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Planck-LFI CPV: CRYO_02 functionality test

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#### ACRONYMS 1

Assembly, Integration, Verification					
Application Software					
Back End Module					
Back End Unit					
Central Check-out System					
Central Data Management Unit					
Calibration Performance Verification					
Centre Spatiale de Liège					
Data Acquisition Electronics					
Digital Processing Unit					
Electrical ground Support Equipment					
Front End Module					
Instrument EGSE					
Integrated Satellite Test					
On Board Clock					
Radiometer Array Assembly					
Radiometric Electronic Box Assembly					
Spacecraft					
Spacecraft Control and Operation System					
Sorption Cooler System					
Signal Processing Unit					
Start- Up Software					
Service Module					
To Be Checked					
To Be Written					
Telecommand					
Telemetry					
Unit Functional Test					



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# 2 APPLICABLE AND REFERENCE DOCUMENTS

#### 2.1 Applicable Documents

test

- [AD1] Herschel/Planck Instrument Interface document Part A, SCI-PT-IIDA-04624 Issue 3.3
- [AD2] Herschel/Planck Instrument Interface document Part B, SCI-PT-IIDB-04142 Issue 3.1
- [AD3] Herschel/Planck Instrument Interface document Part B, SCI-PT-IIDB-04142 Issue 3.1, Annex 3, ICD 750800115
- [AD4] Herschel/Planck Instrument Interface document Part A, SCI-PT-IIDA-04624 Issue 3.3 Annex 10
- [AD5] Data analysis and scientific performance of the LFI FM instrument, PL-LFI-PST-AN-006 3.0
- [AD6] Planck-LFI TV-TB test report: executive summary, PL-LFI-PST-RP-040 1.1
- [AD7] Testing plan of the LFI instrument during the Planck Commissioning and CPV phase, PL-LFI-PST-PL-043 (4.2)

#### 2.2 Reference Documents

- [RD1] Planck Instrument Testing at PFM S/C levels, H-P-3-ASP-TN-0676, Issue 1.0
- [RD2] Planck LFI User Manual, PL-LFI-PST-MA-001 Issue 2.1
- [RD3] Quick look and data analysis of LFI from CRYO-02 functional test (Ph-5-03-b0 of TV/TB tests) PL-LFI-PST-RP-046



# 3 Introduction

This document describes the activities performed during the CRYO_02 functionality test. This test consists in two hours data acquisition in which the radiometers are run in switching mode and during which all the four possible phase switch configurations are tested.

The objective of this test is to verify that the radiometers are functional from the point of view of the front-end amplifiers and that the pseudo-correlation differential scheme is effective in reducing 1/f noise instabilities.

Therefore we perform two independent sanity checks:

- 1. that drain currents are comparable with those measured during the same test performed in CSL ( $\pm$  5%), and
- 2. that the 1/f noise knee frequency is reduced to less than 1 Hz after differencing sky and reference load datastreams.

**Important notice:** the check on knee frequency is done just to verify that there is a reduction operated by the switching scheme. The requirement is that the knee frequency is reduced from several Hz to values less than 1 Hz. Because this test is run in conditions that are far from being nominal (before tuning, with the 4K reference load at 20 K and not stability-optimised) no comparison must be made with 1/f scientific requirements.



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### 4 Test Execution

#### 4.1 Test configuration

The test configuration is the following

SCOS 2K EGSE 3.1 Release 1.2 RTSILib version 1.0 RTSI Client version 1.2 LEVEL1 (TMH/TQL) version 5.1 LIFE Machine version OM 3.00 IDIS 2.7.3.4

LFI Personnel involved during the test is:

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Industry support	Paola Battaglia

4.2 Pass-fail criteria, verification matrix

 CPV
 P_PVP_LFI_0003_01

 June, 16 2009 02:20z DoY 167
 OD 33

 Duration
 2:00:34

 Test name:
 Cryogenic functional test CRYO_02

 This test is the same test performed on ground at cryogenic temperature during TV-TB test campaign in CSL, with exactly the same biases, and front end module at 20 K stable temperature (TSA tuned).



Verification matrix								
Chack			Passed?	Recov	Recovered?			
Check	Yes	No	Notes	Yes	No			
No unexpected events packets	Yes							
TC procedure	Yes							
Power consumption as expected	Yes							
Current consumption from FEMs as expected	Yes		Drain current from LFI26M2 is marginally above the limit of ± 5% with respect the CSL value. No problems in the radiometric response, however, have been noticed					
Data saved and stored at DPC	Yes							

#### 4.3 **Procedure/** Test sequence and environmental conditions

#### 4.3.1 Test procedure

The test has been run during OD33 (June  $16^{th}$  200), starting at 2:20 AM (UTC) and lasting 2 hours and 34 seconds later.

The test procedure (serving also as a checklist) is reported in the following table.

Step	Description	START REF.	DURATION	Time (local)	RCA	YES	NO	Notes
8	CRYO-2 (UM section 13.1.2.5)	0:00:00						
8.1	Disable A/C 4kHz	0:00:00	0:00:02		All	Yes		
8.2	Disable B/D 4kHz	0:00:02	0:00:02		All	Yes		
8.3	Set A/C P/S Status (0)	0:00:04	0:00:02		All	Yes		
8.4	Set B/D P/S Status (0)	0:00:06	0:00:02	2009/06/16 04:20:03	All	Yes		
8.5	Set Cryo values on all RCAs (CSL values)	0:00:08	0:00:06	2009/06/16 04:20:05	All	Yes		See sheet attached with CRYO02 biases at CSL and in CPV
8.6	Enable A/C 4kHz	0:00:14	0:00:02	2009/06/16 04:20:11	All	Yes		Check tables here with phase switches
8.7	Acquire Data	0:00:16	0:30:00	2009/06/16 04:20:13		Yes		configurations during different steps
8.8	Set B/D P/S Status (1)	0:30:16	0:00:02	2009/06/16 04:50:13	All	Yes		
8.9	Acquire Data	0:30:18	0:30:00	2009/06/16		Yes		



				04 50 45			
				04:50:15			
8.10	Disable A/C 4kHz	1:00:18	0:00:02	2009/06/16 05:20:15	All	Yes	
8.11	Set A/C P/S Status (0)	1:00:20	0:00:02	2009/06/16 05:20:17	All	Yes	
8.12	Set B/D P/S Status (0)	1:00:22	0:00:02	2009/06/16 05:20:19	All	Yes	
8.13	Enable B/D 4kHz	1:00:24	0:00:02	2009/06/16 05:20:21	All	Yes	
8.14	Acquire Data	1:00:26	0:30:00	2009/06/16 05:20:23		Yes	
8.15	Set A/C P/S Status (1)	1:30:26	0:00:02	2009/06/16 05:50:23	All	Yes	
8.16	Acquire Data	1:30:28	0:30:00	2009/06/16 05:50:25		Yes	
8.17	Disable B/D 4kHz	2:00:28	0:00:02	2009/06/16 06:20:25	All	Yes	
8.18	Set A/C P/S Status (0)	2:00:30	0:00:02	2009/06/16 06:20:27	All	Yes	
8.19	Apply Default DAE Configuration as current configuration	2:00:32	0:00:02	2009/06/16 06:20:29	All		

### 4.3.2 Temperatures

Table 17 –	- Main temper	ratures (average	value) during	the CRYO-02 test in	n CSL and during CPV
I able I /	main compo	avai es (avei age	, and c) a an ing		i coll und during ci v

	CSL	CPV
Tsky (K)	4.27	2.76
Tref (K)	23.25	21.52
TFEU (K)	19.85 - 20.79	19.60 - 20.43
TBEU (C)	9.86 - 30.75	15.11 - 37.15



*Figure 1 – Reference load temperature during CRYO-02 test in CSL (left) and during CPV (right)* 

Image: 2h: 33m 555 (1.564.066 520: 33, 19.7054691(53))       Dataset TSR: Rights 19.4498 0.00566448 TSR: Rights 20.379 0.00645207 TSR: Rights 20.579 0.00656247 TSR: Rights 20.579 0.00751401       State Cold N 20.005 TSR: Rights 20.579 0.00556247 TSR: Rights 20.579 0.0055647 TSR: Rights 20.	Reset Save Print 🔍 🗍 👟 ≼ ≽	Selection Scientific Info	Housekeeping Info	Boost Biot Cours Biot Zoom Select Das	Plot Data Informa	tion Scientific Info	Housekeeping Info
Table 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 33, 19: 70: 540: 656 20: 34, 19: 70: 540: 656 20: 340: 70: 556 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 540: 70: 576 70: 70: 70: 70: 70: 70: 70: 70: 70: 70:		Dataset M	lean Sigma 🔺		Housekeeping Info	mation	
	range: 2h 33m 55s (1,594,066,920.93 , 19.7654681631)	TS1R: Right B 19.849	8 0.0056064	Start: OD 33, 13:10:00 Length: 1h 57m 59s (1,623,816,574.89, 20.001822748)	Dataset	Mean	Sigma
Image:		TS2R: Cone R 20.487	9 0.00643047		Right Bottom (	19.5962 0.00	414834
200 00 00 00 00 00 00 00 00 00		TS3R: Right Si 20.370	9 0.0064837		Cone Right Part	20.2268 0.00	395754
1       1558, FH28 Fl.       20, 2577       0.0055327         206       1552, 20, 00754713       11, Let 804       0.0575413         1511, Let 804       0.0575414       0.0075414         1520, Cold Pl.       2046       0.0075414         1531, Let 804       0.0075414         1531, Let 804       0.0075414         1531, Let 804       0.0075414         1531, Let 804       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0       0.0075144         0	20.8	TS4R: Cold Pl 20.013	8 0.00594867		Right Side Wall	20.1172 0.00	412112
00       1584.769/11.241.253.2       0.00754713         1511.Let 854       0.0051409         1511.Let 854       0.0051409         1511.Let 854       0.0051409         00       0.0057518         1511.Let 854       0.0057518         1511.Let 854       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.0051198       0.0051209         00.00511		TS5R: FH28 Fl 20.357	7 0.00653521		Cold Plate Far	19.7558 0.00	356523
200 00 00 00 00 00 00 00 00 00		TS6R: Right B 20.553	2 0.00754713	20.4	FH28 Flange	20.1015 0.00	400314
202 202 202 202 1534.560.00 1594.665.00 1594.665.00 1594.665.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.666.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.00 1594.660.0		TS1L: Left Sid 20.592	1 0.00851489		Right Bottom (	20.2867 0.00	437655
204 204 204 204 204 204 204 204	20.6	TS2L: Cold Pl 20.444	0.0074014		Left Side Wall	20.3206 0.00	510478
20 4 20 7010 0.0057551 T55L: Cold PL 20 70100 0.0057551 T55L: Cold PL 20 70100 0.0057551 T55L: C		TS3L: Cold Pl 20.058	8 0.0065247		Cold Plate Left	20.1828 0.00	436477
204 204 202 202 202 202 202 202		TS4L: Left Bott 20.709	6 0.00875516	20.2	Cold Plate Big	19.8014 0.00	388626
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Figure 2 – Front-end temperature during CRYO-02 test in CSL (left) and during CPV (right)





*Figure 3 – Front-end temperature stability during CRYO-02 test in CSL (left) and during CPV (right)* 



Figure 4 – Back-end temperature during CRYO-02 test in CSL (left) and during CPV (right)



Figure 5 – Back-end temperature during CRYO-02 test in CSL (left) and during CPV (right)

#### 4.3.3 Bias and DAE configuration

The test has been run in the same bias configuration that was used for CSL, i.e. the set of biases that resulted from the tuning activity performed during instrument-level tests. The biases for all 44 ACAs and phase switches are reported in the following table.

RCA	FEM arm	vg1	vg2	vd	11	12
	S2	200	204	114	255	255
LFI18	S1	200	196	138	255	255
	M1	195	189	126	255	255
	M2	198	196	125	255	255
	S2	220	201	125	255	255
LFI19	S1	215	204	120	255	255
	M1	215	198	124	255	255
	M2	220	196	126	255	255
	S2	198	201	127	255	255
LFI20	S1	210	211	132	255	255
	M1	225	204	121	255	255
	M2	231	206	127	255	255
	S2	201	213	132	255	255
LFI21	S1	196	197	136	255	255
	M1	201	207	141	255	255
	M2	210	187	136	255	255
	S2	220	199	130	255	255
LFI22	S1	204	184	128	255	255
	M1	179	204	125	255	255
	M2	178	176	130	255	255
LFI23	S2	186	223	122	255	255
	S1	197	166	118	255	255
	M1	223	182	120	255	255
	M2	226	195	119	255	255

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	M2	227	204	183	91	255	
LFI24	M1	226	204	200	152	252	
	S2	219	225	152	96	255	
	S1	219	213	157	87	234	
	M1	222	221	184	124	255	
LFI25	M2	224	212	185	89	255	
	S1	226	216	167	93	255	
	S2	219	220	166	121	255	
	M2	232	219	170	136	255	
LFI26	M1	232	221	169	118	255	
	S2	232	217	169	114	255	
	S1	228	226	172	159	255	
	M1	240	108	156	148	210	
I FI27	M2	245	108	157	169	214	
	S1	238	86	157	138	192	
	S2	250	126	156	148	184	
	M1	243	101	157	153	180	
1 5100	M2	240	112	156	169	214	
LFIZO	S1	270	88	157	138	102	
	S2	235	121	158	148	184	

The DAE gain values were all set to 0 (corresponding to a physical value of 1) while the DAE offsets were optimised in order to avoid saturation. The DAE offset values used in this test are listed in the following table.

RCA	DAE channel	DAE offset in CSL	DAE offset in CPV
	M-00	0	2
LFI18	M-01	0	2
	S-10	204	1
	S-11	204	1
	M-00	214	0
LFI19	M-01	204	0
	S-10	255	0
	S-11	224	0
	M-00	204	1
LFI20	M-01	204	1
	S-10	153	1
	S-11	143	1
	M-00	194	0
LFI21	M-01	204	0
	S-10	255	0
	S-11	255	0
	M-00	255	0
LFI22	M-01	255	0
	S-10	255	0
	S-11	255	0
LFI23	M-00	173	1
	M-01	122	1



				Date.	
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	S-10	255	0		
	S-11				
		255	0		
	M-00	255	0		
LFI24	M-01	255	0		
	S-10	255	0		
	S-11	255	0		
	M-00	255	0		
LFI25	M-01	255	0		
	S-10	255	0		
	S-11	255	0		
LFI26	M-00	255	0		
	M-01	255	0		
	S-10	255	0		
	S-11	255	0		
	M-00	21	2		
LFI27	M-01	0	2		
	S-10	51	1		
	S-11	92	2		
	M-00	102	1		
LFI28	M-01	41	2		
	S-10	112	1		
	S-11	143	1		

#### 4.3.4 Phase switch configuration

The test consisted in four acquisitions of  $\frac{1}{2}$  hour each in which the following four phase switch configurations have been exercised:

	Switching	A/C pos	B/D pos
Acquisition 1	A/C	0	0
Acquisition 2	A/C	0	1
Acquisition 3	B/D	0	0
Acquisition 4	B/D	1	0

#### 4.3.5 Non nominal features

The procedure was executed correctly without anomalies.



#### 4.4 Data Analysis

#### 4.4.1 Drain current comparison with CSL

In Fig. 6 we show a comparison of drain currents measured during CPV and in CSL during the CRYO-02 test for the four phase switch configurations. The percentage variation is defined as [Id(CPV) - Id(CSL)] / Id(CSL). Where no bars are displayed it means that the drain current variation was less than 0.1 mA.

The results show that all the drain currents (with the exception of LFI26M2) have been found reproducible within  $\pm 2\%$ .

The case of LFI26M2 is the only noticeable exception, as for this amplifier we have recorded a drain current that was about 8.6 % ( $\sim$ 1 mA) higher than in CSL. Although the reason of this discrepancy has not been understood yet the LNA shows full functionality as proved by the CRYO-01 drain current verification tests.



Fig. 6 – Comparison of drain currents measured during CRYO-02 test in CPV and in CSL. The percentage variation is defined by (Id(CPV) - Id(CSL))/Id(CSL). Where no bars are displayed it means that the drain current variation was less than 0.1 mA



#### 4.4.2 Knee frequency analysis

Knee frequencies have been calculated from differenced datastreams from all 44 detectors in the four tested switch configurations. Results are summarised in Fig. 7 and the complete differenced spectra are provided in Appendix 1.

From the results we can conclude the following:

- Knee frequencies from differential datastreams are all below 1 Hz, several of them being of the order of tens to few hundred mHz;
- knee frequencies measured during CPV are consistent with those measured in CSL. In this case the consistency is not sought at a level of few %, but of a factor 2-3;
- the radiometer LFI23M still displays anomalous behaviour when its switching configuration is in B/D switching. This anomaly was already seen in CSL and can be avoided by setting the phase switch in the A/C switching condition.

In summary the LFI receivers behave correctly when operating in nominal switching condition.



CRYO-02 step1 S-11 M-01 S-10 M-00 Cryo02-CPV Cryo02-CSL vo02-CPV Cryo02-CPV (Hz) / Cryo02-CPV Cryo02-CSL (hz) (Hz) (Hz) <nul>(Hz) (Hz) 0.8 0.8 0.8 0.6 0.6 0.6 0.6 0.4 0.2 CRYO-02 step2 M-00 M-01 S-10 S-11 Cryo02-CPV Cryo02-CSL Cryo02-CPV Cryo02-CSL Cryo02-CP\ Cryo02-CSL Cryo02-CPV Cryo02-CSL (FI) requency (Hz) requency (Hz) inee frequency (Hz) 0.8 0.8 0.8 0.8 ency 0.6 0.6 0.6 0,6 <nee ( nee CRYO-02 step3 M-00 M-01 S-10 S-11 Cryo02-CPV Cryo02-CP\ Cryo02-CPV Cryo02-CSL Cryo02-CP Ĩ (hee frequency (Hz) frequency (Hz) Jency (Hz) 0.8 n 8 n s 0.6 0.6 0.1 0.6 0.4 0.2 (nee dan CRYO-02 step4 M-01 M-00 S-10 S-11 Cryo02-CPV Cryo02-CSL Cryo02-CPV Cryo02-CP Cryo02-CPV (ZH) 0.6 requency (Hz) requency (Hz) (nee frequency (Hz) 0.8 0.0 0.6 0. 0.6 (nee nee nee

*Fig.* 7 – *Knee frequencies of differenced data streams acquired during CRYO-02 in the four phase switch configurations* 

#### 4.4.3 Known anomalies

- The radiometer LFI23M does not work correctly when its switching configuration is in B/D switching. In this case the residual knee frequency after differencing is of several Hz
- The receiver LFI28 inverts the sky-ref tag when the switch configuration is in B/D switching, A/D = 0

#### 4.4.4 New anomalies

- The ACA LFI26M2 displays a drain current which is  $\sim$ 8.6 % higher than what has been measured in CSL



#### 4.5 Conclusions and recommendations

The CRYO-02 functionality test proved full functionality of the LFI in switching conditions. Also known anomalies regarding LFI23M and LFI28 have been reproduced.

The only anomaly is the drain current of LFI26M2 which has displayed a discrepancy of about 8.6 % (about 1 mA) with respect to CSL. There is no reason to believe that this unexpected discrepancy indicates a loss of functionality in this channel.

We recommend, nevertheless to monitor this channel in future tests, in particular looking for:

- Changes in drain current not linked to a bias changes
- Anomalous channel isolation
- Anomalous knee frequency