SPIRE INSTRUMENT

DETECTOR READOUT & CONTROL UNIT

SUBSYSTEM SPECIFICATION

SPIRE-SAP-PRJ-000461

	Name and Function	Date	Signature
Prepared by:	C.CARA - DRCU engineer		
Verified by:	J. FONTIGNIE - Electronics PA		
Approved by:	PA Manager		
Approved by:	JL. AUGUERES Project Manager		

Document change record

Issue/Revision	Date	Modified pages
0.1	18/05/2000	All: document creation - Draft
0.2	14/06/2000	All
0.3	19/06/2000	§4.2.2.1 - §4.2.2.2 - §4.2.2.3: values added/modified
0.4	21/06/2000	§4.2.4.2: table updated according to IID-A 0.3 §10: chapter inserted
0.5	15/12/2000	Document structure deeply modified
0.6	09/03/2001	§3.1.1 Text / figure updated All document: specifications are linked to upper level requirements 4.2.3.1. New table for thermometry channels Maximum allowed dissipated power table added New chapter 4.2.4 PSU Updated power budget table
0.7		Acronym list updated Figure 2.1-a updated SCU function list updated REQ-22 updated REQ-48 updated: list of frame compliant with ICD DCU HK parameters list updated
0.92	26/06/2002	§2.1 reference to EGSE & shutter removed / figure 2.1-a simplified §2.2 reference to Shutter removed §3.1.2 Board geometry updated §3.2 physical requirement updated according to ICD §3.3 updated according to ICD §4.1.1 added DCU-FUNC-05b §4.1.2 added MCU-FUNC-09b DRCU-REQ-30 table completed §4.2.3 DRCU-REQ-32 / DRCU-REQ-34 updated according to BDA-SSSD v3.0 §4.2.4.3 Power supplies table corrected §4.3.2 DRCU-REQ-53 table completed §4.3.4.3 Table corrected §4.4.2 Added PSU remote control signals §4.4.2 / DRCU-REQ-79 /DRCU-REQ-83 tables completed §4.4.3 tables updated/corrected §4.4.3 DRCU-REQ-88/89 updated cross reference to PCAL/SCAL ICD §4.4.4 DRCU_REQ-96 table corrected §4.5 Sec. Power lines table corrected §4.6.1 grounding scheme added §4.7.5 table corrected SPIRE INIT -> DRCU OFF §4.9.3 Added redundancy schemes §12 Model description table corrected §14 table updated
1.0	14/02/2003	§2.1 Figure corrected following DDR comments §2.2 Figure updated: distribution electronics removed §4.2.2 DRCU REQ-30b added (secondary voltage measures) DRCU REQ-20 number of JFET supplies corrected §4.2.5 Figure corrected following DDR comments §4.4.2 DRCU_REQ-83: word size for ScuStatus added

		§4.4.3 Temperature range for T_SCAL2 & T_SCAL4 corrected DRCU REQ-85/86: AD reference corrected §4.5.1 : Table updated according to sub-unit power consumption §4.7.3 DRCUREQ-120b: added / output low during initialisation §4.7.5 Mode of operation table corrected according to RD1 §4.9.1 DRCU REQ-122 updated according to DDR comments §4.9.3 Figure enlarged following DDR comments §12 Model characteristic table corrected following DDR comments §14 table corrected §15 Table filled

Distribution list

Jean-Louis AUGUÈRES	CEA	
Frederic PINSARD	CEA	
Ken KING	RAL	
Bruce SWINYARD	RAL	
Colin CUNNINGHAM	ROE	
Didier FERRAND	LAM	
Dominique POULIQUEN	LAM	
Patrick LEVACHER	LAM	
Jamie BOCK	JPL	
Jerry LILIENTHAL	JPL	
Riccardo CERULLI	IFSI	
Renato ORFEI	IFSI	
Goran OLOFSSON	SO	
Hans-Gustav FLOREN	SO	

List of Acronyms

ADC	Analog to Digital Converter
AMUX	Analog Multiplexer
BDA	Bolometer Detector Array
BPF	Band Pass Filter
BSM	Beam Steering Mirror
DCE	Detector Control Electronics
DCU	Detector Control Unit
DMUX	Digital Multiplexer
DPU	Data Processing Unit
DRCU	Detector Readout & Control Unit
FPU	Focal Plane Unit
FTS	Fourier Transform Spectrometer
JFET	Junction Field Effect Transistor
LIA	Lock-in amplifier
LPF	Low Pass Filter
MCE	Mechanisms Control Electronics
MCU	Mechanisms Control Unit
NA	Not Applicable
OEP	Optical Encoder Preamplifier
PDU	Power Distribution Unit
PSU	Power Supply Unit
S/W	Software
SCE	Sub-system Control Electronics
SCU	Sub-system Control Unit
SMEC	Spectrometer Mechanism Control
SMPS	Switching Mode Power Supply
SNR	Signal over Noise Ratio
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
WIH	Warm Interconnect Harnesses

Table of contents

1. Introduction

1.1. Purpose

The purpose of this document is to explicit the DRCU Specification in term of performances and design. However this document is voluntary limited to specification common to all the subsystem and especially for the MCU. In other words this means for that particular sub-system specific requirement will not be part of this document since this specifications are given by its Subsystems Specification Document. This document also includes requirement related to the integration of a given sub-system within a common unit or electrically linked with another DRCU sub-system.

1.2. Scope

The scope of this document comprises all the electronics functions included in the DRCU.

1.3. Applicable Documents

AD1	SPIRE Instrument Requirements Documents	SPIRE-RAL-PRJ-000034	1.1 10/01/2002
AD3	FIRST/PLANCK Instrument Interface Document Part A	PT-IID-A-04624	3.0 / 01/07/02
AD4	FIRST/PLANCK Instrument Interface Document Part B / Instrument SPIRE	SCI-PT-IIDB/SPIRE-02124	2.2 / 07/06/02
AD5	DRCU ICD	SAp-SPIRE-CCa-75-00	1.0 / 14/02/03
AD6	Space Product Assurance - Electrical, Electronic and Electromechanical Components	ECSS-Q-60A	19/04/96
AD7	Space product assurance - Materials, mechanical parts and processes	ECSS-Q-70A	19/04/96
AD8	De-rating Requirements & Application Rules for Electronic Components.	PSS-01-301	2.0 / /4/92
AD9	Reliability Prediction of Electronic Equipment	MIL-HDBK-217F	02/12/91
AD10	Operating Modes for the SPIRE Instrument	SPIRE-RAL-PRJ-000320	3.0 / 04/01/02
AD11	DPU Interface Control Document	SPIRE-IFS-PRJ-650	1.0 / 02/04/01
AD12	FIRST L-2 Radiation Environment	ESA/ESTEC/WMA/HE/FIRST/3	04/03/97
AD13	DRCU/DPU ICD	SAp-SPIRE-CCa-76-00	1.0 / 14/02/03
AD14	SPIRE Product Tree	SAp-FIRST-DR-71-02	1.2 / xx/xx/xx
AD15	DRCU & WIH Development Plan	SAp-SPIRE-JLA-47-01	3.0 23/11/2001
AD16	HERSCHEL SPIRE harness definition	SPIRE-RAL-PRJ-000608	1.0 08/07/2002
AD17	SPIRE Instrument Grounding Philosophy	SPIRE-RALPRJ-000624	1.0 01/10/2002

AD18	Spectrometer Mirror Mechanism subsystem specifications	LAM-PJT-SPI-NOT-200002	0.7 / 12/07/01
AD19	Beam Steering Mirror subsystem specification	SPIRE-ATC-PRJ-0460	2.0 / 01/11/00
AD20	BDA SSSD	SPIRE-JPL-PRJ-000456	3.1 / 29/01/02
AD21	Sorption cooler drive electronics specification	HSO-SBT-SP-015	0.2 / 10/10/02
AD22	PCAL ICD	HSO-CDF-ICD-013	2.0 / 06/02/02
AD23	SCAL ICD	HSO-CDF-ICD-011	2.0 / 06/02/02
AD24	Engineering Change Request	HR-SP-RAL-ECR-023	23/11/01

1.4. Reference Documents

RD1	Operating Modes for the SPIRE Instrument	SPIRE-RAL-DOC-768	3.0 / 04/01/02
RD2	SPIRE Power Supply Unit - Cahier des charges technique	SAP-SPIRE-DS-012-02	1.0 / 24/10/02

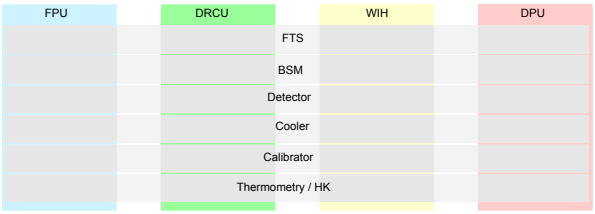
2. General description

2.1. Overview

The DRCU is an electronic unit housed into two boxes: the FCU and the DCU connected between the FPU and the DPU. This unit along with the DPU and the WIH constitutes the system called "SPIRE Warm Electronics". The DRCU includes the front-end electronics of the following sub-systems:

- Detector,
- Fourier Transform Spectrometer,
- Beam Steering Mirror,
- Cooler,
- Calibrators,
- Thermometry & analogue Housekeeping,

each sub-system being associated with "cold elements" located in the FPU and high-level control functions located in the DPU OBS.



The DRCU comprises 4 physical sub-units, which are:

- the DCU includes the Detector Control Electronics
- the MCU includes the Mechanisms (FTS+BSM) Control Electronics
- the SCU includes the Sub-system Control Electronics
- the PSU includes multi-outputs SMPS DC/DC converters

In order to limit the mechanical properties of this unit it is now divided into two boxes, which are respectively the DCU and the FCU including the MCU, the SCU and PSU.

While DCU and MCU units correspond to single FPU functions respectively the bolometer focal planes and the mechanisms, the SCU function is manifold. It is in charge of interfacing FPU sub-systems such as the cooler heaters, the calibrators and the thermometry sensors plus housekeeping parameters with the DPU through digital interfaces. This function covers the sensors biasing, the signal amplification and the digitisation of the analog parameters. The SCU is also in charge of controlling the PSU by means of signal lines for remotely controlled S/S supplying. In addition the PSU secondary line voltages are monitored at supplied level S/S for safety purpose; the corresponding digitised housekeeping data are transmitted on demand to the DPU.

As illustrated below the DRCU has electrical interfaces with:

- the FPU
- the DPU
- the PDU (S/C)

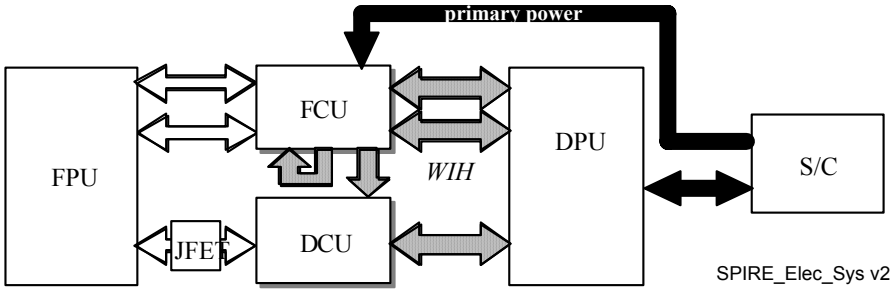


Figure 2.1-a Overall SPIRE electrical system

2.2. Overall Architecture

A complete DRCU block diagram including the various interfaces and the elementary units as well is shown figure 2.2-a. For each unitl higher level functional architecture is shown.

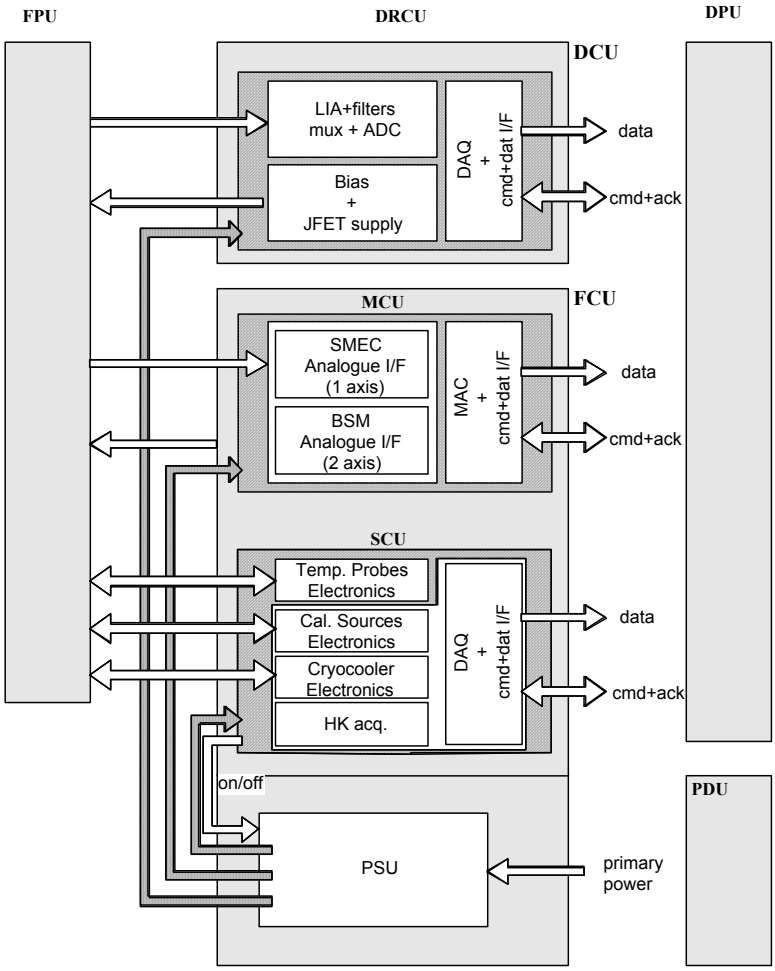


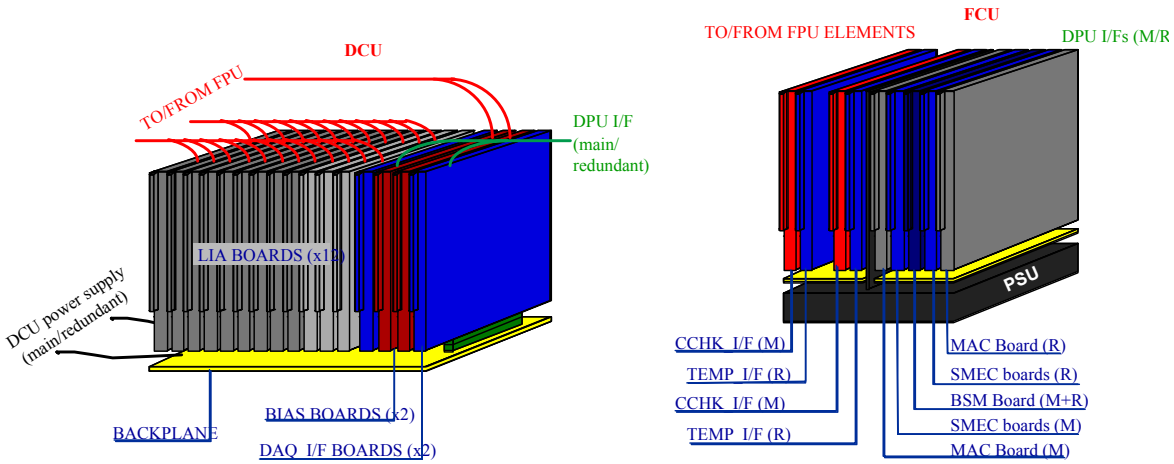
Figure 2.2-a - DRCU top level block diagram

3. Physical Characteristics

3.1. Physical description

3.1.1. DRCU housing

Two boxes include all the electronics modules of the 4 DRCU sub-units: respectively the DCU, the MCU, the SCU and the PSU. While one specific box is dedicated to the DCU only, the second one called FCU includes the MCU, the SCU and the PSU.
Internally back-planes printed circuit boards insure sub-unit individual module-to-module connections. Since no electrical interface is foreseen, except for secondary power distribution, between the various sub-units no connection between these back-planes is required: a sub-unit is fully testable independently from the two other sub-units.
Dedicated external harnesses connected to the PSU achieve secondary power routing to the DCU, the MCU and the SCU.
Practically the PSU is housed into a specific box having and located underneath the FCU box and then having the same footprint. However the DRCU delivery will be done after PSU and FCU mechanical and electrical lower level integration.



3.1.2. Board Geometry

The board geometry is defined commonly to all the sub-systems and sub-unit (except the back planes and the PSU). This common board design includes stiffeners and defines printed circuit board circuit size, back connector position, front panel geometry and board locks.

This design defines the standard DRCU board geometry. However adaptation of this geometry could be applied in specific cases. The geometry allows placement of SMD parts on the both sides of the board.

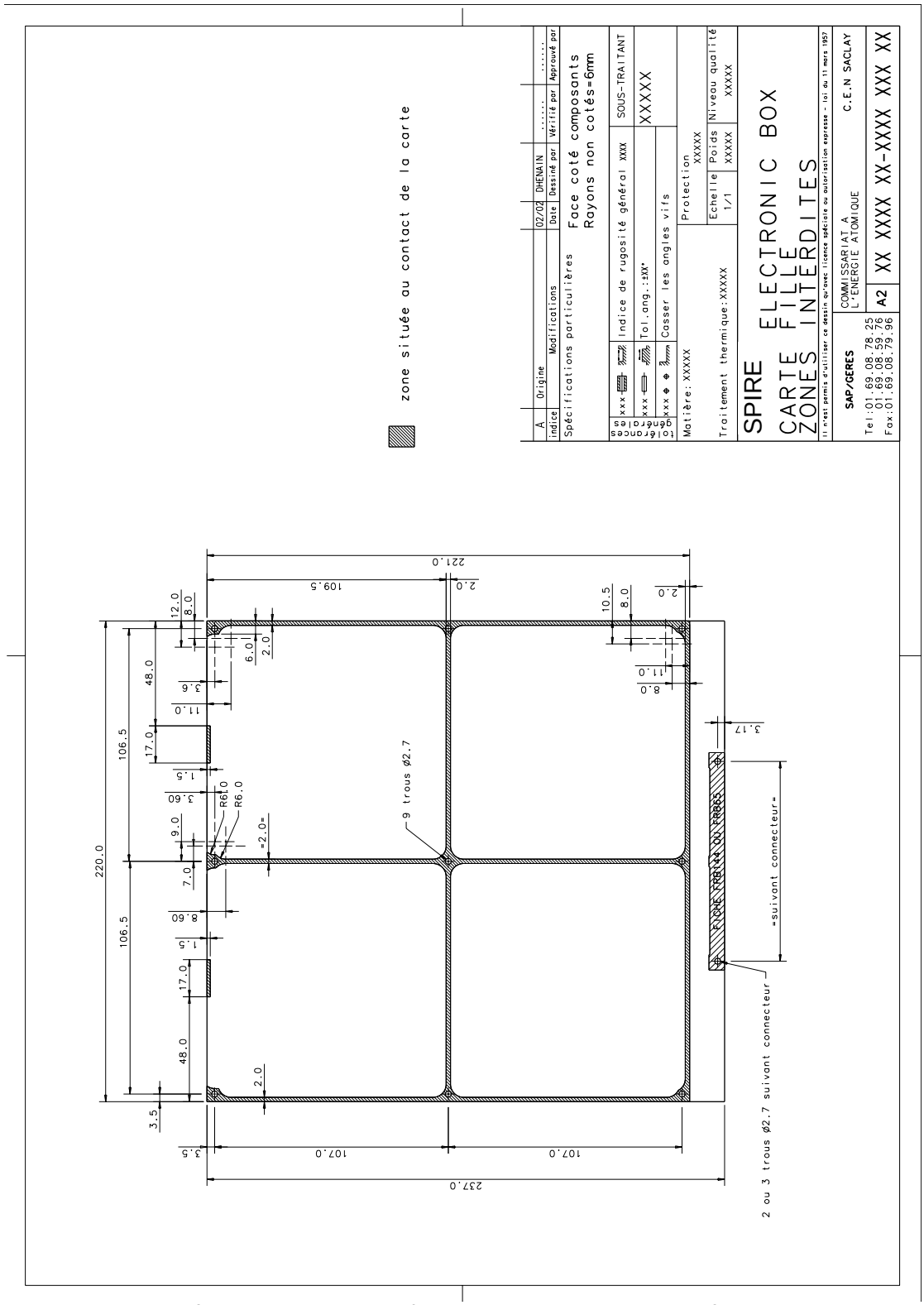


Figure 3.1-a Board Common Geometry Overview

3.1.3. Back plane to module connectors

DRCU REQ-1.: The electrical interface between the back planes and the modules shall be based on multipoint connectors type HE 801/808 (manufacturer: FRB CONNECTRON)

3.2. Physical requirements

3.2.1. Mass

The DRCU unit total mass shall be compliant with the allocated mass of 30.5 kg as specified by AD4 (current issue).

3.2.1.1. DCU

DRCU REQ-2.: The DCU mass shall be compliant with the allocation specified by AD4 (current issue), which is of 15.5 kg.

3.2.1.2. FCU

DRCU REQ-3.: The FCU mass shall be compliant with the allocation specified by AD4 (current issue), which is of 15 kg

3.2.2. Dimension

3.2.2.1. DCU

DRCU REQ-7.: The dimension of the DCU shall be compliant with the envelope given in AD4 as reminded below:

- 494 mm x 289 mm (footprint)
- 305 mm (height)

3.2.2.2. FCU

DRCU REQ-8.: The dimension of the FCU shall be compliant with the envelope given in AD4 as reminded below:

- 370 mm x 325 mm (footprint)
- 336 mm (height)

3.3. Power Budget Allocation

3.3.1. DCU

DRCU REQ-10.: The DCU maximum power dissipation shall be compliant with the value given in AD4 as reminded below:

$$P_{DCU} \leq 37.0 \text{ W}$$

3.3.2. FCU

DRCU REQ-11.: The DCU maximum power dissipation shall be compliant with the value given in AD4 as reminded below:

$$P_{FCU} \leq 42.9 \text{ W}$$

4. Requirements

4.1. Overall Functional Description

4.1.1. DCU Functions

The **D**etector **C**ontrol **U**nit supports all the functions related to the detector operation. This covers:

• the detector bias generation	DCU-FUNC-01
• the bolometer analog signal processing	DCU-FUNC-02
• the bolometer signal digitisation	DCU-FUNC-03
• the clock/timing generation	DCU-FUNC-04
• the JFET box amplifier biasing	DCU-FUNC-05
• the JFET box heaters biasing	DCU-FUNC-05b
• the low level command decoding	DCU-FUNC-06
• the low level command acknowledgement	DCU-FUNC-07
• the relative timestamp generation	DCU-FUNC-08
• the housekeeping parameters digitisation	DCU-FUNC-09
• the digitised data (bolometers + hk param. + rel. timestamp) transfer	DCU-FUNC-10
• the DCU power distribution	DCU-FUNC-11

4.1.2. MCU Functions

The **M**echanisms **C**ontrol **U**nit supports all the functions related to the FTS and Beam Steering mirrors operation. This covers:

• the FTS mirror position motion + speed control	MCU-FUNC-01
• the FTS mirror position measurement	MCU-FUNC-02
• the FTS mirror actuator powering	MCU-FUNC-03
• the FTS mirror position digitisation	MCU-FUNC-04
• the FTS mirror actuator current digitisation	MCU-FUNC-05
• the BSM positions control	MCU-FUNC-06
• the BSM positions (2 axis) measurement	MCU-FUNC-07
• the BSM actuators (2 axis) powering	MCU-FUNC-08
• the BSM actuator current digitisation	MCU-FUNC-09
• the launch latch actuators powering	MCU-FUNC-09b
• the low level command decoding	MCU-FUNC-10
• the low level command acknowledgement	MCU-FUNC-11
• the relative timestamp generation	MCU-FUNC-12
• the housekeeping parameters digitisation	MCU-FUNC-13
• the digitised data (position + currents + hsk + rel. timestamp) transfer	MCU-FUNC-14
• the MCU power distribution	MCU-FUNC-15

4.1.3. SCU Functions

The Sub-system Control Unit supports various functions essential to achieve full performances of the detector:

- to bias the cryo-cooler recycling heater, SCU-FUNC-01
- to bias the cryo-cooler gas switches heaters, SCU-FUNC-02
- to bias a heater on the cooler cold tip SCU-FUNC-03
- to bias the calibrators heaters, SCU-FUNC-04
- to acquire the calibrators (spectrometer only) temperatures SCU-FUNC-05

It also implements the following additional functions:

- to acquire cold instrument temperature channels, SCU-FUNC-06
- to acquire analogue housekeeping channels, SCU-FUNC-07

- to decode the low level commands, SCU-FUNC-08
- to respond to a low level command, SCU-FUNC-09
- to generate the relative timestamp, SCU-FUNC-10
- to digitise the acquired analog parameters, SCU-FUNC-11
- to transfer the digitised data (data + hsk + relative timestamp) SCU-FUNC-12

- to command on/off switching of sub-unit power supplies, SCU-FUNC-13
- to distribute SCU power SCU-FUNC-14

4.1.4. PSU Functions

Finally the PSU sub-system is in charge of:

- to interface with S/C power bus according to AD3 PSU_FUNC-01
- to generate sub-unit secondary power supply generation, PSU-FUNC-02
- to protect sub-units & PSU built-in DC/DC converters from over-current PSU-FUNC-03

4.2. DCU Subsystem

4.2.1. Subsystem General Description

The DCU is divided into 3 functional entities:

- the Analogue Electronics module which comprises lock-in amplifiers and analogue multiplexers,
- the Bias Generator and JFET power supply generator,
- the Data Acquisition and DPU Interface Module.

An analogue module comprises analogue channels for processing the incoming signals generated by the cold electronics (bolometers + JFET followers) based on lock-in amplifiers (or PSD). After demodulation and low path filtering the signals are applied to differential multiplexers before being digitised by the Data Acquisition and Interface module.

This module is in charge of the generation of sine biases for bolometers and provides JFET and JFET heater power supply.

4.2.2. Functional requirement

DRCU REQ-15.: The analogue electronics module shall have the following number of channels:

Number of channel	Channel Type	Comments
48	P-LW	Include 3 T/C channels
96	P-MW	
144	P-SW	
24	S-LW	
48	S-SW	

DRCU REQ-16.: In order to avoid the loss of the totality of the analogue channels and/or ADC in the case a short circuit occurs in one of the electronic parts, channel subset have to be defined and individually protected by current limiters.

DRCU REQ-17.: The bias electronics module shall have the following number of channels:

Channel Type	Number of Channel	Origin
Photometer BDA	3	BDA-DRCU-05
Spectrometer BDA	2	BDA-DRCU-05
Temperature control	1	BDA-DRCU-05

DRCU REQ-18.: Each bias channel shall be individually adjustable by means of a low-level command in term of amplitude only (BDA-DRCU-05).

DRCU REQ-19.: The frequency of all the sine biases of a set (photometer / spectrometer / temperature) shall be adjustable by means of a low-level command (BDA-DRCU-05).

DRCU REQ-20.: The Bias module shall provide DC JFET bias and DC JFET heater bias according to the following channel number:

Channel Type	Number of channel	Origin
JFET bias	16	BDA-DRCU-06
JFET heater bias	2	BDA-DRCU-10

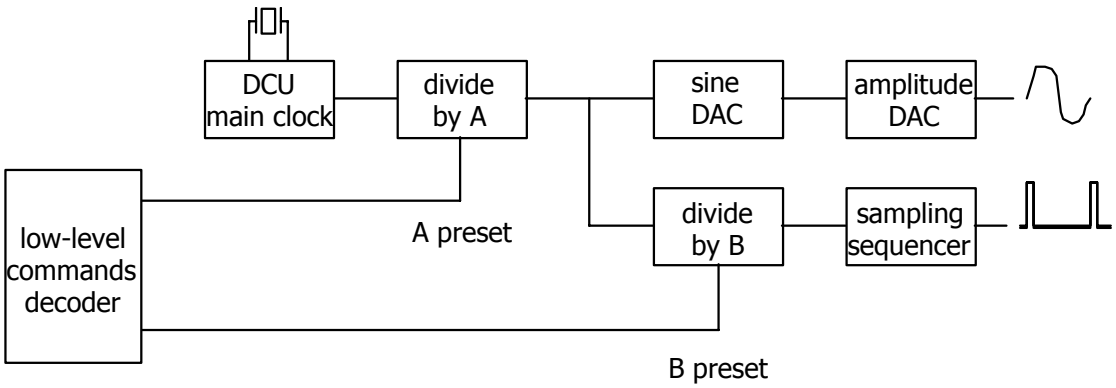
DRCU REQ-21.: Each JFET (both Vdd and Vss) bias channel shall be individually commandable ON/OFF by means of low-level commands (BDA-DRCU-09).

DRCU REQ-22.: Each JFET heater bias shall be commandable ON/OFF independently by means of low-level commands.

DRCU REQ-23.: The DCU shall implement two electrically and physically independent BIAS modules (1 main + 1 redundant).

DRCU REQ-24.: The DCU shall implement two electrically and physically independent DAQ_IF modules (1 main + 1 redundant).

DRCU REQ-25.: The data transfer rate from the DAQ_IF module shall be derived from the bias frequency by division by any integer between 1 and 128 (as illustrated bellow). However the transfer rate shall not exceed 150 Hz for both photometer and spectrometer.



DRCU REQ-26.: The number of blocks to be transferred successively shall be selectable by means of a DCU low-level command. The number of packets to be transferred successively shall be continuous or selectable between 1 and 16.

DRCU REQ-27.: The DCU shall include temperature measurement of each of its printed circuit board (except back plane) at location where hot spot or high power dissipation parts are identified.

DRCU REQ-28.: Temperature measurement shall be done using an AD590 probe in F02 package glued on the printed circuit board.

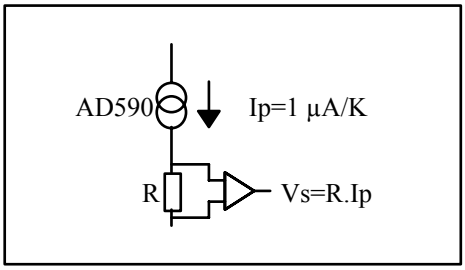


Figure 4.2.1.1.3-a Unit internal temperature monitoring

DRCU REQ-29.: The temperature measurement shall have the following performances:

Temperature Range	-40°C to 88 °C
Temperature resolution	0.5°C

DRCU REQ-30.: The DCU shall report the following housekeeping parameters when requested by low-level commands:

Parameter Name	Word size (bits)	Comments
T/C_1	16	Offset = 0
T/C_2	16	Offset = 0
T/C_3	16	Offset = 0
BIAS_BDA_1	8	Ph. Bolo. Bias 1 ampl. setting
BIAS_BDA_2	8	Ph. Bolo. Bias 2 ampl. setting
BIAS_BDA_3	8	Ph. Bolo. Bias 3 amplitude setting
BIAS_BDA_4	8	Sp. Bolo. Bias 1 amplitude setting
BIAS_BDA_5	8	Sp. Bolo. Bias 2 amplitude setting
BIAS_TEMP_5	8	T/C. Bias 1 ampl. Setting
F_BIAS_PH/TC	8	Ph. & T/C Bias Freq div. setting
F_BIAS_SP	8	Sp. Bias Freq div. setting
JFET_VSS_PLW_1	8	PLW_1 JFET VSS setting
JFET_VSS_PLW_2	8	PLW_2 JFET VSS setting
JFET_VSS_PMW_1	8	PMW_1 JFET VSS setting
JFET_VSS_PMW_2	8	PMW_2 JFET VSS setting
JFET_VSS_PMW_3	8	PMW_3 JFET VSS setting
JFET_VSS_PMW_4	8	PMW_4 JFET VSS setting
JFET_VSS_PSW_1	8	PSW_1 JFET VSS setting
JFET_VSS_PSW_2	8	PSW_2 JFET VSS setting
JFET_VSS_PSW_3	8	PSW_3 JFET VSS setting

JFET_VSS_PSW_4	8	PSW_4 JFET VSS setting
JFET_VSS_PSW_5	8	PSW_5 JFET VSS setting
JFET_VSS_PSW_6	8	PSW_6 JFET VSS setting
JFET_VSS_SLW_1	8	SLW_1 JFET VSS setting
JFET_VSS_SSW_1	8	SSW_1 JFET VSS setting
JFET_VSS_SSW_2	8	SSW_2 JFET VSS setting
PH_HEATER_PWR	8	Spectrometer JFET heater setting
SP_HEATER_PWR	8	Photometer JFET heater setting
LIA_B1_TEMP	8	LIA board 1 temperature
LIA_B2_TEMP	8	LIA board 2 temperature
LIA_B3_TEMP	8	LIA board 3 temperature
LIA_B4_TEMP	8	LIA board 4 temperature
LIA_B5_TEMP	8	LIA board 5 temperature
LIA_B6_TEMP	8	LIA board 6 temperature
LIA_B7_TEMP	8	LIA board 7 temperature
LIA_B8_TEMP	8	LIA board 8 temperature
LIA_B9_TEMP	8	LIA board 9 temperature
LIA_B10_TEMP	8	LIA board 10 temperature
LIA_B11_TEMP	8	LIA board 11 temperature
LIA_B12_TEMP	8	LIA board 12 temperature
BIAS_TEMP	8	BIAS board temperature
DAQ_I/F_TEMP	8	DAQ_I/F board temperature
PWR_STATUS	12	LIA 1 to LIA12 +5V/+9V/-9V status
BDAQ_P5	8	BIAS/DAQ_IF +5V voltage (before post regulator)
BQAD_P9	8	BIAS/DAQ_IF +9V voltage (before post regulator)
BDAQ_N9	8	BIAS/DAQ_IF -9V voltage (before post regulator)
LIAP_P5	8	LIAP +5V voltage (before post regulator)
LIAP_P9	8	LIAP +9V voltage (before post regulator)
LIAP_N9	8	LIAP -9V voltage (before post regulator)
LIAS_P5	8	LIAS +5V voltage (before post regulator)
LIAS_P9	8	LIAS +9V voltage (before post regulator)
LIAS_N9	8	LIAS -9V voltage (before post regulator)

DRCU REQ-30b : The analogue channels for sub-systems supply voltage reporting shall have the following characteristics:

Number of channel	9
Voltage range	≥ nominal voltage + 20 %
Voltage resolution	1 %

4.2.3. Performance Requirements

DRCU REQ-31.: The conducted RF current on all lines shall be less than 0.1 nA/√Hz rms **(TBC)** in the range 0 to 10 GHz **(TBC)** (BDA-DRCU-23).

DRCU REQ-32.: The analogue module shall have the following characteristics:

Item	Name	Limit	Comment	From
-1	Input Signal: AC amplitude	≤ 11 mVrms ≤ 17 mVrms ≤ Vbias	Photometer (inc TC) Spectrometer Functional	BDA-DRCU-05
-2	Input Signal: DC level	≤ 13 mV	JFET V_{OSmax}	
-3	Output Signal: AC amplitude	≤ +/- 5V pp	for DRCU REQ-32-1 input levels	
-4	Common mode offset	≤ 1 V DC		
-5	Cross talk (channel to channel)	< 0.05 %		BDA-DRCU-25
-6	Noise allocation	< 7 nVrms/√Hz	0.05 to 25 Hz[1]	BDA-DRCU-01 BDA-DRCU-18
-7	Input capacitance	< 100 pF		BDA-DRCU-03
-8	Input impedance (DC)	> 1 MΩ	@ V_{CM} = 1	BDA-DRCU-04
-9	Base band signal bandwidth	0.03 to 5 Hz± 1% 0.03 to 25 Hz± 1 % 0.03 to 5 Hz± 1%	Photometer Spectrometer Thermometry	BDA-DRCU-13 BDA-DRCU-14
-10	Pre demodulation BPF bandwidth	50 - 300 Hz		
-11	Post demodulation LPF order	4 (Bessel type) 6 (Bessel type)	Photometer (inc TC) Spectrometer	HR-SP-RAL-ECR-001
-12	Common mode rejection	- 60 dB	In band 50–300 Hz	BDA-DRCU-11
-14	Interface Type	balanced signal	Individual shield	

[1]: for 10 mVrms AC/5 mV DC with 1V DC common mode voltage and bias frequency in the range 50 to 300 Hz.

DRCU REQ-33.: Noise performance shall be maintained under a warm electronics thermal drift of 1 K / hour.

DRCU REQ-34.: The Bias module shall provide sine bolometer bias according to the following tables:

• photometer BDA bias channels

Max amplitude	0 - 200 mV rms		BDA-DRCU-05
Frequency	50 to 300 Hz	in 5 ± 0.1 Hz steps	
Amplitude resolution	1/256		
Load impedance	Rbolo + Cwire	> 60 kΩ // < 1 nF	
Interface Type	balanced signal		
Bias Type	Sine wave		
Noise	< 20 nHz/√Hz	in band 50-300 Hz	BDA-DRCU-05
Sync. Signal phase	0 to 360°	in 256 steps	

• spectrometer BDA bias channels

Modulation amplitude	0 - 200 mVrms		BDA-DRCU-05
Modulation frequency	50 to 300 Hz	in 5 ± 0.1 Hz steps	
Amplitude resolution	1/256		
Load impedance	Rbolo + Cwire	> 200 kΩ // < 1 nF	
Interface Type	balanced signal		
Bias Type	Sine wave		
Noise	< 20 nHz/√Hz	in band 50-300 Hz	BDA-DRCU-05
Sync. Signal phase	0 to 360°	in 256 steps	

• temperature readout bias channels

Modulation amplitude	0 - 500 mVrms		BDA-DRCU-05
Modulation frequency	50 to 300 Hz	Common with photo channels	
Amplitude resolution	1/256		
Load impedance	Rbolo + Cwire	> 3 MΩ // < 1 nF	
Interface Type	balanced signal		
Bias Type	Sine wave		
Noise	< 20 nHz/√Hz	in band 50-300 Hz	BDA-DRCU-05
Sync. Signal phase	0 to 360°	Common with photo channels	

DRCU REQ-35.: Each DC JFET bias channel shall have the following performances:

Interface Type	Shielded twisted pair		
Bias Type	DC		
Nominal Voltage	-5v ≤ Vss ≤ 0v 1.5v ≤ Vdd ≤ 4v	1/256 resolution adjustable by design typical: 2.5 V	BDA-DRCU-06 BDA-DRCU-07

Current range	1 mA to 5 mA		BDA-DRCU-08
Voltage Noise	Vn < 1 µV/√Hz[1] Vn < 0.3 µV/√Hz[1]	for Vss for Vdd	
Voltage stability (dV/V)	< 500 ppm/K		BDA-DRCU-21
Load impedance	R + C	1kΩ // < 1 nF	

[1]: bandwidth: 30 to 300 Hz / measured at DCU BIAS connectors level

DRCU REQ-36.: When switching on the JFET biases (Vss & Vdd), the DCU shall not overshoot of more than 10% of the nominal voltage (t < 10 ms).

DRCU REQ-37.: The Bias module shall provide DC JFET heater bias according to the following table:

Interface Type	Double wired		BDA-DRCU-10
Nominal Voltage	0 to 5 V 0 to 3 V	for Photometer for Spectrometer	
Current range	25 mA 10 mA	for Photometer for Spectrometer	

DRCU REQ-38.: The Data Acquisition Module shall have the following characteristics:

ADC resolution	16 bits		BDA-DRCU-12
Total acquisition time	≤ 6.2 ms ≤ 1.2 ms	for photometer for spectrometer	1/10 of sampling rate for limited smearing
Input Signal DC level	≤ 5 V		
DC offset resolution	4 bits		

DRCU REQ-39.: The DAQ_I/F module shall support the following data frames:

- Photo. Array Subset (PLW, PMW, PSW)
- Spectro. Array Subset (SLW, SSW)
- Photo. Full Array
- Spectro. Full Array
- Test Pattern
- Photo. Offset table
- Spectro Offset table

See AD13-AD11 for full descriptions.

4.2.4. Interface Requirements

4.2.4.1. Electrical interfaces

DRCU REQ-40.: Both DCU data and command interfaces shall be compliant with AD11.

4.2.4.2. Mechanical Interfaces

DRCU REQ-41.: The DCU electronics shall be implemented into 16 DRCU boards (220 x 237 mm PCB) as described in §3.1.2. Total allocated volume is then 237 x 220 x 440.

DRCU REQ-42.: The geometry of the back plane of the DCU shall be compliant with the dimensions given by the figure 4.2-a.

4.2.4.3. Power supplies

DRCU REQ-43.: The DCU electronics shall operate with the following set of supplies:

Module	Supply name	Supply voltage	min. current	max. current
LIA_P	DCU_LIA_P_A_P9	+11.50 -0.1/+0.23 V	0.85	1.30 A
	DCU_LIA_P_A_N9	-11.50 -0.23/+0.1 V	0.85	1.30 A
	DCU_LIA_P_D_P5	+5.20 -0.05/+0.05 V	0.14	0.22 A
LIA_S	DCU_LIA_S_A_P9	+11.50 -0.1/+0.23 V	0.28	0.44 A
	DCU_LIA_S_A_N9	-11.50 -0.23/+0.1 V	0.28	0.44 A
	DCU_LIA_S_D_P5	+5.20 -0.05/+0.05 V	0.04	0.09 A
DAQ_I/F-BIAS_P-BIAS-S	DCU_DAQ_P9	+9.0 -0.1/+0.1 V	0.25	0.40 A
	DCU_DAQ_N9	-9.0 -0.1/ +0.1 V	0.25	0.40 A
	DCU_DAQ_P5	+ 5.20 -0.1/+0.05 V	0.25	0.40 A
Allocated average power	**33.2 W (photometer)**			
	16.0 W (spectrometer)			

DRCU REQ-44.: When powered inrush current shall be limited by the DCU according to the following limits:

TBD - from PSU specification document.

DRCU REQ-45.: The DCU shall provide proper supply line filtering to restrict the conducted emissivity as specified bellow:

TBD - from PSU specification document.

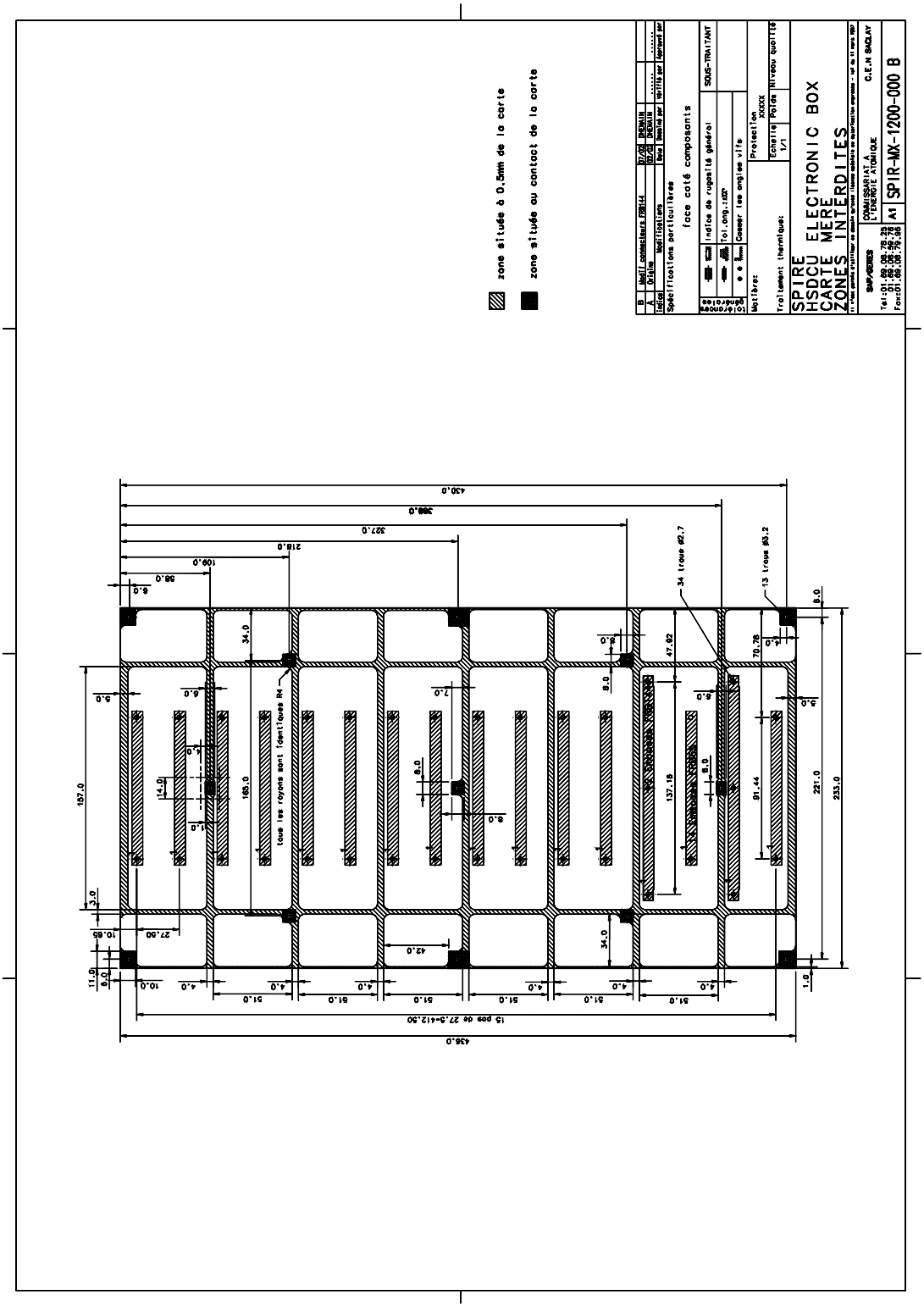


Figure 4.2-a DCU back plane geometry

4.2.5. Block Diagram

A block diagram is shown for information in the next figure.

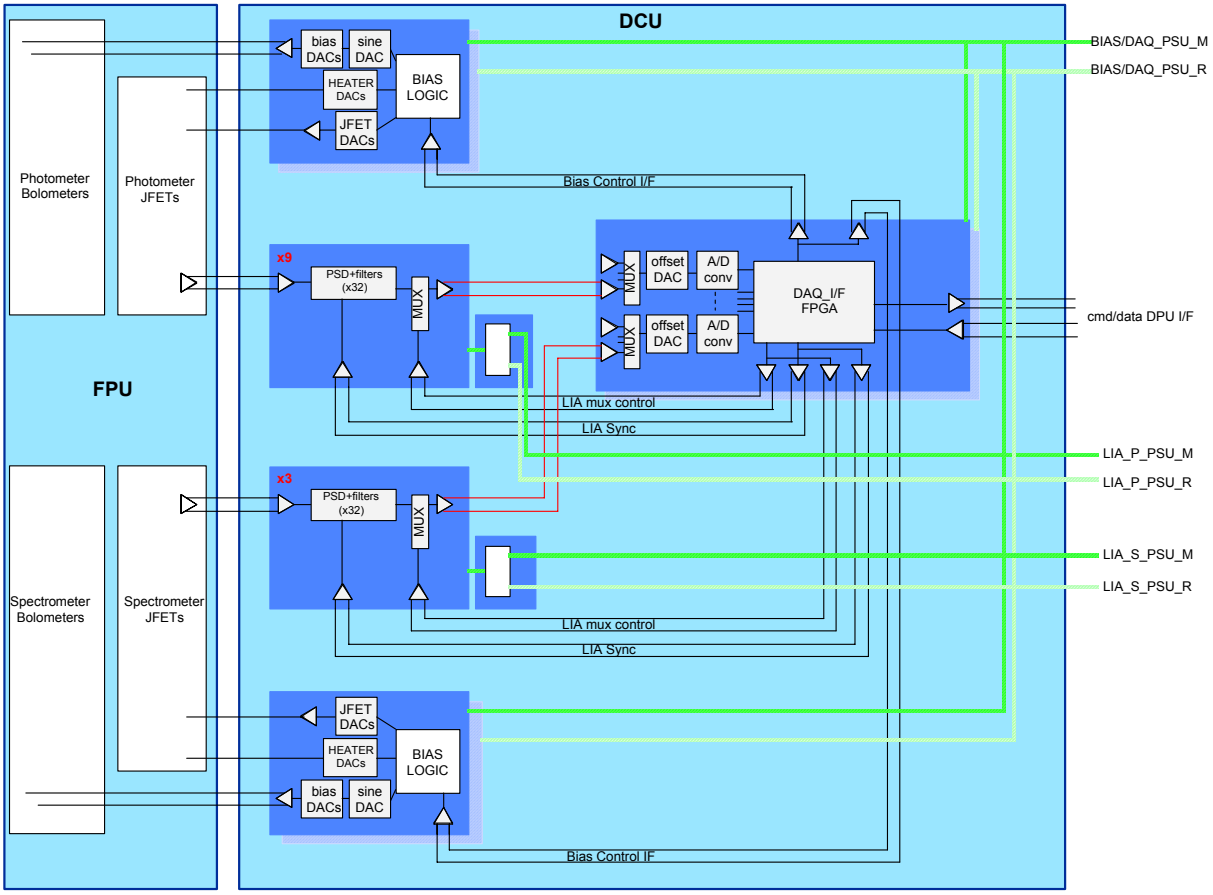


Figure 4.2.-b - DCU block diagram

4.3. MCU

The MCU is divided into 3 functional entities:

- the MAC Module,
- the SMEC Module,
- the BSM Module.

4.3.1. Subsystem General Description

The MAC module is in charge of FTS mirror motion control and Beam Steering Mirror position controls (2 axis). A S/W running on a DSP based embedded computer executes the digital servo loop.
The MAC module interfaces with the SMEC and BSM module by means of analogue signals: ADC and DAC are located on the MAC module.
The MAC includes also an interface circuit to transfer mechanism relative data and housekeeping as well as to receive low-level commands from the DPU.

The SMEC supports the analogue functions required to control the FTS mechanism motion. It implements power amplifiers to drive the translation mirror and the launch latch actuators, sensors (position, current) amplifier, LVDT biasing and signal conditioning, position sensors LED & photodiode biasing and signal conditioning, …
All “high level” input or output analogue signals are interfacing to the converters (A to D and D to A) of the MAC module.

4.3.2. Functional Performances

DRCU REQ-46.: Both data and command interfaces shall be compliant with AD11.

DRCU REQ-47.: The MCU shall implement two electrically independent MAC Modules (1 prime + 1 redundant).

DRCU REQ-48.: The MCU shall transfer the following data formats:

- Spectrometer,
- Steering Mirror,
- Trace,
- Test.

DRCU REQ-49.: The number of data blocks to be transferred successively shall be selectable by means of a MCU low-level command. The number of packets to be transferred successively shall be continuous or selectable between 1 and 16.

DRCU REQ-50.: The MCU shall include temperature measurement of each of its printed circuit board (except back plane) at location where hot spot or high power dissipation parts are identified.

DRCU REQ-51.: Temperature measurement shall be done using an AD590 probe in F02 package glued on the printed circuit board.

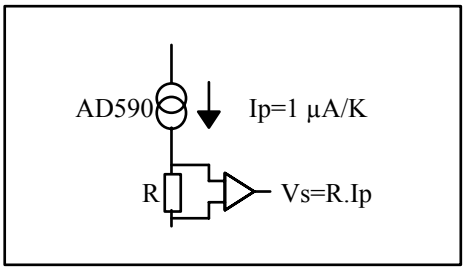


Figure 4.3-a Unit internal temperature monitoring

DRCU REQ-52.: The temperature measurement shall have the following performances:

Temperature Range	-40°C to 88 °C
Temperature resolution	0.5°C

DRCU REQ-53.: The MCU shall report at least the following housekeeping parameters when requested by low-level commands:

Parameter Name	Word size (bits)	Comments
MAC_TEMP	8	MAC board temperature
SMEC_TEMP	"	SMEC board temperature
BSM_TEMP	"	BSM board temperature
MAC_STATUS	"	Status word of MAC electronics
MCU_DIG_P5	"	Digital power supply voltage
MCU_P15	"	Positive analog power supply voltage
MCU_N15	"	Nositive analog power supply voltage
MCU_DRV_P13	"	Positive drivers power supply voltage (internal)
MCU_DRV__N13	"	Negative drivers power supply voltage (internal)

DRCU REQ-54.: The analogue channels (for sub-systems supply voltage reporting) shall have the following characteristics:

Number of channel	5
Voltage range	≥ nominal voltage + 20 %
Voltage resolution	1 %

DRCU REQ-55.: The MCU shall implement two electrically independent SMEC electronics (1 main + 1 redundant) each connected to a MAC (without cross-strapping) and to a set of actuators/sensor located in the FPU.

DRCU REQ-56.: The MCU shall implement two electrically independent BSM electronics (1 main + 1 redundant) each connected to a MAC (without cross-strapping) and to a set of actuators/sensor located in the FPU.

4.3.3. Performance requirements

The MCU performance requirements are excluded from the scope of this document. Those specific requirements will be found in AD18 and AD19.

4.3.4. Interfaces Requirements

4.3.4.1. Electrical Interfaces

DRCU REQ-57.: The data packet transmitted to the DPU shall be compliant with definition given in AD11 (ICD).

4.3.4.2. Mechanical Interfaces

DRCU REQ-58.: The MCU electronics shall be implemented into 5 DRCU boards (220 x 237 mm PCB) as described §3.1.2. Total allocated volume is then 237 x 220 x 137.5 (dimensions in millimetres).

DRCU REQ-59.: The geometry of the back plane of the MCU shall be compliant with the dimensions given by the figure 4.3-b.

DRCU REQ-60.: The mass allocation for the MCU elements (daughter boards + back plane) is 3.445 kg.

4.3.4.3. Power supplies

DRCU REQ-61.: The MCU electronics shall operate with the following set of supplies and the associated maximum average currents:

Supply name	Supply voltage	Min. current	Max. current
MCU_DIG_P5	5.20 -0.1/+0.05 V	0.64 A	2.00 A
MCU_P15	+15.20 -0.10/+0.15 V	0.20 A	0.48 A
MCU_N15	-15.20 -0.15/+0.10 V	0.15 A	0.42 A
Allocated average power	**18.7 W**		

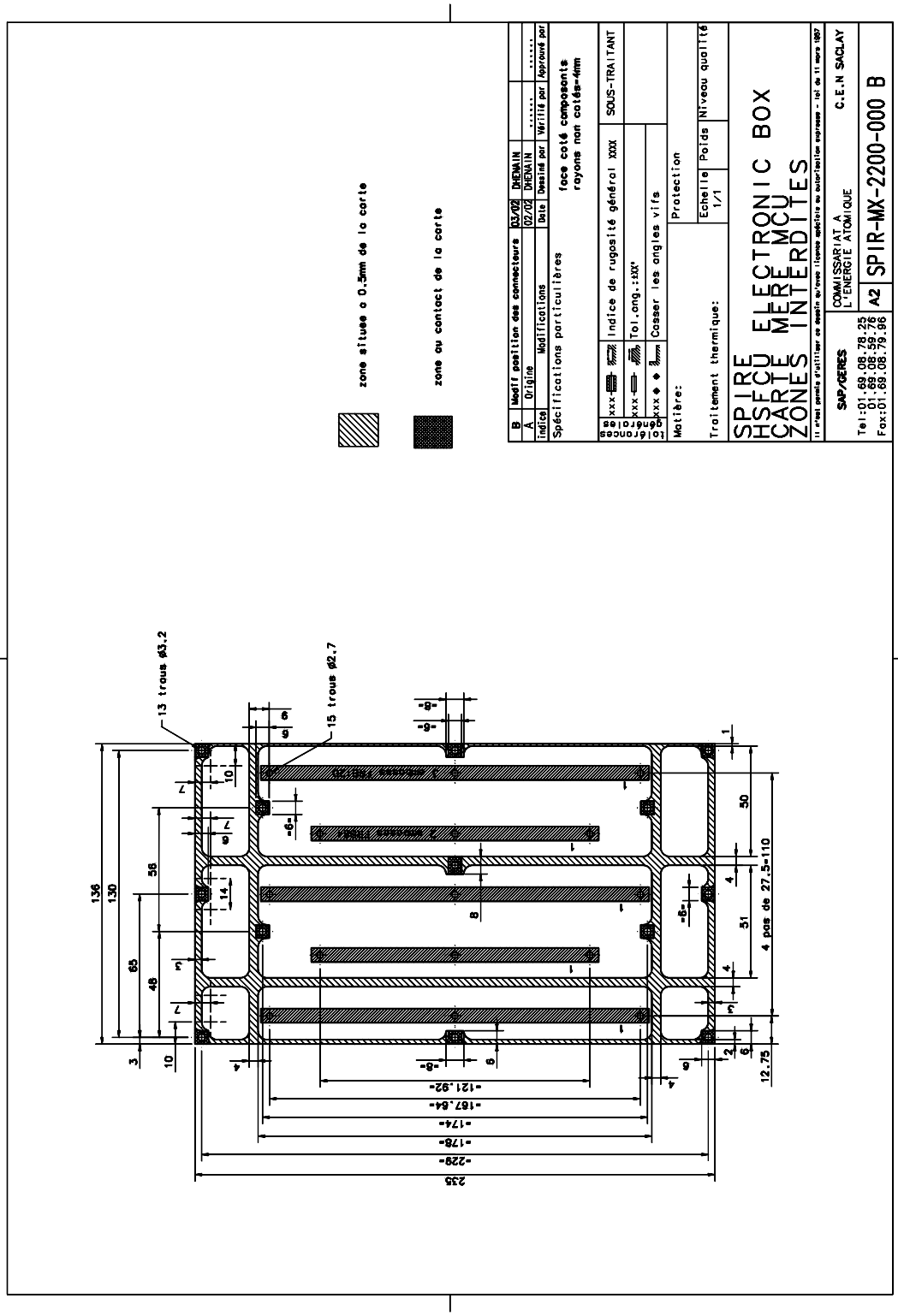


Figure 4.3-b MCU back plane geometry

DRCU REQ-62.: When powered inrush current shall be limited by the MCU according to the following limits:

TDB - from PSU specification document.

DRCU REQ-63.: The MCU shall provide proper supply line filtering to restrict the conducted emissivity as specified bellow:

TDB - from PSU specification document.

4.4. SCU

4.4.1. Subsystem General Description

The photometer calibrator consists of a heater mounted in an integrating cavity on the BSM structure. The SCU has to bias this heater with a variable amplitude and frequency waveform.

The spectrometer calibrator consists of a heater mounted on blackened plate associated with a second heater mounted as in the photometer calibrator. The SCU has to supply those heaters with a variable amplitude bias and to monitor the blackened plate temperature (already included in the “Thermometry” sub-system).

The cooler consists of an evaporator filled with helium 3. After full evaporation the gas has to be pumped by active charcoal heated by a resistor. Additional gas switches enable to connect / disconnect the cooler with the super fluid helium tank.

In addition to the temperature monitoring of FPU elements the SCU have to monitor warm electronics analogue parameters; those parameters are:

- SCU supply voltages
- SCU & PSU DC/DC converter internal temperature channels (see §4.2.1.1.3)

4.4.2. Functional Requirements

DRCU REQ-64.: The SCU shall implement totally electrically independent main and redundant thermometry channels according to the numbers given by the table 4.2.3.1-a.

Number of channels	16 standards +1 subK	Prime channels
	16 standards +1 subK	Redundant channels
Interface type	4-wire + shield	None connected to ground except shield - 2 wires for bias - 2 wires for sense

Table 4.4-a Thermometry channels summary

DRCU REQ-65.: Temperature probe bias shall be individually switched on/off by a low level command.

DRCU REQ-66.: The SCU shall have two independent photometer/spectrometer calibrator interfaces and associated electronics: 1 for the main configuration + 1 for the redundant configuration (IRD-CALP-R15).

DRCU REQ-67.: Calibrator bias current shall be controlled individually by a low-level command.

DRCU REQ-68.: Both voltage and current of the photometer/spectrometer calibrators shall be monitored by the SCU and transmitted to the DPU after digitisation.

DRCU REQ-69.: The SCU is not required to store the calibrator current waveform. Waveforms are generated step by step by the DPU S/W by sending low-level commands regularly (with requirement on the timing accuracy).

DRCU REQ-70.: The SCU shall have two independent cryo-cooler and thermal control heaters interfaces and associated electronics: 1 for the main configuration + 1 for the redundant configuration.

DRCU REQ-71.: Cryo-cooler heaters currents shall be selectable individually with a resolution of 1/4096 w.r.t. the maximum power by independent low-level commands.

DRCU REQ-72.: Thermal control heaters current shall be selectable individually with a resolution of 1/256 w.r.t. the maximum power by an independent low-level command.

DRCU REQ-73.: The SCU shall feature 3 bi-level redundant commands for PSU converter group remote control commands. The signal shall be active high and shall drive a minimum current of 1 mA.

Driver voltage	CMOS level
Driver current	-
Signal type	Level sensitive: 0 = off 1 = on

The following table lists those remote commands:

Group Name	Corresponding Functions
DCU_LIA_P	Photometer analogue electronics
DCU_LIA_S	Spectrometer analogue electronics
MCU	All MCU functions

DRCU REQ-74.: PSU remote commands status shall be configurable by means of SCU low-level commands except for nominal / redundant switching.

DRCU REQ-75.: The SCU shall implement two electrically independent DPU Interface modules (1 main + 1 redundant).

DRCU REQ-76.: The interface electronics shall transfer fixed size data blocks to the DPU via the fast data interface according to AD11.

DRCU REQ-77.: The number of block to be transferred successively shall be selectable by means of a DCU low-level command. The number of packets to be transferred successively shall be continuous or selectable between 1 and 16.

DRCU REQ-78.: The sampling rate of these data block shall be programmable by means of a low-level command between 0.3125 Hz and 80 Hz in 256 steps.

DRCU REQ-79.: The interface module shall transfer the following data (24 words) within a single data format:

Parameter Name	Word size (bits)	Comments
T_PL0	16	Photometer detector box temperature
T_SL0	"	Spectrometer detector box temperature
T_SOB	"	SPIRE Optical Bench temperature
T_SUB	"	Optical sub-bench temperature
T_BAF	"	FPU input baffle temperature
T_FTSM	"	SMEC mechanism temperature
T_FTSS	"	SMEC/SOB I/F temperature
T_SCL4	"	Spectrometer calibrator 4% temperature
T_SCL2		Spectrometer calibrator 2% temperature
T_SCST	"	Spectrometer calibrator flange temperature
T_CEV	"	Cryo-cooler evaporator temperature
T_CPHP	"	Cryo-cooler sorption pump temperature
T_CEHS	"	Cryo-cooler evaporator heat switch temperature

T_CPHS	"	Cryo-cooler sorption pump heat switch temperature
T_CSHT	"	Cryo-cooler thermal shunt temperature
T_BSMM	"	BSM mechanism temperature
T_BSMS	"	BSM/SOB I/F temperature
PhCalBias	"	Bias current of photometer calibrator
PhCalVolt	"	Voltage across photometer calibrator
SCal4Bias	"	Bias current of spectrometer calibrator (4%)
SCal4Volt	"	Voltage across spectrometer calibrator (4%)
SCal2Bias	"	Bias current of spectrometer calibrator (2%)
SCal2Volt	"	Voltage across spectrometer calibrator (2%)
TCHeaterBias		TC heater bias current

DRCU REQ-80.: The SCU shall include temperature measurement of each of its printed circuit board (except back plane) at location where hot spot or high power dissipation parts (i.e. DC/DC converter switching transistors) are identified.

DRCU REQ-81.: Temperature measurement shall be done using an AD590 probe in F02 package glued on the printed circuit board.

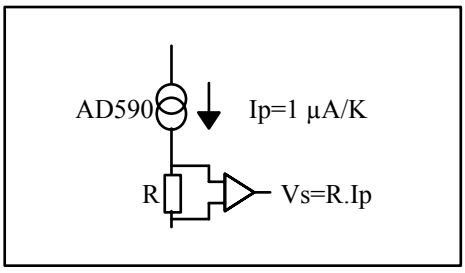


Figure 4.4-a Unit internal temperature monitoring

DRCU REQ-82.: The temperature measurement shall be compliant with the following table:

Temperature Range	-40°C to 88 °C
Temperature resolution	0.5°C

DRCU REQ-83.: The SCU shall report the following housekeeping parameters when requested by low-level commands:

Parameter Name	Word size (bits)	Comments
T_PL0	16	Photometer detector box temperature
T_SL0	"	Spectrometer detector box temperature
T_SOB	"	SPIRE Optical Bench temperature
T_SUB	"	Optical sub-bench temperature
T_BAF	"	FPU input baffle temperature
T_FTSM	"	SMEC mechanism temperature
T_FTSS	"	SMEC/SOB I/F temperature

Parameter Name	Word size (bits)	Comments
T_SCL4	"	Spectrometer calibrator 4% temperature
T_SCL2		Spectrometer calibrator 2% temperature
T_SCST	"	Spectrometer calibrator flange temperature
T_CEV	"	Cryo-cooler evaporator temperature
T_CPHP	"	Cryo-cooler sorption pump temperature
T_CEHS	"	Cryo-cooler evaporator heat switch temperature
T_CPHS	"	Cryo-cooler sorption pump heat switch temperature
T_CSHT	"	Cryo-cooler thermal shunt temperature
T_BSMM	"	BSM mechanism temperature
T_BSMS	"	BSM/SOB I/F temperature
PhCalBias	"	Bias current of photometer calibrator
PhCalVolt	"	Voltage across photometer calibrator
SCal4Bias	"	Bias current of spectrometer calibrator (4%)
SCal4Volt	"	Voltage across spectrometer calibrator (4%)
SCal2Bias	"	Bias current of spectrometer calibrator (2%)
SCal2Volt	"	Voltage across spectrometer calibrator (2%)
TCHeaterBias	"	TC heater bias current
TsuTempRd	"	Temperature module temperature
CsuTempRd	"	Cal/Cool/HK module temperature
PsuTempRd	"	PSU internal temp.
ScuCHTp05	"	SCU +5V power supply voltage
ScuCHTp09	"	SCU +9V power supply voltage
ScuCHTn09	"	SCU -9V power supply voltage
DRelOnOff	3	Status of PSU remote command
ScuStatus	2	Status of SCU electronics

DRCU REQ-84.: The analogue channels (for sub-systems supply voltage reporting) shall have the following characteristics:

Voltage channels number	3
Voltage range	≥ nominal voltage + 20 %
Voltage resolution	1 %

4.4.3. Performance Requirements

DRCU REQ-85.: The thermometry sub-system (main part) shall have the following channels according to AD24 except for cryo-cooler related temperature probes (text in blue) where AD21 is considered:

Acronym	Location	Sensor Type	Temperature Range	Resolution	Accuracy
T_PL0	Photometer detector box temperature	CX-1030	1 K -10 K	2 mK	2 mK
T_SL0	Spectrometer detector box temperature	CX-1030	1 K -10 K	2 mK	2 mK
T_SOB	SPIRE Optical Bench temperature	CX-1030	3 K - 300 K	10 mK	10 mK
T_SUB	Optical sub-bench temperature	CX-1030	3 K-100 K	25 mK	25 mK
T_BAF	FPU input baffle temperature	CX-1030	3 K-100 K	10 mK	10 mK
T_FTSM	SMEC mechanism temperature	CX-1030	3 K - 20 K	10 mK	10 mK
T_FTSS	SMEC/SOB I/F temperature	CX-1030	3 K - 100 K	25 mK	50 mK
T_SCL4	Spectrometer calibrator 4% temperature	CX-1030	4 K - 150 K	5 mK	5 mK
T_SCL2	Spectrometer calibrator 2% temperature	CX-1030	4 K - 150 K	5 mK	5 mK
T_SCST	Spectrometer calibrator flange temperature	CX-1030	1K - 50 K	10 mK	10 mK
T_CEV	Cryo-cooler evaporator temperature	CX-1030	0.25 K - 10 K	0.1 mK	5 mK
T_CPHP	Cryo-cooler sorption pump temperature	CX-1030	1.5 K - 50 K	0.5 K	1 K
T_CEHS	Cryo-cooler evaporator heat switch temperature	CX-1030	1.5 K - 25 K	0.5 K	1 K
T_CPHS	Cryo-cooler sorption pump heat switch temperature	CX-1030	1.5 K - 25 K	0.5 K	1 K
T_CSHT	Cryo-cooler thermal shunt temperature	CX-1030	1.5 K 10 K	0.1 K	0.1 K
T_BSMM	BSM mechanism temperature	CX-1030	3 K - 20 K	10 mK	10 mK
T_BSMS	BSM/SOB I/F temperature	CX-1030	3K - 80 K	5 mK	5 mK

Table 4.4-b Detailed main thermometry channel list

Note : Resolution is applicable to the lower end of the nominal temperature range.

DRCU REQ-86.: The thermometry sub-system (redundant part) shall have the following channels according to AD20 except for cryo-cooler related temperature probes (text in blue) where RD05 is considered:

Acronym	Location	Sensor Type	Temperature Range	Resolution	Accuracy
T_PL0	Photometer detector box temperature	CX-1030	1 K -10 K	2 mK	2 mK
T_SL0	Spectrometer detector box temperature	CX-1030	1 K -10 K	2 mK	2 mK
T_SOB	SPIRE Optical Bench temperature	CX-1030	3 K - 300 K	10 mK	10 mK
T_SUB	Optical sub-bench temperature	CX-1030	3 K-100 K	25 mK	25 mK
T_BAF	FPU input baffle temperature	CX-1030	3 K-100 K	10 mK	10 mK
T_FTSM	SMEC mechanism temperature	CX-1030	3 K - 20 K	10 mK	10 mK
T_FTSS	SMEC/SOB I/F temperature	CX-1030	3 K - 100 K	25 mK	50 mK
T_SCL4	Spectrometer calibrator 4% temperature	CX-1030	4 K - 150 K	5 mK	5 mK
T_SCL2	Spectrometer calibrator 2% temperature	CX-1030	4 K - 150 K	5 mK	5 mK
T_SCST	Spectrometer calibrator flange temperature	CX-1030	1K - 50 K	10 mK	10 mK
T_CEV	Cryo-cooler evaporator temperature	CX-1030	0.25 K - 10 K	0.1 mK	5 mK
T_CPHP	Cryo-cooler sorption pump temperature	CX-1030	1.5 K - 50 K	0.5 K	1 K
T_CEHS	Cryo-cooler evaporator heat switch temperature	CX-1030	1.5 K - 25 K	0.5 K	1 K

T_CPHS	Cryo-cooler sorption pump heat switch temperature	CX-1030	1.5 K - 25 K	0.5 K	1 K
T_CSHT	Cryo-cooler thermal shunt temperature	CX-1030	1.5 K 10 K	0.1 K	NA
T_BSMM	BSM mechanism temperature	CX-1030	3 K - 20 K	10 mK	10 mK
T_BSMS	BSM/SOB I/F temperature	CX-1030	3K - 80 K	5 mK	5 mK

Table 4.4-c Detailed redundant thermometry channel list

Note: Resolution is applicable to the lower end of the nominal temperature range.

DRCU REQ-87.: In order to avoid probe self-heating the biases shall not exceed the values given by the following table:

Probe Type	Max. bias
Sub-K probes	40 nA
Standard probes	10 mV

Table 4.4-d Probe maximum bias level

DRCU REQ-88.: The SCU shall provide PCAL bias current according to the following performances:

Heater Bias Current Range	0 to 7 mA	in 4096 steps	AD22-7.2.1 &AD22-7.2.2
Maximum dissipated power limitation	10 mW		AD22-7.2.1
Heater Resistance Range	200 to 500 Ω	≤100 Ω for lead resistance	AD22-7.2
Stability / Repeatability	0.5 % or 5 µA	Whichever is greater	AD22-7.2.5
Maximum drive voltage	3.9 V	Worst case	AD22-7.2.3
Bias waveform	square	Spec. for DPU	
Waveform frequency	0 to 5 Hz	Spec. for DPU	
Waveform resolution	100 ms	Spec. for DPU	
Interface Type	2x2-wire	None connected to ground	

DRCU REQ-89.: The SCU shall provide SCAL (4% and 2%) biases according to the following performances:

Heater Bias Current Range	0 to 5.5 mA	in 4096 steps	AD23-6.3
Maximum dissipated power limitation	15 mW		AD23-6.2
Heater Resistance Range	500 Ω	≤100 Ω for lead resistance	AD23-6.1
Stability / Repeatability	0.5 % or 5 µA	Whichever is greater	AD23-6.5
Maximum drive voltage	3.1 V	Worst case	AD23-6.4
Bias waveform	DC		
Electrical Interface Type	2x2-wire	None connected to ground	

DRCU REQ-90.: The above stability and repeatability shall be achieved for operating time of 1 hour (typical observation duration) and assuming a S/C temperature drift of 3K/hour.

DRCU REQ-91.: The calibrator current shall be limited by hardware to 110 ± 2 % of specified maximum.

DRCU REQ-92.: The SCU shall provide cryo-cooler heater biases according to the following performances:

Type	Number	Heater Resistance	Lead Resistance	Power	Absolute max. voltage	Interface type
Heat Switch [1]	2	402 Ω	≤100 Ω	0 / 1 mW	15 V	2x2-wire
Sorption Pump[1]	1	402 Ω	≤100 Ω	0 to 500 mW	15 V	2x2-wire
TC heater[2]	1	6 kΩ	≤ 1kΩ	300 mV / 50 µA		

[1]: from AD21
[2]: from BDA-DRCU-17 of AD20

4.4.4. Interface Requirement

4.4.4.1. Electrical Interfaces

DRCU REQ-93.: Both data and command interfaces shall be compliant with AD11.

4.4.4.2. Mechanical Interfaces

DRCU REQ-94.: The SCU electronics shall be implemented into 5 DRCU boards (220 x 237 mm PCB) as described §3.1.2. Total allocated volume is then 237 x 220 x 137.5 (dimensions in millimetres)

DRCU REQ-95.: The geometry of the back plane of the SCU shall be compliant with the dimensions given by the figure 4.4-b.

4.4.4.3. Power supplies

DRCU REQ-96.: The SCU electronics shall operate with the following set of supplies with associated maximum average current:

Supply name	Supply voltage	min. current	max. current
SCU_ANA_P9 SCU_ANA_N9	+9.0 -0.1/+0.1 V -9.0 -0.1/+0.1 V	0.11 A 0.08 A	0.32 A 0.28 A
SCU_DIG_P5	+ 5.20 -0.05/+0.05V	0.13 A	0.22 A
Allocated average power	**4.7 W**		

DRCU REQ-97.: When powered inrush current shall be limited by the SCU according to the following limits:

TBD - from PSU specification document.

DRCU REQ-98.: The SCU shall provide proper supply line filtering to restrict the conducted emissivity as specified bellow:

TBD - from PSU specification document.

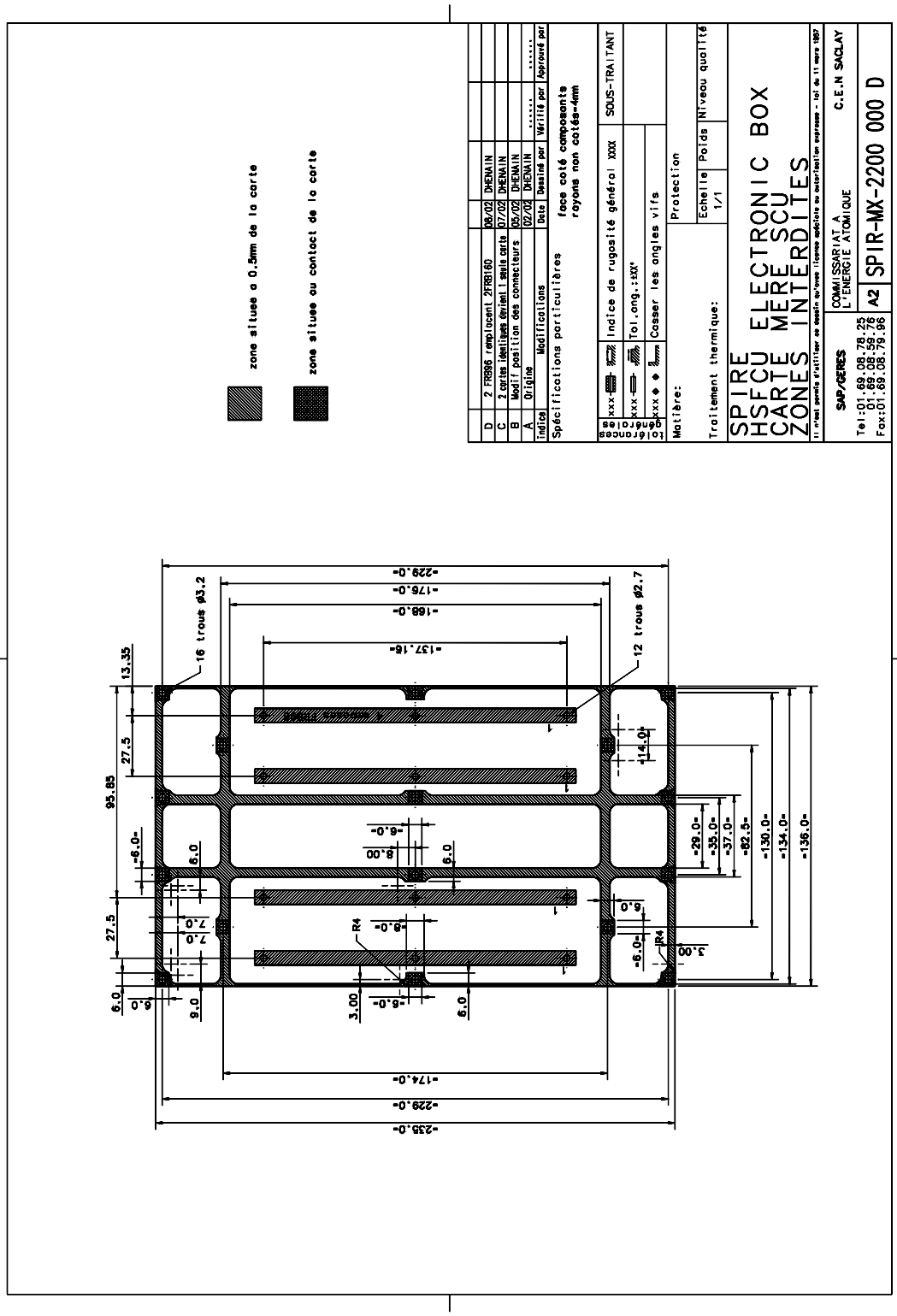
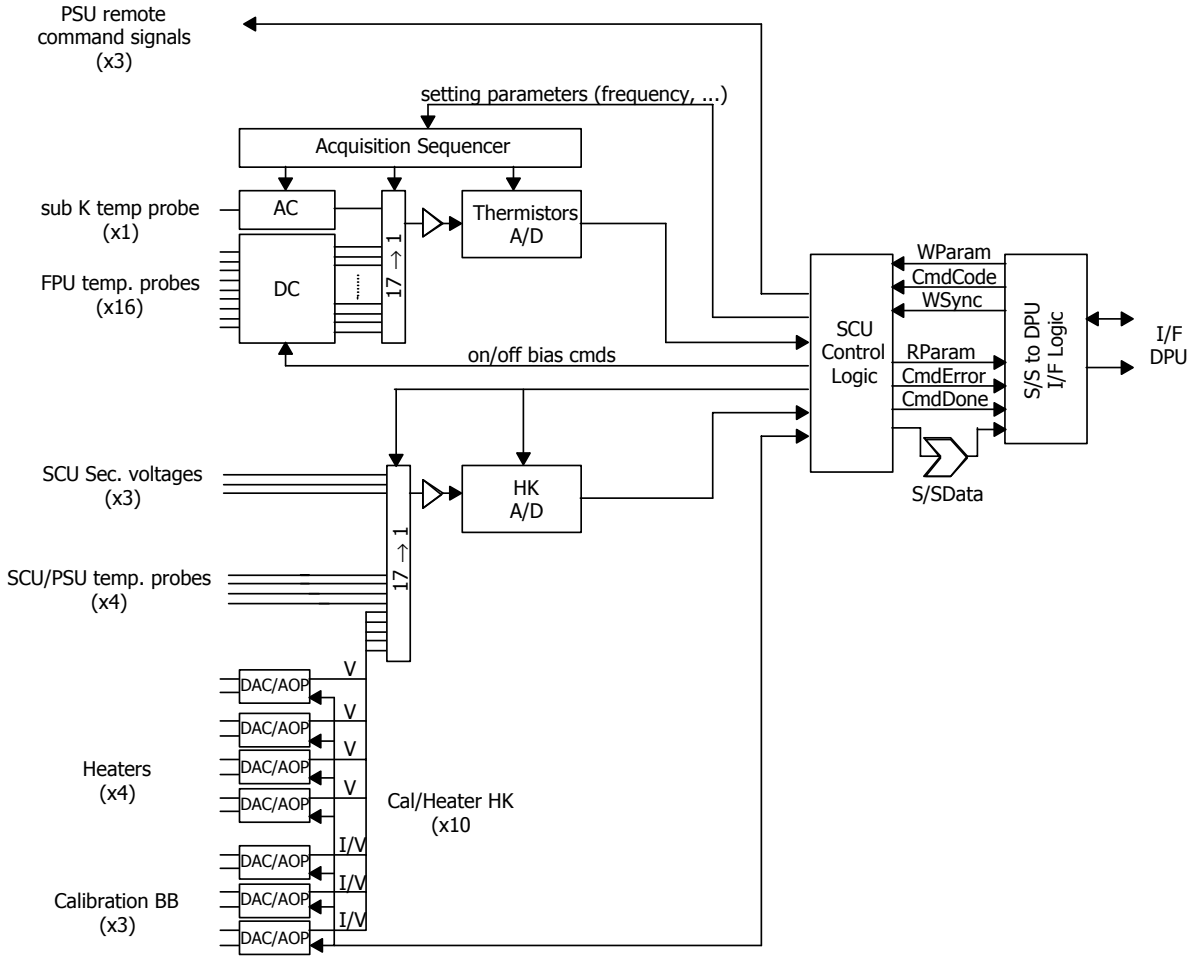


Figure 4.4-b SCU back plane geometry

4.4.5. SCU block diagram

A typical functional diagram is shown for information by the following figure. The SCU is designed around an acquisition sequencer configured according to low-level commands.



4.5. PSU (DC/DC converters unit)

4.5.1. Secondary power lines

DRCU REQ-99.: Each DC/DC set of converters (1 main + 1 redundant) shall have the following outputs lines with the given current capabilities:

Sub-unit	Sub-system	Supply Name	Voltage	Accuracy 0/+ % V	Current consumption		
					min	average	max
MCU	all	MCU_DIG_P5	5.2 V	1	640	1700	2000
		MCU_P15	+15.2 V	1	200	350	480/ 800*
		MCU_N15	-15.2 V	1	150	300	420/ 800*
DCU	LIA_P**	DCU_LIA_P_P5	+5.2 V	1	140	180	220
		DCU_LIA_P_P9	+11.5 V	2	850	1080	1300
		DCU_LIA_P_N9	-11.5 V	2	850	1080	1300
	LIA_S**	DCU_LIA_S_P5	+5.2 V	1	40	60	90
		DCU_LIA_S_P9	+11.5 V	2	280	360	440
		DCU_LIA_S_N9	-11.5 V	2	280	360	440
	BIAS/DAQ_IF	DCU_DAQ_P5	+5.2 V	1	250	320	400
		DCU_DAQ_P9	+9.0 V	1	250	320	400
		DCU_DAQ_N9	-9.0 V	1	250	320	400
SCU	all	SCU_DIG_P5	+ 5.2 V	1	130	200	270
		SCU_ANA_P9	+9.0 V	1	110	220	320
		SCU_ANA_N9	-9.0 V	1	80	180	280

* ≤ 50 ms for both +15 V and -15 V
** Not to be "ON" together
Note: for a complete PSU specification refer to RD2

4.5.2. Primary power line

DRCU REQ-100.: Each PSU set of DC/DC converters (main/redundant) shall have an independent electrical interface with the satellite power bus.

DRCU REQ-101.: The interface shall be compliant with the requirement listed in AD3 §5.9.5.4 and with the signal characteristics AD3 (§5.9.5.2 and 5.9.5.3) as summarised below:

Nominal voltage	28 V
PSU operating range	26-29 V
Input voltage range	0 to 35 V

DRCU REQ-102.: Switching between prime and redundant electronics shall be achieved autonomously simply by switching between nominal and redundant PSU. That is no low-level command is required.

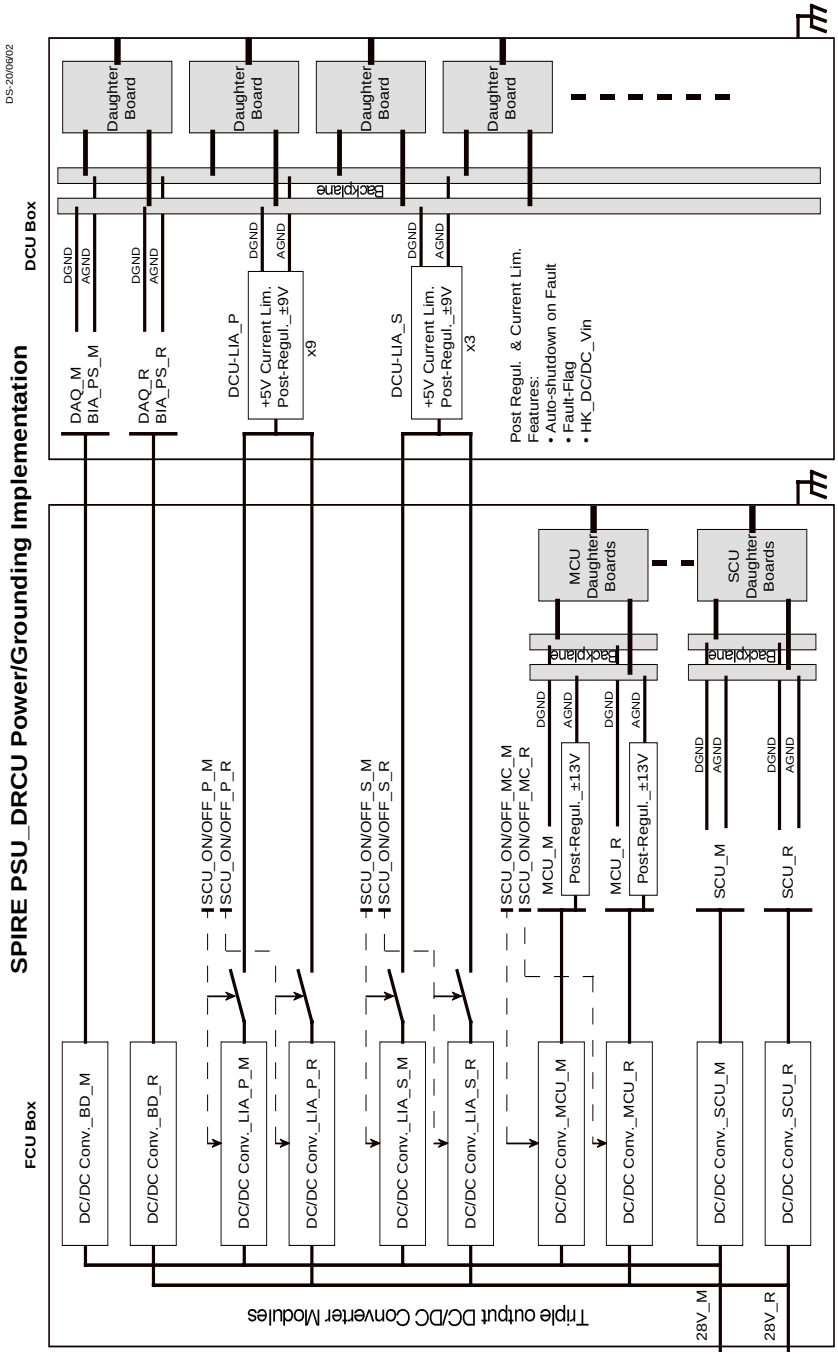
4.5.3. Efficiency

DRCU REQ-102b.: In order to keep FCU power dissipation compliant with allocated power the global efficiency of the PSU shall be better or equal to 70%

4.6. DRCU electrical configuration

4.6.1. DRCU Power Distribution Scheme

The following figure shows the DRCU power distribution scheme as required by the various sub-systems.



4.6.2. Grounding and isolation

DRCU REQ-103.: One secondary power shall not be distributed to more than one unit.

DRCU REQ-104.: The spacecraft structure shall not be used as return path for power and signals.

DRCU REQ-105.: Each secondary power return shall be connected to a single ground.

DRCU REQ-106.: When a single converter supplies via multiple windings one or more equipments the secondary power network shall be connected to a single location within the supplied unit(s).

DRCU REQ-107.: When the secondary power return is disconnected from the ground, the isolation between the secondary power return and the chassis shall be at least 1MΩ shunted by no more than 50 pF.

4.6.3. Bonding

DRCU REQ-108.: Bonding interfaces shall be designed to carry fault currents of 1.5 times the maximum S/S protection device rating for an infinite time.

DRCU REQ-109.: Bonding interfaces shall be designed to be corrosion resistant. Use of bonding strap shall be as much as possible avoided: conductive mounting surface is the preferred method.

DRCU REQ-110.: If the mounting feet are used to bond equipment to the S/C structure the contact area (each foot) shall not be less than 1cm^2 and the DC resistance between the equipment chassis and the S/C shall not exceed 10 mΩ.

DRCU REQ-111.: Flat, clean and conductive surfaces shall be used for bonding. The permitted surfaces are:

- Clean metal
- Gold plate
- Alodine 1200 or similar.

DRCU REQ-112.: The DC resistance between any two adjacent faces of the equipment chassis shall not exceed 2.5 mΩ.

DRCU REQ-113.: Each unit shall provide a bonding lug. The DC resistance between the stud (M4x6) and the inner side of the mounting feet shall not exceed 2.5 mΩ.

DRCU REQ-114.: The DC resistance between the secondary power reference and the bonding lug shall be less than 5 mΩ. The secondary reference shall be connected to the equipment chassis via a low inductance strap (max. length: 3 cm).

4.7. Modes of Operation

4.7.1. General

DRCU REQ-115.: The Modes of Operation of the DRCU shall be:

- Off
- Initialisation
- Running

4.7.2. Off (OFF) Mode

DRCU REQ-116.: In this mode the DRCU shall be completely OFF. The DRCU do not receive power from either the Prime or Redundant Primary Power line.

4.7.3. Initialisation (INIT) Mode

This mode is defined as intermediate between the Off Mode and the Run Mode. When in Initialisation Mode the S/W based functions are booting: S/W and H/W integrity are checked then S/W starts execution.

Note: this mode and its definition are restricted to the MCU. Other sub-units will switch directly to the Run Mode.

DRCU REQ-117.: The DRCU sub-units shall enter this mode whenever a power-on occurs.

DRCU REQ-118.: When all the activities corresponding to the Initialisation Mode have been successfully completed the DRCU sub-unit shall enter the Run Mode after reception of the proper low-level command.

DRCU REQ-119.: In the case the Initialisation Mode cannot be executed entirely the DRCU sub-unit shall respond to a low-level command with an “initialisation failure” acknowledge.

DRCU REQ-120.: A DRCU sub-unit shall enter this mode whenever an internal S/W crash occurs (valid for MCU only).

DRCU REQ-120b.: During the init phase sub-unit design shall guaranty low electrical levels on output lines toward FPU.

4.7.4. Run (RUN) Mode

This mode is the nominal status of the DRCU.

DRCU REQ-121.: The DRCU has its full functionality when in this mode.

4.7.5. Relation to SPIRE Modes of Operation

The following table gives the relation between SPIRE mode of operation as described in AD10 and DRCU mode of operation as defined earlier in this document.

SPIRE Mode of Operation	DRCU Mode of Operation	Note
OFF	OFF	
ON	OFF	
INIT	OFF	
REDY	INIT/RUN	SCU is on MCU is on DCU is partially on (LIA_P/LIA_S are off)
PHOT STBY	RUN	JFET units are supplied BSM is initialised / in (0,0) position DCU is partially on (LIA_S is off) Only HK transmission
SPEC STBY	RUN	JFET units are supplied BSM is initialised / at (0,0) position SMEC is initialised / at home position DCU is partially on (LIA_P is off) Only HK transmission
OBSV	RUN	Scientific data + HK transmission
CREC	RUN	SCU is on MCU is off DCU is partially on (LIA_P/LIA_S are off)
SAFE	OFF	TBC

According to RD1.

4.7.6. Transition between Modes of Operations

Here below is shown the transition diagram relevant to the mode of operation of the DRCU.

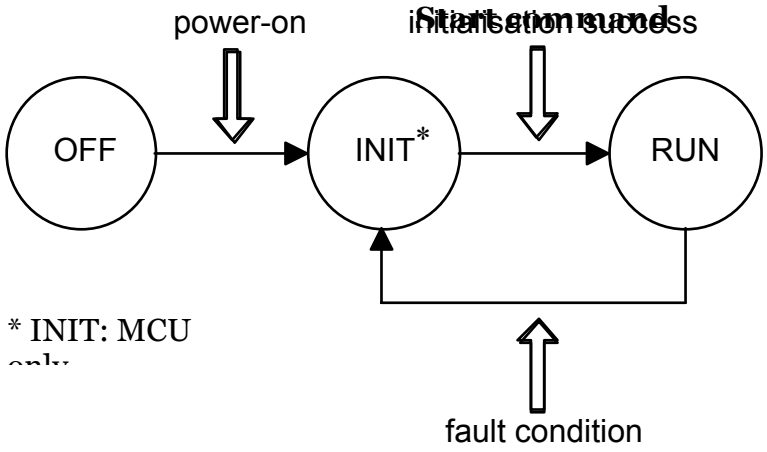


Figure 4.7-a DRCU Mode of Operation Transition Diagram

4.8. Cross reference of capabilities

Below is a summary of the DRCU capabilities with respect to the DRCU Modes of Operation.

Mode of Operation	Active functions			
	DCU	MCU	SCU	PSU
OFF	-	-	-	-
INIT	DCU-FUNC-01 to -11	MCU-FUNC-10 to -15	SCU-FUNC-01 to -14	PSU-FUNC-01 to 03
RUN	DCU-FUNC-01 to -11	MCU-FUNC-01 to -15	SCU-FUNC-01 to -14	PSU-FUNC-01 to 03

4.9. Failure detection isolation and recovery

4.9.1. Failure Detection

DRCU REQ-122.: The DRCU shall provide capabilities for the DPU to detect internal failures.

DRCU REQ-122b.: The MCU shall provide capabilities to detect and handle failures in the sub-system that might cause immediate danger to the mechanism.

4.9.2. Failure Isolation

From an electrical point of view the DRCU shall be designed in such a way to match the following requirements:

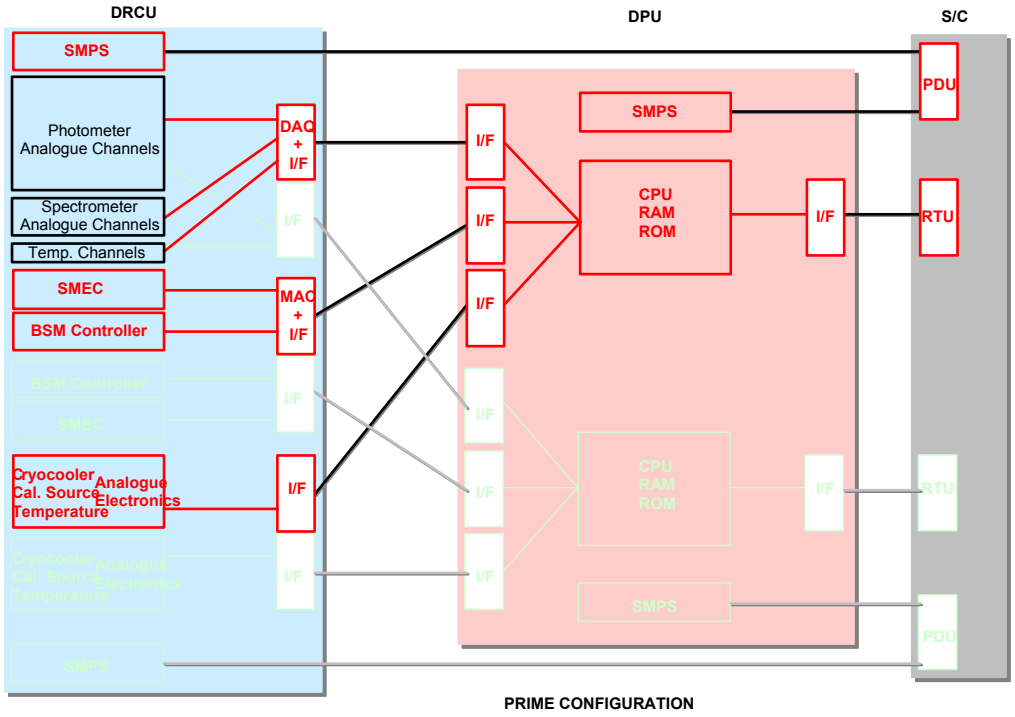
DRCU REQ-123.: Any failure within the DRCU shall not induce any failure to other units.

DRCU REQ-124.: Any failure within the DRCU shall not provoke incorrect execution of operations by other units up-stream the DRCU (e.g. issuing of wrong parameters).

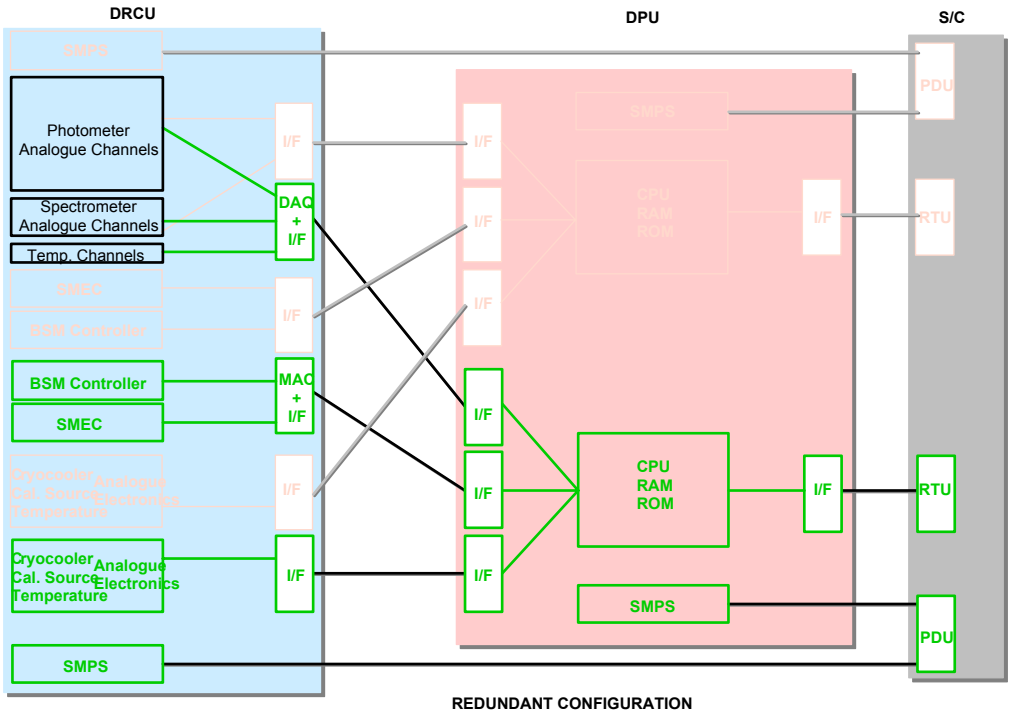
DRCU REQ-125.: Any first failure of one cold redundant part of the DRCU shall not induce any failure to the other cold redundant part of the unit.

4.9.3. Redundancy

The redundancy concept is depicted by the followings figures respectively for the main and redundant configurations:



PRIME CONFIGURATION



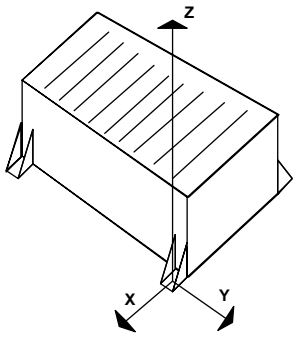
REDUNDANT CONFIGURATION

5. DRCU Interfaces

5.1. Mechanical Interface

DRCU has mechanical interface only with SVM of the S/C. This interface shall be described in the relevant "External Interface Control Drawing" document.

5.1.1. Coordinate system

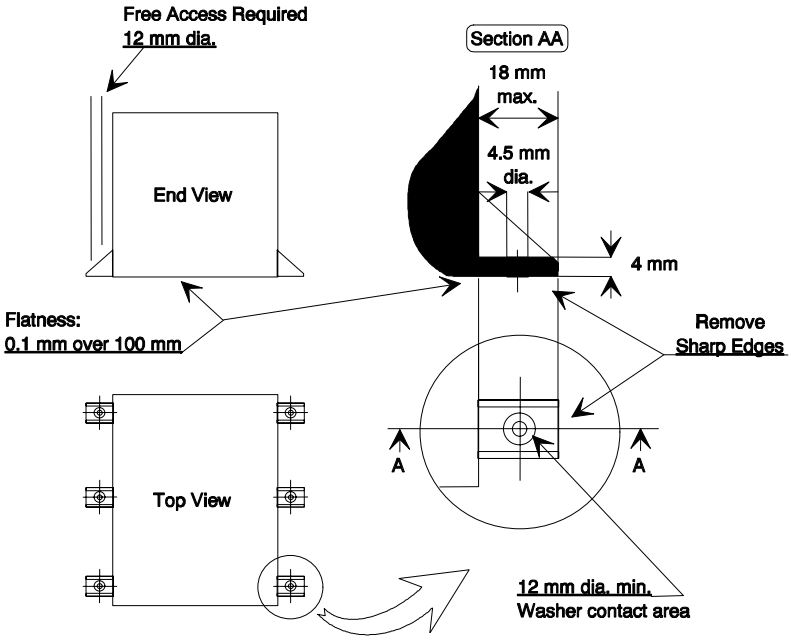


5.1.2. Functional requirements

Attachment points provide controlled contact between the unit and the structure for the purpose of mechanical, thermal control and electrical bonding of the unit.

5.1.3. Design requirements

DRCU REQ-126.: The attachment point shall be designed according to the following figure:



DRCU REQ-127.: If more than 4 attachment points are required the Project shall approve.

DRCU REQ-128.: For highly dissipative units the number and the location of attachment point shall be based on thermal consideration.

DRCU REQ-129.: One of the fixation holes shall be identified as the Reference Hole. The positive X-axis of the S/C shall be parallel and in the same orientation as far as reasonable.

DRCU REQ-130.: The distance between two adjacent attachment points shall be between 30 and 300 mm.

5.2. Thermal Interfaces

DRCU has thermal interface only with the S/C: the heat due to the unit power dissipation is exclusively evacuated by conduction to the payload structure through the box feet.

DRCU-REQ-131.: The unit power dissipation shall be limited by the value given in the AD4 §5.9.3.

Note: This unit power dissipation corresponds to the DRCU sub-unit dissipation summed with the PSU DC/DC converter loss.

5.3. Electrical interfaces

5.3.1. Interface with S/C

The DRCU interfaces with S/C only by means of a primary power interface including a '+28 V / return' couple and PSU synchronisation clock. This interface is doubled, each set of lines being connected to one of the two DRCU PSU (1 main + 1 redundant).

5.3.2. Interface with DPU

The DRCU interfaces with the DPU by means of 3 high-speed data interfaces and 3 low-speed command lines for direct data/command transfer between the DPU and the 3 DRCU sub-units.
The sub-units will transfer scientific raw data and housekeeping parameters via the high-speed data interface at a unique (predefined by a low level command) rate.

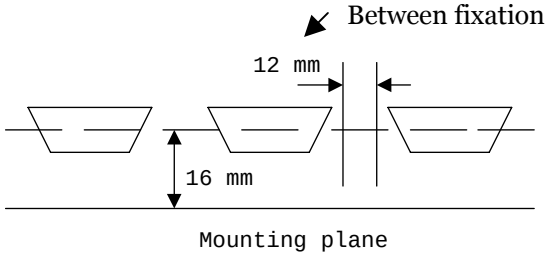
5.3.3. Interfaces with FPU

All the DRCU sub-units have interfaces with the FPU. Interfaces between the FPU and the DRCU are exclusively analogue and are typically: sensors biases, actuator power, and sensors signals. Each analogue interface is specific of the considered sub-system: its description is given in the respective "Subsystem Specification" documents.

5.3.4. Requirements

DRCU-REQ-132.: External connectors shall be DxMA type with crimp able pins. All other connecting type shall be considered carefully to prevent soldering defect assuming vibration environment.

DRCU REQ-133.: The minimum distance between shall be compliant with AD03 §5.10.1.3 has shown bellow.



DRCU REQ-134.: The housing of connectors shall be electrically connected to the unit structure.

DRCU REQ-135.: All connectors supplying power shall have socket contacts.

DRCU REQ-136.: Savers shall protect flight quality connectors.

DRCU REQ-137.: Connectors shall be mechanically connected to prevent inadvertent disconnection.

DRCU REQ-138.: Separate connectors shall be used for each of the redundant system or S/S.

DRCU REQ-139.: If different EMC class are allocated to the same connector, they shall be physically separated as much as possible within the connector.

5.3.4.1. Definition of EMC class

Class	Signal Type
1	Primary/Secondary Power
2	Digitals Signals / High level analogue signals
3	Low level sensitive analogue signals
4	RF signals

5.3.4.2. Connectors Identification

DRCU-REQ-140.: The identifier of the connectors on the box shall be as shown bellow according to AD3 (§5.1.3) and the corresponding label shall be located closely adjacent to the appropriate connector.

- HSDCU_Jxx for the DCU box connectors
- HSFCU_Jxx for the FCU box connectors

5.3.4.3. Connector definition

DRCU-REQ-140b.: Connector types and pin-outs shall be compliant with AD16. A full description of the DRCU electrical shall be in the DRCU ICD (AD5).

6. EMC Requirements

DRCU REQ-141.: The DRCU shall cope with the EMC requirements stated in AD3.

7. Environmental Requirements

DRCU REQ-142.: The unit shall operate with the temperatures illustrated here below:

Operating		Start-up	Switch-off	Non-Operating	
min.	max.			min.	max.
-15° C	+45° C	-30° C	+50°C	-35° C	+60° C

DRCU REQ-143.: The DRCU shall cope with the environmental requirements stated in AD3.

DRCU REQ-144.: The DRCU shall cope with the radiation environment described in AD12.

8. Reliability

DRCU REQ-145.: The reliability of the DRCU shall be equal to or greater than ***TBD*** for a period of 5 years.

DRCU REQ-146.: The method for reliability calculations shall comply with AD9.

9. Design and Construction

DRCU REQ-147.: All processes, materials and parts shall comply with AD6 and AD7 applicable documents.

DRCU REQ-148.: Electronics design shall comply with AD8.

10. Identification and Labelling

DRCU REQ-149.: The name and the model shall be indicated on each box. The label shall be easily readable even when harnesses are connected on the unit. In addition the enclosures shall indicate in an unambiguous way the name of each module.
Additionally a module shall be serialized and the serial number shall be visible even when the module is plugged into the enclosure.

11. Product Tree

DRCU REQ-150.: All the elementary components of the DRCU shall be identified in compliance with the DRCU Product Tree as shown by figure 11-a and describe in AD14.

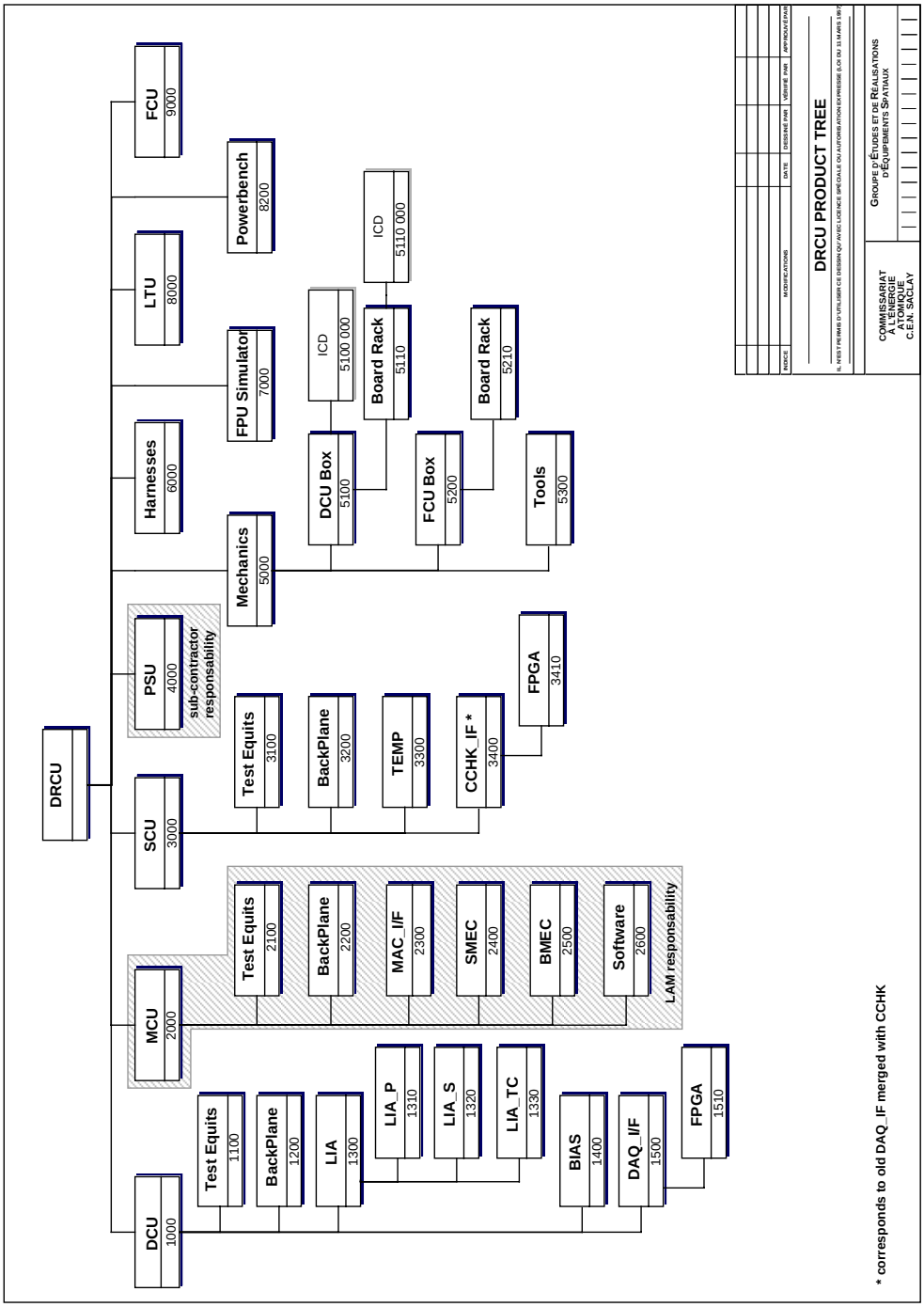


Figure 11-a DRCU Product Tree

12. Model characteristics and definition

According to AD15 the various model characteristics are listed bellow:

Model	Box(es)	DCU	MCU	SCU	PSU	Part Grade	Perf.
QM1	Pro -	Feq * NR	Feq * NR	Feq * NR	Ext	Com/Ind	NNP
QM2	Feq -	FEq RE	FEq RE	FEq RE	Ext	FEq	NNP
PFM	F -	F RE	F RE	F RE	F	F	NoP
FS	F ?	F ?	F ?	F ?	F ?	F	NoP

Ext : External (Power Supply only)
Pro : Prototype
FEq : Flight Equivalent (any grade but nominal size, consumption and performances)
F : Flight
NR : Cold Redundancy Not implemented
RE : Cold Redundancy implemented
DeP : Degraded Performance acceptable
NNP : Near Nominal Performance
NoP : Nominal Performance
(*) : The number of readout channels implemented shall at least correspond to the number of detectors of the instrument CQM (photometer and spectrometer).

Model	FCU								DCU			
	MCU				SCU			PSU				
	MAC	SMEC	BSM	BP	CCHK_IF	TEMP	BP		LIA_S	LIA_P	DAQ_IF	BP
QM1	1	1	1/2*	1	1	1	1	-	1	1	1	1
QM2	2	2	1	1	2	2	1	-	3	9	2	1
PFM	2	2	1	1	2	2	1	1	3	9	2	1
FS	2**	2**	1**	1**	1	1	1	1	1	2	1	1

* Board partially equipped
**for information (not under CEA responsibility)

13. Precedence

DRCU REQ-151.: The requirements concerning the Failure Detection and Failure Isolation capabilities shall have precedence on any other requirement.

14. Unit Requirement Verification

DRCU REQ-152.: The requirements of this specification shall be verified by inspection (I) or analysis (A) or test (T) or by a combination thereof as shown by the following matrix.

Requirement	Analysis	Test	Inspection
DRCU REQ-01			x
DRCU REQ-02		x	
DRCU REQ-03		x	
DRCU REQ-04	Na	Na	Na
DRCU REQ-05	Na	Na	Na
DRCU REQ-06	Na	Na	Na
DRCU REQ-07			x
DRCU REQ-08			x
DRCU REQ-10		x	
DRCU REQ-11		x	
DRCU REQ-12	Na	Na	Na
DRCU REQ-13	Na	Na	Na
DRCU REQ-14	Na	Na	Na
DRCU REQ-15			x
DRCU REQ-16			x
DRCU REQ-17			x
DRCU REQ-18		x	
DRCU REQ-19		x	
DRCU REQ-20			x
DRCU REQ-21		x	
DRCU REQ-22		x	
DRCU REQ-23		x (electrical)	x (mechanical)
DRCU REQ-24		x (electrical)	x (mechanical)
DRCU REQ-25		x	
DRCU REQ-26		x	
DRCU REQ-27			x
DRCU REQ-28			x
DRCU REQ-29		x	
DRCU REQ-30		x	
DRCU REQ-30b		x	
DRCU REQ-31		x	
DRCU REQ-32		x	
DRCU REQ-33		x	
DRCU REQ-34		x	
DRCU REQ-35		x	
DRCU REQ-36		x	
DRCU REQ-37		x	
DRCU REQ-38		x	
DRCU REQ-39		x	
DRCU REQ-40		x	
DRCU REQ-41			x
DRCU REQ-42			x
DRCU REQ-43		x	

Requirement	Analysis	Test	Inspection
DRCU REQ-44		x	
DRCU REQ-45		x	
DRCU REQ-46		x	
DRCU REQ-47		x	
DRCU REQ-48		x	
DRCU REQ-49		x	
DRCU REQ-50			x
DRCU REQ-51			x
DRCU REQ-52		x	
DRCU REQ-53		x	
DRCU REQ-54		x	
DRCU REQ-55		x	
DRCU REQ-56		x	
DRCU REQ-57		x	
DRCU REQ-58			x
DRCU REQ-59			x
DRCU REQ-60		x	
DRCU REQ-61		x	
DRCU REQ-62		x	
DRCU REQ-63		x	
DRCU REQ-64			x
DRCU REQ-65		x	
DRCU REQ-66		x	
DRCU REQ-67		x	
DRCU REQ-68		x	
DRCU REQ-69		x	
DRCU REQ-70		x	
DRCU REQ-71		x	
DRCU REQ-72		x	
DRCU REQ-73		x	
DRCU REQ-74		x	
DRCU REQ-75		x	
DRCU REQ-76		x	
DRCU REQ-77		x	
DRCU REQ-78		x	
DRCU REQ-79		x	
DRCU REQ-80		x	
DRCU REQ-81			x
DRCU REQ-82			x
DRCU REQ-83		x	
DRCU REQ-84		x	
DRCU REQ-85	x	x	
DRCU REQ-86	x	x	
DRCU REQ-87		x	
DRCU REQ-88		x	
DRCU REQ-89		x	
DRCU REQ-90		x	
DRCU REQ-91		x	
DRCU REQ-92		x	
DRCU REQ-93		x	

Requirement	Analysis	Test	Inspection
DRCU REQ-94			x
DRCU REQ-95			x
DRCU REQ-96		x	
DRCU REQ-97		x	
DRCU REQ-98		x	
DRCU REQ-99		x	
DRCU REQ-100		x	
DRCU REQ-101		x	
DRCU REQ-102		x	
DRCU REQ-102b	x		
DRCU REQ-103	x		
DRCU REQ-104	x		
DRCU REQ-105	x		
DRCU REQ-106	x		
DRCU REQ-107		x	
DRCU REQ-108	x		
DRCU REQ-109	x		
DRCU REQ-110		x	x
DRCU REQ-111	x		
DRCU REQ-112		x	
DRCU REQ-113		x	
DRCU REQ-114		x	
DRCU REQ-115	x		
DRCU REQ-116		x	
DRCU REQ-117		x	
DRCU REQ-118		x	
DRCU REQ-119		x	
DRCU REQ-120		x	
DRCU REQ-120b		X	
DRCU REQ-121		x	
DRCU REQ-122	x (FMECA)		
DRCU REQ-122b	x (FMECA)		
DRCU REQ-123	x (FMECA)		
DRCU REQ-124	x (FMECA)		
DRCU REQ-125	x (FMECA)		
DRCU REQ-126			x
DRCU REQ-127	x		
DRCU REQ-128	x		
DRCU REQ-129			x
DRCU REQ-130			x
DRCU REQ-131		x	
DRCU REQ-132			x
DRCU REQ-133			x
DRCU REQ-134		x	
DRCU REQ-135			x
DRCU REQ-136			x
DRCU REQ-137			x
DRCU REQ-138			x
DRCU REQ-139			x
DRCU REQ-140			x

Requirement	Analysis	Test	Inspection
DRCU REQ-140b			x
DRCU REQ-141		x	
DRCU REQ-142		x	
DRCU REQ-143		x	
DRCU REQ-144	x		
DRCU REQ-145	x (FMECA)		
DRCU REQ-146			x
DRCU REQ-147			x
DRCU REQ-148			x
DRCU REQ-149			x
DRCU REQ-150			x
DRCU REQ-151	x		

15. Traceability Matrix versus System Requirements [AD1]

Instrument Level Requirements	DRCU requirement
2.1.4.8 mission lifetime	DRCU REQ-145
2.1.4.9 radiation environment	DRCU REQ-144
IRD-MODE-R01 operating mode	DRCU REQ-115
IRD-CMD-R05 control of individual devices IRD-CMD-R06 set the state of a device (rather than toggle)	DRCU REQ-18 DRCU REQ-21 DRCU REQ-22 DRCU REQ-65 DRCU REQ-67 DRCU REQ-71 DRCU REQ-72
IRD-CMD-R07 command (affecting devices) verification	DRCU REQ-30 DRCU REQ-53 DRCU REQ-83
IRD-TLM-R07 science data packet in obs. mode	DRCU REQ-121
IRD-INST-R14 instrument models	See AD15
IRD-SAFE-R04 housekeeping telemetry generation	DRCU REQ-121
IRD-SAFE-R06 subsystem damage	DRCU REQ-122b
IRD-SAFE-R08 failure propagation	DRCU REQ-123 DRCU REQ-124
IRD-SAFE-R09 failure propagation to redundant	DRCU REQ-125
IRD-REL-R01 failure of a subsystem IRD-REL-R03 cold redundant hardware	DRCU REQ-17 DRCU REQ-23 DRCU REQ-24 DRCU REQ-47 DRCU REQ-55 DRCU REQ-56 DRCU REQ-66 DRCU REQ-70 DRCU REQ-73 DRCU REQ-75 DRCU REQ-99
IRD-EMC-R01 comply with Ins. Grounding Philo (AD17)	See AD5
IRD-SUBS-R01 environmental tests at subsystem level	See AD15
IRD-WE-R02 command reception & execution	DCU-FUNC-06 MCU-FUNC-10 SCU-FUNC-08
IRD-WE-R03 telemetry data generation	DCU-FUNC-10 MCU-FUNC-14 SCU-FUNC-12
IRD-WE-R04 housekeeping data generation	DCU-FUNC-9 MCU-FUNC-13 SCU-FUNC-11
IRD-WE-R05 operating modes	DRCU REQ-121
IRD-WE-08 photometer detector readout IRD-WE-09	DRCU REQ-15 DRCU REQ-30 DRCU REQ-31 DRCU REQ-32 DRCU REQ-33 DRCU REQ-38

	DRCU REQ-39
IRD-WE-R13 PCAL control IRD-WE-R14 SCAL control	DRCU REQ-66 DRCU REQ-67
IRD-WE-R24 WE anomalies IRD-WE-R25 subsystem anomalies	DRCU REQ-122
IRD-WE-R27 minimise likelihood of failure	See §4.9.3
IRD-WE-R28 life time	DRCU REQ-145
IRD-WE-R29 short circuit / unplugging	---
IRD-WE-R30 failure propagation to S/C	DRCU REQ-30 DRCU REQ-53 DRCU REQ-83 DRCU REQ-101
IRD-WE-R31 failure from S/C	---
IRD-WE-R32 failure propagation	Verified by AMDEC
IRD-WE-R33 mass allocation	DRCU REQ-2 DRCU REQ-3
IRD-WE-R34 volume allocation	DRCU REQ-7 DRCU REQ-8
IRD-VE-R35 power allocation	DRCU REQ-10 DRCU REQ-11