SPIRE INSTRUMENT

DETECTOR READOUT & CONTROL UNIT

SUBSYSTEM SPECIFICATION

	Name and Function	Date	Signature
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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
0.8		

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List of Acronyms

ADC	Analog to Digital Converter
AMUX	Analog Multiplexer
BSM	Beam Steering Mirror
DPU	Data Processing Unit
DCE	Detector Control Electronics
DCU	Detector Control Unit
DMUX	Digital Multiplexer
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
SMEC	Spectrometer Mechanism Control
SCE	Sub-system Control Electronics
SCU	Sub-system Control Unit
PSU	Power Supply Unit
SMPS	Switching Mode Power Supply
SNR	Signal over Noise Ratio
S/W	Software
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
WIH	Warm Interconnect Harnesses

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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/N/0034	
AD3	FIRST/PLANCK Instrument Interface Document Part A	PT-IID-A-04624	
AD4	FIRST/PLANCK Instrument Interface Document Part B / Instrument SPIRE	SCI-PT-IIDB/SPIRE-02124	2.0 / 31/07/01
AD5	DRCU Interface Control Document	SAp-SPIRE-CCa-25-00	
AD6	Component Selection, procurement, & Control for ESA Spacecraft & Associated Equipment.	PSS-01-60	
AD7	Material & Process Selection & Quality Control for ESA Spacecraft & Associated Equipment.	PSS-01-70	
AD8	De-rating Requirements & Application Rules for Electronic Components.		
AD9	Reliability Prediction for Electronic Equipment	MIL-HDBK-217	
AD10	SPIRE Instrument Command	SPIRE-RAL-DOC-000	
AD11	DPU Interface Control Document	SPIRE-IFS-PRJ-650	1.0 / 02/04/01
AD12	FIRST L-2 Radiation Environment	FT-04040	
AD18	Spectrometer Mirror Mechanism subsystem specifications	LAM-PJT-SPI-NOT-200002	
AD19	Beam Steering Mirror subsystem specification		0.8 / 12/10/01
AD20	Engineering Change Request	HR-SP-RAL-ECR-023	23/11/2001

1.4. Reference Documents

RD1	Operating Modes for the SPIRE Instrument	SPIRE-RAL-DOC-768	0.1 / 24/07/01
RD2	Detector Subsystem Specifications	SPIRE-JPL-PRJ-456	3.0 / 06/09/01
RD3	FTS Subsystem Specifications		
RD4	BSM Subsystem Specifications		
RD5	Sorption Cooler Drive Electronics Specifications	HSO-SBT-SP-015	0.1 / 15/10/01
RD6	DPU Subsystem Specifications		
RD7	Calibrators Electrical Interface Requirements	SPIRE-QMW-PRJ-649	1.1 / 10/04/01

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 a multi-outputs SMPS DC/DC converter

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 distributing and interrupting to all the sub-systems the secondary power supply lines generated by the PSU. In addition the PSU secondary line voltages are monitored 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)
- the EGSE (for shutter ground test only)

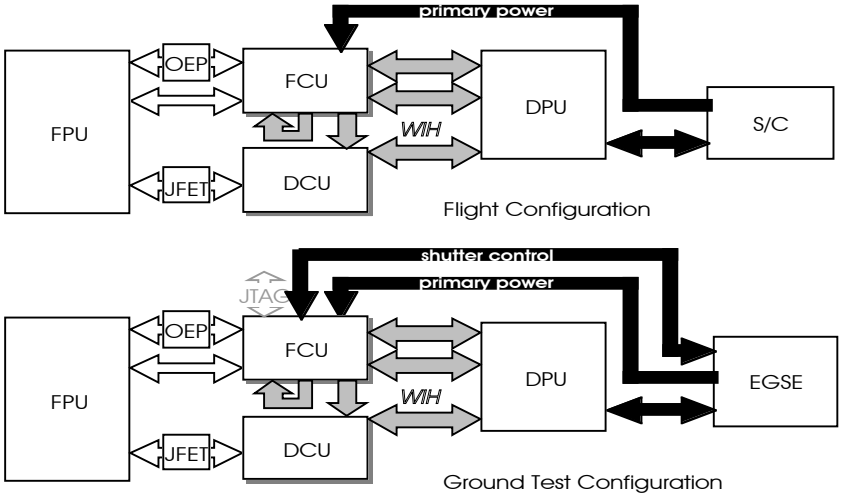


Figure 2.1-a

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.

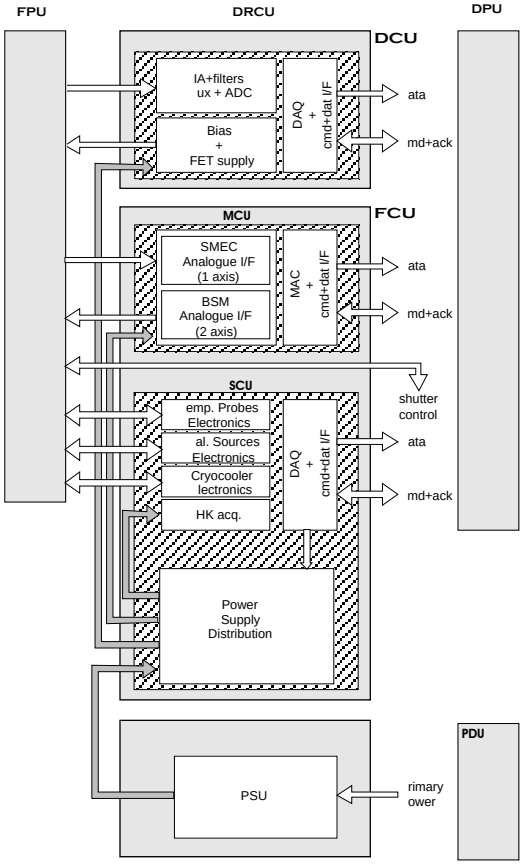


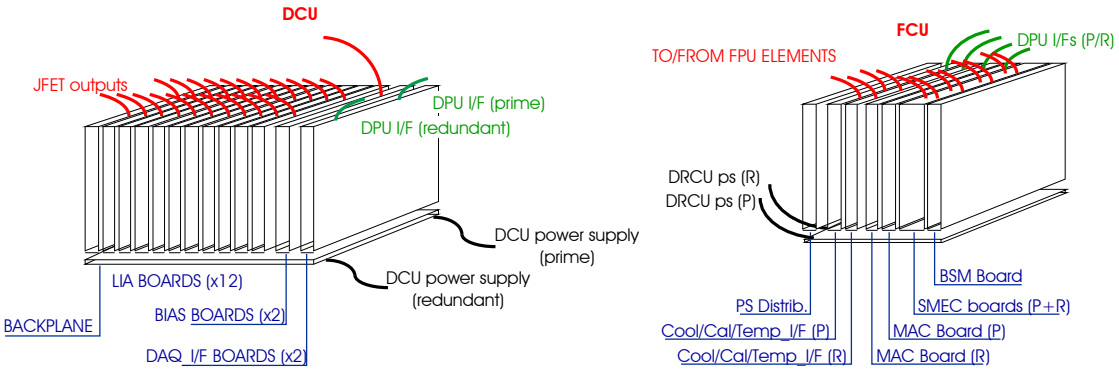
Figure 2.2-a - DRCU block diagram

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 to 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 connections. Since no electrical interface is foreseen, except for secondary power distribution, between the various sub-unit 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 distribution module (part of the SCU) achieve secondary power routing to the DCU and the MCU.
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). 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: i.e. for the distribution board. The geometry allows placement of SMD parts on the both sides of the board.

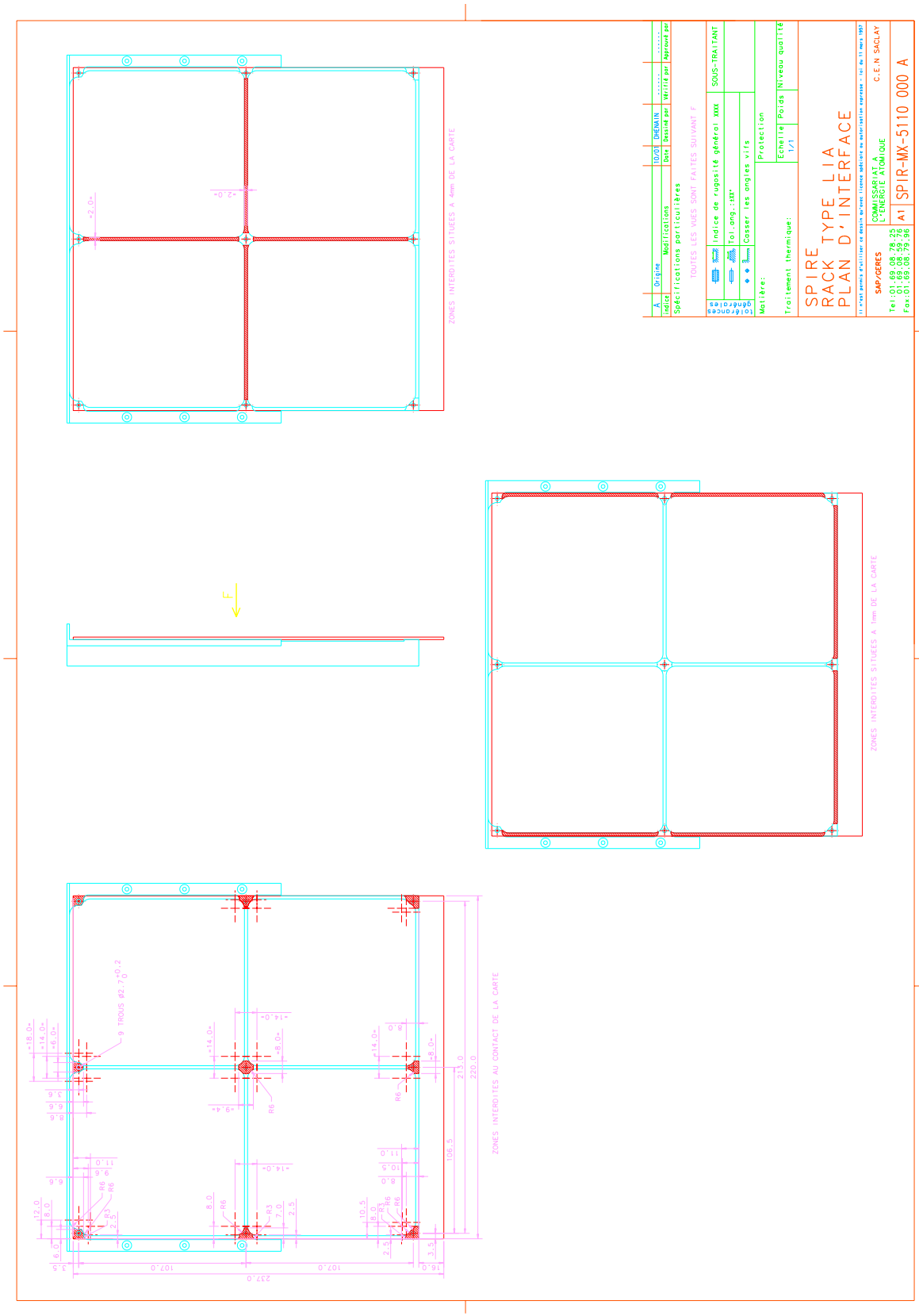


Figure 3.2-a Board Common Geometry Overview

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 23 kg as specified by AD4 (current issue).

3.2.1.1. DCU

DRCU REQ-2.: The DCU mass shall be compliant with the value given in the DRCU ICD (AD5), which is of 15.41 kg.

3.2.1.2. FCU

DRCU REQ-3.: The DCU mass shall be compliant with the value given in the DRCU ICD (AD5), which is of 14.28 kg

DRCU REQ-4.:
DRCU REQ-5.:
DRCU REQ-6.:

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 the DRCU ICD as reminded below:

- 494 (xxx) mm x 289 mm (footprint)
- 305 (352.5) mm (height)

3.2.2.2. FCU

DRCU REQ-8.: The envelope of the FCU sub-unit shall be within : hhh x lll x ppp – see AD14 for details

- 334 (xxx) mm x 329 mm (footprint)
- 330.5 (377.9) mm (height)

3.3. Power Budget Allocation

3.3.1. DRCU

DRCU REQ-9.: The DRCU total power consumption on the 28V bus shall be compliant with the power budget of 71.3 W as specified by AD4 (current issue).

3.3.2. DCU

DRCU REQ-10.: The DCU maximum power dissipation shall be compliant with the value given in the DRCU ICD (AD5), which is of 40.57 W

3.3.3. FCU

DRCU REQ-11.: The DCU maximum power dissipation shall be compliant with the value given in the DRCU ICD (AD5), which is of 51.27 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 signal processing	DCU-FUNC-02
• the bolometer signal digitisation	DCU-FUNC-03
• the timing cycling	DCU-FUNC-04
• the JFET box biasing	DCU-FUNC-05
• the low level command decoding	DCU-FUNC-06
• the low level command acknowledge	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

Complete DCU specification is given in RD2.

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 measurement	MCU-FUNC-01
• the FTS mirror actuator powering	MCU-FUNC-02
• the FTS mirror position motion + speed control	MCU-FUNC-03
• the FTS mirror position digitisation	MCU-FUNC-04
• the FTS mirror actuator current digitisation	MCU-FUNC-05
• the BSM positions (2 axis) measurement	MCU-FUNC-06
• the BSM actuators (2 axis) powering	MCU-FUNC-07
• the BSM positions control	MCU-FUNC-08
• the BSM actuator current digitisation	MCU-FUNC-09
• the low level command decoding	MCU-FUNC-10
• the low level command acknowledge	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

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 black bodies,	SCU-FUNC-04
• to measure the calibrators temperature	SCU-FUNC-05

It also implements

• to measure cold instrument temperature channels,	SCU-FUNC-06
• to measure 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 housekeeping parameters,	SCU-FUNC-11
• to transfer the digitised data (data + hsk + relative timestamp)	SCU-FUNC-12
• to switch on/off sub-unit power supplies,	SCU-FUNC-13

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:

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

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	Channel Number	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	Channel Number	Origin
JFET bias	15	BDA-DRCU-06
JFET heater	2	BDA-DRCU-10

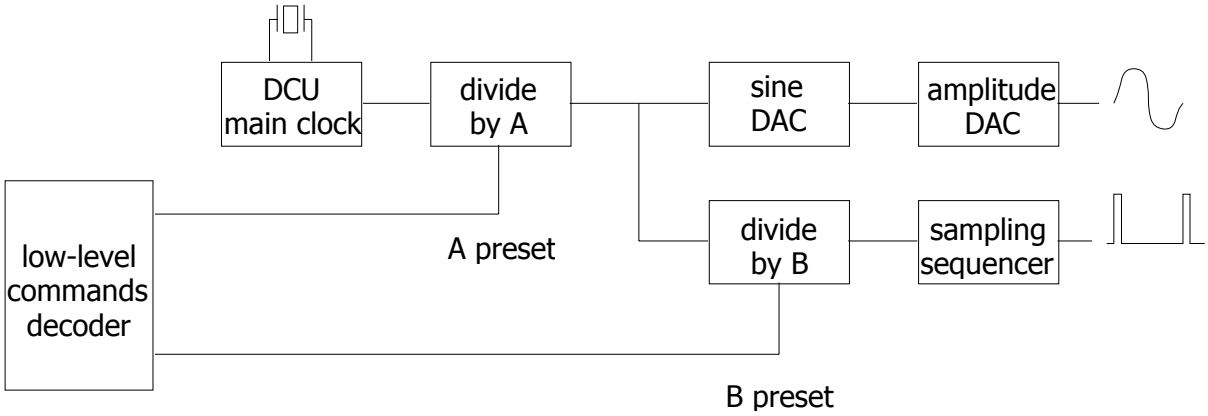
DRCU REQ-21.: Each JFET (both Vdd and Vss) power channel shall be individually commandable ON/OFF by means of low-level commands (BDA-DRCU-09).

DRCU REQ-22.: Each 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.

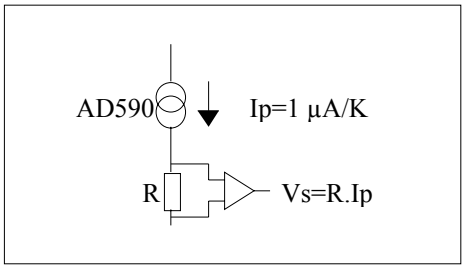


Figure 4.2.1.1.3-a Unit internal temperature monitoring

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	20-TBC	16-bit ADC + 4-bit offset
T/C_2	20-TBC	16-bit ADC + 4-bit offset
T/C_3	20-TBC	16-bit ADC + 4-bit offset
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
BIAS_BDA_4	8	Sp. Bolo. Bias 1 Amplitude
BIAS_BDA_5	8	Sp. Bolo. Bias 2 Amplitude
BIAS_TEMP_5	8	T/C Therm. 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_PWR_PLW_1	8	
JFET_PWR_PLW_2	8	
JFET_PWR_PMW_1	8	
JFET_PWR_PMW_2	8	
JFET_PWR_PMW_3	8	
JFET_PWR_PMW_4	8	
JFET_PWR_PSW_1	8	

JFET_PWR_PSW_2	8	
JFET_PWR_PSW_3	8	
JFET_PWR_PSW_4	8	
JFET_PWR_PSW_5	8	
JFET_PWR_PSW_6	8	
JFET_PWR_SLW_1	8	
JFET_PWR_SSW_1	8	
JFET_PWR_SSW_2	8	
HTR_PWR_1	8	
HTR_PWR_2	8	
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

4.2.3. Performance Requirements

DRCU REQ-31.: The analogue module shall have the following characteristics:

Signal AC amplitude	≤ 11 mVrms ≤ 17 mVrms ≤ Vbias	Photometer Spectrometer Functional	BDA-DRCU-22
Signal DC level	≤ 5 mV	JFET V_{OSmax}	
AC gain	375 ± 0.5 % 265 ± 0.5 %	for photometer for spectrometer	
Common mode offset	≤ 1 V	DC	
Noise allocation	< 7 nVrms/rt(Hz)	0.05 to 25 Hz[1]	BDA-DRCU-01 BDA-DRCU-18
Input capacitance	< 100 pF		BDA-DRCU-03
Input impedance	> 1 MΩ		BDA-DRCU-04
Base band signal bandwidth (Hz)	DC to 5 ± 1% DC to 25 ± 1 % DC to 5 ± 1%	Photometer Spectrometer Thermometry	BDA-DRCU-13 BDA-DRCU-14
Pre PSD BPF bandwidth			
Post PSD LPF order	4 (Bessel type) 6 (Bessel type)	Photometer Spectrometer	HR-SP-RAL-ECR-001
Common mode rejection	- 60 dB	50–300 Hz	BDA-DRCU-11

Channel cross talk	≤ 0.05%		BDA-DRCU-25
Interface Type	balanced signal + shield		

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

DRCU REQ-32.: Noise performance shall be maintained under a warm electronics thermal drift of 1 K / hour.

DRCU REQ-33.: The Bias module shall provide sine bolometer bias according to the following tables:

• photometer BDA bias channels

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

• spectrometer BDA bias channels

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

• temperature readout bias channels

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

Rbolo+Cwire values are required to define test set-up

DRCU REQ-34.: Each DC JFET bias channel shall have the following performances:

Interface Type	shielded twisted pair		
Bias Type	DC		
Nominal Voltage	-5v ≤ Vss ≤ 0v	in 256 steps	BDA-DRCU-06

	1.5v ≤ Vdd ≤ 4v	adjustable by design	BDA-DRCU-07
Current range	1 mA to5 mA		BDA-DRCU-08
Voltage Noise	Vn < 1 µV/√Hz[1] Vn < 0.3 µV/√Hz[1]	for Vss for Vdd	
Voltage Stability		parameter needed asap	
Load impedance	R + C	xx Ω // < 1 nF	

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

Load impedance: must be specified (especially C) in order to characterize on/off transcients.

DRCU REQ-35.: When switching on the JFET biases, the DCU shall not generate any overshoot.

DRCU REQ-36.: 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-37.: 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		
Input signal AC	≤ 0.7 V ≤ 1.0 V	for photometer for spectrometer	

DRCU REQ-38.: The DAQ_I/F module shall support the following data frames:

- Photo. Array Subset (P-LW, P-MW, P-SW)
- Spectro. Array Subset (S-LW, S-SW)
- 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-39.: Both DCU data and command interfaces shall be compliant with AD11.

4.2.4.2. Mechanical Interfaces

DRCU REQ-40.: The DCU electronics shall be implemented into 16 DRCU boards (220 x 237 mm PCB) as described §3.1.2. Total allocated volume is then 237 x 220 (TBC) x 440.

DRCU REQ-41.: The back plane of the DCU shall be 220 x … mm as show bellow:

4.2.4.3. Power supplies

DRCU REQ-42.: The DCU electronics shall operate with the following set of supplies:

Module	Supply name	Supply voltage	Max. current	Min. current
LIA_P	DCU_LIA_P_A_P9 DCU_LIA_P_A_N9 DCU_LIA_P_D_P5	+9 V -9 V +5.2 V	1.90 A 1.90 A 0.65 A	
LIA_S	DCU_LIA_S_A_P9 DCU_LIA_S_A_N9 DCU_LIA_S_D_P5	+9 V -9 V +5.2 V	0.64 A 0.63 A 0.22 A	
BIAS_P	DCU_BIA_P_P9 DCU_BIA_P_N9	+9 V -9 V	0.36 A 0.36 A	
BIAS_S	DCU_BIA_S_P9 DCU_BIA_S_N9	+9 V -9 V		
DAQ_I/F	DCU_DAQ_P9 DCU_DAQ_N9 DCU_DAQ_P5	+9 V -9 V + 5.2V	0.06 A 0.06 A 0.53 A	

DRCU REQ-43.: When powered inrush current shall be limited by the DCU according to the following limits:

DRCU REQ-44.: The DCU shall provide proper supply line filtering to restrict the conducted emissivity as specified bellow:

4.2.5. Block Diagram

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

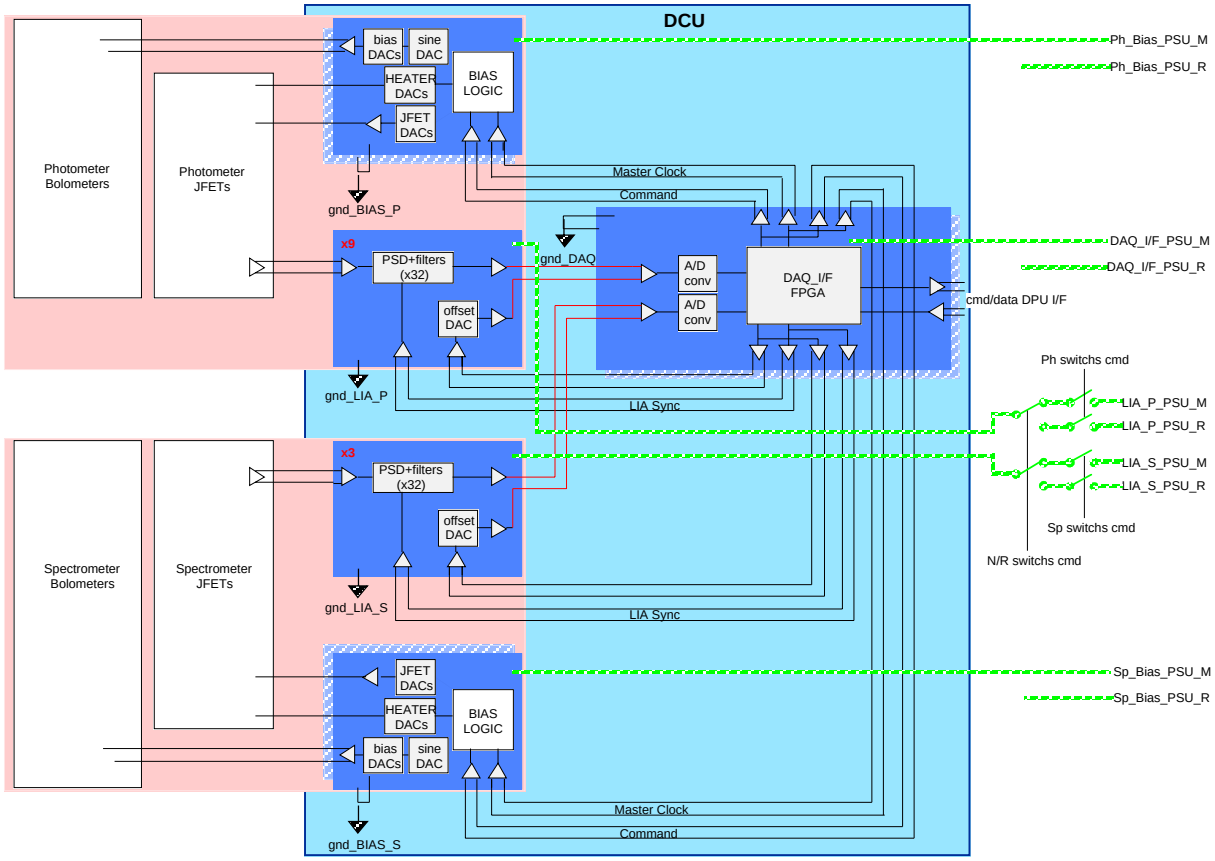


Figure 4.2.1.5-a - DCU block diagram

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 a power amplifier to drive the mirror, sensors (position, current) amplifier, …
All high level the input or output analogue signals are connected to the converters (A to D and D to A) of the Mac Module.

4.3.2. Functional Performances

DRCU REQ-45.: Both data and command interfaces shall be compliant with AD11.

DRCU REQ-46.: The MCU shall implement two electrically independent MAC Modules (1 prime + 1 redundant).

DRCU REQ-47.: The MCU shall transfer the following data formats:

- Spectrometer,
- Steering Mirror,
- Trace.

DRCU REQ-48.: 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-49.: 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-50.: Temperature measurement shall be done using an AD590 probe in F02 package glued on the printed circuit board.

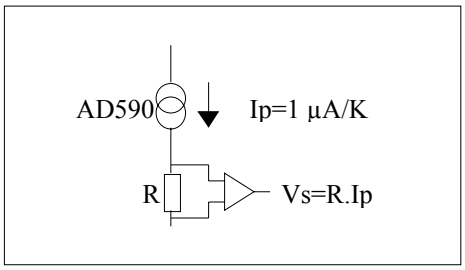


Figure 4.2.1.1.3-a Unit internal temperature monitoring

DRCU REQ-51.: The temperature measurement shall have the following performances:

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

DRCU REQ-52.: 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	"	
VP_MCU_DIG	"	
VP_MCU_ANA	"	
VN_MCU_ANA	"	
VP_MCU_DRV	"	
VN_MCU_DRV	"	

DRCU REQ-53.: The analogue channels (for sub-systems supply voltage reporting) shall have the following characteristics:

Voltage channels number	3
Voltage resolution	1 %

DRCU REQ-54.: 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-55.: 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

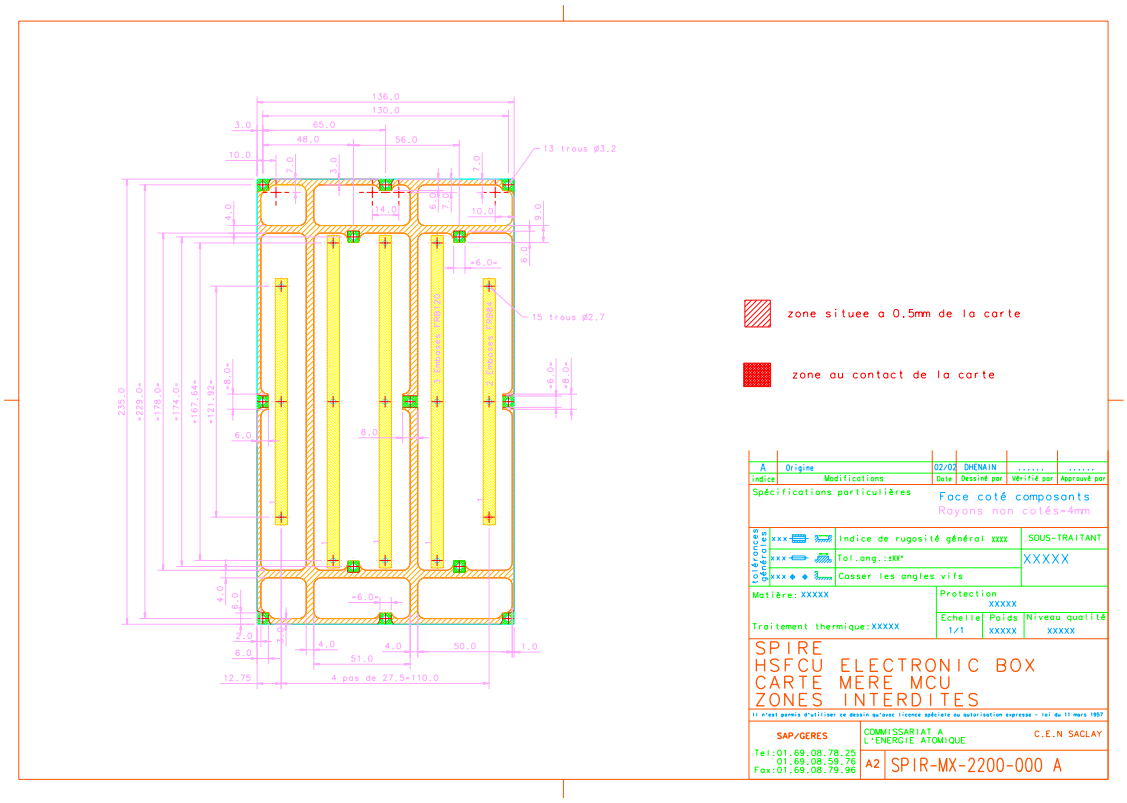
4.3.4.1. Electrical Interfaces

DRCU REQ-56.: The data packet transmitted to the DPU shall be compliant with definition given in AD11 (ICD).

4.3.4.2. Mechanical Interfaces

DRCU REQ-57.: 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 (TBC) x 137.5 (dimensions in millimetres).

DRCU REQ-58.: The back plane of the MCU shall be 235 x 136 mm as show bellow:



4.3.4.3. Power supplies

DRCU REQ-59.: The MCU electronics shall operate with the following set of supplies and the associated maximum average currents:

Module	Supply name	Supply voltage	Max current	Min. current
MAC	MCU_DIG_P5	5 V	2.97 A (peak only)	1.76 A
MAC / SMEC	MCU_ANA_P13 MCU_ANA_N13	+13 V - 13 V	0.18 A 0.16 A	
SMEC / BSM	MCU_DRV_P15 MCU_DRV_N15	+15 V -15 V	0.11 A 0.11 A	0.01 A 0.01 A

DRCU REQ-60.: When powered inrush current shall be limited by the MCU according to the following limits:

DRCU REQ-61.: The MCU shall provide proper supply line filtering to restrict the conducted emissivity as specified bellow:

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)

DRCU REQ-62.: The distribution module shall be able to break independently the following group of secondary power lines:

Group Name	Supply Line list	Corresponding Functions
DCU_LIA_P		Photometer analogue electronics
DCU_LIA_S		Spectrometer analogue electronics
DCU_BIAS_P		Photometer bias
DCU_BIAS_S		Spectrometer bias

4.4.2. Functional Requirements

DRCU REQ-63.: 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	17	Prime channels
	17	Redundant channels
Interface type	4-wire shield	None connected to ground except shield

Table 4.2.3.1-a Thermometry channels summary

DRCU REQ-64.: Biases shall be individually and by a low level command switched off.

DRCU REQ-65.: The SCU shall have two independent photometer calibrator interfaces and associated electronics: 1 for the main configuration + 1 for the redundant configuration (IRD-CALP-R15).

DRCU REQ-66.: Bias current shall be controlled by a low-level command.

DRCU REQ-67.: Both voltage and current of the photometer/spectrometer calibrators shall be monitored by the SCU and transmitted to the DPU after digitisation.

DRCU REQ-68.: 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-69.: The SCU shall have two independent cooler heaters interfaces and associated electronics: 1 for the main configuration + 1 for the redundant configuration.

DRCU REQ-70.: Cryo-cooler heaters currents shall be selectable with a resolution of 1/4096 except for the thermal strap heater w.r.t. the maximum power by independent low-level commands.

DRCU REQ-71.: Thermal strap heaters power shall be selectable with a resolution of 1/256 w.r.t. the maximum power by an independent low-level command.

DRCU REQ-72.: The SCU shall include the necessary functions to drive PSU primary power switching:

Driver number	4
Driver voltage	CMOS level
Driver current	-
Signal type	Level sensitive: 0 = off 1 = on

DRCU REQ-73.: Distribution module relays status shall be configurable by means of SCU low-level commands except for nominal / redundant switching.

DRCU REQ-74.: The SCU shall implement two electrically independent DPU Interface modules (1 main + 1 redundant).

DRCU REQ-75.: The Interface Module shall transfer fixed size data blocks to the DPU via the fast data interface according to AD11.

DRCU REQ-76.: 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-77.: 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-78.: The interface module shall transfer the following data (22 words) within a single data format:

Parameter Name	Word size (bits)	Comments
T_PL0_1	16	
T_SOB_1	"	
T_SUB_1	"	
T_BAF_1	"	
T_FTS_1	"	
T_FTS_3	"	
T_SCAL_1	"	
T_SCST_1	"	
T_CPMP_1	"	
T_CEV_1	"	
T_CPHS_1	"	
T_CEHS_1	"	
T_CSHT_1	"	
T_BSM_1	"	
T_FTBS_1	"	
T_FTBP_1	"	
I_SCALP	"	
U_SCALP	"	
I_SCALS_P	"	
U_SCALS_P	"	
I_SCALS_F	"	
U_SCALS_F	"	

DRCU REQ-79.: 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-80.: Temperature measurement shall be done using an AD590 probe in F02 package glued on the printed circuit board.

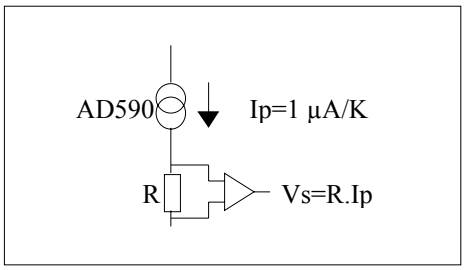


Figure 4.2.1.1.3-a Unit internal temperature monitoring

DRCU REQ-81.: The temperature measurement shall be compliant with the following table:

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

DRCU REQ-82.: The SCU shall report the following housekeeping parameters when requested by low-level commands:

Parameter Name	Word size (bits)	Comments
T_PL0_1	16	
T_SOB_1	"	
T_SUB_1	"	
T_BAF_1	"	
T_FTS_1	"	
T_FTS_3	"	
T_SCAL_1	"	
T_SCST_1	"	
T_CPMP_1	"	
T_CEV_1	"	
T_CPHS_1	"	
T_CEHS_1	"	
T_CSHT_1	"	
T_BSM_1	"	
T_FTBS_1	"	
T_FTBP_1	"	
I_SCALP	"	
U_SCALP	"	
I_SCALS_P	"	
U_SCALS_P	"	
I_SCALS_F	"	
U_SCALS_F	"	
U_HSP	16	Voltage across heater pump heat switch
U_HSE	"	Voltage across evaporator heat switch
U_SPH	"	Voltage across sorption pump heater

Parameter Name	Word size (bits)	Comments
U_TS	"	Voltage across thermal strap heater
T_TEMP	8	Temperature module temperature
T_CCHK_IF	"	Cal/Cool/HK module temperature
T_PSU	"	PSU internal temp.
VP_SCU_DIG	"	
VP_SCU_ANA	"	
VN_SCU_ANA	"	

DRCU REQ-83.: The analogue channels (for sub-systems supply voltage reporting) shall have the following characteristics:

Voltage channels number	3
Voltage resolution	1 %

4.4.3. Performance Requirements

DRCU REQ-84.: The thermometry sub-system (main part) shall have the following channels according to AD20 except for cryo-cooler related temperature probes (text in blue) where RD05 is considered:

Unit	Location	Acronym	Sensor Type	Temperature Range	Resolution	Accuracy
HSFPU	PHOT Level 0 box	T_PL0_1	CX-1030	1 K -10 K	2 mK	2 mK
HSFPU	FPU SOB/BSM I/F	T_SOB_1	CX-1030	3 K - 300 K	10 mK	10 mK
HSFPU	Optical sub-bench	T_SUB_1	CX-1030	3 K-100 K	25 mK	25 mK
HSFPU	Input Baffle	T_BAF_1	CX-1030	3 K-100 K	10 mK	10 mK
HSFPU	SMEC Mechanism	T_FTS_1	CX-1030	3 K - 20 K	10 mK	10 mK
HSFPU	SMEC/SOB Interface	T_FTS_3	CX-1030	3 K - 100 K	25 mK	50 mK
HSFPU	SPEC Calibrator 4%	T_SCL4_1	CX-1030	10 K - 80 K	5 mK	5 mK
HSFPU	SPEC Calibrator 2%	T_SCL2_1	CX-1030	10 K - 80 K	5 mK	5 mK
HSFPU	SPEC Calibrator Structure	T_SCST_1	CX-1030	10 K - 100 K	10 mK	10 mK
HSFPU	Cooler Sorption Pump	T_CPMP_1	CX-1030	1.5 K - 50 K	0.5 K	1 K
HSFPU	Cooler Evaporator	T_CEV_1	CX-1030	0.25 K - 10 K	0.1 mK	5 mK
HSFPU	Cooler Pump heat switch	T_CPHS_1	CX-1030	1.5 K - 25 K	0.5 K	1 K
HSFPU	Cooler Evap. Heat switch	T_CEHS_1	CX-1030	1.5 K - 25 K	0.5 K	1 K
HSFPU	Cooler Shunt	T_CSHT_1	CX-1030	1.5 K 10 K	0.1 K	NA
HSFPU	BSM Mechanism	T_BSM_1	CX-1030	3 K - 20 K	10 mK	10 mK
~~HSJFS~~	~~SPEC JFET chassis~~	~~T_FTBS_1~~	~~CX-1030~~	~~3 K - 100 K~~	~~25mK~~	~~50 mK~~
~~HSJFP~~	~~PHOT JFET box~~	~~T_FTBP_1~~	~~CX-1030~~	~~3 K - 100 K~~	~~25 mK~~	~~50 mK~~
HSFPU	SPEC level 0 box	T_SL0_1	CX-1030	1K – 10 K	2 mK	2 mK

Table 4.2.3.1-b Detailed main thermometry channel list

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

DRCU REQ-85.: 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:

Unit	Location	Acronym	Sensor Type	Temperature Range	Resolution	Accuracy
HSFPU	PHOT Level 0 box	T_PL0_2	CX-1030	1 K -10 K	2 mK	2 mK
HSFPU	FPU SOB/BSM I/F	T_SOB_2	CX-1030	3 K - 300 K	10 mK	10 mK
HSFPU	Optical sub-bench	T_SUB_2	CX-1030	3 K-100 K	25 mK	25 mK
HSFPU	Input Baffle	T_BAF_2	CX-1030	3 K-100 K	10 mK	10 mK
HSFPU	SMEC Mechanism	T_FTS_2	CX-1030	3 K - 20 K	10 mK	10 mK
HSFPU	SMEC/SOB Interface	T_FTS_4	CX-1030	3 K - 100 K	25 mK	50 mK
HSFPU	SPEC Calibrator 4%	T_SCL4_2	CX-1030	10 K - 80 K	5 mK	5 mK
HSFPU	SPEC Calibrator 2%	T_SCL2_2	CX-1030	10 K - 80 K	5 mK	5 mK
HSFPU	SPEC Calibrator Structure	T_SCST_2	CX-1030	10 K - 100 K	10 mK	10 mK
HSFPU	Cooler Sorption Pump	T_CPMP_2	CX-1030	1.5 K - 50 K	0.5 K	1 K
HSFPU	Cooler Evaporator	T_CEV_2	CX-1030	0.25 K - 10 K	0.1 mK	5 mK
HSFPU	Cooler Pump heat switch	T_CPHS_2	CX-1030	1.5 K - 25 K	0.5 K	1 K
HSFPU	Cooler Evap. Heat switch	T_CEHS_2	CX-1030	1.5 K - 25 K	0.5 K	1 K
HSFPU	Cooler Shunt	T_CSHT_2	CX-1030	1.5 K 10 K	0.1 K	NA
HSFPU	BSM Mechanism	T_BSM_2	CX-1030	3 K - 20 K	10 mK	10 mK
~~HSJFS~~	~~SPEC JFET chassis~~	~~T_FTBS_2~~	~~CX-1030~~	~~3 K - 100 K~~	~~25mK~~	~~50 mK~~
~~HSJFP~~	~~PHOT JFET box~~	~~T_FTBP_2~~	~~CX-1030~~	~~3 K - 100 K~~	~~25 mK~~	~~50 mK~~
HSFPU	SPEC level 0 box	T_SL0_2	CX-1030	1K – 10 K	2 mK	2 mK

Table 4.3.2.1-c Detailed redundant thermometry channel list

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

DRCU REQ-86.: 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	20 mV

Table 4.3.2.1-d Probe maximum bias level

DRCU REQ-87.: The SCU shall provide PCAL bias current according to the following performances:

Heater Bias Current Range	0 to 7 mA	in 4096 steps	IRD-CALP-R12
Maximum dissipated power into heater	10 mW		
Heater Resistance Range	200 to 500 Ω	+60 Ω for lead resistance	
Stability / Repeatability	0.5 % or 5 µA	Whichever is greater	IRD-CALP-R05
Maximum drive voltage	4.0 V	Worst case	IRD-CALP-R14
Bias waveform	square	Spec. for DPU	
Waveform frequency	0 to 5 Hz	Spec. for DPU	IRD-CALP-R07

Waveform resolution	100 ms	Spec. for DPU	
Interface Type	4-wire	None connected to ground	

DRCU REQ-88.: The SCU shall provide SCAL biases according to the following performances:

Point source			
Heater Bias Current Range	0 to 7 mA	in 4096 steps	IRD-CALS-R09 IRD-CALS-R03
Maximum dissipated power into heater	10 mW		
Heater Resistance Range	200 to 500 Ω	+60 Ω for lead resistance	
Stability / Repeatability	0.5 % or 5 µA	Whichever is greater	IRD-CALS-R05
Maximum drive voltage	4.0 V	Worst case	IRD-CALS-R08
Bias waveform	DC		
Electrical Interface Type	4-wire + shield	None connected to ground	
Flood source			
Heater Bias Current Range	0 to 9 mA	in 4096 steps	IRD-CALS-R09 IRD-CALS-R03
Maximum dissipated power into heater	15 mW		
Bias waveform	DC		
Stability	0.5 % or 5 µA	Whichever is greater	IRD-CALS-R05
Heater Resistance Range	200 Ω	+60 Ω for lead resistance	
Maximum drive voltage	5.0 V		IRD-CALS-R08
Interface type	2-wire TBC	None connected to ground	

DRCU REQ-89.: The above stability and repeatability shall be achieve for operating time of 1 hour (typical observation duration) and assuming a S/C temperature drift of 3K/hour.

DRCU REQ-90.: The calibrator current shall be limited by hardware to 110% of specified maximum.

DRCU REQ-91.: The SCU shall provide cry-cooler heater biases according to the following performances:

Type	Number	Heater Resistance	Lead Resistance	Power	Max. Voltage	Interface type
Gas [1]	2	402 Ω	TBD	0 / 1 mW	15 V	4-wire
Charcoal pump[1]	1	402 Ω	TBD	0 to 500 mW	15 V	4-wire
Thermal strap[2]	1	3 kΩ	-	300 mV / 50 µA		

[1]: from BDA-DRCU-17 of RD2
[2]: from RD5

4.4.4. Interface Requirement

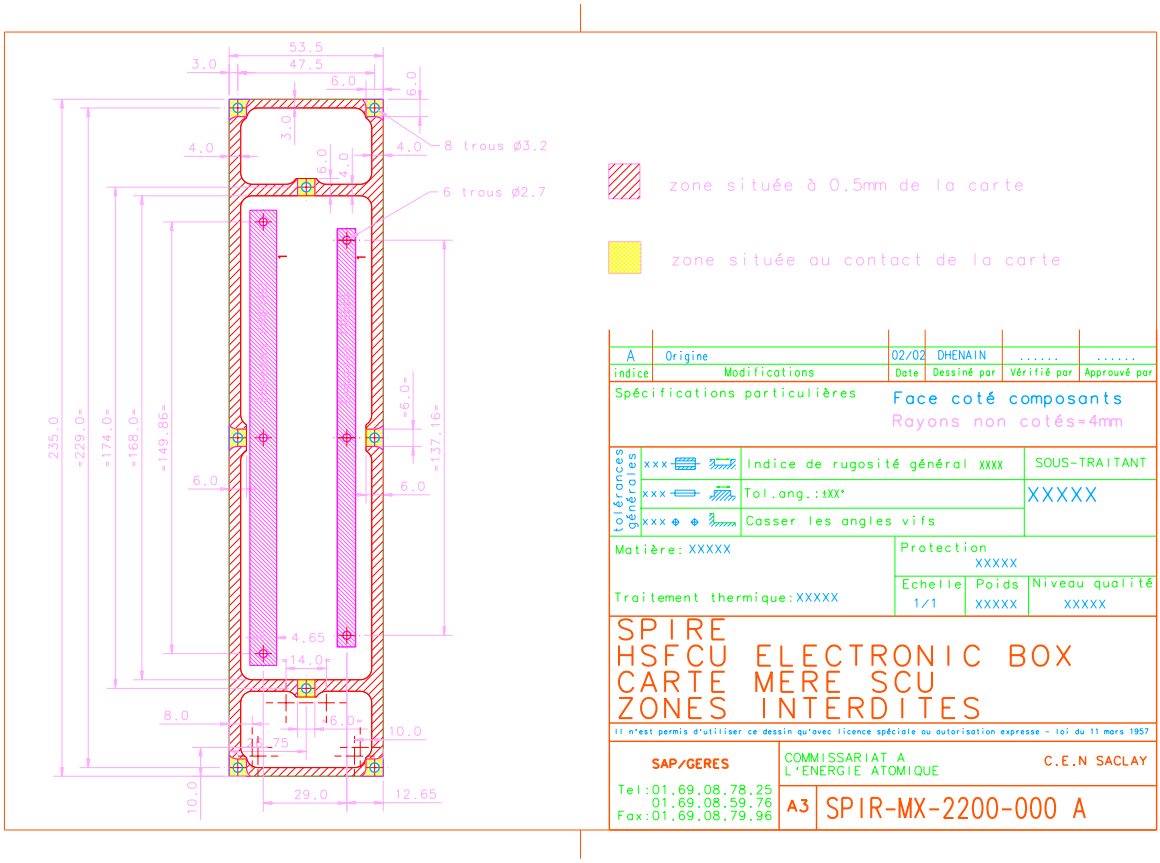
4.4.4.1. Electrical Interfaces

DRCU REQ-92.: Both data and command interfaces shall be compliant with AD11.

4.4.4.2. Mechanical Interfaces

DRCU REQ-93.: 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

DRCU REQ-94.: The back plane of the SCU shall be 220 x … mm as show bellow:



4.4.4.3. Power supplies

DRCU REQ-95.: The SCU electronics shall operate with the following set of supplies with associated maximum average current:

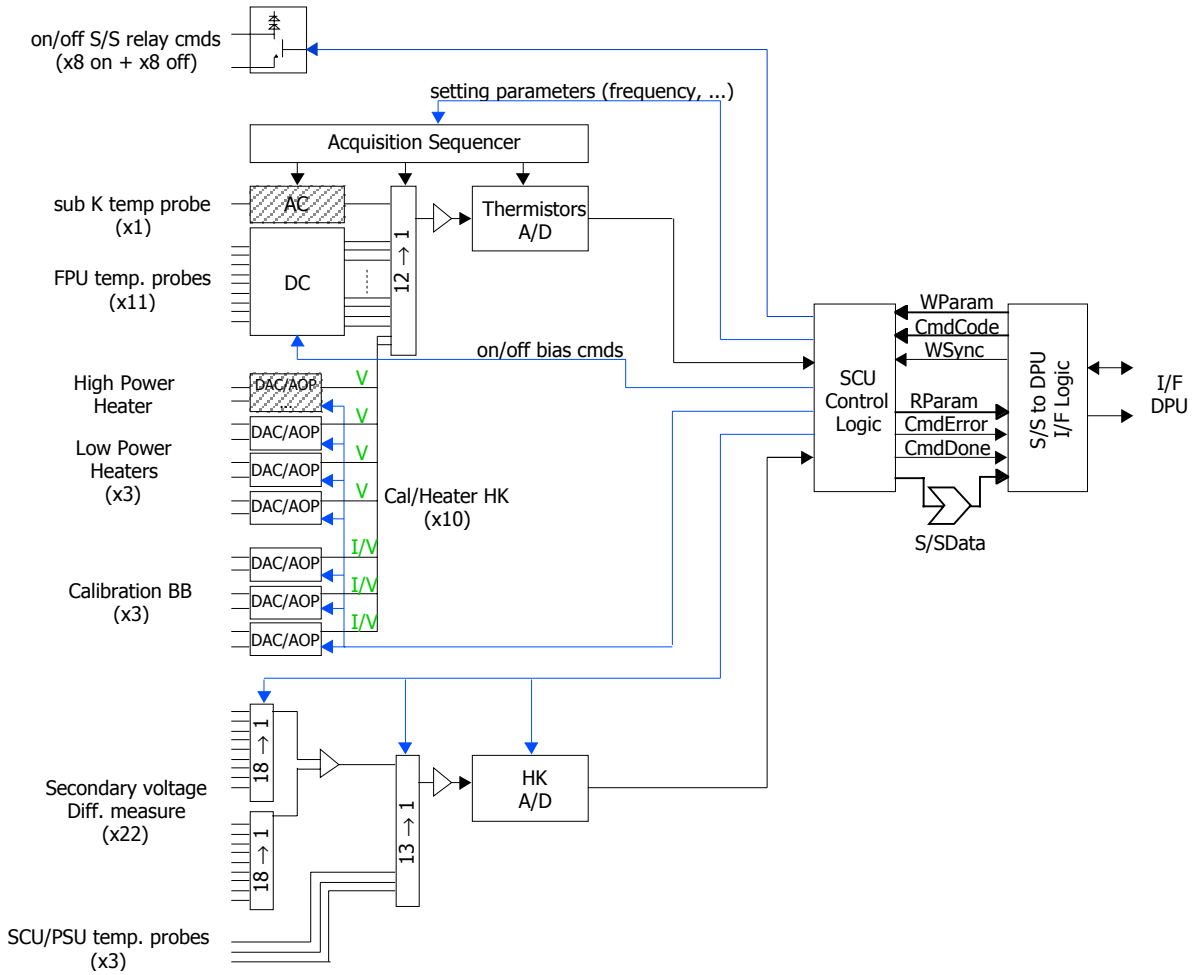
Module	Supply name	Supply voltage	Max. current	Min. current
TEMP / CCHK_I/F	SCU_ANA_P9 SCU_ANA_N9	+9 V -9 V	0.32 A 0.30 A	
CCHK_I/F	SCU_DIG_P5	+ 5.2 V	0.22 A	0

DRCU REQ-96.: When powered inrush current shall be limited by the SCU according to the following limits:

DRCU REQ-97.: The SCU shall provide proper supply line filtering to restrict the conducted emissivity as specified bellow:

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)

4.5.1.1. Secondary power lines

DRCU REQ-98.: Each DC/DC converter (1 main + 1 redundant) shall have the following outputs with independent return lines (except +/- MCU_ANA and +/- MCU_DRV connected inside the PSU):

Sub-system	Supply Name	Voltage	Current (Average)	Current (Peak)
MCU	MCU_DIG_P5	+5.2	1.76	2.97
	MCU_ANA_P13	+13	0.18	-
	MCU_ANA_N13	-13	0.16	-
	MCU_DRV_P15	+15	0.01	0.1
	MCU_DRV_N15	-15	0.01	0.1
DCU	DCU_LIA_P_P9	+9	1.90	
	DCU_LIA_P_N9	-9	1.90	
	DCU_LIA_P_P5	+5.2	0.65	
	DCU_LIA_S_P9	+9	0.64	
	DCU_LIA_S_N9	-9	0.64	
	DCU_LIA_S_P5	+5.2	0.22	
	DCU_BIA_P_P9	+9	0.39	
	DCU_BIA_P_N9	-9	0.33	
	DCU_BIA_S_P9	+9	0.13	
	DCU_BIA_S_N9	-9	0.10	
	DCU_DAQ_P5	+5.2	0.53	
	DCU_DAQ_P9	+9	0.10	
	DCU_DAQ_N9	-9	0.10	
SCU	SCU_DIG_P5	+5.2	0.22	?
	SCU_ANA_P9	+9	0.32	?
	SCU_ANA_N9	-9	0.30	?
	SCU_REL_P12	+12		0.69

4.5.1.2. Primary power line

DRCU REQ-99.: Each PSU DC/DC converter shall have an independent electrical interface with the satellite power bus.

DRCU REQ-100.: 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
DC/DC operating range	26-29 V
Input voltage range	0 to 35 V

DRCU REQ-101.: 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.

4.6. 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 102.: One secondary power shall not be distributed to more than one unit.

DRCU REQ 103.: The spacecraft structure shall not be used as return path for power and signals.

DRCU REQ 104.: Each secondary power return shall be connected to a single ground.

DRCU REQ 105.: 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 106.: 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 107.: 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. 108.: 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. 109.: 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 10mΩ.

DRCU REQ. 110.: Flat, clean and conductive surfaces shall be used for bonding. The permitted surfaces are:

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

DRCU REQ. 111.: The DC resistance between any two adjacent faces of the equipment chassis shall not exceed 2.5 mΩ.

DRCU REQ. 112.: 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. 113.: 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-114.: The Modes of Operation of the DRCU shall be:

- Off
- Initialisation
- Running

4.7.2. Off Mode

DRCU REQ-115.: 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 Mode

This mode is defined as intermediate between the Off Mode and the Running 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 is restricted to DRCU sub-units including S/W. Other sub-units will switch directly to the Run Mode.

DRCU REQ-116.: The DRCU sub-units shall enter this mode whenever a power-on occurs.

DRCU REQ-117.: When all the activities corresponding to the Initialisation Mode have been successfully completed the DRCU sub-unit shall enter the Run Mode.

DRCU REQ-118.: 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-119.: The DRCU sub-unit shall enter this mode whenever a S/W crash occurs.

4.7.4. Run Mode

This mode is the nominal status of the DRCU.

DRCU REQ-120.: The DRCU has its full functionality when in this mode.

4.7.5. Relation to SPIRE Modes of Operation

SPIRE Mode of Operation	DRCU Mode of Operation	Note
OFF	OFF	
ON	OFF	
INIT	INIT	
REDY	RUN	
STBY	RUN	
OBSV	RUN	
COOL	RUN	
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.

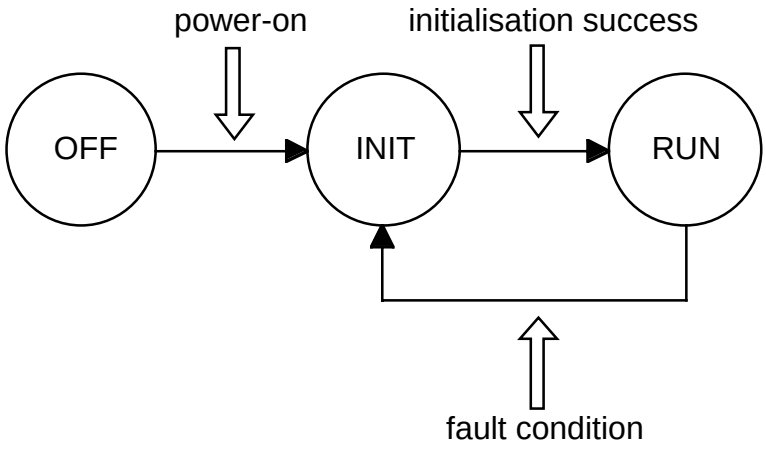


Figure 5.5-a DRCU Mode of Operation Transition Diagram

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	DCU Functions	MCU Functions	SCU Functions
OFF	-	-	-
INIT	DCU-FUNC-01 to -10	MCU-FUNC-10 to -14	SCU-FUNC-01 to -13
RUN	DCU-FUNC-01 to -10	MCU-FUNC-01 to -14	SCU-FUNC-01 to -13

4.9. Failure detection isolation and recovery

4.9.1. Failure Detection

DRCU REQ-121.: The DRCU shall provide capabilities to detect internal failures.

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-122.: Any failure within the DRCU shall not induce any failure to other units.

DRCU REQ-123.: 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-124.: 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.

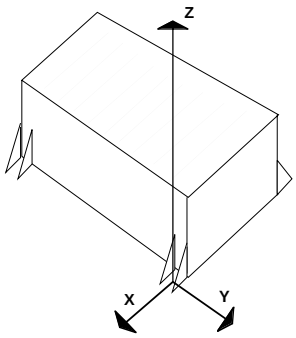
4.9.3. Redundancy

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

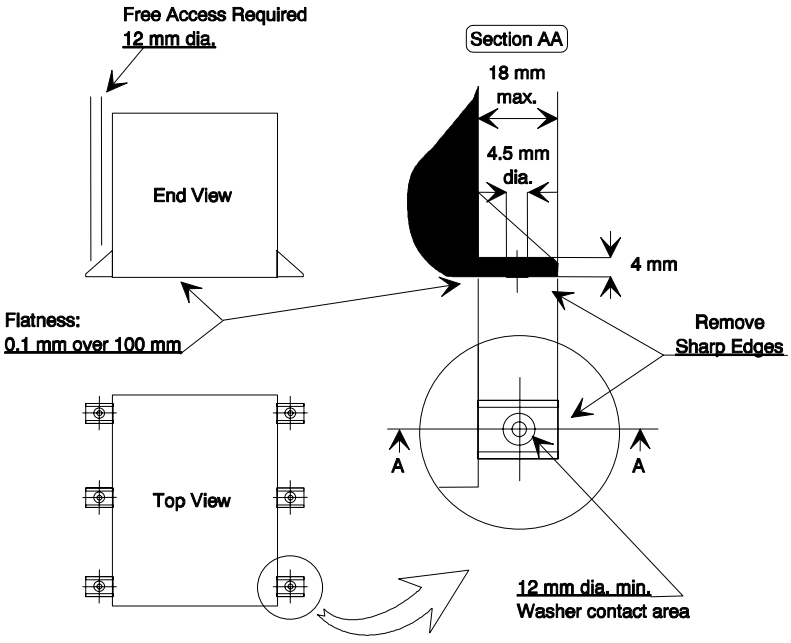


5.1.2. Functional requirements

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-125.: The attachment point shall be designed according to the following figure:



DRCU-REQ-126.: If more than 4 attachment points are required the Project shall approve.

DRCU-REQ-127.: For highly dissipative units the number and the location of attachment point shall be based on thermal consideration.

DRCU-REQ-128.: 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-129.: 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-130.: 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.

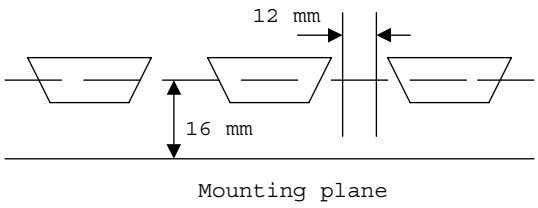
5.3.3. Interfaces with FPU

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-131.: 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-132.: The minimum distance between shall be compliant with AD03 §5.10.1.3 has shown bellow.



DRCU REQ-133.: The housing of connectors shall be electrically connected to the unit structure.

DRCU REQ-134.: All connectors supplying power shall have socket contacts.

DRCU REQ-135.: Savers shall protect flight quality connectors.

DRCU REQ-136.: Connectors shall be mechanically connected to prevent inadvertent disconnection.

DRCU REQ-137.: Separate connectors shall be used for each of the redundant system or S/S.

DRCU REQ-138.: 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-139.: 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.

- HS DCU Jxx for the DCU box connectors
- HS FCU Jxx for the FCU box connectors

6. EMC Requirements

DRCU REQ-140.: The DRCU shall cope with the EMC requirements stated in AD3.

7. Environmental Requirements

DRCU REQ-141.: The unit shall operate with the temperatures illustrated here below:

Operating		Min. Switch-On	Non-Operating	
Min.	Max.		Min.	Max.
-15° C	+45° C	-30° C	-35° C	+60° C

DRCU REQ-142.: The DRCU shall cope with the environmental requirements stated in AD3.

DRCU REQ-143.: The DRCU shall cope with the radiation environment described in AD12.

8. Reliability

DRCU REQ-144.: The reliability of the DRCU shall be equal to or greater than ***TBD*** for a period of 4.25 years.

DRCU REQ-145.: The method for reliability calculations shall comply with AD9.

9. Design and Construction

DRCU REQ-146.: All processes, materials and parts shall comply with AD6 and AD7 applicable documents.

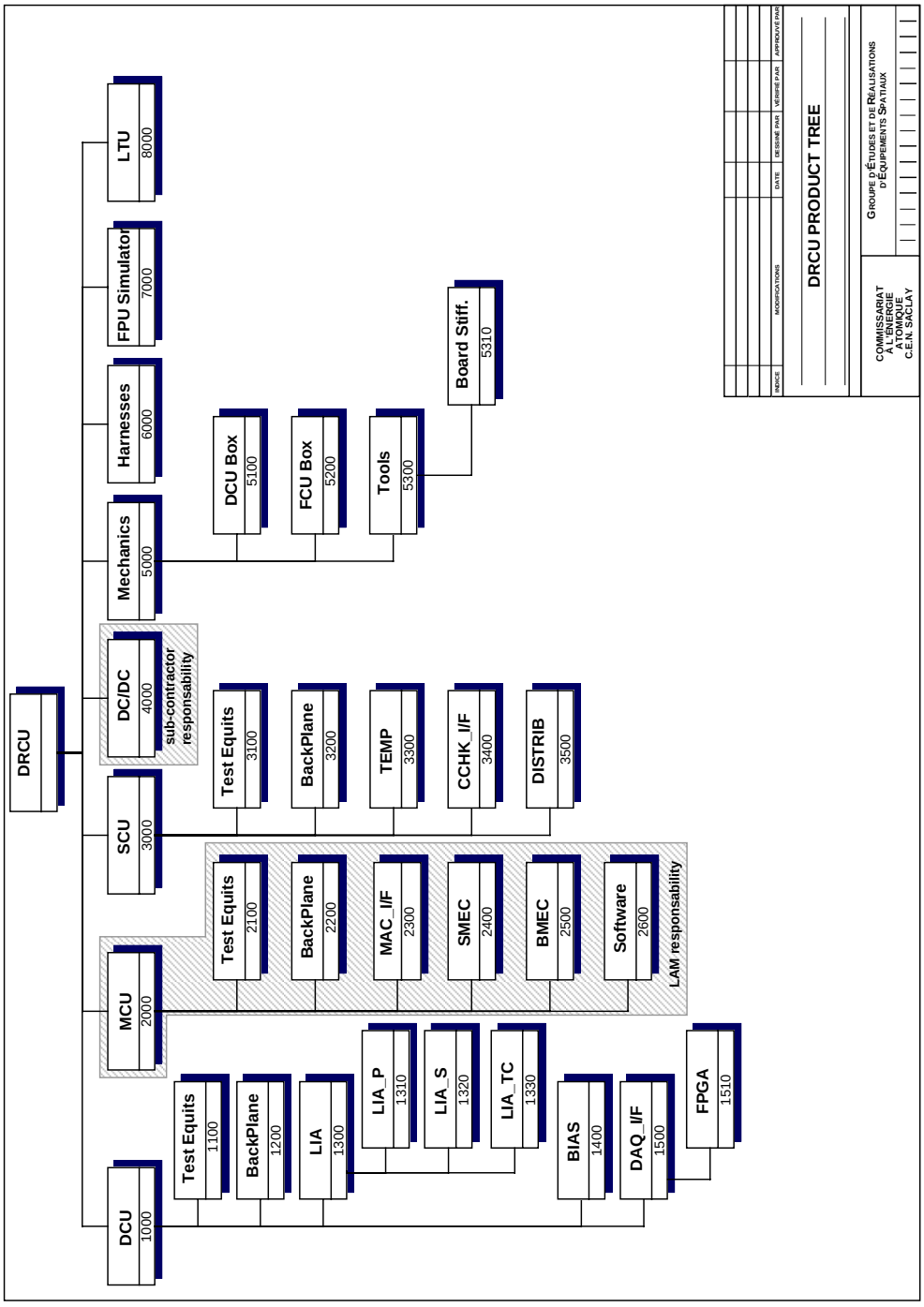
DRCU REQ-147.: Electronics design shall comply with AD8.

10. Identification and Labelling

DRCU REQ-148.: TBW

11. Product Tree

DRCU REQ-149.: All the elementary components of the DRCU shall be identified in compliance with the DRCU Product Tree as shown by figure 10-a and describe in AD17.



12. Model characteristics and definition

According to AD19 the various model characteristics are listed bellow:

DRCU	Box(es)	DCU	MCU	SCU	DC/DC	Part Grade	Perform.
QM1	FEq -	FEq(*) NR	FEq NR	FEq NR	FEq NR	FEq	NNP
QM2	FEq -	FEq RE	FEq RE	FEq RE	FEq RE	FEq	NNP
FM	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					
	Box	MAC	SMEC	BSM	BP	CCHK_I/F	TEMP	DISTRIB	BP		Box	LIA_S	LIA_P	DAQ_I/F	BP
QM1	FEq	1	1/2	1/2	1	1	1/2	1	1	Std	Pro	1	1	1	1
QM2	FEq	2	1	1	1	2	1	1	1	2	FEq	3	9	2	1
PFM	F	2	1	1	1	2	1	1	1	2	F	3	9	2	1
FS	-	?	?	?	?	1	1	1	1	1	-	1	2	1	1

13. Precedence

DRCU REQ-150.: The requirements concerning the Failure Detection and Failure Isolation capabilities shall have precedence on any other requirement.

14. Unit Requirement Verification

DRCU REQ-151.: 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		x	
DRCU REQ-05		x	
DRCU REQ-06		x	
DRCU REQ-07		x	
DRCU REQ-08		x	
DRCU REQ-09			x
DRCU REQ-10			x
DRCU REQ-11		x	
DRCU REQ-12			x
DRCU REQ-13			x
DRCU REQ-14			x
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	
DRCU REQ-24		x	
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-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	

Requirement	Analysis	Test	Inspection
DRCU REQ-39		x	
DRCU REQ-40		x	
DRCU REQ-41		x	
DRCU REQ-42		x	
DRCU REQ-43		x	
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 (FMECA)		
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	

Requirement	Analysis	Test	Inspection
DRCU REQ-84		x	
DRCU REQ-85	x		
DRCU REQ-86		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	
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-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	
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-121		x	
DRCU REQ-122		x	
DRCU REQ-123		x ?	
DRCU REQ-124		x	
DRCU REQ-125	x (FMECA)		
DRCU REQ-126	x (FMECA)		
DRCU REQ-127	x (FMECA)		
DRCU REQ-128	x (FMECA)		
DRCU REQ-129	x (FMECA)	x	

Requirement	Analysis	Test	Inspection
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	x	
DRCU REQ-138	x		
DRCU REQ-139			x
DRCU REQ-140			x
DRCU REQ-141			x
DRCU REQ-142			x
DRCU REQ-143			x
DRCU REQ-144	x		
DRCU REQ-145			x

15. Trace ability Matrix versus System Requirements

Instrument Level Requirements	DRCU requirement
IRD-PHOT-R11	
IRD-PHOT-R13	
IRD-MODE-R01	
SPIRE.WE.FUN	