FIRST / SPIRE
ELECTRICAL SYSTEM DESIGN

	Name and Function	Date	Signature
Prepared by :	C.CARA	21/06/00	
Verified by :			
Approved by :			

Document change record

Issue/Revision	Date	Modified pages
0.1	18/05/00	All : document creation
0.2	21/06/00	§1.3 table updated §1.4 table updated §2.1 text corrected, figure added §2.2.1 figure added §2.2.2 figure corrected §2.2.3 chapter created §3.3 text updated §5.2 text updated §5.4 table added §6 chapter split, figures added §7 table added

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	
ESA SPIRE Team	ESA	
Riccardo CERULLI	IFSI	
Renato ORFEI	IFSI	
Goran OLOFSSON	SO	
Hans-Gustav FLOREN	SO	

List of Acronyms

BSM	Beam Steering Mirror
DCE	Detector Control Electronics
DCU	Detector Control Unit
DPU	Data Processing Unit
DRCU	Detector Readout & Control Unit
LIA	Lock-in amplifier
MCE	Mechanisms Control Electronics
MCU	Mechanisms Control Unit
SMEC	Spectrometer Mechanism
SCE	Sub-system Control Electronics
SCU	Sub-system Control Unit
SMPS	Switch Mode Power Supply
WE	Warm Electronics
WIH	Warm Interconnect Harnesses

Table of contents

1. Introduction

1.1 Purpose

The purpose of this document is to describe the Electrical System design of the SPIRE Instrument. It gives an overall description in terms of architecture and interfaces of the electronics system.

1.2 Scope

The scope of this document includes all the electronics systems of the SPIRE instrument from the FPU and up to the S/C interface.

1.3 Applicable Documents

AD1	FIRST / Planck IID A	PT-IID-A-04624
AD2	FIRST IID B	PT-SPIRE-02124
AD3	FIRST / Planck Packet Structure ICD	SCI-PT-ICD 07527
AD4		

1.4 Reference Documents

RD1	DPU/DRCU Electrical Interface Control Drawing	Sap-SPIRE-CCa-
RD2	DPU Subsystem specification Document	tbd
RD3	SMEC Electronics Design Report	tbd
RD4	DRCU Specification Document	Sap-SPIRE-CCa-25-00
RD5	Note on the DPU/DRCU Operations Protocoles	

2 General description

2.1 Overview

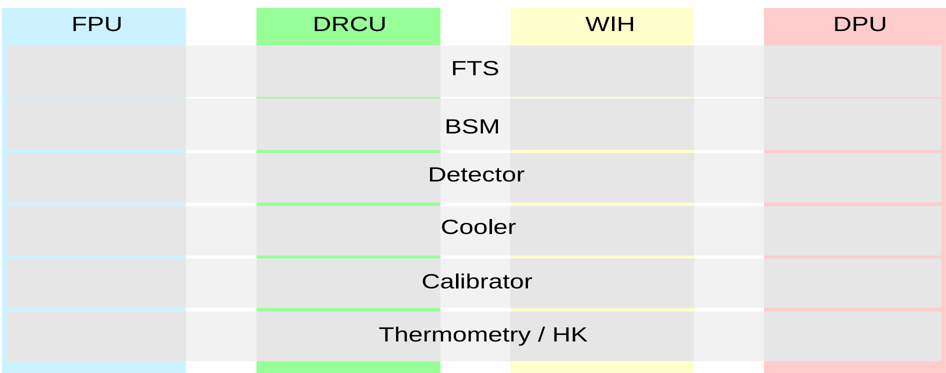
The SPIRE instrument includes both optical, mechanical, thermal and electrical functions.
All the optical and thermal functions are located inside a cryo-vacuum vessel for operating between 0.300 K and 4 K. The most critical mechanical functions are also located inside the CVV.
The electrical functions are splinted into two sub assemblies : the FPU (located inside the CVV) and the Warm Electronics. The Warm Electronics elements are located on the Service Module. While the FPU Electronics operates at cryogenic temperature (between 0.300 K and 15 K), the Warm Electronics operates at 300 K.
The main functions of this electrical systems are to operate the detectors according to the instrument scientific requirement and to the different modes of operation and to collect detector signal. This covers the detector biasing, the processing of the detector signals, the conversion of this signal into digitised values and the data packing for transfer to S/C. Additional functions are related to the moving mirror motion, detector cooler and calibration source control. Finally a function is in charge of various instrument sub-system temperature and analogue housekeeping acquisition.

The following sub-systems are defined :

- Detector
- Fourier Transform Spectrometer
- Beam Steering Mirror
- Cooler
- Calibration Sources
- Shutter
- Thermometry & Analogue Housekeeping

This sub-systems are physically implemented into 3 units :

- the FPU
- the DRCU
- the DPU

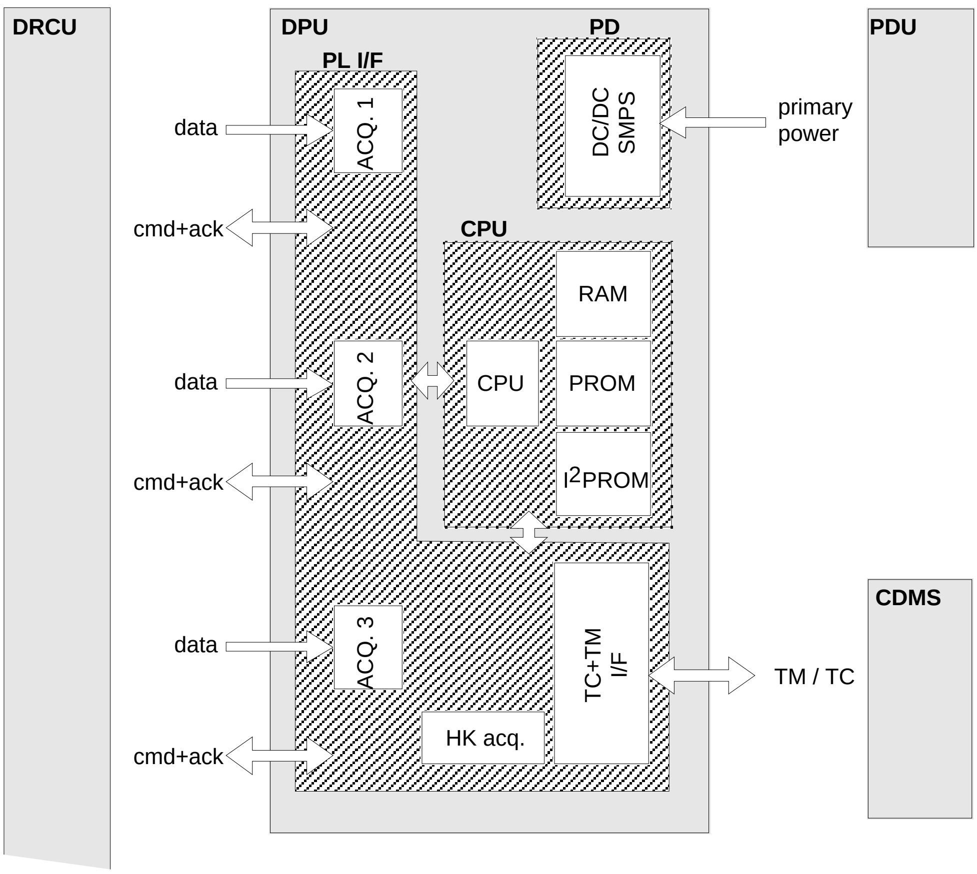


It has to be noticed that sub-systems are split into more than one unit as illustrated above : the FPU is the unit where the sensors/actuators are mounted while the DRCU integrates the associated front end electronics and finally the DPU supports highest level functions.
Links between DRCU and DPU are defined as an additional sub-system : the Warm Interconnect Harnesses while links between DRCU and FPU is defined as the Cold Interconnect Harnesses.

2.2 Units definition

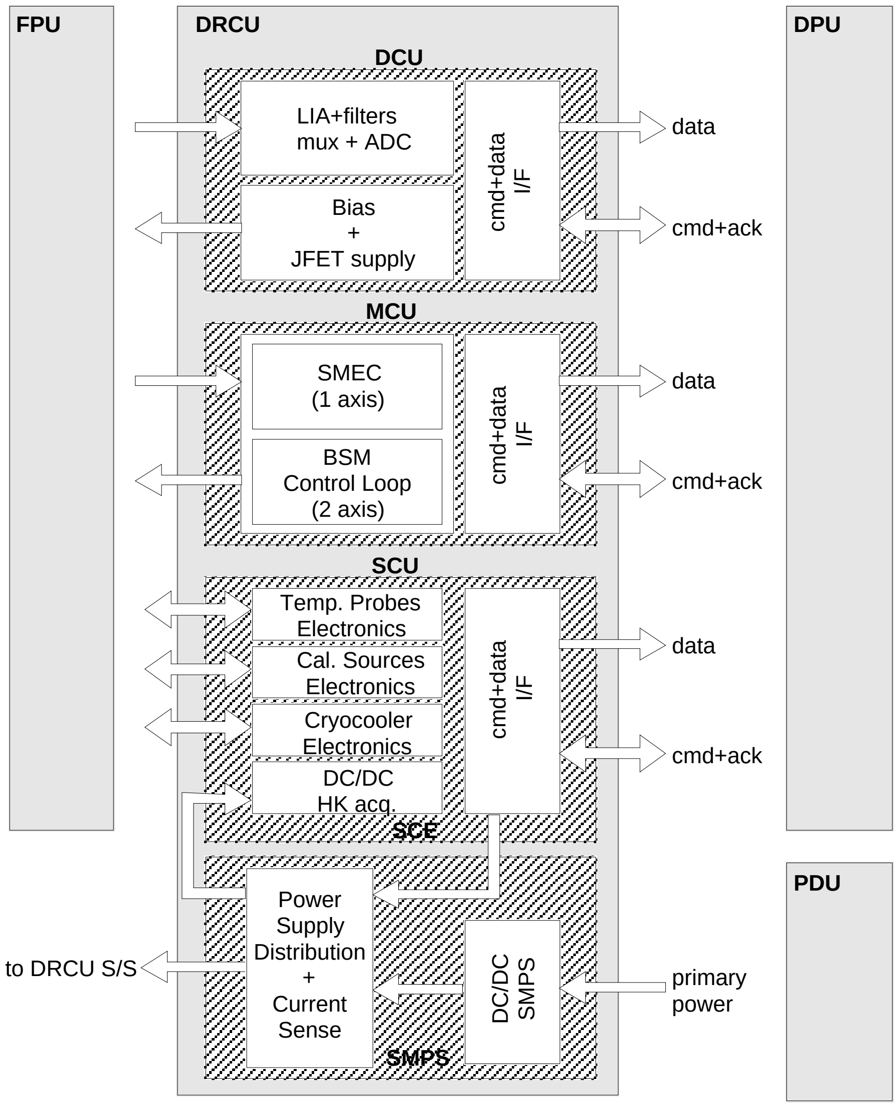
2.2.1 DPU

The DPU is in charge of receiving and interpreting Tele-Commands coming from the CDMS before decomposition and dispatching into elementary commands to the WE sub-systems. It is secondly in charge of performing digitised data acquisition. This include both scientific and housekeeping data. Finally the data are formatted according to ESA Packet Structure definition (AD3) for transfer to the CDMS. The DPU is basically a microprocessor board running an embedded software (identified as the OBS for On-board Software).



2.2.2 DRCU

The DRCU is divided into 3 independent sub-units housed in one box. Each sub-units has interfaces (exclusively analogue) with the FPU and with the DPU for data transfer and commanding (digital only).
The sub-units are :
• the DCU for Detector Control Unit; in charge of biasing the bolometers and processing the bolometer signals before digitised data transfer to the DPU,
• the MCU for Mechanism Control Unit; in charge of the FTS mirror motion and the Beam Steering Mirror position control,
• the SCU for Subsystem Control Unit; in charge of interfacing the DPU with the cry-cooler, the calibrators and provides the instrument with various temperature measurement channels.



An common SMPS (with several outputs) is part of the DRCU box. The secondary output lines of this SMPS supply the sub-systems via a distribution electronics whose function is to monitor the current consumption of each sub-system and enables switching off in case of over current.
Each sub-unit is totally electrically independent from the other one and is defined mechanically as a set of boards plugged on a back-plane. Electrical interface with the FPU are located in the front cover of each board while interface with DPU are located in the rear cover of the DRCU box : this configuration minimises wiring length and risk of cross-talk of sensitive analogue signals of the FPU/DRCU interface.
Each DRCU sub-system is specified in a dedicated Subsystem Specification Document including requirement on electronics.

2.2.3 FPU

In addition to the **detectors** the FPU includes the following elements of the electrical system for each sub-system :

- Detector :

  JFET amplifier : this unit reduces the electrical output impedance of the bolometers in order to increase the electrical bandwidth (function of this impedance and of wiring straight capacitance). Each bolometer is connected to a differential JFET follower : the total number of JFETs is then (288+56+8)x2=704. This unit is cooling at 15 K, however the active electronics operates at 120 K due to transistor self-heating.

  RF filter : RF filters are inserted on every detector wire (on both input and output signals) to avoid electrical perturbation above 1 GHz . These filters are feed-through capacitors located on the instrument 15 K cover.

- FTS :

  the **Moiré fringes sensor**, the **linear actuator** and the **home/limit switches** of the FTS sub-system are the three major elements of the FTS sub-system located inside the FPU. They are operating at 4 K.

  the **optical encoder preamplifier** amplifies the 3 infrared photo-detectors (0°,120°,240°) of the position encoder. This small unit is located outside the CVV but close to the feed-through connector and operates at 100 K.

- BSM :

  the **position sensors** (jiggle and chop axis) and the **voice coil actuators** (jiggle and chop axis) are located inside the FPU. They operate at 4 K and are connected to the warm electronics without any intermediate electronics (TBC).

- Calibrators :

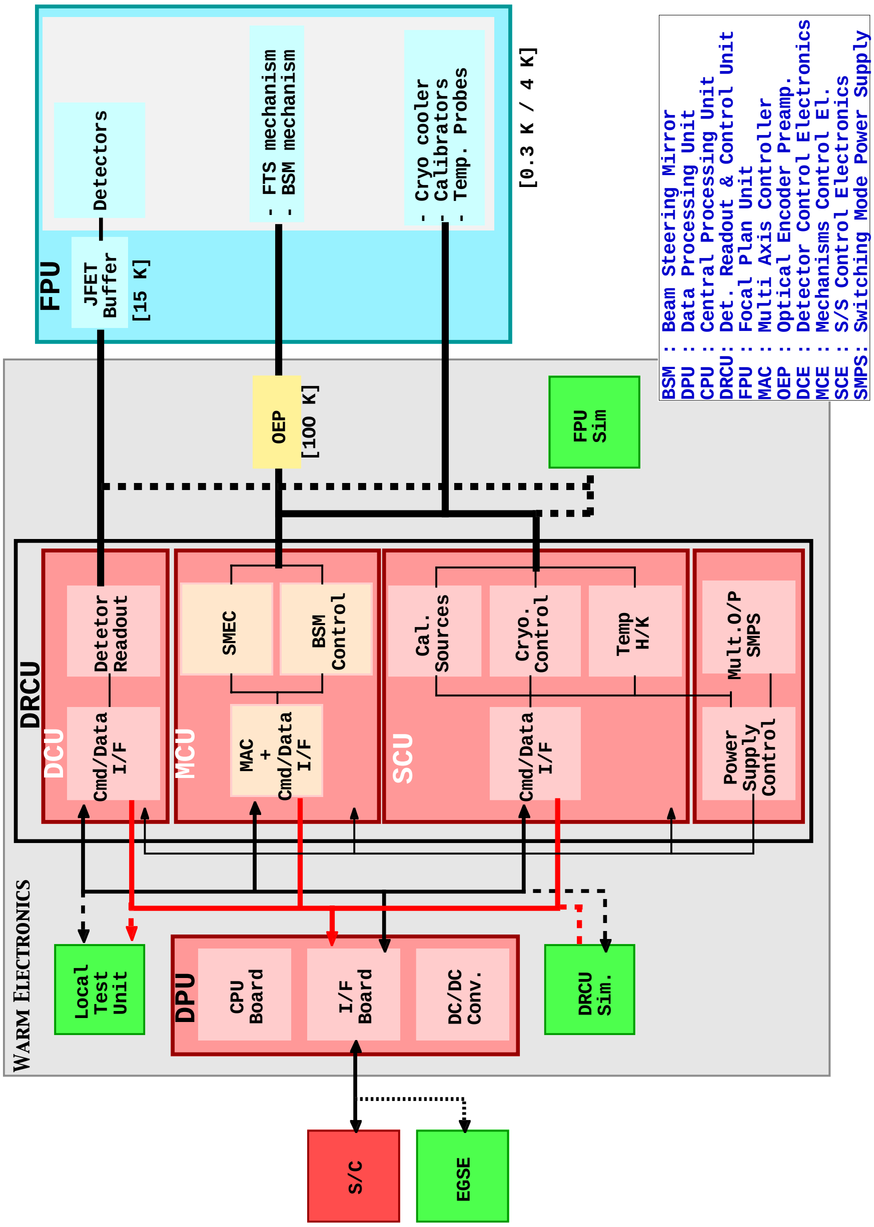
  the black body **heaters** (2+1) and the **temperature sensor** are the only calibrator sub-system elements located inside the FPU. They operate at 4 K.

- Cooler :

  the **gas switch heaters** (2) and the charcoal **sorption pump heater** are resistor mounted on the cryo-cooler mechanism. They operate depending on the heater location and the cooler phase (cooling or recycling) between 0.3 K and 40 K.
- Thermometry :

  a large number of thermal sensors are mounted inside the FPU. **Silicon diodes** and **germanium varistors** or **blind bolometers** are used according to the temperature range.

The next diagram shows a global view of the electrical system : the units with their respective sub-systems as well as harnesses and test equipments are showned.



3 Interfaces with S/C

3.1 Mechanical interfaces

Unit mechanical interface are described in the respective "Mechanical Interface Control Drawing" documents.
• the FPU interface is restricted to interface with the optical bench.
• the Warm Electronics units interface mechanically with the service module
• the "optical encoder preamplifier" interfaces with the outer shell of the CVV

3.2 Thermal Interfaces

TBW

3.3 Electrical interfaces

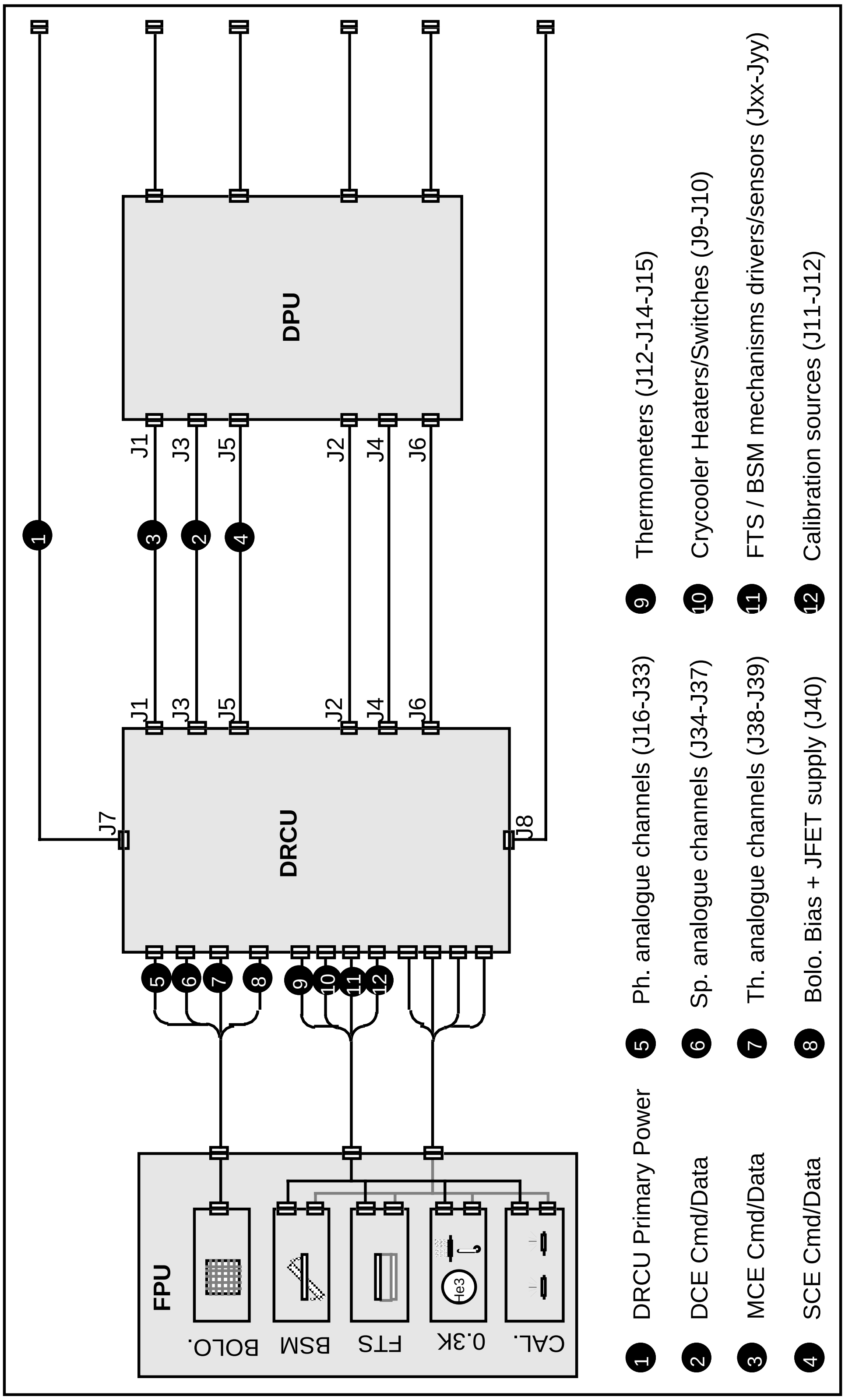
The SPIRE instrument interfaces with the S/C by means of 3 types of interface :

• TM/TC
• primary power supply
• discrete analogue lines

Two TM/TC interfaces are required to configure and to collect data from the SPIRE electrical system. One interface corresponds to the prime configuration while the second corresponds to the redundant configuration of this instrument This interface is defined in terms of electrical standard as well as protocol and packet definition by ESA documentation.

Four primary power supply interfaces will feed the SPIRE electrical system with 28 V and converter synchronisation clock : two interfaces correspond to the prime configuration while two others interfaces correspond to the redundant configuration of the system. No mixed configuration is foresee since no cross strapping between prime and redundant DPU/DRCU has been implemented.

The discrete analogue lines are connected to instrument unit temperature measurement channels. A complete list of temperature channels is given in AD2 including those who are interfacing with the satellite. These temperature measurements will allow in particularly unit power-on temperature control.


DPU
DRCU
FPU
J1
J3
J5
J2
J4
J6
J7
J8
BOLO.
BSM
FTS
0.3K
CAL.
He3
1 DRCU Primary Power
2 DCE Cmd/Data
3 MCE Cmd/Data
4 SCE Cmd/Data
5 Ph. analogue channels (J16-J33)
6 Sp. analogue channels (J34-J37)
7 Th. analogue channels (J38-J39)
8 Bolo. Bias + JFET supply (J40)
9 Thermometers (J12-J14-J15)
10 Crycooler Heaters/Switches (J9-J10)
11 FTS / BSM mechanisms drivers/sensors (Jxx-Jyy)
12 Calibration sources (J11-J12)

4 FPU/Warm Electronics Interfaces

All the DRCU sub-units have interfaces with the FPU (except SPMS).
Interfaces between the FPU and the DRCU are exclusively analogue and are typically : sensors biases, actuator power, sensors signals. Each analogue interface is specific of the considered sub-system : their descriptions are given in the respective "Subsystem Specification" documents. The electrical link between the FPU and the DRCU defines the Cold Interconnect Harness. The capacitance(due to the length (5 meters)) are key parameters for the design of the FPU/DRCU interfaces.

5 Warm Electronics Interfaces

5.1 Overview

Interfaces between the DRCU and the DPU are exclusively digital : digitised data and low level commands are transferred between these units. Each DRCU sub-unit (DCU, MCU & SCU) have their own interfaces. These sub-units interface comply with common protocols (Data & Command). The only specificity concerns the Data Packet definition. A global list of command is defined : some of them have a single sub-unit target while others have multiple sub-unit targets (this commands are defined as "Broadcast command" – and are mainly defined for synchronisation between sub-units and DPU). A specification of this interfaces including both electrical and logical protocol is given in the RD1 (DPU/DRCU EICD).

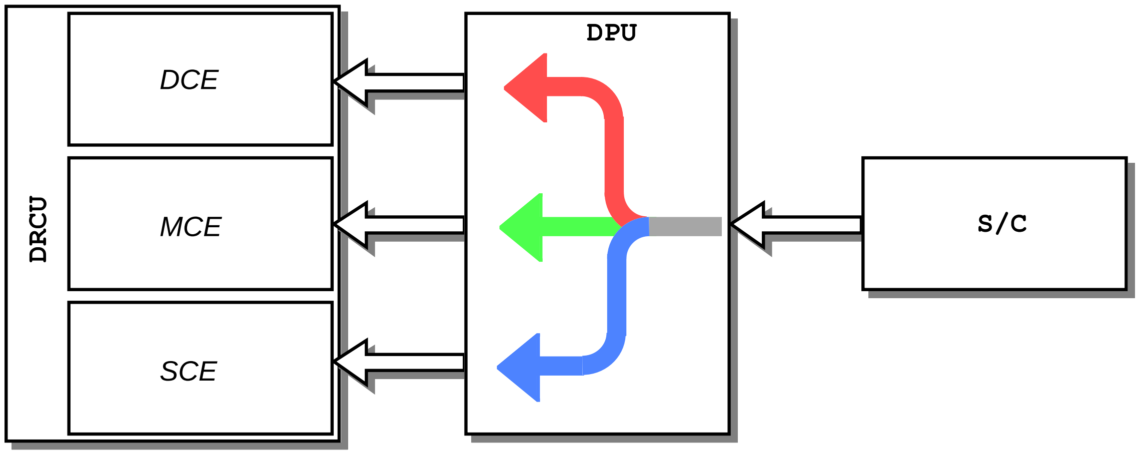
5.2 Tele-command distribution

The following diagram illustrates the instrument command distribution concept : the DPU receives Tele-Commands from S/C through a MIL-1553 based interface and translates them into individual (low-level) command for sub-system configuration. Since a sub-system might be implemented within several units a Tele-Command will be possibly exploded into several low level commands for controlling OBS tasks and for controlling sub-unit operation via the DPU to DRCU command interface.
Low-level commands received by the DRCU are intended to have immediate effect.

Low level command verification between the DPU and the DRCU is based on two complementary concepts :

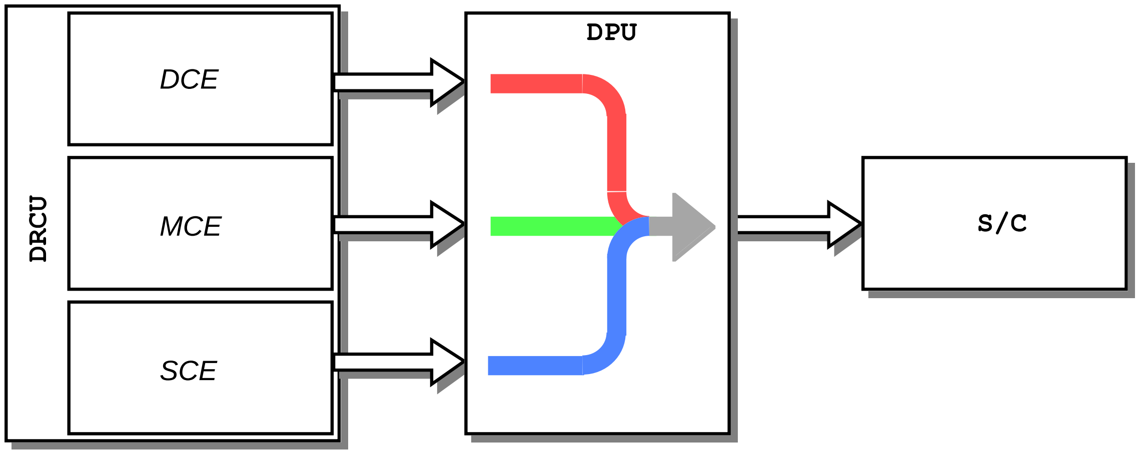
- on request (a specific flag is in set in the command word) the DRCU sub-unit will answer to the command by sending to the DPU an acknowledge word .
- when sending a command the DPU will check its execution by monitoring data and/or housekeeping generated by the corresponding sub-unit.

When addressing a sub-unit the DPU adds to the command word an physical address (2 bits) used by the receiver to enable or disable command decoding. A specific address called "Broadcast Address" is defined : it enables the DPU to send low level command simultaneously to the three DRCU sub-units : this definition is implemented especially for synchronous data acquisition purpose.



5.3 Data flow

Two type of data are flowing through the SPIRE instrument : the scientific data constituted by bolometers photometer and spectrometer response and mechanism motion related parameters and housekeeping data mostly constituted by detector operating parameter such as temperature or biases. This data are collected by the 3 sub-units of the DRCU and transfered via three independent "data link" to the 3 acquisition interfaces electronics of the DPU. The activity on this links is dependent on configuration commands sent by the DPU before starting a "observation" period.
For easy electrical interface checking (i.e. when performing a model's integration) each sub-unit implements a internal test data generator : the purpose of this generator is to transfer predefined known data without requiring external Test Equipment or complete instrument configuration (including the FPU).



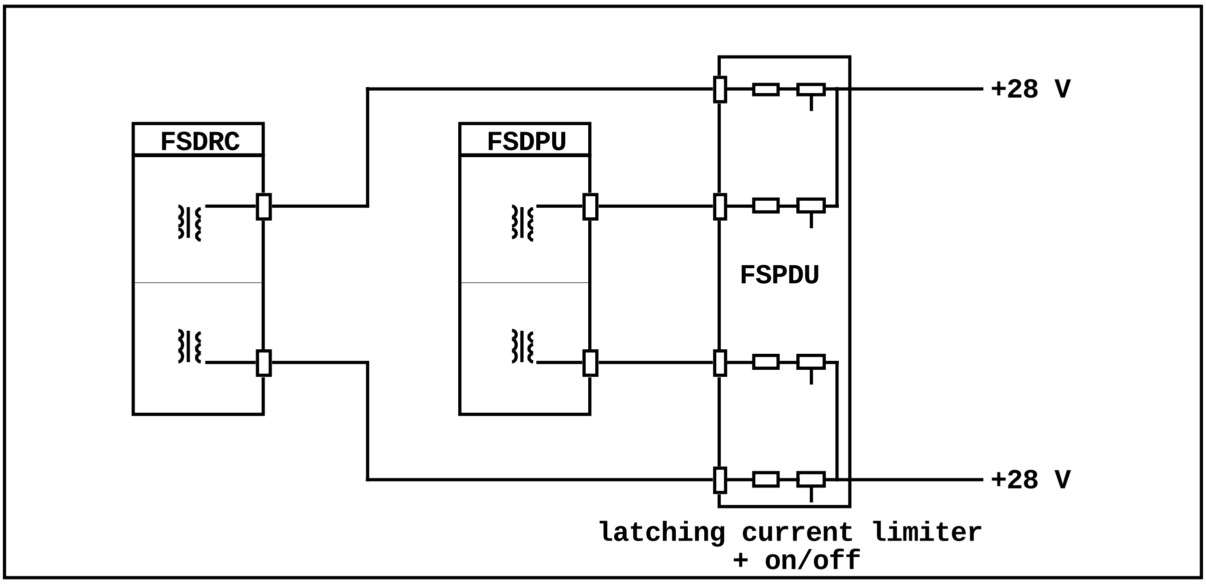
5.4 Data Rates

Unit	Sub-unit/Mode	Bit Rate /s	Note
DRCU			
	DCU	79872 77824	Photometer @ 16 Hz Spectrometer @ 80 Hz + HK @ 16 Hz
	MCU	TBD 1312	Photometer Spectrometer (RD3)
	SCU	416 480	@ 16 Hz(prime) (RD4) @ 16 Hz (redundant)
DPU			
	Photometer	86784	RD5
	Spectrometer	91904	RD5
	Housekeeping	4240	RD5

6 Power distribution and grounding diagram

6.1 Power Distribution

The SPIRE instrument electronics is supplied by the satellite by means of two primary power interfaces : one is connected to the DPU internal SMPS DC/DC converter while the second is connected to the DRCU internal SMPS DC/DC converter.

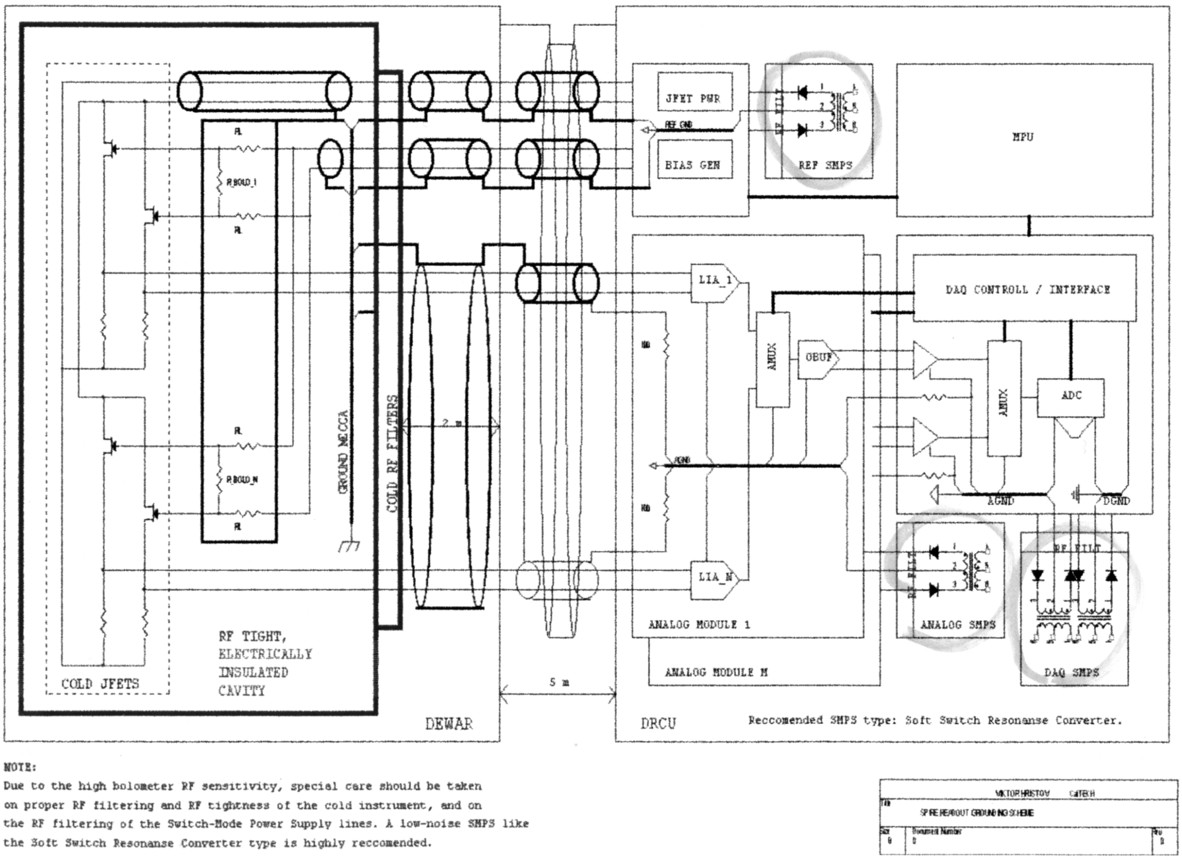


The DRCU SMPS is supplying the 3 DRCU sub-units and the JFET box. The configuration of the secondary lines are defined by the supplied sub-systems. Noise propagation sensitive sub-systems requires to design a SMPS with galvanically isolated outputs : this is especially the case for the Detector Readout Electronics. These isolated outputs prevent ground loops

implementation. Currents monitoring capabilities are added to the SMPS : their purpose is to insure sub-system are working nominally and to allow sub-system switching off in case of an anomaly occurs during autonomous mode.
Switching between prime and redundant electronics is achieved by the S/C by switching from primary power lines to secondary power lines.
The SMPS switching frequency is fixed by the synchronisation clock included in the primary power interface.

6.2 Grounding scheme

The grounding scheme design is mainly driven by critical sub-systems such as Detector Readout and FTS. EMI/EMC effects are reduced by implementing when applicable dual balanced electrical interfaces.

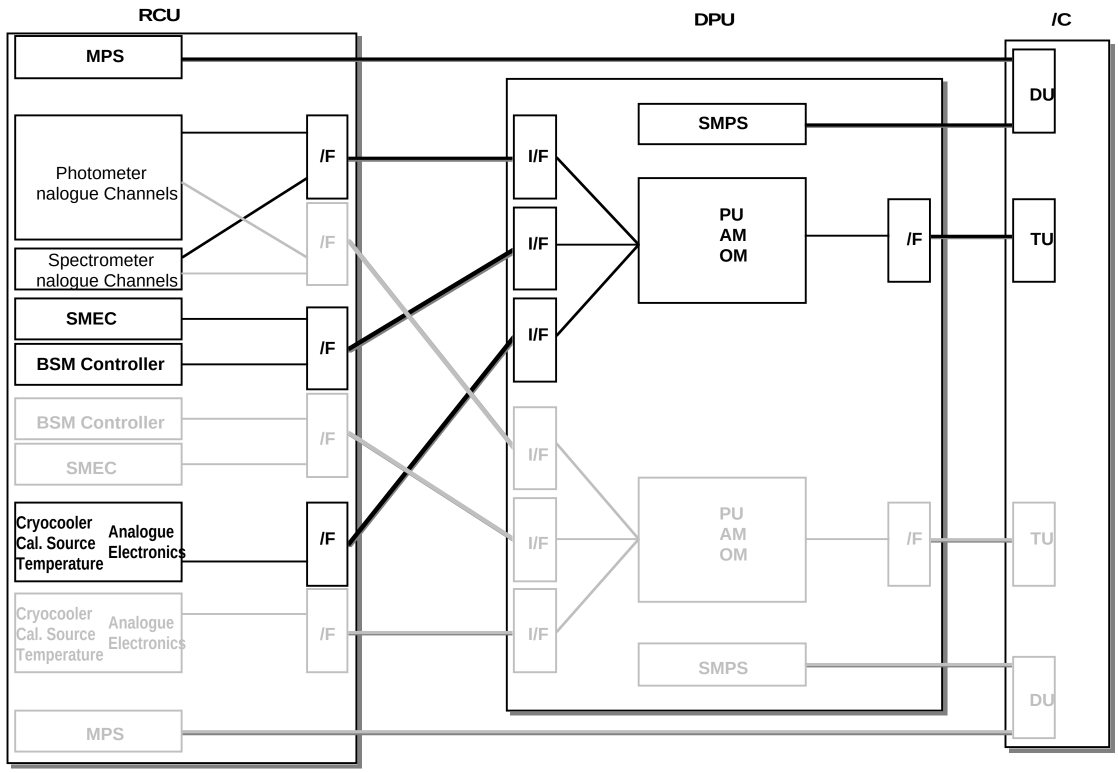


The drawing above shows the grounding diagram as defined for the detector sub-system by JPL. Star point is located inside the CVV and corresponds to the connection of the harness shields, detector box and 15 K instrument cover.

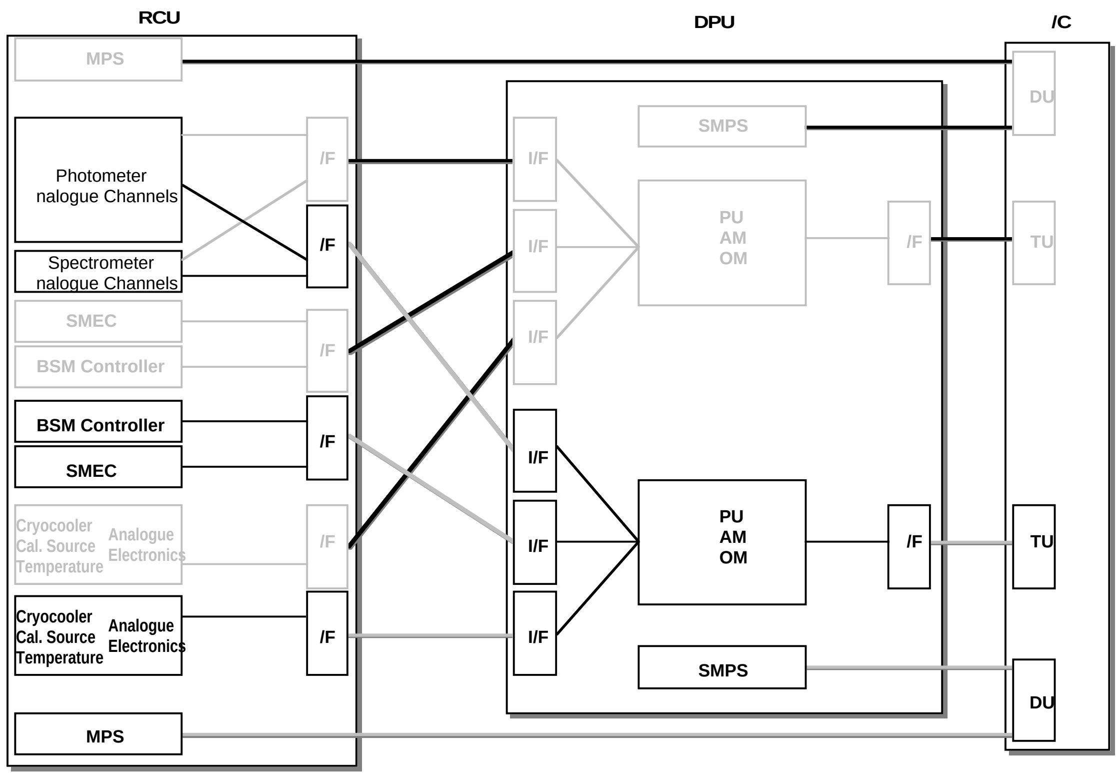
7 Redundancy basics

Redundancy principles are implemented for reliability purpose. This redundancy principles enables to remove the Single Point Failure from the instrument as much as possible. When redundancy can't be implemented the architecture is defined to limit the impact of a failure to the smallest possible "area".
The following table lists the sub-systems and gives the redundancy concept associated with each one or the failure impact when relevant.

Sub-system	Element	Redundancy	Effect	Comment
Detector	JFET	no	1 bolo. lost	
	LIA	no	1 bolo. lost	failure propag. risk
	ADC	yes		
	Data + Cmd I/F	yes		
	Bolo. Bias	yes		
	JFET power	yes		
FTS	Moiré fringe sensor	yes		
	Linear actuator	yes		
	Home/Limit sensors	yes		
	SMEC	yes		
	MAC	yes		
	Data + Cmd I/F	yes		
BSM	Position sensors	TBD		
	Voice coil actuator	TBD		
	BSM Controller	TBD		
Cooler	Gas switch heater	yes		
	Charcoal pump heater	yes		
	AFEE	yes		
	Data + Cmd I/F	yes		
Calibrator	black body heaters	yes		
	Temp. Sensor	yes		
	AFEE	yes		
	Data + Cmd I/F	yes		
Thermometry	probes	yes		
	AFEE	yes		
	Data + Cmd I/F	yes		
DRCU	SMPS	yes		
DPU	All	yes		



Electrical System – Prime Mode



Electrical System – Redundant Mode