1. INTRODUCTION

This document reports on the cool functional tests performed on the SPIRE Flight Instrument on the 2nd February 2007 during the cooldown of PFM5 ILT Test Campaign.

1.1 Scope

To judge the success or failure of a warm functional test by checking that:

- The telecommand sequence generated for a particular functional test is correctly received and executed on board by the SPIRE DPU.
- No error/event reports or command failures are generated during the execution of these commands.
- Telemetry is generated by the instrument as a result of telemetry requests to its different subunits.
- Particular telemetry parameters for each functional test change in an expected manner.
- A particular success criterion/criteria (specified in this document) is/are met.

1.2 Reference Documents

Ref	Document	Name	Version/Issue Nb.
RD01	SPIRE-RAL-DOC-001652	SPIRE Functional Tests Specification	Issue 1.4
RD02	SPIRE-RAL-DOC-001630	SPIRE EGSE-ILT Start-Up Procedures	Issue 0.7
RD03	SPIRE-RAL-PRC-002222	DRCU Switch ON Procedure	Issue 1.0
RD04	SPIRE-RAL-PRJ-001078	SPIRE Data ICD	Issue 2.0
RD05	Sap-SPIRE-CCa-076-02	DRCU/DPU Interface Control Document	Issue 1.2
RD06	LAM.PJT.SPI.NOT.011011	MCU/DPU Command List ICD	Issue 5.0
RD07	SPIRE-IFS-PRJ-001391	SPIRE OBS User Manual	Issue 2.1
RD08		SPIRE ILT Functional Testing Overview	

1.3 Change Record

Document	Change date	Changes
Issue 1.0	03/11/06	Document created

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2. Functional Tests Configuration

2.1 SPIRE Instrument Configuration (MAIN)

SPIRE FPU:

- FPU In Tank. (Highest T is Spectrometer JFET Chassis ~ 110 K, Phot JFET Chassis ~ 104K)
- Cryostat under vacuum:
  - Pump Port Pressure = ~ 1.3×10^{-7} bar
  - Tank Top Pressure = ~ 4.8×10^{-7} bar
- DRCU to Cryostat harnesses connected (Grounding pins not connected)
- Cryo-harness connected to FPU

SPIRE FM DPU:

- DPU Power supply connected on DPU Power MAIN (J01) connector (DPU side).
- 1553 Mil Bus connected on MAIN Connector Bus A (J03) connector (DPU side).
- DPU-DRCU warm interconnect harnesses (flight harnesses):

  - DPU J07 to DCU J01 *DPU to DCU PRIME*
  - DPU J08 to FCU J01 *DPU to MCU PRIME*
  - DPU J09 to FCU J03 *DPU to SCU PRIME*
  - DPU J10 to DCU J02 *DPU to DCU RED*
  - DPU J11 to FCU J02 *DPU to MCU RED*
  - DPU J12 to FCU J04 *DPU to SCU RED*

SPIRE FM DRCU:

- DRCU Power supply connected on DRCU Power MAIN (J05) connector (DRCU side on FCU).
- FCU to DCU PRIME power connectors J7 (FCU) to J03 (DCU) and FCU to DCU REDUNDANT power connectors J06 FCU to J04.

2.2 Software Configuration

The current EGSE software configuration for the PRIME instrument tests:

EGSE component	Version/Build number	Comment
SCOS2000	2.3eP5	Archive: PFM5_TEST1_PRIME MIB : Prime
HCSS	v0.4.1 Build# 1106	
QLA	v3.2	
QLA scripts		
Test Control scripts		
CUS Scripts	**PFM5_CUS_DEFINITIONS_V1**	
OBS	**2.2.D**	2.2.G has been acceptance tested but not yet installed on

		FM DPU
Boot Software	**2.0**	

2.3 EGSE Configuration Checks

To check for the success of failure of a functional test, the real time telemetry of the instrument has to be monitored. The following applications must be running to do so. Before the test sequence starts, make the following checks:

Workstation	EGSE component	Status	Check
Lichfield	EGSE router	Started	✓
Lichfield	EGSE Gateway	Started	✓
Lichfield	Telemetry Ingestion	Started	✓
Lichfield	Packet Display	Started	✓
Lincoln	SCOS2000	Started	✓
Lincoln	EXIF + TOPE	Started	✓
Lincoln	Manual Stack	Started	✓
Gordon	CDMS Simulator	Started	✓
Lincoln	Test Control Server	Started	✓

The following checks were performed to verify the correct initial instrument configuration for the tests.

Step#	Action	Comments (Write any comments under this tab)	Check
1	In SCOS open **DPU_AND_OBS_PARAMETERS display** Check if : TM2N is incrementing by one @1Hz. TM1N is incrementing by one @0.5Hz. - If both are incrementing of only TM2N is incrementing , go to step 5. - If they are not, go to step 2.	**TM2N is incrementing by 1 @ 1Hz** **TM1N is incrementing by 1 @ 0.5Hz** **Will go to step 5**	✓
2	Check if the DPU is powered ON: - If ON, the DPU power supply LCD will show ~ 28V and 0.40A, go to step 4. - If not ON, power ON DPU see comments on the right, then go to step 3.		
3	In SCOS open **Boot_ROM_Memory_Check display** and check no errors are reported: - If no errors are reported, execute DPU_ON from HCSS Test Procedures. Then repeat step 1. - If the (5,2) contains errors: Check the error code in RD07. Then switch OFF the DPU and repeat step 2		
4	Execute **define_new_HK_report.tcl** HCSS Test procedure. Repeat step 1.		
5	In SCOS open **SCU_PARAMETERS display** - If SCUP5V/P9V/M9V are jittering and **BIAS_PARAMETERS display** - If BIASTEMP shows ambient temperature, the DRCU is ON.Go to step 6. - If DRCU is not ON, refer to RD03 on how to start up the DRCU.	**Had to power ON DRCU PRIME:** **SCU VOLTAGES LOOKING GOOD.** SCUP5V = 5.23V SCUP9V = 9.08V SCUM9V = -9.08V **BIAS VOLTAGES LOOKING GOOD.** BIASP5V = 5.12V BIASP9V = 8.98V BIASM9V= -9.05V **BIASTEMP LOOKING GOOD.** **BIASTEMP** = 291.81K	✓
6	**In SCOS open** DPU_AND_OBS_PARAMETERS display **and check that the MODE housekeeping parameter is DRCU_ON.**	**MODE (RAW)= 0x100** **MODE (ENG) = DRCU_ON**	✓

Table 1. Initial configuration check

3. TEST PROCEDURE

The following two sections describe general pass/fail criteria (Section 3.1), the general test procedure layout (Section 3.1) and the detailed procedure for each functional test (Section 3.2).

3.1 GENERAL PASS/FAIL CRITERIA

The general criterion for declaring a single test failed is the repeated failure of 2 consecutive runs of this test. In that case the functional test procedure should be aborted and the overall functional testing declared FAILED.
In the case of a 'first run' failure followed by a successful execution a third run of the same test should be performed and in the unlikely event of this third run being a failure the test procedure should be also aborted and the overall functional testing declared FAILED, as this would imply a not reliable operability of the instrument.
As a general remark ANY failure should be closely analyzed.

Note: If the functional test is declared FAILED refer to section 4.1 for instrument switch OFF.

3.2 GENERAL TEST PROCEDURE LAYOUT

The table below shows the general Short WFT sequence as it should be performed. In each step of this procedure the operator should refer to the detailed procedure in Section 3.2 .Test Control TCL scripts are available to invoke the correspondent CUS script stored in the HCSS database for each functional test. These CUS scripts will generate the appropriate command sequence for the particular functional test.

Step	Subsystem tested	Test Id	Test Purpose
1	SCU	FUNC-SCU-01	SCU Nominal Science Generation Check
2		FUNC-SCU-03	FPU DC Thermometry Check
3		FUNC-SCU-06	FPU AC Thermometry Check
4		FUNC-SCU-07	Sorption Cooler Check
5		FUNC-SCU-04	Photometer Calibrator Check
6		FUNC-SCU-05	Spectrometer Calibrators Check
9	MCU	FUNC-MCU-01	MCU Boot Check
10		FUNC-MCU-02	MCU Nominal Science Generation Check
11	BSMm	FUNC-BSM-01	BSM Switch ON Check
12		FUNC-BSM-03	BSM Open Loop dynamics Check
13	SMECm	FUNC-SMEC-02A/B*	SMEC Launch Latch Open/Close Check
14		FUNC-SMEC-01	SMECm Switch ON Check
15		FUNC-SMEC-03	SMEC LED Integrity Check
16		FUNC-SMEC-04	SMEC Positioning Test (Open Loop)
17	DCU	FUNC-DCU-01	DCU Nominal Science Generation Check
18	Photometer LIAs	FUNC-DCU-04P	Photometer LIAs Check
19	Spectrometer LIAs	FUNC-DCU-04S	Spectrometer LIAs Check

Table 2. General Short WFT sequence

4. Detailed Test Results on MAIN instrument.

The following is a detailed (test by test) procedure including the steps required to perform each functional test individually.

0	Open **SCU_PARAMETERS** display on SCOS Alpha Numeric Displays.	

4.1 FUNC-SCU-01

Test Id:	**FUNC-SCU-01**
Initial Configuration:	**DRCU_ON**
Final Configuration:	**DRCU_ON**
Success Criteria:	Test passed if : 1. Two SCU Nominal Science Report telemetry packets are received on QLA with the following characteristics:

APID	Type	Subtype	SID	FrameID	Frame length
0x508	21	1	0xA20	0x20	0x1E

2. The frame time difference between consecutive SCU frames within these packets corresponds to the sampling rate. Nominal SCU sampling rate is 80Hz ➔ $\Delta t = 12.5$ ms
3. The SPIRE HK parameter SCUFRAMECNT increments by 31.
4. No events are generated during the frame generation.

QLA to give go ahead.

Test Procedure:

Step#	Action
1	Write the initial value of SCUFRAMECNT parameter located in SCU_PARAMETERS display.
2	Run QLA script FUNC-SCU-01.py on QLA console.
3	Run FUNC-SCU-01 test procedure from the HCSS Test Procedure window on TOPE
4	Write the final value of SCUFRAMECNT.
5	Contingency: If test fails repeat steps 1 to 4.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-SCU-01	**SCUFRAMECNT**	**n/ n+ 31**	0/ 31	31	**Success**

Start time @: 13:44
End time @: 13:45
OBSID: 0x30012005
Comments:

```
**************************************************************************
SCU: OBSID = 30012005, BBTYPE = 0x8000, APID = 0x508, SID  = 0xa20
_____________________________________________________________________________
Parameter      Initial    Final     Increment Expect Incre. Packet Chars.

SCUFRAMECNT    0          31         31         31           Packet type = 0x15
TM5N           16383      1          49153      2            subtype = 0x1
FrameTime      12.4960    12.4992                            Frame ID  = 0x20
                                                             Frame Len = 0x1E
STATISTICS ON TIME BETWEEN RECEPTION OF 2 CONSECUTIVE FRAMES:
mean  = 12.49802 ms
sigma = 0.00155 ms
```

4.2 FUNC-SCU-03

Test Id:	FUNC-SCU-03
Initial Configuration:	**DRCU_ON**
Final Configuration:	**DRCU_ON** + DC thermometry ON
Success Criteria:	Test passed if all FPU DC thermometry sensors show temperature values indicating a correct functioning of the sensor, not open/short-circuited. If ANY reading is anomalous check RAW sensor reading. **Open Circuit Criterion:** **RAW reading in the range [0, -100]** **Short Circuit Criterion:** **RAW reading of -32768** **Note:** All calibration with an upper limit of T > ~ 80K are likely to show short circuit readings

Test Procedure:

Step#	Action
1	Record all 16 FPU temperatures on the log
2	Contingency: If test fails execute SCU_OFF procedure from HCSS Test Procedure window on TOPE and then repeat steps 1 and 2.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-SCU-03	**SCUTEMPSTAT**	**0/0xFFFF**	0xFFFF/0xFFFF	**N/A**	**Success**

Start time @: 13:45
End time @: 13:46
OBSID: 0x30012006
Comments:

```
SCU-03 Thermometry Check
OBSID = 0x30012006

PUMPHTRTEMP  54.11   32768
PUMPHSTEMP   37.26   32768
EVAPHSTMP    36.90   32768
SHUNTTEMP    18.71   32768
EMCFILTMP    89.69   50701
SL0TEMP      19.72   32768
PL0TEMP      20.33   32768
OPTTEMP      89.41   42103
BAFTEMP      90.26   44807
BSMIFTEMP    89.95   34750
SCAL2TEMP    89.59   42625
SCAL4TEMP    89.38   42292
SCALTEMP     83.34   32768
SMECIFTEMP   91.19   39859
SMECTEMP     26.54   32768
BSMTEMP      12.80   32768
```

4.3 FUNC-SCU-06

Test Id:	FUNC-SCU-06
Initial Configuration:	**DRCU_ON** + DC thermometry ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON
Success Criteria:	Test passed if SUBKSTAT parameter went from 0 to 1. **Open Circuit Criterion:** **RAW reading in the range 0 -100** **Short Circuit Criterion:** **RAW reading of -32768**

Test Procedure:

Step#	Action
1	Record the current value of SUBKTEMP channel on the log
3	Contingency: If test fails : 1. Send manual command: SEND_DRCU_COMMAND Parameter1 = 0xA0860000 Parameter2 = 0 2. Then repeat steps 1 and 2.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-SCU-06	**SUBKSTAT**	**0/1**	1/1	**N/A**	**Success**

Start time @: 13:46
End time @: 13:46
OBSID: 0x30012007
Comments:

FPU TEMP	TEMP(K)	TEMP(RAW)
Subktemp	**~ 80K**	**Before:32756** **After :32737**

4.4 FUNC-SCU-07

Test Id:	FUNC-SCU-07
Initial Configuration:	DRCU_ON + AC/DC thermometry ON
Final Configuration:	DRCU_ON + AC/DC thermometry ON
Success Criteria:	Test passed if during the execution of the test the following SCU HK parameters give correspondent readings of:

SCU HK parameter	RAW	Converted
SPHSV	**~12715**	**~323mV**
EVHSV	**~12715**	**~323mV**
SPHTRV	**~14390**	**~ 8 V**

Test Procedure:

Step#	Action
1	Run FUNC-SCU-07 test procedure from the HCSS Test Procedure window on TOPE.
2	While the test is running Write the values of current values of SPHSV, EVHSV, SPHTRV located in SCU_PARAMETERS display. (RAW and CONVERTED)
3	Contingency: If test fails repeat steps 1 and 2.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/During test	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-SCU-07	**SPHSV** **EVHSV** **SPHTRV**	**0/ ~ 323 mV** **0/ ~ 323 mV** **0/ ~ 8 V**	**0/323.85mV** **0/323.68mV** **0/8.85V**	**N/A**	**Success**

Start time @: 13:47
End time @: 14:49
OBSID: 0x30012008
Comments:

4.5 FUNC-SCU-04

Test Id:	FUNC-SCU-04
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON
Success Criteria:	Test passed if PCALCURR/PCALV SCU HK parameters show the following values: • PCALCURR HK parameter which shows the measured PCAL current is ~ 0.1 mA. • PCALV HK parameter which shows the measured PCAL voltage is ~ 0.02V

Test Procedure:

Step#	Action	Comments
1	Write the current value of PCALV and PCALCURR located in SCU_PARAMETERS display.	
2	Run FUNC-SCU-04 test procedure from the HCSS Test Procedure window on TOPE	
3	While the test is running Write the values of PCALV and PCALCURR.	
4	Contingency: If test fails repeat steps 1 to 3.	

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/During test	Actual Value Before/ During test	Nb. of frames received	Test Result
FUNC-SCU-04	**PCALCURR** **PCALV**	**0/0.1mA** **0/0.02V**	**0/0.1015mA** **0/0.0205V**	**N/A**	**Success**

Start time @: 13:52
End time @: 13:54
OBSID: 0x300120009
Comments:

4.6 FUNC-SCU-05

Test Id:	FUNC-SCU-05
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON
Success Criteria:	Test passed if : • SCAL2CURR ,SCAL4CURR HK parameters which show the measured current read ~ 0.1 mA • SCAL2V,SCAL4V parameters which show the measured voltage read ~ 0.05V.

Test Procedure

Step#	Action	Comments
1	Write the current value of SCAL2V ,SCAL2CURR,SCAL4V,SCAL4CURR located in SCU_PARAMETERS display.	
2	Run FUNC-SCU-05 test procedure from the HCSS Test Procedure window on TOPE	
3	While the test is running write the values of SCAL2V ,SCAL2CURR,SCAL4V,SCAL4CURR.	
4	Contingency: If test fails repeat steps 1 to 3.	

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/During test	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-SCU-05	**SCAL2CURR** **SCAL2V** **SCAL4CURR** **SCAL4V**	**0/0.1mA** **0/0.05V** **0/0.1mA** **0/0.05V**	**0/0.1003mA** **0/0.0504V** **0/0.1019mA** **0/0.0510V**	**N/A**	**Success**

Start time @: 13:55
End time @: 13:57
OBSID: 0x30012000A
Comments: SCAL4 followed by SCAL2

Step#	Action	Comments
0	Open **MCU_PARAMETERS** display on SCOS Alpha Numeric Displays.	

4.7 FUNC-MCU-01

Test Id:	**FUNC-MCU-01**
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON +MCU ON
Success Criteria:	Test passed if: 1. MCU boots. 2. MCU voltages show expected values. 3. MAC Board Temperature Reading shows ambient temperature.

Test Procedure:

Step#	Action
1	**Run** FUNC-MCU-01 **test procedure from the HCSS Test Procedure window on TOPE**
2	**When procedure is finished Write the values of the MCU voltages.**
3	Contingency: If test fails repeat steps 1 and 2.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-MCU-01	**MCUP5V** **MCUP15V** **MCUP14V** **MCUM14V** **MCUM15V** **MCUMACTEMP** **MCUBSMTEMP** **MCUSMECTEMP**	**N/A/ ~ 5V** **N/A / ~15V** **N/A / ~ 14V** **N/A / ~ -14V** **N/A / ~ -15V** **N/A / ~ 300K**	/ 5.01V / 15.53V / 14.15V / -14.47V / -15.63V / 288.24 K / 293.48 K / 293.08 K	**N/A**	**Success**

Start time @: 14:00
End time @: 14:02
OBSID: 0x3001200B
Comments:

MCU Powered ON I = 0.83
MCU Booted I = 0.87

MCU Booted properly.

4.8 FUNC-MCU-02

Test Id:	FUNC-MCU-02
Initial Configuration:	DRCU_ON + AC/DC thermometry ON +MCU ON
Final Configuration:	DRCU_ON + AC/DC thermometry ON +MCU ON
Success Criteria:	Test passed if : 1. MCU produces each type of the frames requested and with the following characteristics.

Frame	APID	Type	Subtype	SID	FrameID	Frame length
Eng.	**0x508**	**21**	**3**	**0x814**	**0x14**	**0x15**
BSM	**0x508**	**21**	**1**	**0x612**	**0x12**	**0xD**
SMEC	**0x508**	**21**	**1**	**0x410**	**0x10**	**0xC**
BSM +SMEC						

2. No events are generated during the different frames generation.

Test Procedure:

Step#	Action
1	Write the current value of MCUFRAMECNT located in MCU_PARAMETERS display
2	Run QLA script FUNC-MCU-02.py on QLA console.
3	Run FUNC-MCU-02 test procedure from the HCSS Test Procedure window on TOPE
4	When test is finished Write the current value of MCUFRAMECNT.
5	Contingency: If test fails repeat steps 1 to 4.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-MCU-02	**MCUFRAMECNT**	**0/ ~ 6600**	0 / 6493		**Success**

Start time @: 14:03
End time @: 14:06
OBSID: 0x3001200C
Comments:

Step#	Action	Comments
0	Open **CHOP PARAMETERS display** on SCOS Alpha Numeric Displays.	

4.9 FUNC-BSM-01

Test Id:	**FUNC-BSM-01**
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON +MCU ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON +MCU ON + BSM ON (open loop)
Success Criteria:	Test passed if: 1. CHOPSENSPWR HK parameter goes from 0 to 1 2. CHOPSENSIG HK parameter shows variation from off to on 3. JIGGSENSPWR HK parameter goes from 0 to 1 4. JIGGSENSSIG HK parameter shows variation from off to on

Test Procedure

Step#	Action
1	**Run FUNC-BSM-01.py script on QLA**
2	**Run FUNC-BSM-01 test procedure from the HCSS Test Procedure window on TOPE**
3	**When the test is finished record all the Key parameters noted bellow**
	Contingency: If test fails repeat steps 1 and 2.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-BSM-01	**CHOPSENSPWR** **CHOPLOOPMODE** **CHOPSENSSIG** **JIGGSENSPWR** **JIGGLOOPMODE** **JIGGSENSSIG**	**0/1** **3/3** **0/?** **0/1** **3/3** **0/?**	0/1 3/3 0x7FED/~ 0x9353 0/1 3/3 0x7FE4/0xA100	**N/A**	**Success**

Start time @:14:06
End time @:14:07
OBSID:0x3001200D
Comments:

BSM switched ON normally

4.10 FUNC-BSM-03

Test Id:	FUNC-BSM-03
Initial Configuration:	DRCU_ON + AC/DC thermometry ON +MCU ON + BSM ON (open loop)
Final Configuration:	DRCU_ON + AC/DC thermometry ON +MCU ON + BSM ON (open loop)
Success Criteria:	Test passed if the chop sensor signal evolves in the same way as the positions set.(i.e if (pos1 > pos2 ➔ sig1 > sig2) for each jiggle position. **Note:** During warm tests the voltages on both chop and jiggle motors are likely to be saturated (CHOP/JIGGMOTORVOLT RAW values of ~ 0xFFFF) due to the high resistance of the motor coil at ambient temperature.

Test Procedure

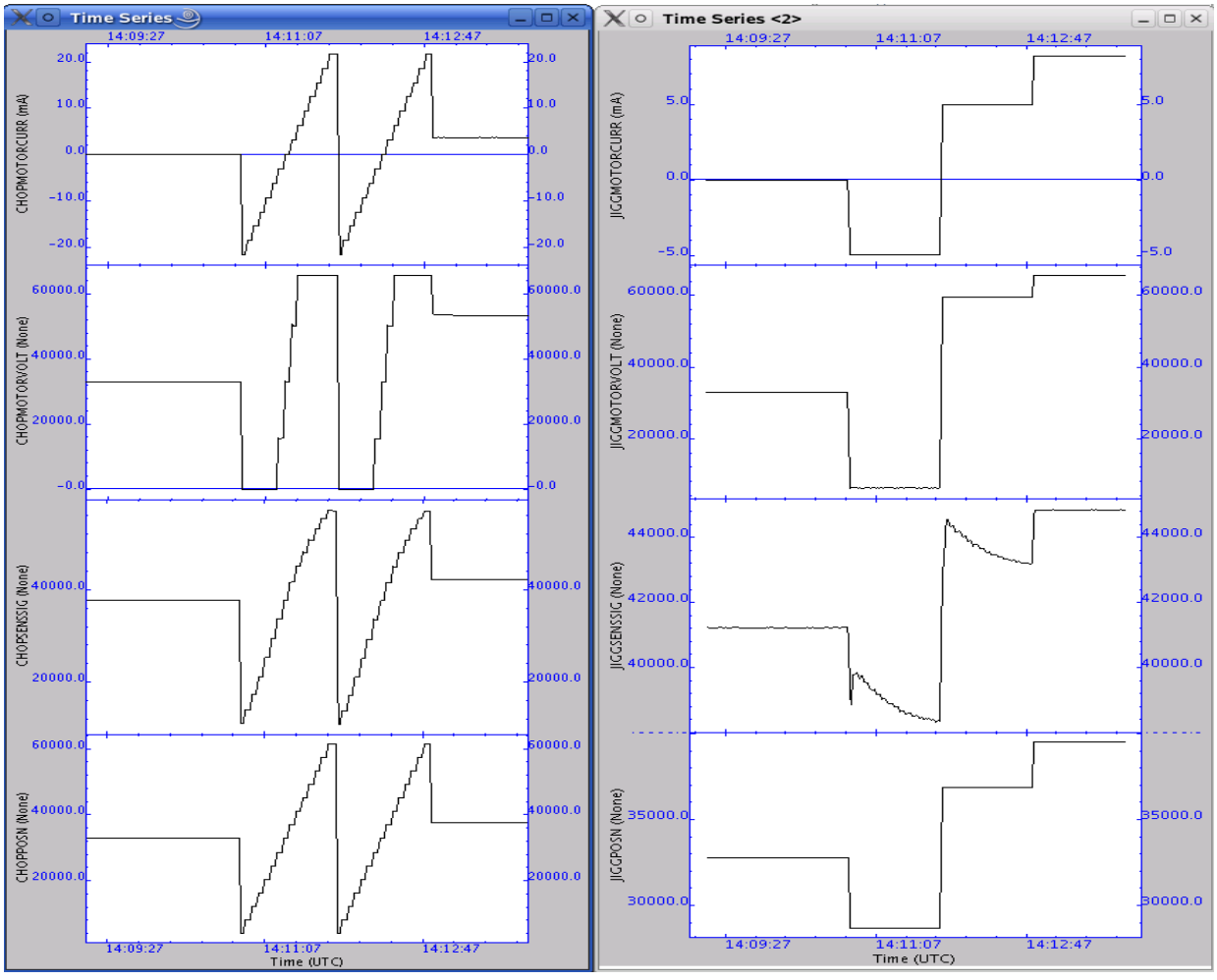
Step#	Action
1	**Run FUNC-BSM-03.py script on QLA**
2	**Run FUNC-BSM-03 test procedure from the HCSS Test Procedure window on TOPE**
3	Contingency: If test fails repeat step 2.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-BSM-03				N/A	Success

Start time @: 14:10
End time @: 14:14
OBSID: 0x3001200E
Comments:
Run the test with the following parameters:
BSM sampling 64Hz

Chop start position = 0x1000
Chop end position = 0xf000
Chop step = 0x1000
Jigg start position = 0x7000
Jigg end position = 0x9000
Jigg step =0x2000
T at each position = 3 sec



Step#	Action	Comments
4	Execute BSM_OFF from HCSS Test Procedures	14:18 Obsid: 0x3001200F

Step#	Action	Comments
0	Open **SMEC PARAMETERS display** on SCOS Alpha Numeric Displays.	

4.11 FUNC-SMEC-03

Test Id:	FUNC-SMEC-03
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON +MCU ON+ SMEC ON (open loop)
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON +MCU ON+ SMEC ON (open loop)
Success Criteria:	Test passed if: SMEC encoder signals 1 and 2 show a variation from one LED illumination level to another.

Test Procedure:

Step#	Action
1	**Run FUNC-SMEC-03.py script on QLA.**
2	**Run FUNC-SMEC-03 test procedure from the HCSS Test Procedure window on TOPE**
3	Contingency: If test fails repeat steps 1 and 2.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-SMEC-03	**SMECENCPWR** **SMECENCSIG1** **SMECENCSIG2**		Values changed from 3 to 5 to 6 as expected	Not relevant	**Success**

Start time @: 14:23
End time @: 14:24
OBSID: 0x30012010
Comments:

Input parameters for TOPE script:
Start level = 3
End level = 6
Step level =1
T at each level = 5

4.12 FUNC-SMEC-01

Test Id:	FUNC-SMEC-01
Initial Configuration:	DRCU_ON + AC/DC thermometry ON +MCU ON+ SMEC ON (open loop)
Final Configuration:	DRCU_ON + AC/DC thermometry ON +MCU ON+ SMEC ON (open loop)
Success Criteria:	Test passed if : 1. SMECENCPWR HK parameter changes from 0 to 6. 2. SMEC encoder signals 1 and 2 level show variation when encoder is switched ON. 3. SMEC LVDT is switched ON. (SMECLVDTPWR HK parameter goes from 0 to 1) 4. SMEC LVDT DC and AC signals show variation when LVDT is switched ON.

Test Procedure:

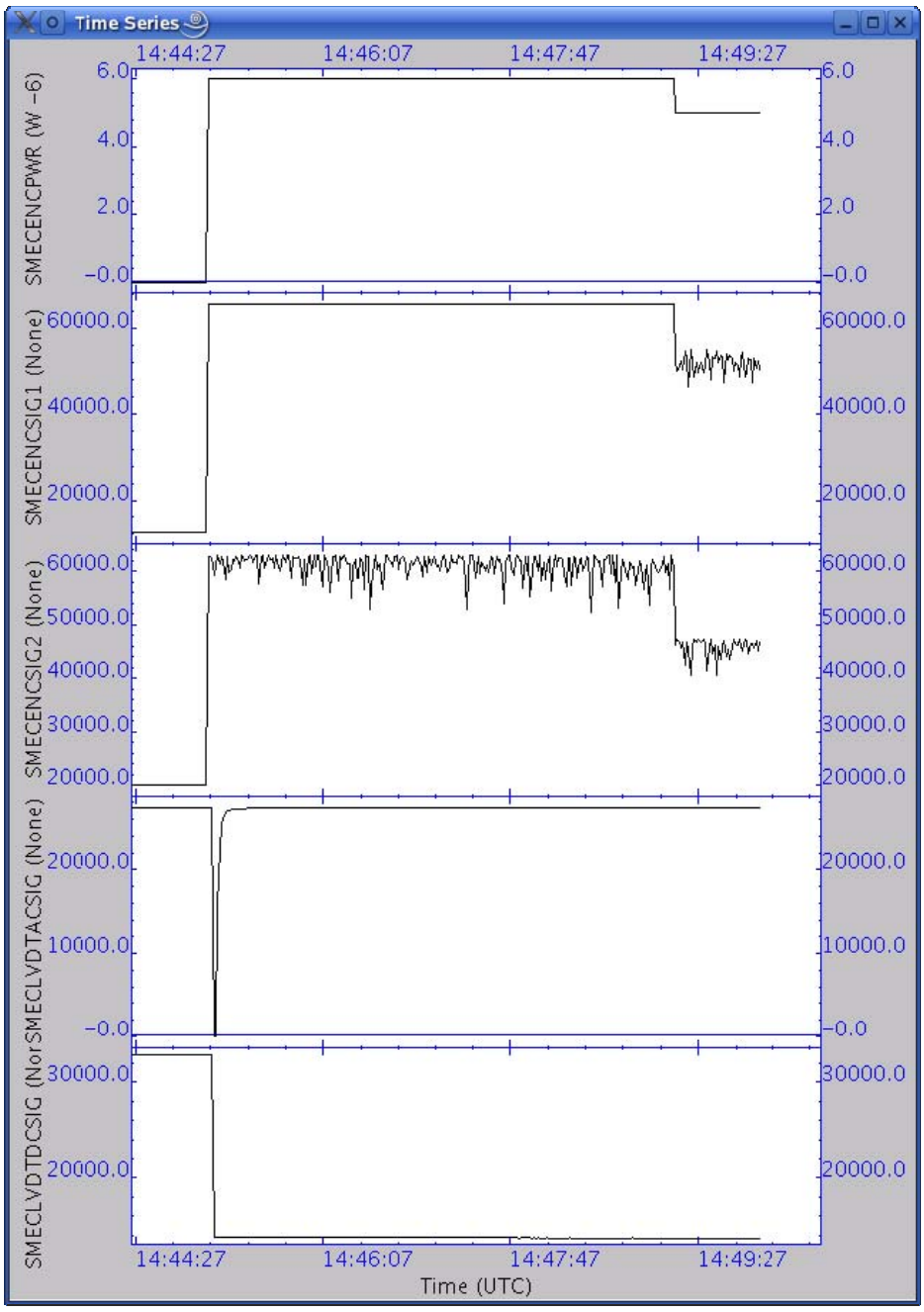
Step#	Action
1	**Run FUNC-SMEC-01.py script on QLA.**
2	Run FUNC-SMEC-01 test procedure from the HCSS Test Procedure window on TOPE
	Contingency: If test fails repeat steps 1.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-SMEC-01	**SMECENCPWR** **SMECLVDTPWR** **SMECENCSIG1** **SMECENCSIG2**		0/ 6 0/ 1 0xFFFF ~ 0xF000	**N/A**	**Success**

Start time @: 14:45
End time @: 14:46
OBSID: 0x30012013
Comments:

Signal 1 is saturated on prime with encoder level 6 as the previous SMEC tests shows.
The encoder level to set is extracted from the SMEC nominal settings caltable. It would be useful to include a third 'thermal' status apart from the warm/cold , 'cool' with different encoder level.
Will manually reduce the encoder level from 6 to 5. (0x90400005)
When this is done the encoder signal 1 comes in range.



4.13 FUNC-SMEC-04a

Test Id:	FUNC-SMEC-04a
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ SMEC ON (open loop)
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ SMEC ON (open loop)
Success Criteria:	Test passed if SMECLVDTDCSIG parameter shows a variation according to the different positions set.

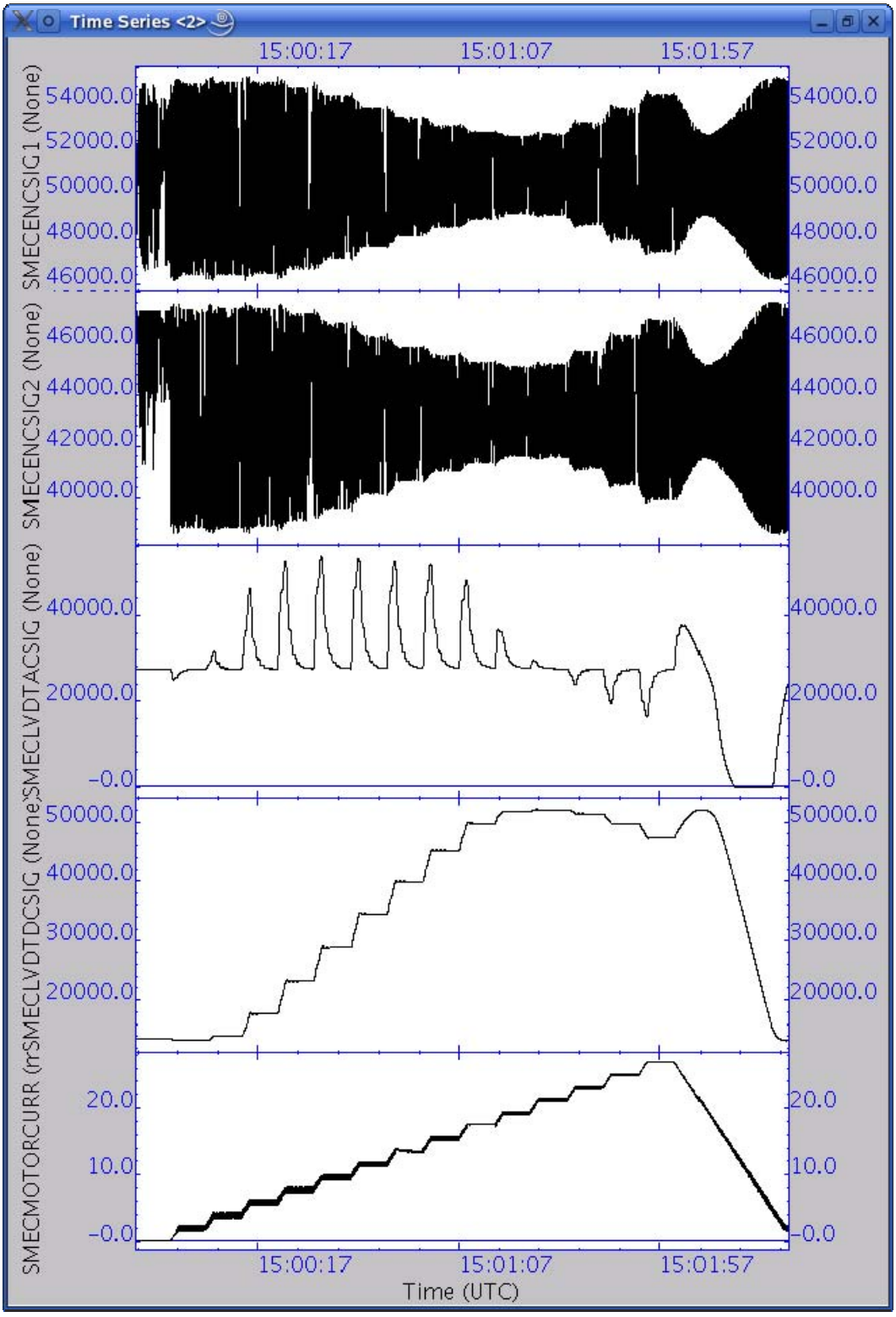
Test Procedure:

Step#	Action
1	**Run FUNC-SMEC-04a.py script on QLA**
2	Run FUNC-SMEC-04a test procedure from the HCSS Test Procedure window on TOPE
3	Contingency: If test fails repeat steps 1.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-SMEC-04a	**SMECLVDTDCSIG**				**Success**

Start time @: 15:00
End time @: 15:03
OBSID: 0x30012015
Comments:



Some extra SMEC functional test added for comparison with the future redundant side tests:

4.14 FUNC-SMEC-09

Test Id:	FUNC-SMEC-09
Test Purpose:	SMEC Open Loop Scan Test.
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ SMEC ON (open loop)
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ SMEC ON (open loop)
Success Criteria:	Test passed if SMECLVDTDCSIG parameter shows a variation according to the different position of the SMEC along the scan.

Test Procedure:

Step#	Action
1	**Run FUNC-SMEC-09.py script on QLA**
2	**Run FUNC-SMEC-09 test procedure from the HCSS Test Procedure window on TOPE**
3	Contingency: If test fails repeat steps 1.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	No. of frames received	Test Result
FUNC-SMEC-09	**All above mentioned in step 2**	**N/A**	**N/A**	**N/A**	**Success**

Start time @: 15:11
End time @: 12:
OBSID: 0x30012016
Comments:

Manually adjusted offsets:
Signal 1 offset = 0x9058BF68
Signal 1 offset = 0x905A9C40

Start point = 1 mm,
End point = 25 mm,
Speed = 0.5 mm/s (forward/revers)
Scans. = 2

Encoder not counting

OBSID: 0x30012017
Comments:

Manually adjusted offsets:
Signal 1 offset = 0x9058C350
Signal 1 offset = 0x905AA410

Start point = 1 mm,
End point = 25 mm,
Speed = 0.5 mm/s (forward/revers)
Scans. = 2

See next test for comparison of MOTORCURRENT

Step#	Action	Comments
0	Execute SMEC_INIT from HCSS Test Procedures	15:14 Obsid: 0x30012018

4.15 FUNC-SMEC-07

Test Id:	FUNC-SMEC-07
Test Purpose:	SMEC Close Loop Scan Test.
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ SMEC ON (close loop)
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ SMEC ON (close loop)
Success Criteria:	Test passed if: SMECENCPOS HK parameter shows identical values as those of the SMECTRAJPOSN HK parameter during the scan.

Test Procedure:

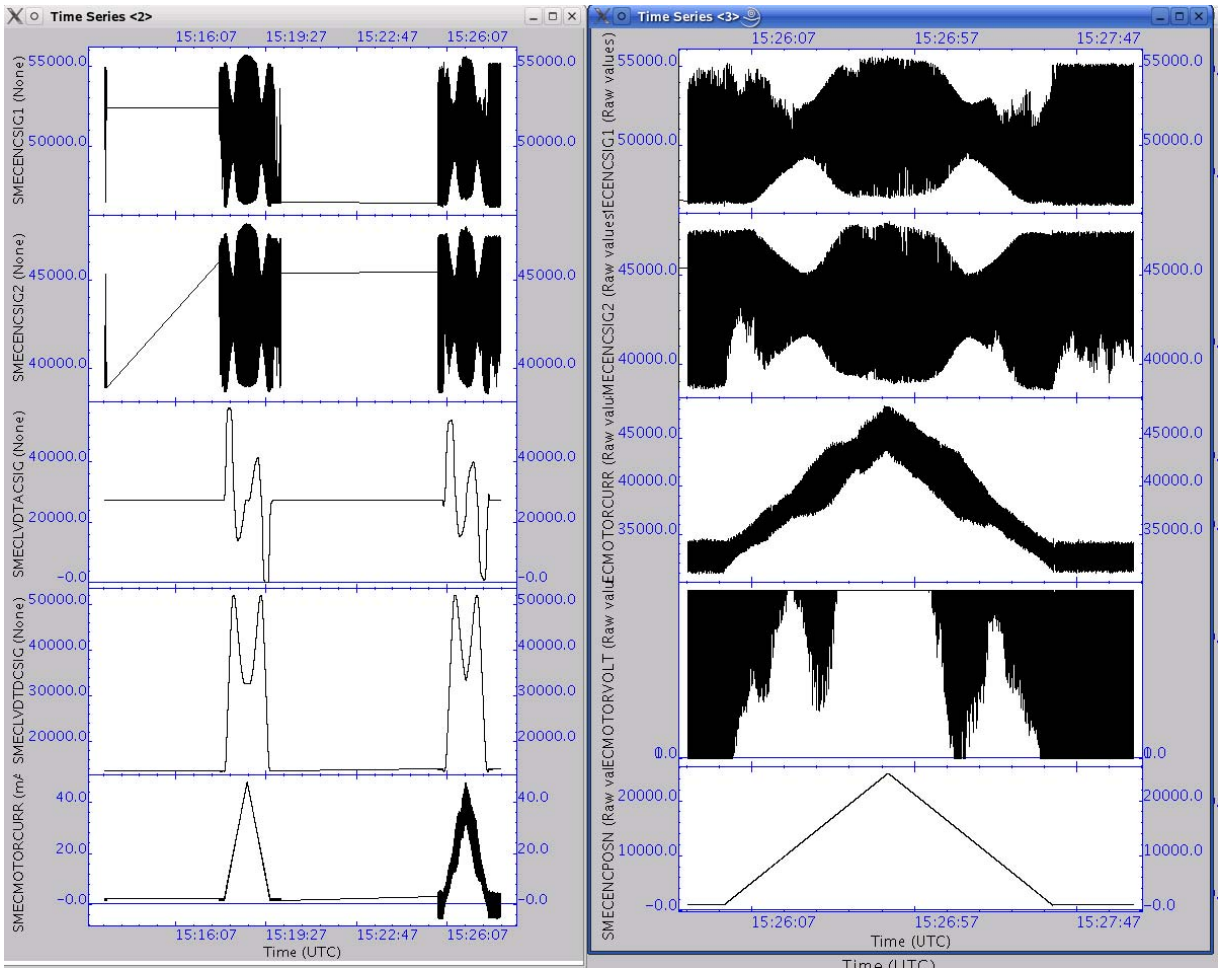
Step#	Action
1	**Run FUNC-SMEC-07.py script on QLA**
2	**Run FUNC-SMEC-07 test procedure from the HCSS Test Procedure window on TOPE**
3	Contingency: If test fails repeat steps 1.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	No. of frames received	Test Result
FUNC-SMEC-07	**All above mentioned in step 1**	**N/A**	**N/A**	**N/A**	**Success**

Start time @: 15:26
End time @: 15:29
OBSID: 0x30012019
Comments:

Start point = 1 mm,
End point = 25 mm,
Speed = 0.5 mm/s (forward/revers)
Scans. = 2



Note:
On the left hand side display the two consecutive (open) then (close) loop scans can be seen. Once gain the jitter on motorcurrent on the close loop points to a wrong set of PID parameters.

Step#	Action	Comments
4	Execute SMEC_OFF from HCSS Test Procedures	15:29 Obsid: 0x3001201A

Step#	Action	Comments
0	Open **DCU PARAMETERS** SCOS Alpha Numeric Display	

4.16 FUNC-DCU-01

Test Id:	**FUNC-DCU-01**
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON
Success Criteria:	Test passed if: 1. DCU produces each type of DCU nominal science frame with the following characteristics.

APID	Type	S.type	SID	Frame ID	Frame type	Nb. Of frames	Nb. of pkts.
0x504	**21**	**1**	**0x200**	**0**	**PF**	**100**	**100**
0x506	**21**	**1**	**0x201**	**1**	**SF**	**100**	**17**
0x504	**21**	**2**	**0x102**	**2**	**PSW**	**100**	**34**
0x504	**21**	**2**	**0x103**	**3**	**PMW**	**100**	**25**
0x504	**21**	**2**	**0x104**	**4**	**PLW**	**100**	**12**
0x506	**21**	**2**	**0x105**	**5**	**SSW**	**100**	**12**
0x506	**21**	**2**	**0x106**	**6**	**SLW**	**100**	**7**

2. The frame time difference between consecutive DCU frames of each type corresponds to the sampling rate.
   Photometer Sampling rate is 15.3Hz → $\Delta t \sim 65.5$ ms
   Spectrometer Sampling rate is 80Hz → $\Delta t = 12.5$ ms
3. The SPIRE HK parameter DCUFRAMECNT increments by 700.
4. No events are generated during the frames generation.

Test Procedure:

Step#	Action
1	**Write the current value of DCUFRAMECNT located d in DCU PARAMETERS AND**
2	**Run FUNC-DCU-01.py script on QLA**
3	**Run FUNC-DCU-01 test procedure from the HCSS Test Procedure window on TOPE**
4	**Write the current value of DCUFRAMECNT located d in DCU PARAMETERS AND**
5	Contingency: If test fails repeat steps 1 to 3.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-DCU-01	**DCUFRAMECNT**	**0/700**	8351/9051	700	**Success**

Start time @: 15:30
End time @: 15: 33
OBSID: 0x3001201B
Comments:

```
**************************************************************************
PHOTF: OBSID = 3001201B, BBTYPE = 0x8800, APID = 0x504, SID  = 0x200
_____________________________________________________________________________
Parameter      Initial    Final     Increment Expect Incre. Packet Chars.

DCUFRAMECNT    8351       8451       100        100          Packet type = 0x15
TM3N           8350       8450       100        100          subtype = 0x1
FrameTime      53.7600    53.7600                            Frame ID  = 0x0
                                                             Frame Len = 0x126
STATISTICS ON TIME BETWEEN RECEPTION OF 2 CONSECUTIVE FRAMES:
mean  = 53.75948 ms
sigma = 0.00119 ms


**************************************************************************
PHOTSW: OBSID = 3001201B, BBTYPE = 0x8802, APID = 0x504, SID  = 0x102
_____________________________________________________________________________
Parameter      Initial    Final     Increment Expect Incre. Packet Chars.

DCUFRAMECNT    8451       8551       100        100          Packet type = 0x15
TM3N           8450       8484       34         34           subtype = 0x2
FrameTime      53.7600    53.7600                            Frame ID  = 0x2
                                                             Frame Len = 0x96
STATISTICS ON TIME BETWEEN RECEPTION OF 2 CONSECUTIVE FRAMES:
mean  = 53.75945 ms
sigma = 0.00121 ms


**************************************************************************
PHOTMW: OBSID = 3001201B, BBTYPE = 0x8803, APID = 0x504, SID  = 0x103
_____________________________________________________________________________
Parameter      Initial    Final     Increment Expect Incre. Packet Chars.

DCUFRAMECNT    8551       8651       100        100          Packet type = 0x15
TM3N           8484       8509       25         25           subtype = 0x2
FrameTime      53.7600    53.7600                            Frame ID  = 0x3
                                                             Frame Len = 0x66
STATISTICS ON TIME BETWEEN RECEPTION OF 2 CONSECUTIVE FRAMES:
mean  = 53.75945 ms
sigma = 0.00122 ms


**************************************************************************
PHOTLW: OBSID = 3001201B, BBTYPE = 0x8804, APID = 0x504, SID  = 0x104
_____________________________________________________________________________
Parameter      Initial    Final     Increment Expect Incre. Packet Chars.

DCUFRAMECNT    8651       8751       100        100          Packet type = 0x15
TM3N           8509       8521       12         12           subtype = 0x2
FrameTime      53.7568    53.7600                            Frame ID  = 0x4
                                                             Frame Len = 0x36
STATISTICS ON TIME BETWEEN RECEPTION OF 2 CONSECUTIVE FRAMES:
mean  = 53.75945 ms
sigma = 0.00121 ms


**************************************************************************
SPECF: OBSID = 3001201B, BBTYPE = 0x8801, APID = 0x506, SID  = 0x201
_____________________________________________________________________________
Parameter      Initial    Final     Increment Expect Incre. Packet Chars.

DCUFRAMECNT    8751       8851       100        100          Packet type = 0x15
TM4N           16383      16         49168      17           subtype = 0x1
FrameTime      12.4928    12.4928                            Frame ID  = 0x1
                                                             Frame Len = 0x4E
STATISTICS ON TIME BETWEEN RECEPTION OF 2 CONSECUTIVE FRAMES:
mean  = 12.49267 ms
sigma = 0.00064 ms
```

4.17 FUNC-DCU-11P

Test Id:	FUNC-DCU-11P
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ Photometer LIAs ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ Photometer LIAs ON + Photometer BIAS ON +Photometer JFETs ON
Success Criteria:	Test passed if Photometer JFET source and drain voltages are correct: 1. PSWJFETVSS1/2/3/4/5/6 (RAW: 0x4C CONVERTED ~ -1.5V). 2. PMLWJFETVSS1/2/3/4 (RAW: 0x4C CONVERTED ~ -1.5V). 3. PSWJFETSTAT = 0x3F 4. PMLWJFETSTAT = 0x1F

Test Procedure:

Step#	Action	Comments
1	Run FUNC-DCU-11P test procedure from the HCSS Test Procedure window on TOPE	
2	After the test Write the values RAW and converted values of: PSWJFETSTAT,PMLWJFETSTAT, PSWJFET1/2/3/4/5/6V PMWJFET1/2/3/4V PLWJFET1/2V located in DCU PARAMETERS AND	
3	Contingency: If test fails repeat steps 1 and 2.	

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-DCU-11P	**PSWJFETSTAT** **PMLWJFETSTAT** **PSWJFET1/2/3/4/5/6V** **PMWJFET1/2/3/4V** **PLWJFET1/2V**	**0/0x3f** **0/0x7f** **0V/-1.5V** **0V/-1.5V** **0V/-1.5V**	0/0x03f 0/0x07f 0/-1.49 0/-1.49 0/-1.49	**N/A**	Success

Start time @: 08:48 05th Feb 2007
End time @: 08:50
OBSID: 0x3001201C

Comments:

PSW:
A10 appear to be dead (no signal before of after, only during the JFET switch on they showed a spike).
G8 and C12 have a much higher output (~ 50000 ADUs against ~ 16400) than the rest of the array.

PMW:
C8 started of with signal an when the JFETS were started the signal went bottom of the scale.
T2 does not have signal. DP1 has now signal against its behaviour during WFTs.

PLW:
Seems to be fine.

4.18 FUNC-DCU-13P

Test Id:	FUNC-DCU-13P
Test Purpose:	Photometer Detectors Check
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ Photometer LIAs ON + Photometer BIAS ON +Photometer JFETs ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON+ Photometer LIAs ON + Photometer BIAS ON +Photometer JFETs ON
Success Criteria:	Test passed if : The photometer detectors show a small linear variation on the output voltage when different bias is applied through the load curve.

Test Procedure:

Step#	Action
1	**On QLA bring up a time series display of a couple of pixels on each of the photometer BDAs**
2	**Run FUNC-DCU-13P.py script on QLA**
3	**Run FUNC-DCU-13P test procedure from the HCSS Test Procedure window on TOPE**
4	Contingency: If test fails repeat step 1 and 2.

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	No. of frames received	Test Result
FUNC-DCU-13P				**N/A**	**To Check**

Ran Proc_Stop_DCU_Data as data still running after DCU-11

Start time @: 08:53
End time @: 09:05
OBSID: 0x3001201D
Comments:

PSW:
F9, B12 and T1 behave differently than the rest of the array with higher response to the increasing bias.
PMW:
No particularities.
PLW:
A7 behaves differently than the rest of the array with higher response to the increasing bias.

See Annexe 2 for full results from every pixel

4.19 FUNC-DCU-14P

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
				N/A	To Check

Start time @: 09:10
End time @: 09:15
OBSID: 0x3001201E
Comments:
Executed ILT-PERF-DNA-P
Input parameters:
Array = PF
Time = 300 sec

Step#	Action	Comments
1	From TOPE HCSS Test Procedures run **PDET-OFF**	**Executed @: 09:16** **OBSID 0x3001201F**

4.20 FUNC-DCU-11S

Test Id:	FUNC-DCU-11S
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON + Spectrometer LIAs ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON + Spectrometer LIAs ON + Spectrometer BIAS ON + Spectrometer JFETs ON
Success Criteria:	Test passed if SCUDCDCSTAT goes from 4 to 6, Spectrometer LIAs voltages are correct and SJFET voltages are also correct.

Test Procedure:

Step#	Action	Comments
1	Run FUNC-DCU-11S test procedure from the HCSS Test Procedure window on TOPE	
2	After the test Write the values RAW and converted values of: LIASTAT SLIAP5V, SLIAP9V, SLIAN9V, SSWJFETSTAT,SLWJFETSTAT, SSWJFET1V,SLWJFET2V located in DCU PARAMETERS AND	
3	Contingency: If test fails repeat steps 1 and 2.	

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
FUNC-DCU-11S	**SCUDCDCSTAT** **LIASTAT** **SLIAP5V** **SLIAP9V** **SLIAN9V** **SPECJFETSTAT** **SSWJFET1V** **SSWJFET2V** **SLWJFET1V**	**6/6** **0/0** **0V/ ~ 5V** **0V/~11V** **0V/-11V** **0/7** **0V/-2.07V** **0V/-1.59V** **0V/-1.68V**	6/6 0/0 ~0/5.23 ~0/11.57 ~0/-11.53 0/0x7 0V/-2.07V 0V/-1.59V 0V/-1.68V	**N/A**	**Success**

Start time @: 09:18
End time @:
OBSID: 0x30012020
Comments:

Generally all pixels looking responsive

SSW: D5 seem to show higher RAW ouput (~ 40000 ADUs against ~ 164000 ADUs) then the rest.
SLW: C2,B3 seems to show low responsivity
DP2 seems dead.

4.21 FUNC-DCU-13S

Test Id:	FUNC-DCU-13S
Test Purpose:	Spectrometer detectors check
Initial Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON + Spectrometer LIAs ON + Spectrometer BIAS ON + Spectrometer JFETs ON
Final Configuration:	**DRCU_ON** + AC/DC thermometry ON+MCU ON + Spectrometer LIAs ON + Spectrometer BIAS ON + Spectrometer JFETs ON
Success Criteria:	Test passed if : The spectrometer detectors show a small linear variation on the output voltage when different bias is applied through the load curve.

Test Procedure:

Step#	Action	Comments
1	On QLA bring up a time series display of a couple of pixels on each of the spectrometer BDAs	
2	Run FUNC-DCU-13S test procedure from the HCSS Test Procedure window on TOPE	
3	Contingency: If test fails repeat steps 1 and 2	

Test Log:

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	No. of frames received	Test Result
FUNC-DCU-13S				**N/A**	**To Check**

Start time @: 09:22
End time @: 09:33
OBSID: 0x30012021

SSW:
A3 and C6 show a higher response to the increasing bias than the rest.
D5 behaving as during PFM4.
SLW:
C1 show a higher response to the increasing bias than the rest.

See Annexe 2 for full results from every pixel

4.22 FUNC-DCU-14S

Test Id	Key Parameter(s)	Expected Value Before/After	Actual Value Before/After	Nb. of frames received	Test Result
				N/A	To Check

Start time @: 09:37
End time @: 09:42
OBSID: 0x30012022
Comments:
Executed ILT-PERF-DNA-S
Input parameters:
Array = SF
Time = 300 sec

Step#	Action	Comments
1	From TOPE HCSS Test Procedures run **SDET-OFF**	**Executed @: 09:45** **OBSID 0x30012023**

5. END TEST SEQUENCE

The following table shows the necessary steps to be followed to end the warm functional test sequence.

Step#	Action	HK parameters	Expected Value	Comments	Check
1	Check BSM is OFF	CHOPSENSPWR JIGGSENSPWR	0 0	0 0	✓ ✓
2	Check SMEC is OFF	SMECENCPWR	0	0	✓
3	Run MCU-OFF from the HCSS Test Procedure window on TOPE	SCUDCDCSTAT	0	0	✓
4	Check Instrument Configuration	MODE	0x100/ DRCU_ON	DRCU_ON	✓
5	Run SCU_OFF from the HCSS Test Procedure window on TOPE	SCUTEMPSTAT SUBKSTAT	0 0	0 0	✓
6	Run DRCU_OFF from the HCSS Test Procedure window on TOPE	MODE	0/ DPU_ON	***** undefined	✓

6. ANNEXE1 (INSTRUMENT NOMINAL CONFIGURATION/MODES)

	OFF	INIT	DPU_ON	DRCU_ON	REDY	PHOT STBY	SPEC STBY	CREC	SAFE
DPU		**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**
Essential Hsk packets			0.5Hz	0.5Hz	0.5Hz	0.5Hz	0.5Hz	0.5Hz	0.5Hz
Normal Hsk packets			1.0Hz	1.0Hz	0.25Hz	0.25Hz	0.25Hz	1.0Hz	0.25Hz
TC Acceptance		TBC	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Event packets		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Science packets									
VM								Cooler_Recycle	
VM1						Det_Temp_Ctrl			
VM2									
VM3									
MODE			0x0000	0x0100	0x0200	0x0300	0x0400	0x0600	0x0900
DRCU			**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	
SCU									
Temp Channels powered					Yes	Yes	Yes	Yes	
SubK Channel powered					Yes	Yes	Yes	Yes	
PCAL source powered									
SCAL sources powered							TBD		
TC Heater powered						Yes			
Cooler SP Heater powered								Yes	
Cooler EV HS powered								Yes	
Cooler SP HS powered					Yes	Yes	Yes	Yes	
DCU									
Photometer BIAS						Yes			
Photometer JFETS						Yes			
Photometer LIAs						Yes			
TC BIAS						Yes			
TC JFETS						Yes			
TC LIAs						Yes			
Spectrometer BIAS							Yes		
Spectrometer JFETS							Yes		
Spectrometer LIAs							Yes		
MCU									
DSP					On	On	On	On	
BSM						Hold	Hold		
SMEC							Hold		

7. ANNEXE 2 (RESULTS OF LOAD CURVES)

The following graphs (1-12) show the response of the 288 Photometer detectors to the input voltage during the Load Curve (FUNC-DCU-13). The graph (13) shows the response of the 3 PTC channels to the input voltage during the Load Curve. The graphs (14-16) show the spectrometer 78 detectors output voltage during the load curve performed on the spectrometer side. These plots are for OBSIDs 3001201D for phot and 30012021 for spec.

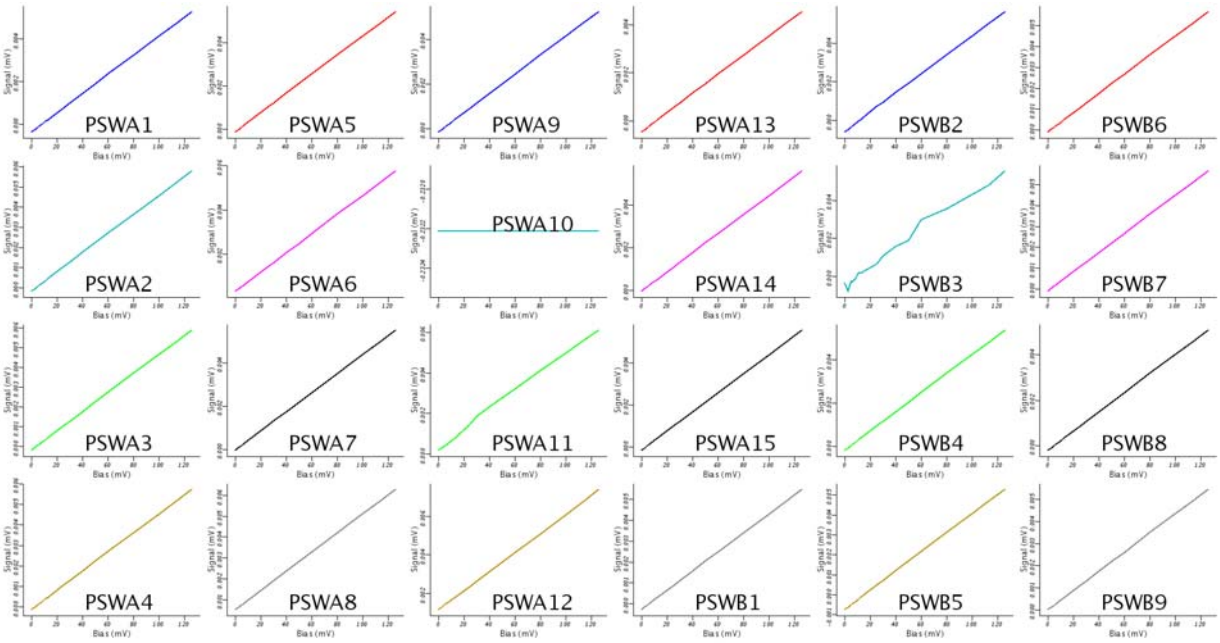


Figure 1. PSW Detectors (1)

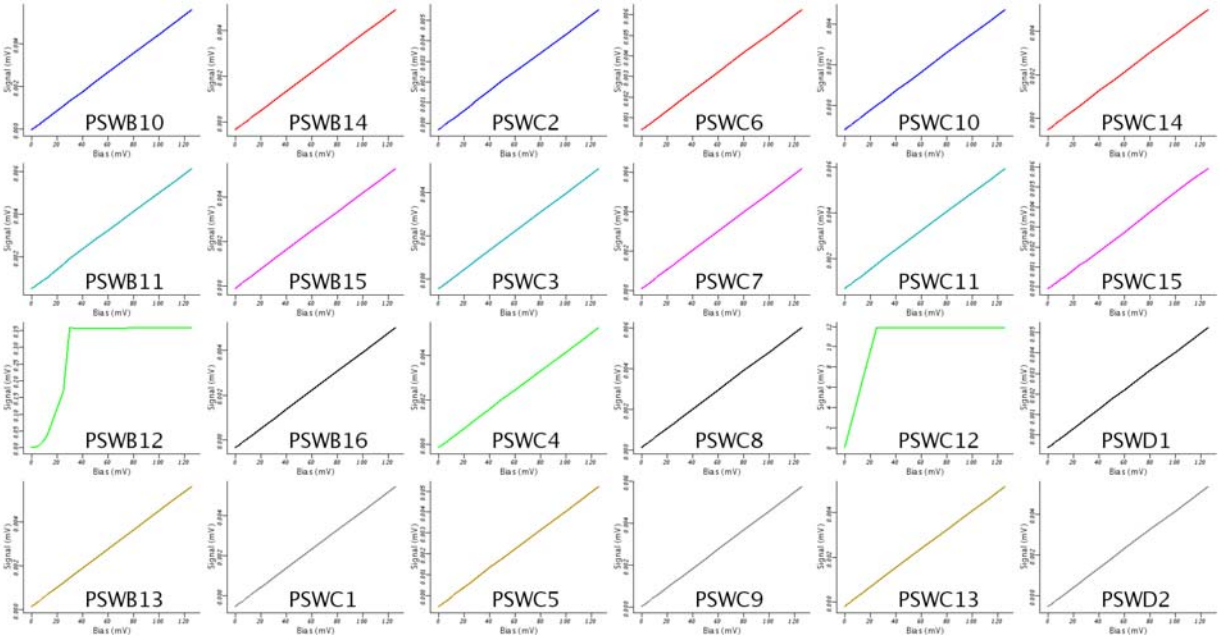


Figure 2. PSW Detectors (2)

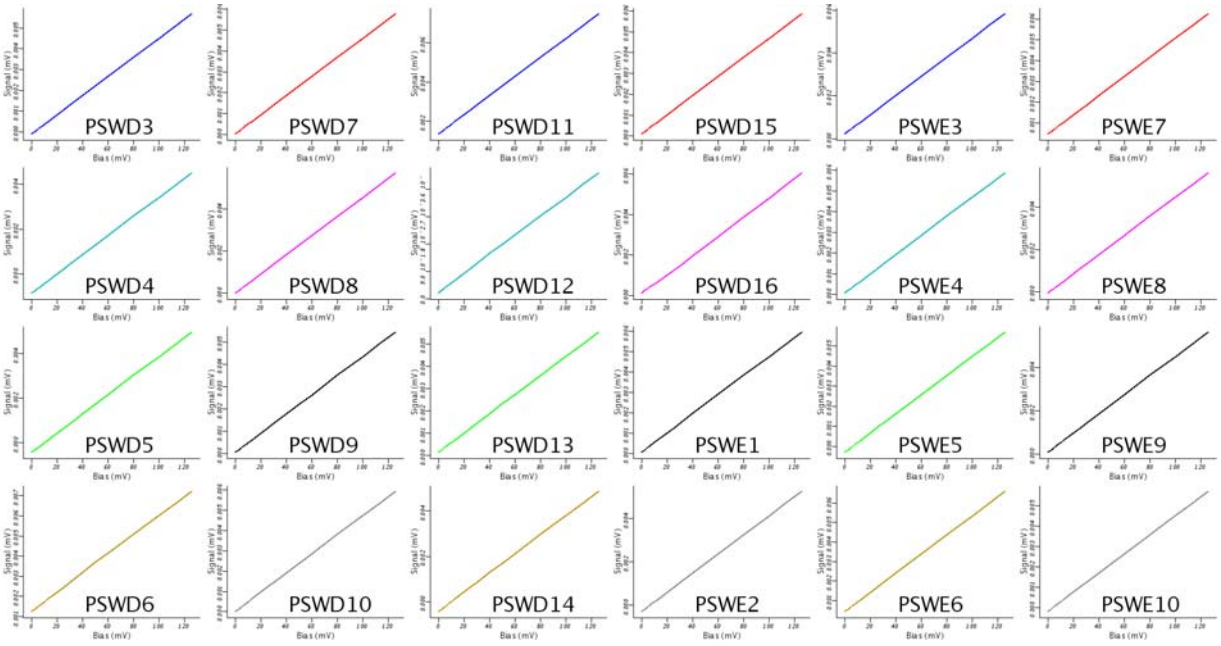


Figure 3. PSW Detectors (3)

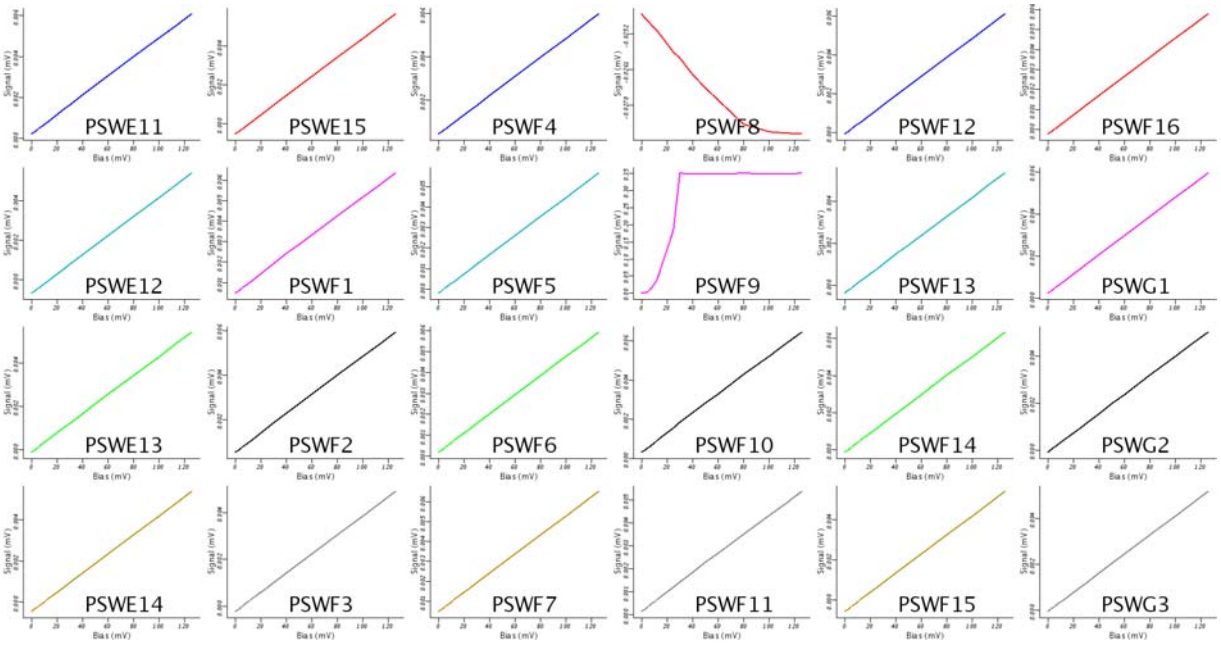


Figure 4. PSW Detectors (4)

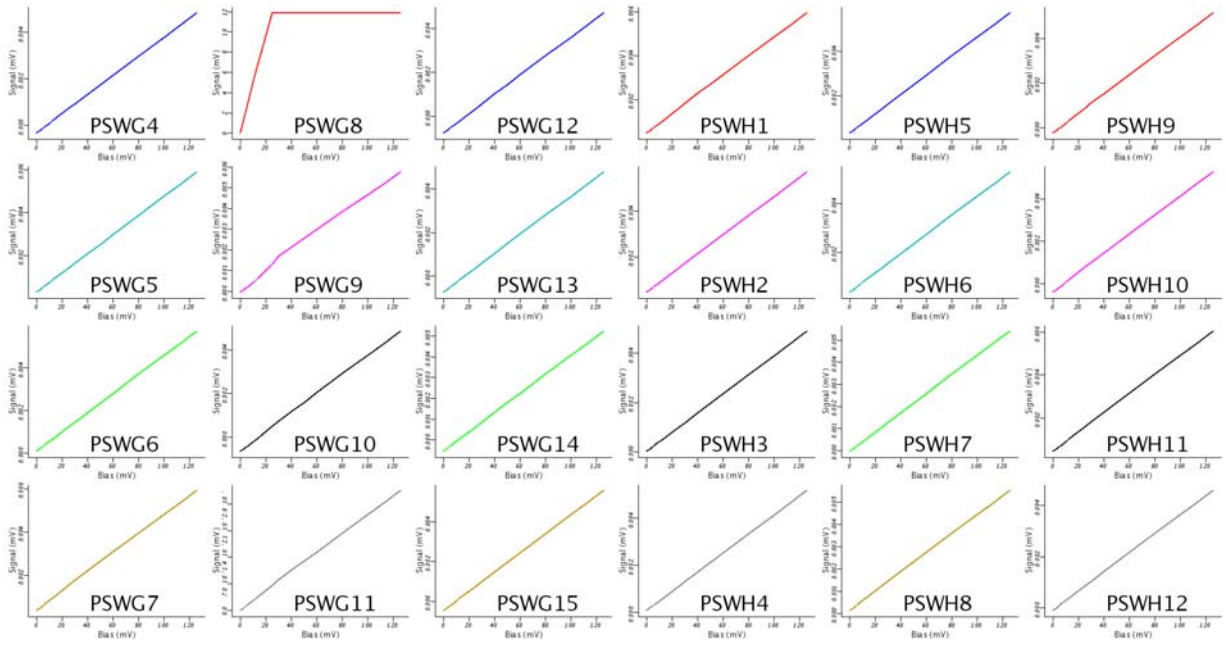


Figure 5. PSW Detectors (5)

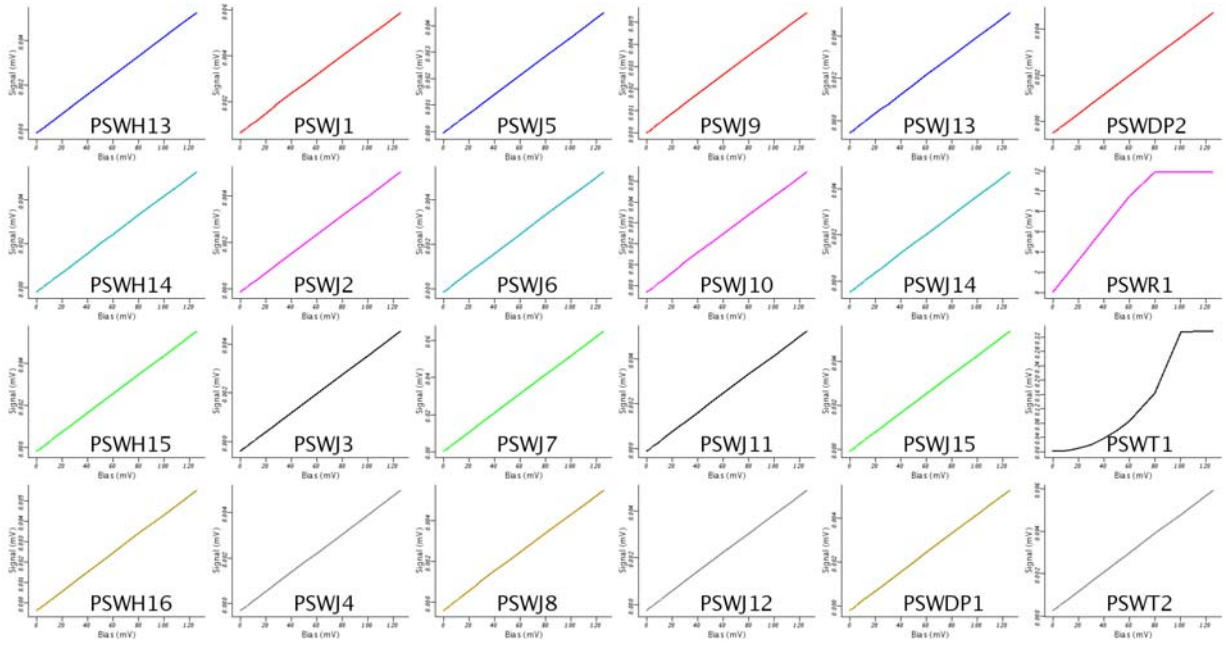


Figure 6. PSW Detectors (6)

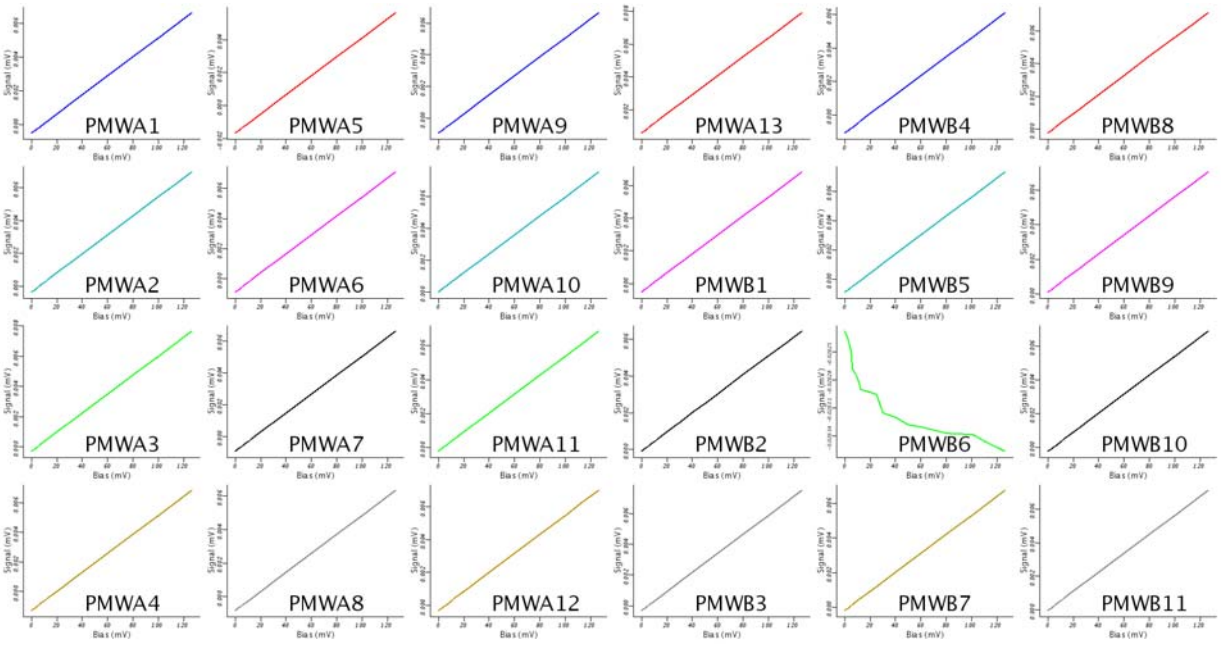


Figure 7. PMW Detectors (1)

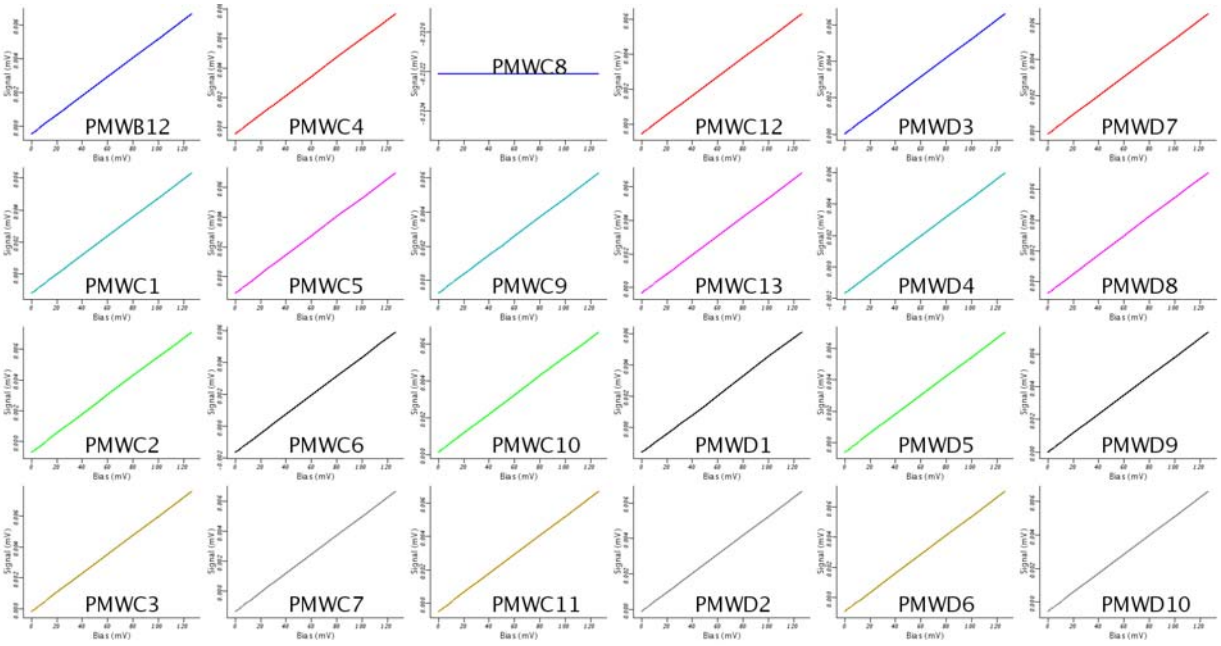


Figure 8. PMW Detectors (2)

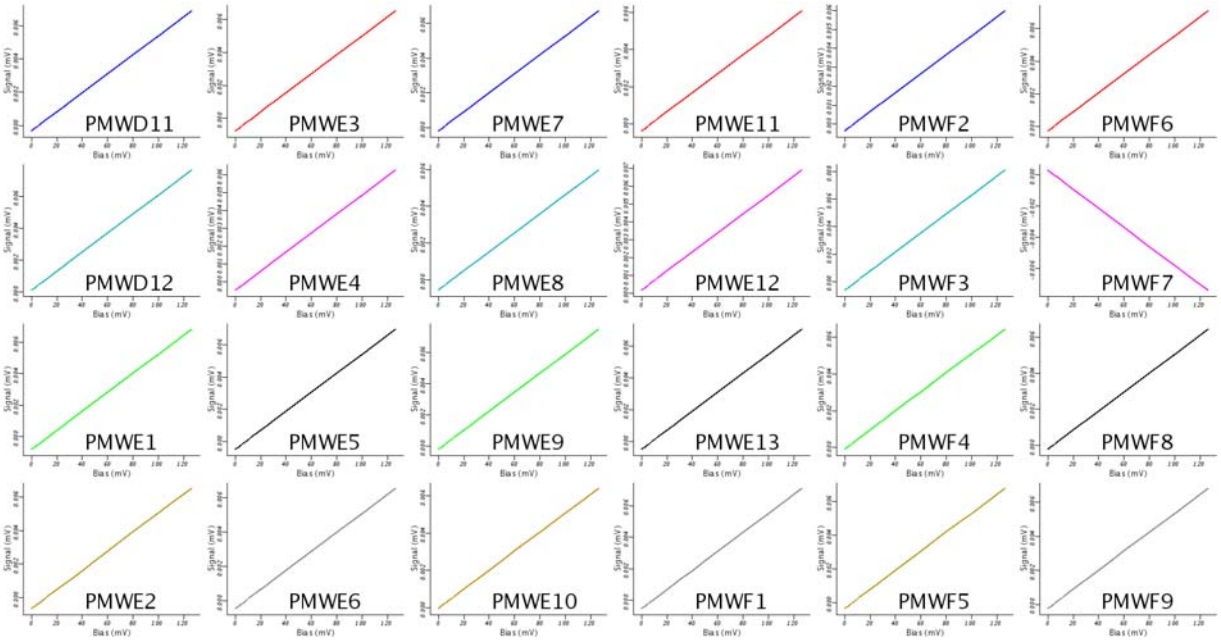


Figure 9. PMW Detectors (3)

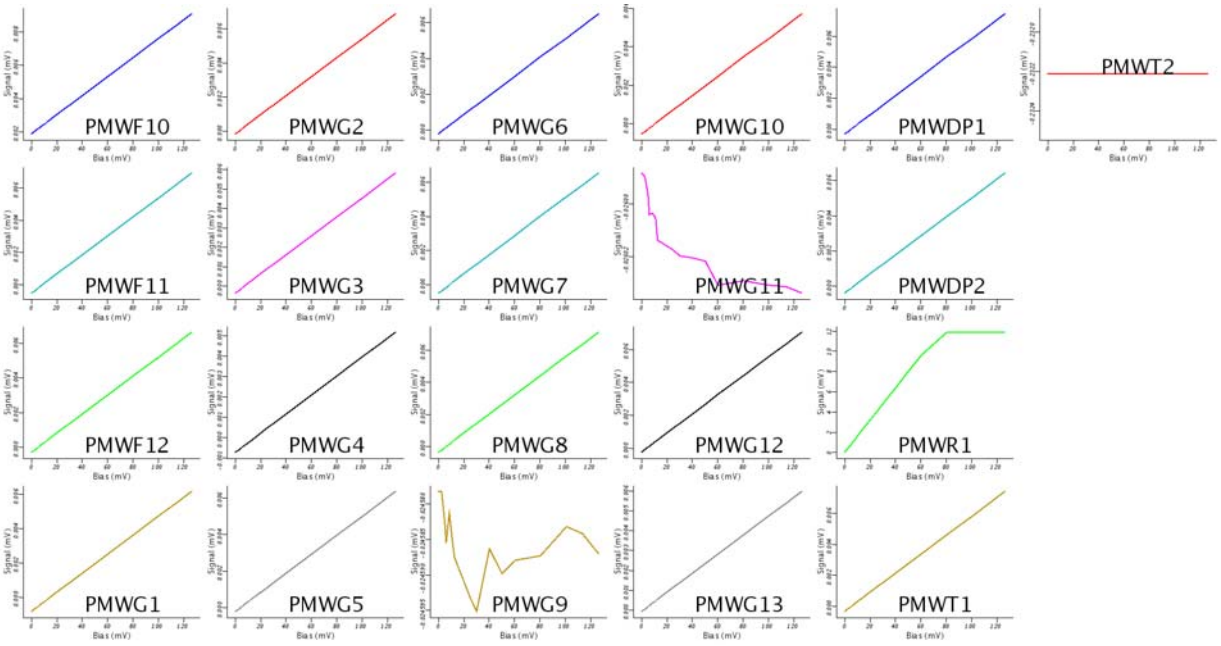


Figure 10. PMW Detectors (4)

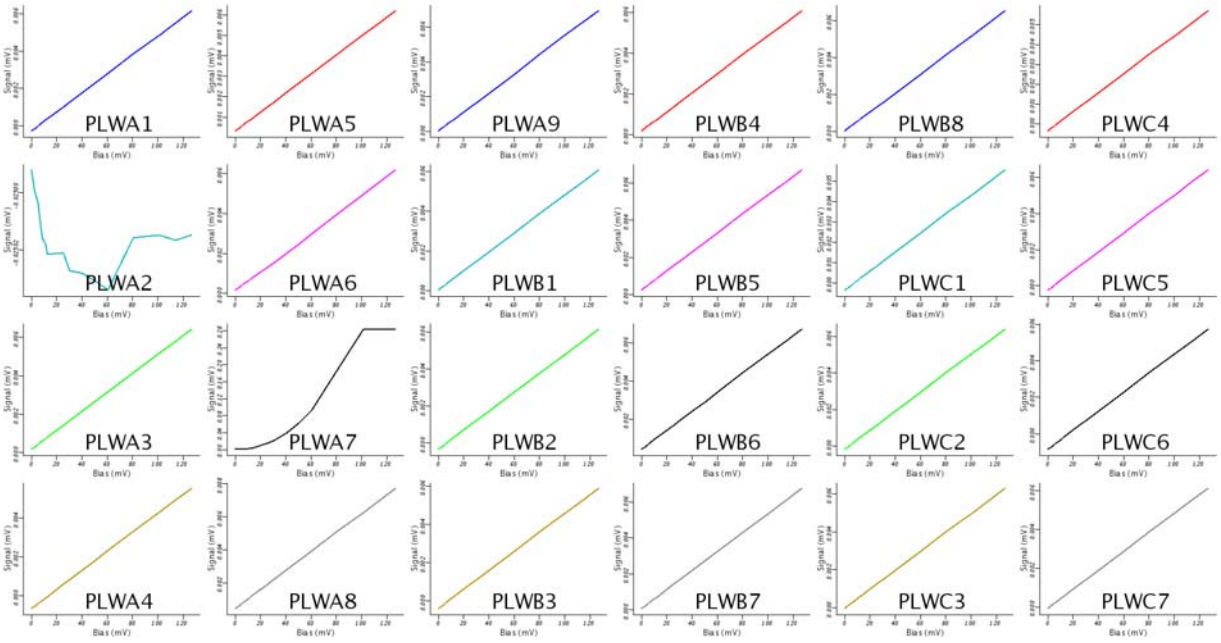


Figure 11. PLW Detectors (1)

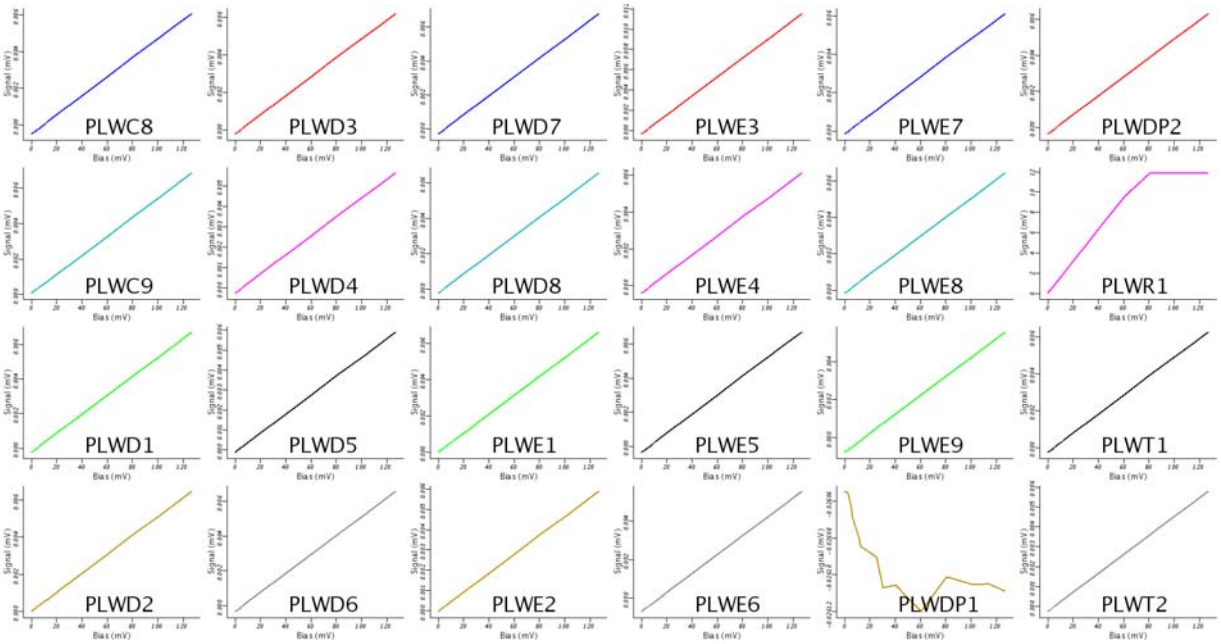


Figure 12. PLW Detectors (2)

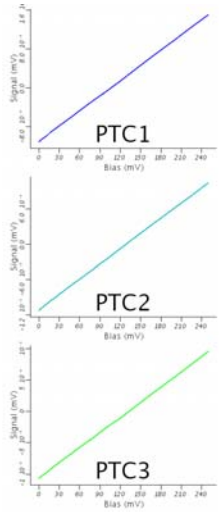


Figure 13. PTC Detectors (1)

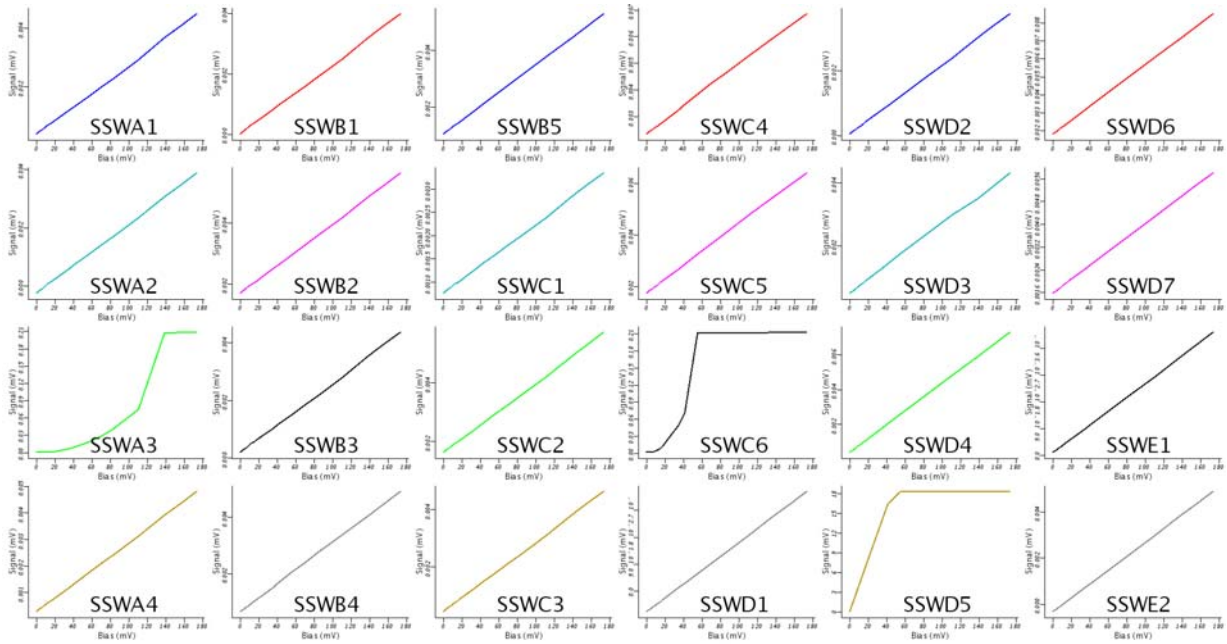


Figure 14. SSW Detectors (1)

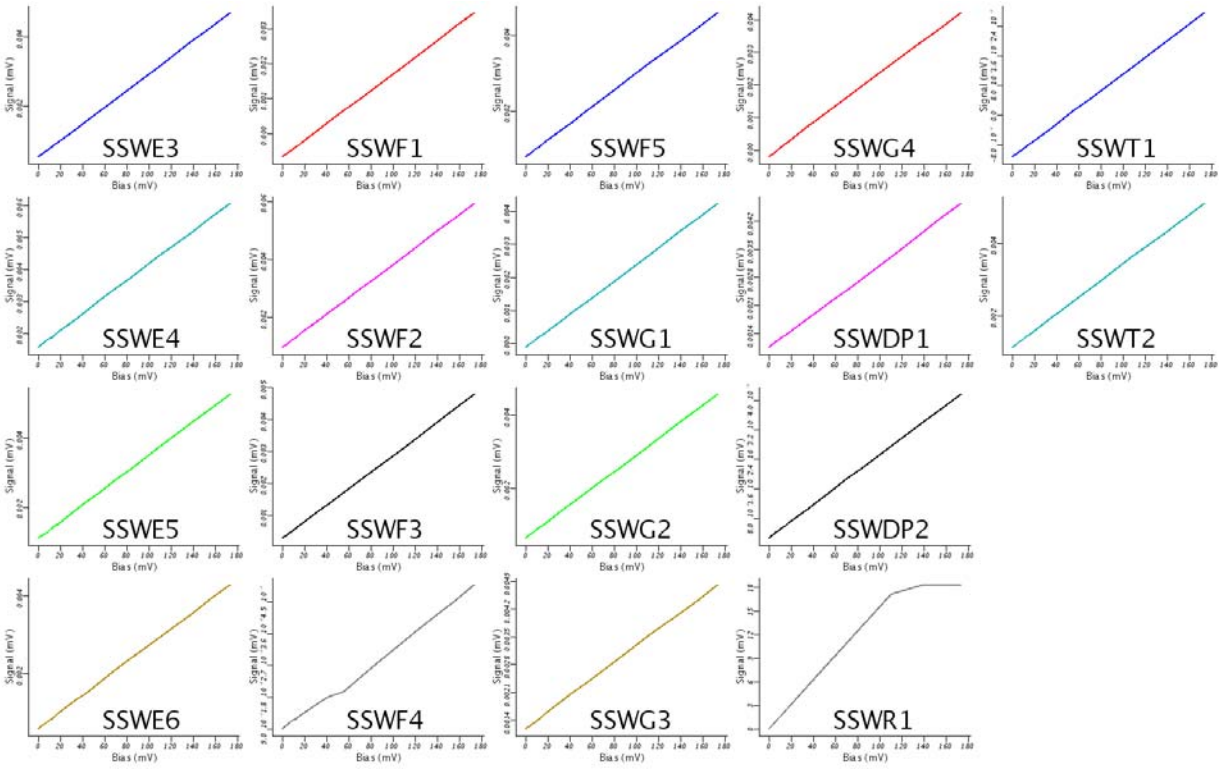


Figure 135. SSW Detectors (2)

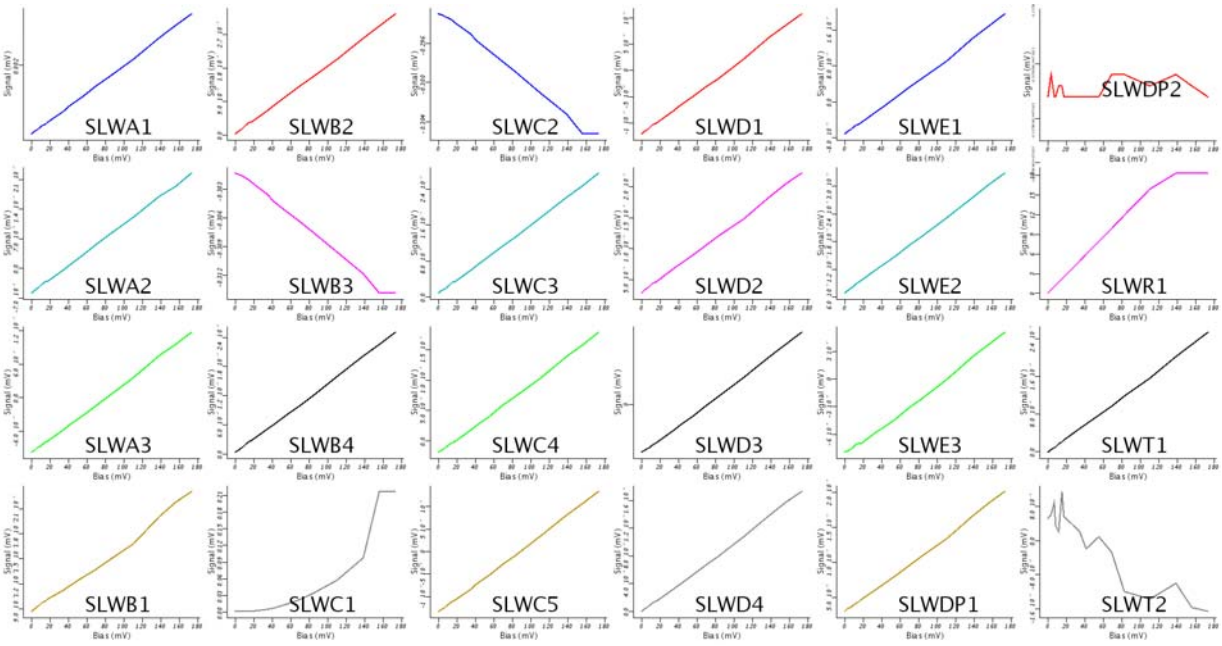


Figure 146. SLW Detectors (1)