Physikalisch-Meteorologisches Observatorium Davos
World Radiation Center

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Author: Matthias Gander
Date: 02.02.2018

DARA

Controller Board Irradiation Test Report

FOR PUBLICATION ON ESCIES

	Name	Signature	Date
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TABLE OF CONTENT

I. Change Log

Please note: Major changes require an x-increase in the format x.1
Minor changes require an x-increase in the format 1.x
Draft versions shall be numbered 0.x
Released versions shall start with 1.x

Issue	Release date	Changes
0.1	23.11.2017	Initial draft version
1.0	16.01.2018	Report completed
1.1	29.01.2018	Added memory W/R test result
1.2	02.02.2018	Report is FOR PUBLICATION ON ESCIES

II. Abbreviations

DARA	Digital Absolute RAdiometer
PMOD	Physikalisch-Meteorologisches Observatorium Davos
RTS	Radiation Test Sample: the DARA Controller Board that was tested

III. Applicable Documents

Some additional documents of RT-0066 can be found in the supplements folder.

Applic. Doc.	Doc. Number	Title	Issue
AD 1	0015-D10-DARA	Irradiation Testplan (Document created by ELSE)	1.2
AD 2	PR3-DARA-TP-0063	Electrical Testplan Controller Board	1.0
AD 3	PR3-DARA-RT-0066	Electrical Test Report before Irradiation Test	1.0
AD 4	PR3-DARA-RT-0066	Electrical Test Zener Diodes	1.0
AD 5	PR3-DARA-RT-0066	Radiation Test Monitor	1.2
AD 6	PR3-DARA-RT-0066	Electrical Test Report after Repair	1.0
AD 7	RA0002657	Radiation Summary DARA RTS (Document created by ESTEC)	1.0
AD 8	PR3-DARA-RT-0066	Measurements and graphs collection	1.0

IV. Reference Documents

Ref. Doc.	Doc. Number	Title	Issue
RD 1	0001-D1-DARA	Declared Component List	1.5
RD 2	0017-D29-DARA	Controller Board Assembly Plan	1.3
RD 3	---	RTS Controller Board Fabrication Log	1.1

1 Scope / Introduction

This document outlines the results of the irradiation tests done with the DARA Controller Board RTS. This is the main document which provides the summary of the results. There are several other supplement reports and documents.

2 Test summary

2.1 CPU and digital circuits

Irradiation

The +5V supply started increasing at ~7.5 krad. The CPU failed at an irradiation dose of ~14.6 krad.
The +5V current consumption was drifting while irradiation, from 136 mA to 450 mA in maximum.
Since the CPU failed and the control bus signals were corrupted, the +3.3 V power consumption of the MRAM increased as well. At some point the +3.3 V voltage supply had to be switched of manually, because the current reached critical high value.

Annealing

The CPU did not recover while annealing.
The +5V current consumption slightly decreased while annealing.
The +3.3 current was still way to high and stable.

Ageing

The CPU still failed after ageing.
The +5V current consumption was slightly decreased after ageing.
The +3.3 current was still way to high and stable.

Repair

When the CPU was replaced, the digital circuits worked properly again. The current consumption of the +5V and +3.3V supply were back in limits.

2.2 MRAM write/read test

Irradiation

A file was stored/written to the MRAM. Then the file had been read back and checked, if still the same content is in it. This test was performed manually while irradiation several times. The test always passed.

Ageing

After the ageing procedure the write/read test still passed.

2.3 Precision +5V voltage reference

Irradiation

The voltage reference started drifting at ~1.9 krad. During the irradiation there was a continuous drifting, at the end of the test the reference voltage reached 5.009 V at a dose of 40.1 krad.

Annealing

While annealing there was first a slightly increase of the reference voltage to 5.010 V, followed by a decrease to 5.008 V.

Ageing

After ageing the reference reached 5.007 V. From this point on, there was no more drifting, the reference voltage is stable at 5.007 V.

2.4 Power supply +12V

Irradiation

The current consumption of the +12V power supply was drifting over irradiation test from originally 8 mA to 34 mA. The drifting started at 16.7 krad.

Annealing

Over the annealing the current consumption decreased from 34 mA to 23 mA.

Ageing

After ageing, the consumption was between 7 mA to 8 mA and stable.

It's not known, if the current consumption of one of the OpAmps or/and the Voltage Reference drifted.

2.5 Oscillator

The Oscillator was properly working over the irradiation tests. The pulse counter had miscounts, before during and after the irradiation test in the same way.
See the Measurements and graphs collection [AD 8].

2.6 Analog digital data acquisition

The housekeeping signals (GND, VCC, and thermistor levels) were only available when the CPU was working. The measurements during beginning of the irradiation and after the repair were alright.
See the Measurements and graphs collection [AD 8].

2.7 Zener diodes

The diodes were disassembled, and the Zener voltage was measured, before and after the irradiation.
The test passed, no significant change of the Zener voltage caused by the irradiation. The Zener voltage increased slightly, 0.6 mV in minimum and 1.6 mV in maximum of the 10 tested diodes.
See report Electrical Test Zener Diodes [AD 4].

2.8 Overview of main electronic parts

The table below shows the main parts of the DARA Controller Board RTS and the test results. For complete part list, see Declared Component List [RD 1].

Part functionality	Name	Part Number	Test result
CPU (central processing unit)	TS68332	5962-9150102MXA	Failed at ~14.6 krad
Watchdog	ISL705CRHVF	5962R1121303VXC	Endured 40.1 krad
Oscillator	QT3005CX-18.432MHz	QT3005CX-18.432MHz	Endured 40.1 krad
MRAM (magneto resistive ran-dom-access memory)	EV2A16AMNYU35	EV2A16AMNYU35	Endured 40.1 krad
SRAM (Static random-access memory)	WS512K32N	5962-9461105HTA	Endured 40.1 krad
Level shifter (3.3V <-> 5V logic)	RHRAC164245K01V	5962R9858008VYC	Endured 40.1 krad
Decoder (4 to 16 lines)	M54HC154KG	9205/023/01F	Endured 40.1 krad
Logic components	Several parts, see Declared Component List [RD 1]		Endured 40.1 krad
Voltage reference	REF02AZQMLR	5962R8551401VPA	Started drifting (failed) at ~1.9 krad
ADC (analog digital converter)	ADC128S102WGRQV	5962R0722701VZA	Endured 40.1 krad
Analog multiplexer	ADG725	ADG725	Endured 40.1 krad
OpAmps (operational amplifier)	ISL70419SEHVF	5962F1422601VXC	Endured 40.1 krad
	LM124AWRLQMLV	5962R9950402VDA	Endured 40.1 krad
RS-422 receiver	HS-26C32RH-8	5962F9568901QXC	Endured 40.1 krad
RS-422 driver	HS-26C31RH-8	5962F9666301QXC	Endured 40.1 krad

3 Sequence of tests

This section shows all the test steps and events in chronological order.
The order of tests was given by the Irradiation Testplan [AD 1].

3.1 Commissioning and corrections

Number	Title	Description	Document reference
1	Board assembling	The Controller Board RTS was assembled according the Declared Component List and assembling plan.	Declared Component List [RD 1] Assembling Plan [RD 2]
2	Design changes and completion of assembling	Some of the latest design changes have been done by PMOD/WRC, and some parts were assembled at PMOD/WRC too.	RTS Fabrication Log [RD 3]
3	Board commissioning, corrections and inspection of board.	Commissioning was done by PMOD/WRC. Some corrections were done because of assembling mistakes and defect of a circuit. A final inspection was done, no defects on the board left.	RTS Fabrication Log [RD 3]

3.2 Initial electrical test

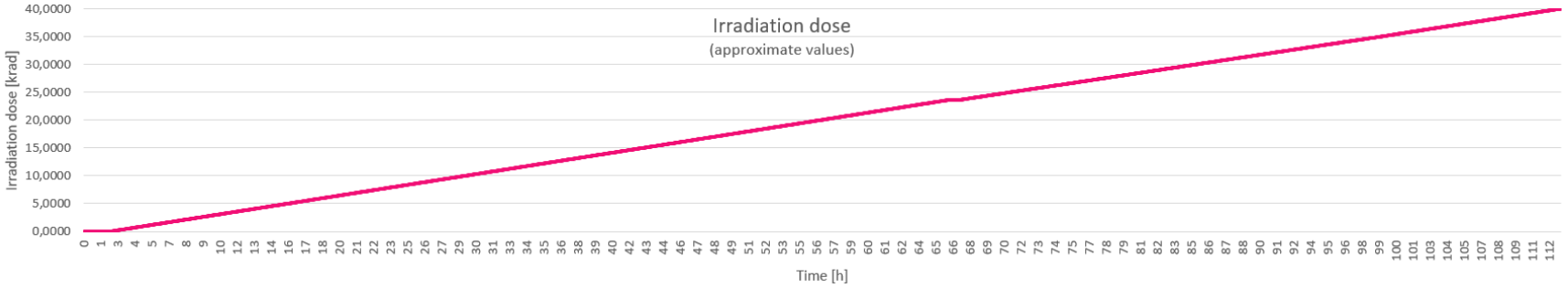
Before the irradiation test, electrical tests were done with the RTS by PMOD/WRC.

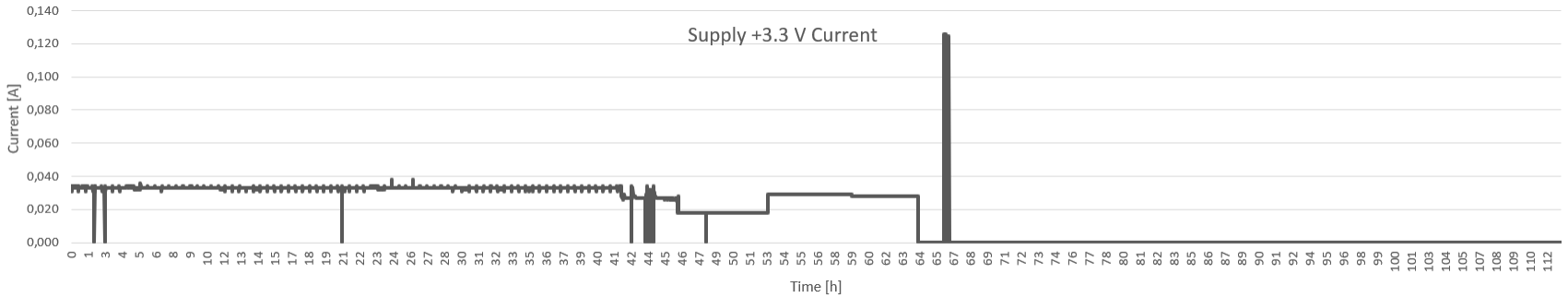
Number	Title	Description	Document reference
1	Standard electrical test	The RTS was tested according the standard test plan for DARA Controller Board. The tests passed, no defects or fail functions were known.	Electrical Testplan Controller Board [AD 2] Electrical Test Report before Irradiation Test [AD 3]
2	Zener diodes measurements	The diodes were disassembled, and the Zener voltage was measured. All diodes were working properly, and Zener voltage was in limits.	Electrical Test Zener Diodes [AD 4]

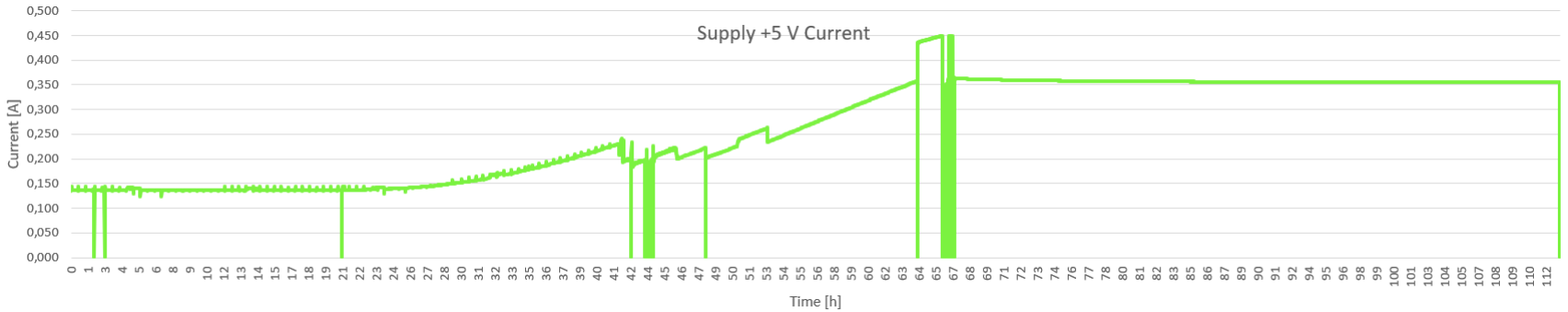
3.3 Irradiation test

The irradiation tests were done at ESTEC, accompanied and supervised by ELSE and PMOD/WRC.
The original measurements and graphs can be found at the Measurements and graphs collection [AD 8].

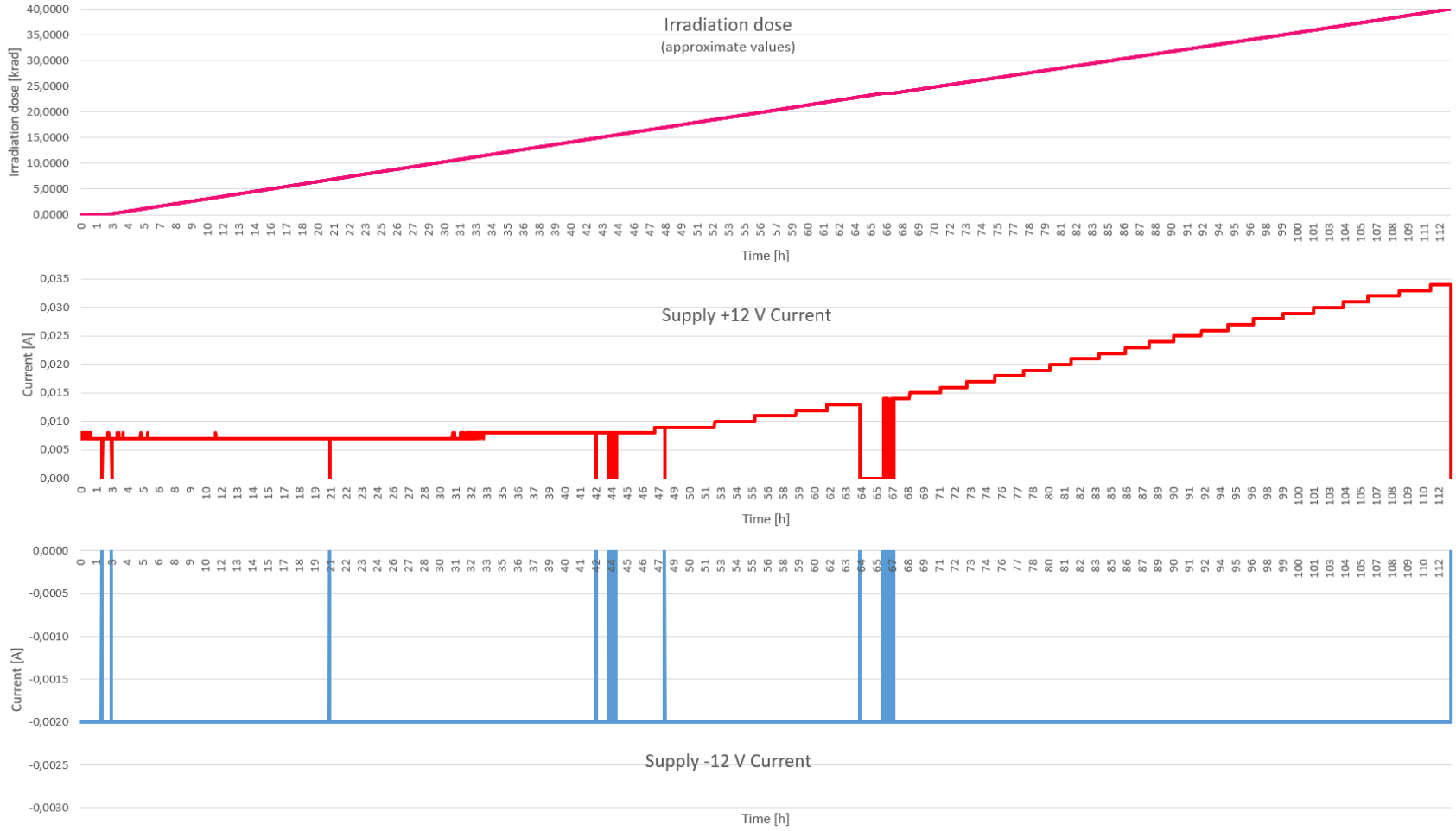
The following graphs show the drift of the digital power supplies over the irradiation test. If there is a peak going to zero, this means, the supply was switched off temporarily.



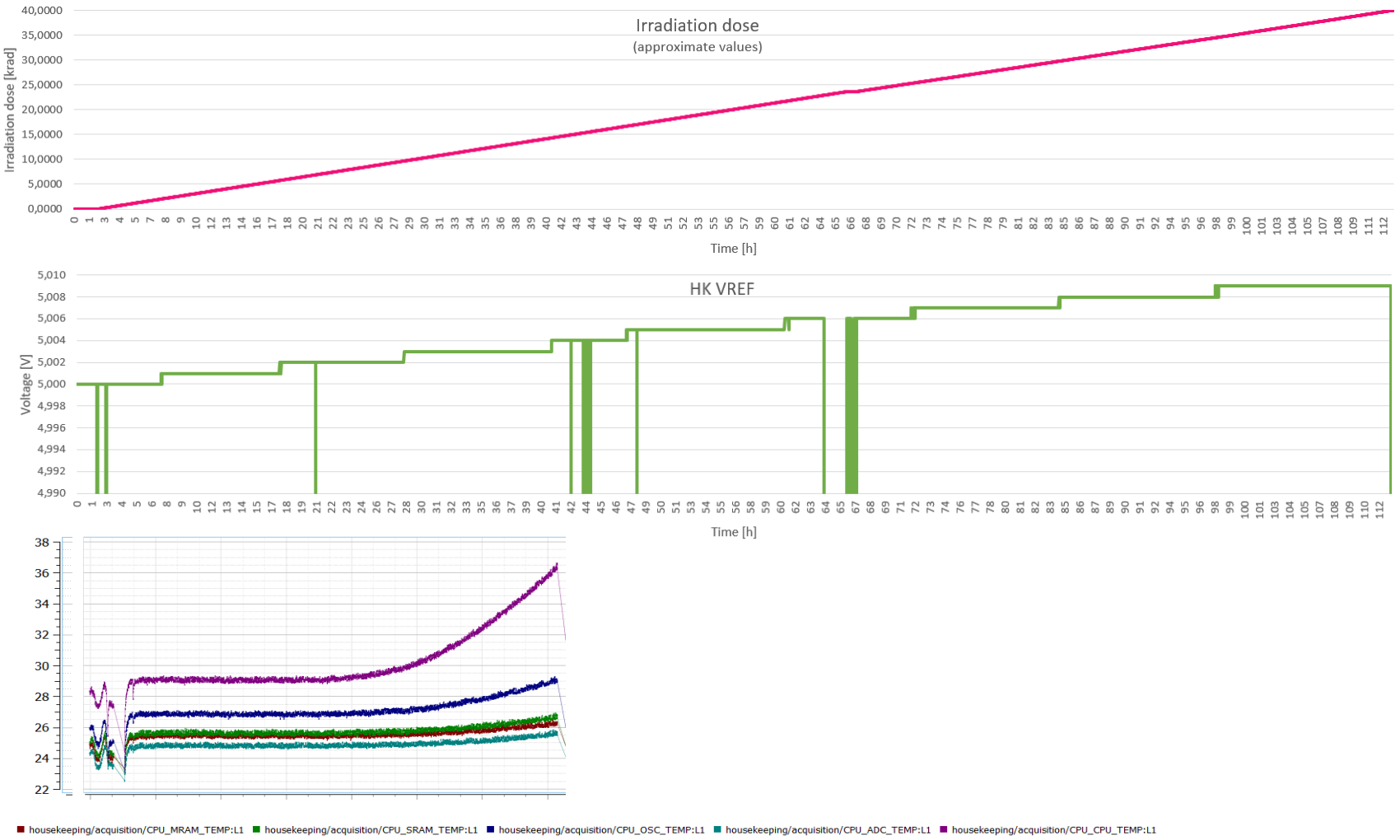




The following graphs show the drift of the analog power supplies over the irradiation test. If there is a peak going to zero, this means, the supply was switched off temporarily.



The following graphs show the drift of the reference voltage over the irradiation test. If there is a peak going to zero, this means, the supply was switched off temporarily. The RTS on-board temperatures are as well showed, until the CPU failed, and no more housekeeping data was available.



Following the overview of the most important events while irradiation test:

<table>
<tr><th>Number</th><th>Test state</th><th>Description</th><th>Document reference</th></tr>
<tr><td>1</td><td>Pre-run</td><td>Pre-run before irradiation was active, RTS is installed in test chamber.
All values are in limits:

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose</td><td>0.0 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>1.0 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Running</td><td>OK</td></tr>
<tr><td>Supply +3V3</td><td>33 mA</td><td>OK</td></tr>
<tr><td>Supply +5V</td><td>136 mA</td><td>OK</td></tr>
<tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>7 mA</td><td>OK</td></tr>
<tr><td>HK VREF</td><td>5.000 V</td><td>OK</td></tr>
<tr><td>ADC CLK</td><td>9.219 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>61</td><td>OK</td></tr>
</table></td><td>Radiation Test Monitor [AD 5]</td></tr>
<tr><td>2</td><td>Run, irradiation active</td><td>Irradiation started, all values are in limits.
Started: 10.11.2017 at 15:10
Finished: 15.11.2017 at 09:48
Total dose: 40.1 krad

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose</td><td>~0.0 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>2.1 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Running</td><td>OK</td></tr>
<tr><td>Supply +3V3</td><td>33 mA</td><td>OK</td></tr>
<tr><td>Supply +5V</td><td>136 mA</td><td>OK</td></tr>
<tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>7 mA</td><td>OK</td></tr>
<tr><td>HK VREF</td><td>5.000 V</td><td>OK</td></tr>
<tr><td>ADC CLK</td><td>9.219 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>127</td><td>OK</td></tr>
</table></td><td>Radiation Summary DARA RTS [AD 7]</td></tr>
</table>

<table>
<tr>
<td>3</td>
<td>Run, irradiation active</td>
<td>The reference voltage HK VREF begins to drift.

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose</td><td>~1.9 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>7.2 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Running</td><td>OK</td></tr>
<tr><td>Supply +3V3</td><td>33 mA</td><td>OK</td></tr>
<tr><td>Supply +5V</td><td>136 mA</td><td>OK</td></tr>
<tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>7 mA</td><td>OK</td></tr>
<tr><td>HK VREF</td><td>5.001</td><td>Begin of drifting</td></tr>
<tr><td>ADC CLK</td><td>9.216 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>434</td><td>OK</td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Run, irradiation active</td>
<td>The +5V current consumption begins to drift. The temperature of the CPU (highest curve on the previous temperature graph) begins as well to increase.

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose</td><td>~7.5 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>22.2 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Running</td><td>OK</td></tr>
<tr><td>Supply +3V3</td><td>33 mA</td><td>OK</td></tr>
<tr><td>Supply +5V</td><td>138 mA</td><td>Begin of drifting</td></tr>
<tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>7 mA</td><td>OK</td></tr>
<tr><td>HK VREF</td><td>5.002</td><td>Further drifting</td></tr>
<tr><td>ADC CLK</td><td>9.214 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>1335</td><td>OK</td></tr>
</table>
</td>
<td></td>
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</table>

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Run, irradiation active</td><td>CPU is no longer running. The CPU housing temperature raised from ~ 29.0 °C, the stabilized temperature after irradiation test was started, to ~36.5 °C, when the CPU failed. The increase of temperature correlated with the increase of the +5V current consumption, which is the power supply of the CPU.

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose</td><td>~14.6 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>41.5 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Failure</td><td>No more communication with EGSE</td></tr>
<tr><td>Supply +3V3</td><td>33 mA</td><td>OK</td></tr>
<tr><td>Supply +5V</td><td>231 mA</td><td>Further drifting</td></tr>
<tr><td>Supply-12V</td><td>-0.2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>8 mA</td><td>OK, increased from 7 mA to 8 mA, but stable then for long time.</td></tr>
<tr><td>HK VREF</td><td>5.004</td><td>Further drifting</td></tr>
<tr><td>ADC CLK</td><td>9.216 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>2491</td><td>OK</td></tr>
</table></td><td></td></tr>
<tr><td>6</td><td>Run, irradiation active</td><td>Supply +5V and +3V3 current consumptions have changes up and down.

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose</td><td>~16.2 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>45.9 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Failure</td><td>NOK</td></tr>
<tr><td>Supply +3V3</td><td>18 mA</td><td>Changes up and down for longer time</td></tr>
<tr><td>Supply +5V</td><td>201 mA</td><td>Changes up and down for longer time</td></tr>
<tr><td>Supply-12V</td><td>-0.2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>8 mA</td><td>OK</td></tr>
<tr><td>HK VREF</td><td>5.004</td><td>Drifting in general</td></tr>
<tr><td>ADC CLK</td><td>9.218 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>2757</td><td>OK</td></tr>
</table></td><td></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Run, irradiation active</td><td>Supply +12V current started increasing.

<table><tr><th>Signal</th><th>Measured value</th><th>State</th></tr><tr><td>Radiation dose</td><td>~16.7 krad</td><td>OK</td></tr><tr><td>Running time</td><td>47.2 h</td><td>OK</td></tr><tr><td>CPU</td><td>Failure</td><td>NOK</td></tr><tr><td>Supply +3V3</td><td>18 mA</td><td>Changes up and down for longer time</td></tr><tr><td>Supply +5V</td><td>213 mA</td><td>Changes up and down for longer time, the starting to increase drastically</td></tr><tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr><tr><td>Supply +12V</td><td>9 mA</td><td>Begin of drifting</td></tr><tr><td>HK VREF</td><td>5.004 V</td><td>Drifting in general</td></tr><tr><td>ADC CLK</td><td>9.219 MHz</td><td>OK, sometimes a miscount probably</td></tr><tr><td>Log number</td><td>2832</td><td>OK</td></tr></table></td><td></td></tr>
<tr><td>8</td><td>Run, irradiation paused</td><td>Supply +3V3 and 5V current increased drastically.
Irradiation was switched off, to see if the RTS may recover.
There were attempts made, switching off and on the supplies, to bring the RTS in a better state again, but without success.

<table><tr><th>Signal</th><th>Measured value</th><th>State</th></tr><tr><td>Radiation dose</td><td>~23.6 krad</td><td>OK</td></tr><tr><td>Running time</td><td>66.0 h</td><td>OK</td></tr><tr><td>CPU</td><td>Failure</td><td>NOK</td></tr><tr><td>Supply +3V3</td><td>124 mA</td><td>Current consumption highly increased</td></tr><tr><td>Supply +5V</td><td>346 mA</td><td>Current consumption highly increased</td></tr><tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr><tr><td>Supply +12V</td><td>14 mA</td><td>Drifting in general</td></tr><tr><td>HK VREF</td><td>5.006 V</td><td>Drifting in general</td></tr><tr><td>ADC CLK</td><td>9.207 MHz</td><td>OK, sometimes a miscount probably</td></tr><tr><td>Log number</td><td>3961</td><td>OK</td></tr></table></td><td></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>9</td><td>Run, irradiation active again</td><td>Supply +3V3 and 5V current still very high.
The +3V3 supply finally was switched off, because current consumption out of control.
Supply +5V was increased to 5.25 V, because of the high voltage drop over the latch up circuit on the RTS.
The CPU’s supply voltage is high enough, so that there is no brown out reset.
Irradiation switched on again.

<table><tr><th>Signal</th><th>Measured value</th><th>State</th></tr><tr><td>Radiation dose</td><td>~23.7 krad</td><td>OK</td></tr><tr><td>Running time</td><td>66.9 h</td><td>OK</td></tr><tr><td>CPU</td><td>Failure</td><td>NOK</td></tr><tr><td>Supply +3V3</td><td>0 mA</td><td>Switched off</td></tr><tr><td>Supply +5V</td><td>364 mA</td><td>Current consumption drastically increased</td></tr><tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr><tr><td>Supply +12V</td><td>14 mA</td><td>Drifting in general</td></tr><tr><td>HK VREF</td><td>5.006 V</td><td>Drifting in general</td></tr><tr><td>ADC CLK</td><td>9.22 MHz</td><td>OK</td></tr><tr><td>Log number</td><td>4013</td><td>OK</td></tr></table></td><td></td></tr>
<tr><td>10</td><td>Run, irradiation active</td><td>Supply +5V stared slightly do decrease, but still very high.

<table><tr><th>Signal</th><th>Measured value</th><th>State</th></tr><tr><td>Radiation dose</td><td>~24.0 krad</td><td>OK</td></tr><tr><td>Running time</td><td>67.8 h</td><td>OK</td></tr><tr><td>CPU</td><td>Failure</td><td>NOK</td></tr><tr><td>Supply +3V3</td><td>0 mA</td><td>Switched off</td></tr><tr><td>Supply +5V</td><td>362 mA</td><td>Current consumption to high, but slightly decreasing</td></tr><tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr><tr><td>Supply +12V</td><td>14 mA</td><td>Drifting in general</td></tr><tr><td>HK VREF</td><td>5.006 V</td><td>Drifting in general</td></tr><tr><td>ADC CLK</td><td>9.208 MHz</td><td>OK</td></tr><tr><td>Log number</td><td>4070</td><td>OK</td></tr></table></td><td></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>11</td><td>Measurement to be stopped, irradiation finished</td><td>All supplies and irradiation will be switched off.

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose (total dose)</td><td>~40.1 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>112.7 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Failure</td><td>NOK</td></tr>
<tr><td>Supply +3V3</td><td>0 mA</td><td>Switched off</td></tr>
<tr><td>Supply +5V</td><td>356 mA</td><td>Current consumption to high, but slightly decreasing</td></tr>
<tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>34 mA</td><td>Drifting in general</td></tr>
<tr><td>HK VREF</td><td>5.009 V</td><td>Drifting in general</td></tr>
<tr><td>ADC CLK</td><td>9.211 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>6761</td><td>OK</td></tr>
</table></td><td></td></tr>
</table>

3.4 Annealing

The annealing was performed at PMOD/WRC.

<table>
<tr><th>Number</th><th>Title</th><th>Description</th><th>Document reference</th></tr>
<tr><td>1</td><td>Pause after irradiation test</td><td>Setup: RTS not biased
Duration: ~ 29 h</td><td></td></tr>
<tr><td>2</td><td>Annealing</td><td>Setup: RTS biased, continuous monitoring with Radiation Test Monitor
Duration: 168 h (7 days)
Started: 16.11.2017 at 14:16
Finished: 23.11.2017 at 14:42
Ambient temperature: 22 °C +/- 3 °C (room temperature)</td><td>Irradiation Testplan [AD 1]

Radiation Test Monitor [AD 5]</td></tr>
<tr><td>3</td><td>Electrical tests</td><td>Additional between tests while annealing: no additional effects or failure occurred</td><td>Not reported</td></tr>
<tr><td>4</td><td>Run, annealing</td><td>After a pause after irradiation test, the current of the +3V3 supply was almost nominal value.

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose (total dose)</td><td>40.1 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>112.7 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Failure</td><td>NOK</td></tr>
<tr><td>Supply +3V3</td><td>36 mA</td><td>Almost back to nominal value</td></tr>
<tr><td>Supply +5V</td><td>355 mA</td><td>Current consumption to high</td></tr>
<tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>33 mA</td><td>Value to high</td></tr>
<tr><td>HK VREF</td><td>5.010 V</td><td>Value to high</td></tr>
<tr><td>ADC CLK</td><td>9.215 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>6764</td><td>OK</td></tr>
</table>
</td><td></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Run, annealing</td><td>After a power off / on, the current from +3V3 supply was again way too high.
The reason is probably the invalid control signals from the CPU, the IO's have random levels.
Nevertheless the supply +3V3 is still switched on.

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose (total dose)</td><td>40.1 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>137.5 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Failure</td><td>NOK</td></tr>
<tr><td>Supply +3V3</td><td>121 mA</td><td>Current consumption again way too high</td></tr>
<tr><td>Supply +5V</td><td>345 mA</td><td>Current consumption to high</td></tr>
<tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>28 mA</td><td>Value to high, bus started to decrease slightly</td></tr>
<tr><td>HK VREF</td><td>5.009 V</td><td>Value to high, bus started to decrease slightly</td></tr>
<tr><td>ADC CLK</td><td>9.213 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>8250</td><td>OK</td></tr>
</table></td><td></td></tr>
<tr><td>6</td><td>Measurement stopped, annealing finished</td><td>The CPU has not recovered while annealing.
Some of the current and voltage values decreased slightly during annealing, but still too high.

<table>
<tr><th>Signal</th><th>Measured value</th><th>State</th></tr>
<tr><td>Radiation dose (total dose)</td><td>40.1 krad</td><td>OK</td></tr>
<tr><td>Running time</td><td>280.5 h</td><td>OK</td></tr>
<tr><td>CPU</td><td>Failure</td><td>NOK</td></tr>
<tr><td>Supply +3V3</td><td>123 mA</td><td>Value to high, almost stable while annealing</td></tr>
<tr><td>Supply +5V</td><td>332 mA</td><td>Value to high, slightly decreased while annealing</td></tr>
<tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr>
<tr><td>Supply +12V</td><td>23 mA</td><td>Value to high, slightly decreased while annealing</td></tr>
<tr><td>HK VREF</td><td>5.008</td><td>Value to high, slightly decreased while annealing</td></tr>
<tr><td>ADC CLK</td><td>9.211 MHz</td><td>OK</td></tr>
<tr><td>Log number</td><td>16831</td><td>OK</td></tr>
</table></td><td></td></tr>
</table>

3.5 Accelerate ageing

The ageing was performed at PMOD/WRC.

<table>
<tr><th>Number</th><th>Title</th><th>Description</th><th>Document reference</th></tr>
<tr><td>1</td><td>Accelerated ageing</td><td>Setup: RTS not biased, stored in oven
Duration: 168 h (7 days)
Started: 23.11.2017 at 14:50
Finished: 30.11.2017 at 14:55
Ambient temperature: 100 °C +/- 3 °C</td><td>Irradiation Testplan [AD 1]</td></tr>
<tr><td>2</td><td>Run after ageing</td><td>The following measurements were done after ageing.

<table><tr><th>Signal</th><th>Measured value</th><th>State</th></tr><tr><td>Radiation dose (total dose)</td><td>40.1 krad</td><td>OK</td></tr><tr><td>Running time</td><td>280.9 h</td><td>OK</td></tr><tr><td>CPU</td><td>Failure</td><td>NOK</td></tr><tr><td>Supply +3V3</td><td>127 mA</td><td>Value to high, slightly increased after ageing</td></tr><tr><td>Supply +5V</td><td>293 mA</td><td>Current consumption to high, decreased after ageing</td></tr><tr><td>Supply-12V</td><td>-2 mA</td><td>OK</td></tr><tr><td>Supply +12V</td><td>7 mA</td><td>Back to normal value after ageing</td></tr><tr><td>HK VREF</td><td>5.007 V</td><td>Value to high, slightly decreased after ageing</td></tr><tr><td>ADC CLK</td><td>9.217 MHz</td><td>OK</td></tr><tr><td>Log number</td><td>16853</td><td>OK</td></tr></table></td><td>Radiation Test Monitor [AD 5]</td></tr>
</table>

3.6 Repair and final electrical test

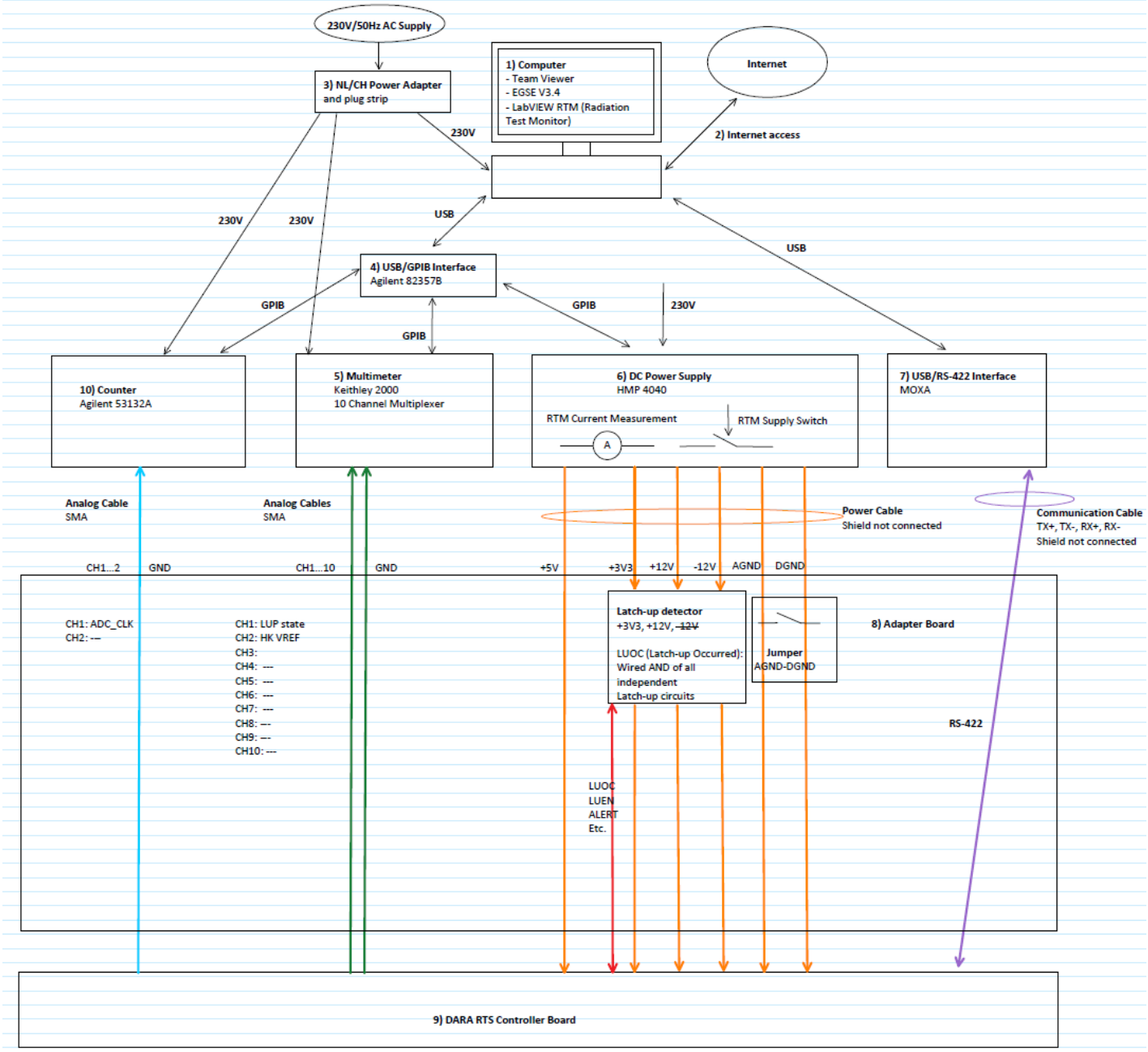
Since the board was not running anymore after the irradiation test, some repairs were made to evaluate which circuits succeeded.

<table>
<tr><th>Number</th><th>Title</th><th>Description</th><th>Document reference</th></tr>
<tr><td>1</td><td>Replaced CPU</td><td>Damaged CPU was replaced.</td><td>RTS Fabrication Log [RD 3]</td></tr>
<tr><td>2</td><td>Run after CPU was replaced</td><td>After replacing the CPU, the board was working properly.
Except the reference voltage was still out of limits:
<table><tr><th>Signal</th><th>Measured value</th><th>State</th></tr><tr><td>Radiation dose (total dose)</td><td>40.1 krad</td><td>OK</td></tr><tr><td>Running time</td><td>281.1 h</td><td>OK</td></tr><tr><td>CPU</td><td>Running</td><td>OK</td></tr><tr><td>Supply +3V3</td><td>33 mA</td><td>OK (33 mA before irradiation test)</td></tr><tr><td>Supply +5V</td><td>134 mA</td><td>OK (136 mA before irradiation test)</td></tr><tr><td>Supply-12V</td><td>-2 mA</td><td>OK (-2 mA before irradiation test)</td></tr><tr><td>Supply +12V</td><td>8 mA</td><td>OK (-7 mA before irradiation test)</td></tr><tr><td>HK VREF</td><td>5.007 V</td><td>NOK</td></tr><tr><td>ADC CLK</td><td>9.213 MHz</td><td>OK</td></tr><tr><td>Log number</td><td>16865</td><td>OK</td></tr></table></td><td>Radiation Test Monitor [AD 5]</td></tr>
<tr><td>3</td><td>Standard electrical test</td><td>The RTS was tested according the standard test plan for DARA Controller Board.
All tests passed, except the voltage reference.</td><td>Controller Board Testplan [AD 2]
Electrical Test Final [AD 6]</td></tr>
<tr><td>4</td><td>Zener diodes measurements</td><td>The diodes were disassembled, and the Zener voltage was measured.
The test passed, no significant change of the Zener voltage, compared to the measurements before the irradiation tests. The Zener voltage increased slightly, 0.6 mV in minimum and 1.6 mV in maximum of the 10 tested diodes.</td><td>Electrical Test Zener Diodes [AD 4]
RTS fabrication log [RD 3]</td></tr>
</table>

4 Test build

4.1 Electrical setup

The following block diagram shows the electrical setup. See Radiation Test Monitor [AD 5] for more details.



4.2 Mechanical setup

The following pictures show the mechanical setup in the irradiation test facility. See Radiation Test Monitor [AD 5] and Radiation Summary DARA RTS [AD 7] for more details.