: **SMU4** SIMCO ID: **57647-323**

Dept: **NONE** PO No: **2002**

Calibration Date: **12/04/2019**	Calibration Interval: **12 Months**	Next Calibration Date: **12/04/2020**
Arrival Condition: **MEETS MANUFACTURER'S SPEC'S.**	Service: **CALIBRATED TO MFR SPEC, & CLEAN**	

Procedure: **2400-902-01 REV D**
Temperature: **72°F** Relative Humidity: **29.2%**

Standards Used:

Manufacturer, Model	Description	SIMCO ID	Due Date	Certificate
FLUKE, 5450A	**Resistance Calibrator**	**15940-812**	**11/16/2020**	**8664094**
AGILENT, 34410A	**Digital Multimeter**	**15940-748**	**09/10/2020**	**8694770**
OMEGA ENGINEERING, RH82	**Thermo Hygrometer W/Dew Point**	**15940-421**	**10/24/2020**	**8734655**

There are 2 Supplementary Data Sheet(s) attached.

Work performed by:
Gregory Bender

Reviewed by:
Daniel Beights

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ON SITE CERTIFICATE OF CALIBRATION FOR APOGEE SEMICONDUCTOR

538 HAGGARD ST.
PLANO, TX 75074

Description: **KEITHLEY, 2400, Source Meter**

Serial No: **4301144** Asset No: **SMU3** SIMCO ID: **57647-322**

Dept: **NONE** PO No: **2002**

Calibration Date: **12/04/2019**	Calibration Interval: **12 Months**	Next Calibration Date: **12/04/2020**

Arrival Condition:	Service:
MEETS MANUFACTURER'S SPEC'S.	**CALIBRATED TO MFR SPEC,& CLEAN**

Procedure: **2400-902-01 REV D**
Temperature: **72°F** Relative Humidity: **29.2%**

Standards Used:

Manufacturer, Model	Description	SIMCO ID	Due Date	Certificate
FLUKE, 5450A	**Resistance Calibrator**	**15940-812**	**11/16/2020**	**8664094**
OMEGA ENGINEERING, RH82	**Thermo Hygrometer W/Dew Point**	**15940-421**	**10/24/2020**	**8734655**
AGILENT, 34410A	**Digital Multimeter**	**15940-748**	**09/10/2020**	**8694770**

There are 2 Supplementary Data Sheet(s) attached.

Work performed by:
Gregory Bender

Reviewed by:
Daniel Beights

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Certificate No. **8935524**

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STATEMENT OF WORK
FOR
APOGEE SEMICONDUCTOR
538 HAGGARD ST.
PLANO, TX 75074

Description: **TEST EQUITY, FS2-1, Oven**

Serial No: **12140106** Asset No: SIMCO ID: **57647-9**

Dept: **NONE** PO No: **2002**

Service Date: **04/24/2020**	Calibration Interval:	Next Calibration Date:
Arrival Condition: **OUT OF SPECIFICATION**	Service: **RETURN "AS-IS"(RAI)-FAILED CAL**	

Procedure: **010-0090 REV 5**
Temperature: **68°F** Relative Humidity: **36%**

Standards Used:

Manufacturer, Model	Description	SIMCO ID	Due Date	Certificate
ONSET COMPUTER CORP, ZW-003	Temperature/Humidity Logger	15940-1023	09/30/2020	8646941
OMEGA ENGINEERING, CL23A	THERMOMETER CALIBRATOR	15940-680	08/21/2020	8661776

Detail Of Work Performed:
UNIT IS OOT AND NOT LINEAR. RAI AT OWNER REQUEST

Calibration Data: * denotes an out of tolerance data point

Parameter	Nominal	Measured Before	Measured After	Tolerance
TEMP	100.0 C	80.8	80.8	+/-5 C
TEMP	*125.0 C	103.8	103.8	+/-5 C
RISE TIME <15MIN	*PASS	0	0	1=PASS0=FAIL

There are 1 Supplementary Data Sheet(s) attached.

Work performed by:
Peter Alexeichik

Reviewed by:
David Whitley

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