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THE FACULTY OF POWER AND AERONAUTICAL ENGINEERING

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INTERFACE CONTROL DOCUMENT

Payload board

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Abbreviated terms

ADCS	Attitude Determination and Control System
COMM	Communication subsystem
DT	Deployment Team
EM	Engineering Model
EPS	Electrical Power System
ESA	European Space Agency
FM	Flight Model
GS	Ground Station
LEO	Low Earth Orbit
MA	Mission Analysis
MDR	Mission Definition Review
PDR	Preliminary Design Review
SC	Spacecraft
SKA	Studenckie Koło Astronautyczne (Students' Space Association)
SSO	Sun-Synchronous Orbit
SW	Software
TBC	To Be Continued
TBD	To Be Defined
WUT	Warsaw University of Technology

1 INTRODUCTION

1.1 SCOPE

The aim of the document is to describe the payload board.

PLD board is placed on the top of PC-104 stack.

In the document the interfaces between PLD and rest PW-Sat are described.

1.2 PAYLOAD BOARD FEATURES

The payload board allows OBC to:

- read reference SunSensor data
- read temperatures on solar panels, cameras and thermal knives
- read photodiode currents on solar panels
- switch between active camera
- store data on external memory (FLASH & FRAM)
- read time from external real time clock

1.3 APPLICABLE PROJECT DOCUMENTS

- [PW-Sat2-C-01.01-ADCS-ICD] – ADCS ICD
- [PW-Sat2-C-10.01-CONF-MICD] – Mechanical ICD of the PW-Sat2

2 System overview

Simplified overview of payload board is following:

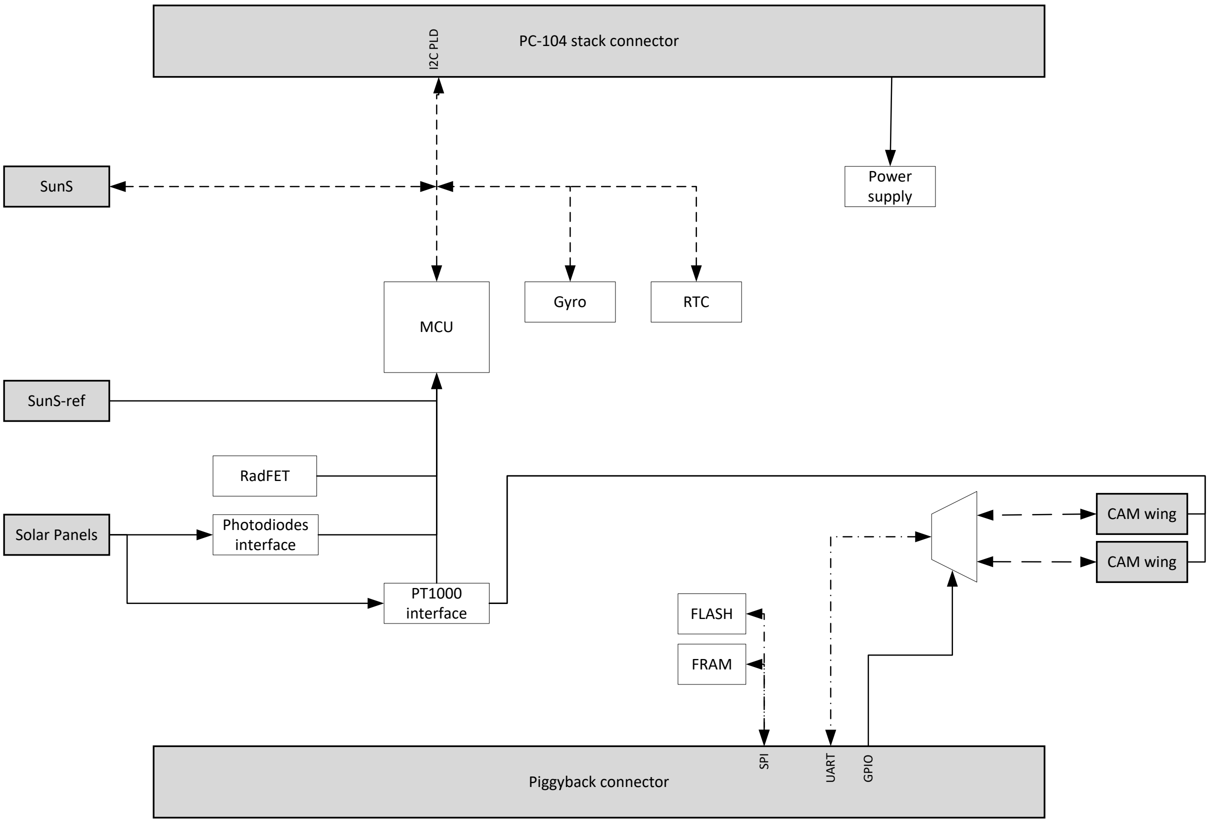

Figure 2-1 PLD overview

2.1 Memories

PLD have two on-board memories for OBC data storage. They are connected via SPI bus (on piggyback connector) to OBC.:

- FLASH - N25Q128A13ESE40G – 128 Mbit
- FRAM - FM25W256 – 256 kbit

2.2 Gyroscope & SunSensor

Gyroscope (on PLD board) and SunSensor (via external connector) are connected to I2C payload bus via separate I2C repeaters – PCA9517.

2.3 CAMERAS

Cameras (4D uCAM-II) are connected to OBC via UART. There are two cameras – and only one UART available. Therefore, multiplexer was implemented on PLD board so OBC can selected active camera.

2.4 RTC

On PLD there is one RTC for use of OBC - PCF8563. It is connected to I2C_PLD via I2C repeater – PCA9517.

RTC has back-up battery (2200uF), which allows to hold time between power cycles. It can run RTC for [TBD] minutes.

2.5 MCU INTERFACE

Rest of systems on PLD board is accessible via microcontroller. It is connected to I2C payload via I2C repeater – also PCA9517.

This microcontroller controls ADC, MUXes and other devices on PLD board. It acts as a low-level controller for OBC.

It controls:

- SunS-ref
- Photodiodes interface for solar panels
- PT1000 interfaces for CAM, thermal knives and solar panels
- RadFET sensor

3 ELECTRICAL INTERFACES

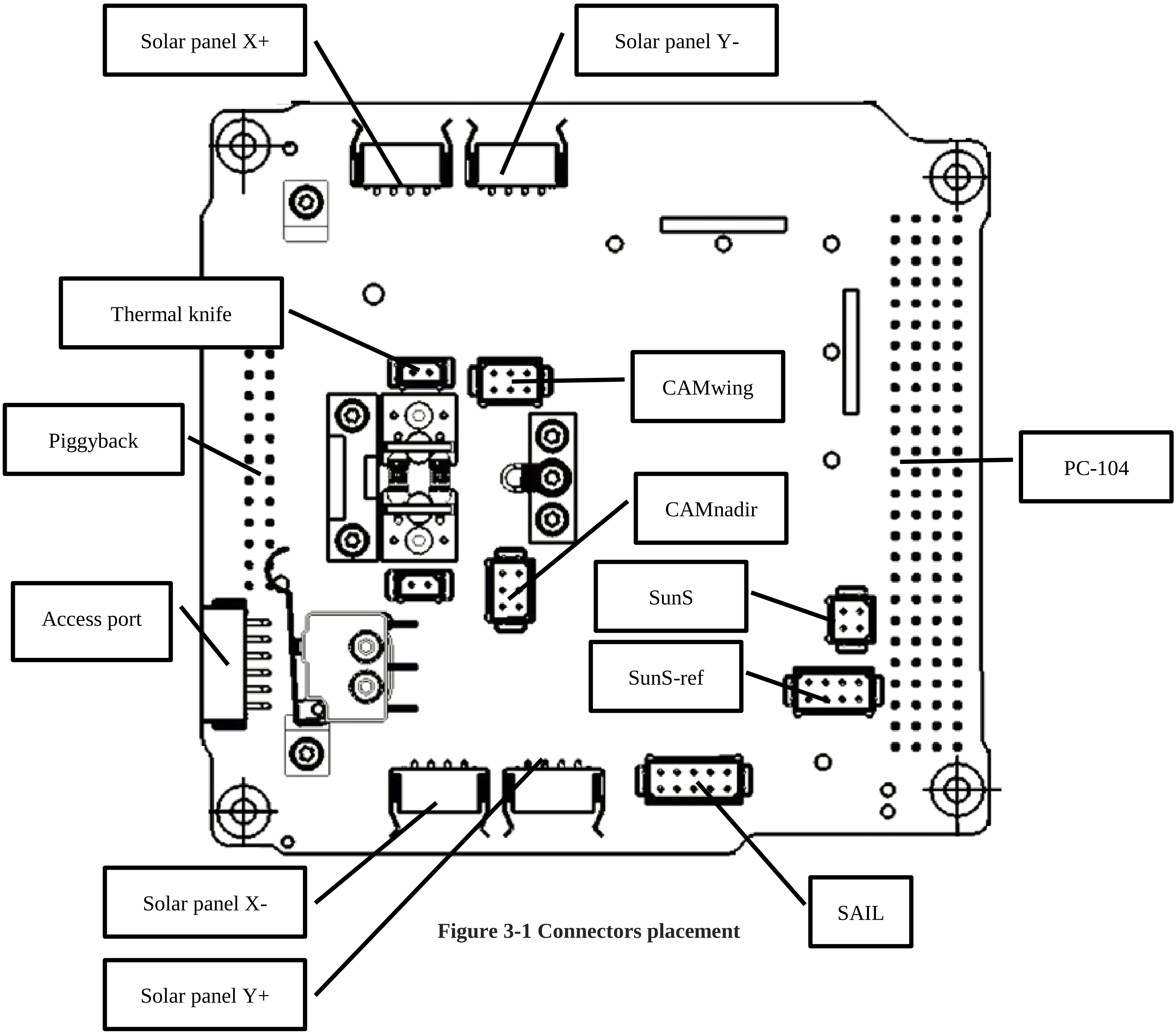

Figure 3-1 Connectors placement

3.1 PC-104 CONNECTOR PIN-OUT

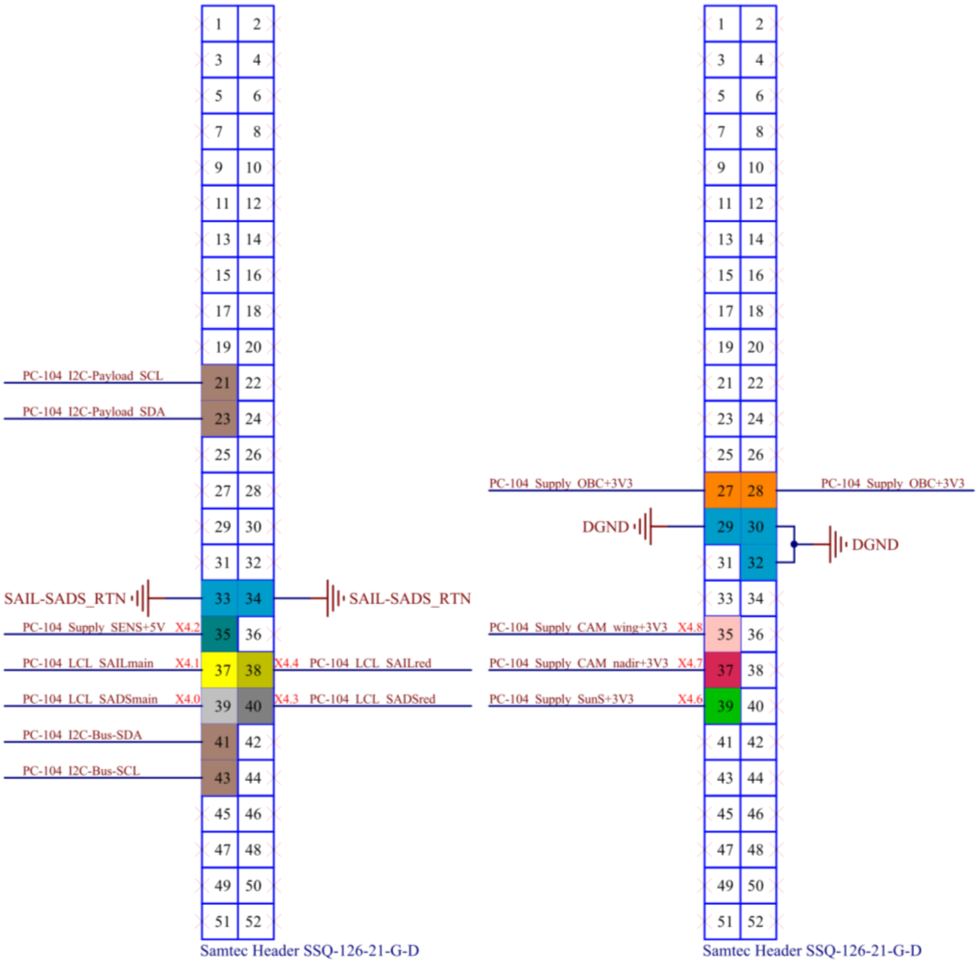

Figure 3-2 PC-104 connector pin-out

Pin	Name	Type	Voltage level	Description
1-21	I2C_PLD_SCL	Signal	0 – 3.3 V	I2C payload – SCL line
1-23	I2C_PLD_SDA	Signal	0 – 3.3 V	I2C payload – SDA line
1-33, 1-34	SAIL-SADS_RTN	Power return	0 V	SAIL and SADS thermal knives current return
1-35	SENS_5V	Power	0 – 5 V	5 V main supply line
1-37	SAIL_NOM	Power	0 – 12 V	SAIL thermal knife current line; nominal
1-38	SAIL_RED	Power	0 – 12 V	SAIL thermal knife current line; redundant
1-39	SADS_NOM	Power	0 – 12 V	SADS thermal knife current line; redundant
1-40	SADS_RED	Power	0 – 12 V	SADS thermal knife current line; redundant

1-41	I2C_BUS_SCL	Signal	0 – 3.3 V	I2C bus – SCL line
1-43	I2C_BUS_SDA	Signal	0 – 3.3 V	I2C bus – SDA line
2-27, 2-28	OBC_3V3	Power	0 – 3.3 V	+3.3 V line for OBC
2-29, 2-30, 2-32	DGND	Power return	0 V	Digital ground – common
2-35	CAM_WING	Power	0 – 3.3 V	Wing camera power supply
2-37	CAM_NADIR	Power	0 – 3.3 V	Nadir camera power supply
2-39	SUNS_3V3	Power	0 – 3.3 V	Sun sensor power supply

Table 3-1 PC-104 pinout

3.2 OBC PIGGYBACK CONNECTOR

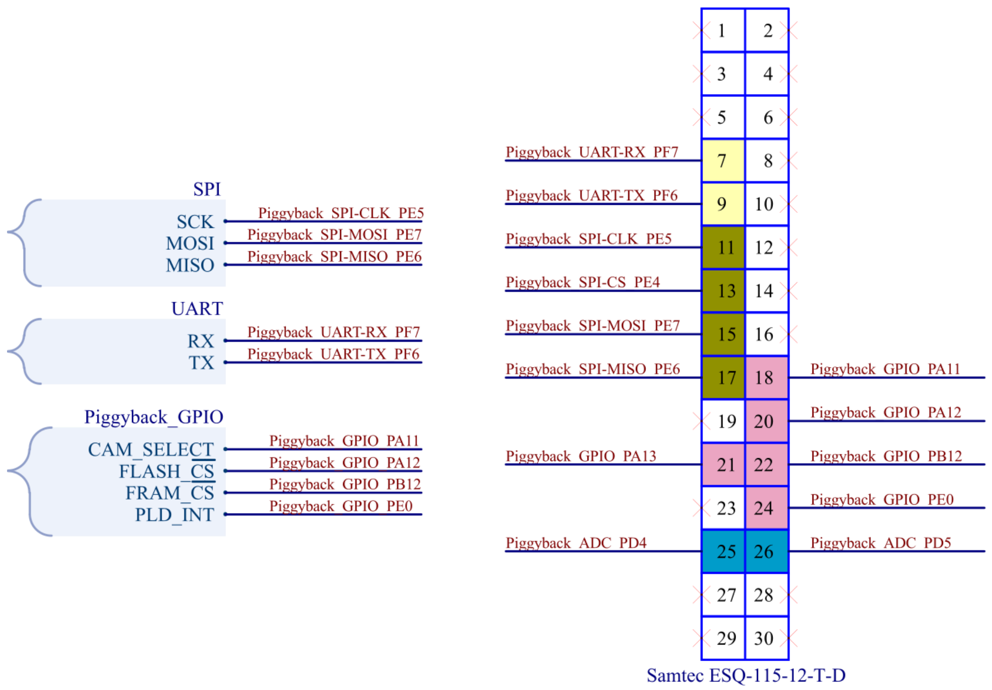

Figure 3-3 OBC piggyback connector

Pin	Name	Type	Voltage level	Description
7	RX	Signal	0 – 3.3 V	UART RX from CAMs – OBC PF7

Pin	Name	Type	Voltage level	Description
9	TX	Signal	0 – 3.3 V	UART TX to CAMs – OBC PF6
11	CLK	Signal	0 – 3.3 V	SPI interface, CLK line – OBC PE5
15	MOSI	Signal	0 – 3.3 V	SPI interface, MOSI line – OBC PE7
17	MISO	Signal	0 – 3.3 V	SPI interface, MISO line – OBC PE6
18	CAM_SELECT	Signal	0 – 3.3 V	Camera select. ‘1’ – wing; ‘0’ – nadir – OBC PA11
20	FLASH_CS	Signal	0 – 3.3 V	Chip select for Flash memory. Active low. Connected to OBC line PA12
22	FRAM_CS	Signal	0 – 3.3 V	Chip select for FRAM memory. Active low. Connected to OBC line PB12
24	INT	Signal	0 – 3.3 V	Interrupt line from PLD processor to OBC. Active on rising edge.

Table 3-2 Piggyback connector pinout

3.3 AccessPort

AccessPort for satellite charging and testing after integration is located on PLD board. This is Harwin M80-8411242 connector.

Full specification for a single connector:

Parameter	Value
Manufacturer	Harwin
Manufacturer part number	M80-8411242
Pins count	6 pins per row, double row = 12 pins
Pitch	2mm
Mounting Style	Through Hole

Table 3-3 SunS connector specification

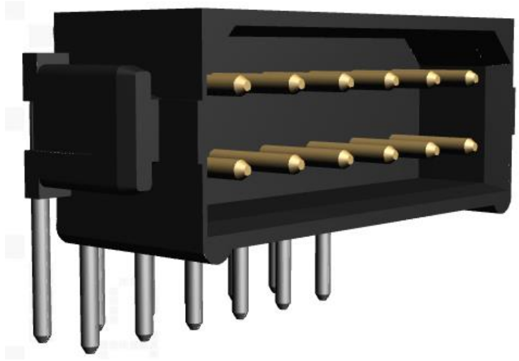

Figure 3-4 Harwin M80-8411242 CAD model

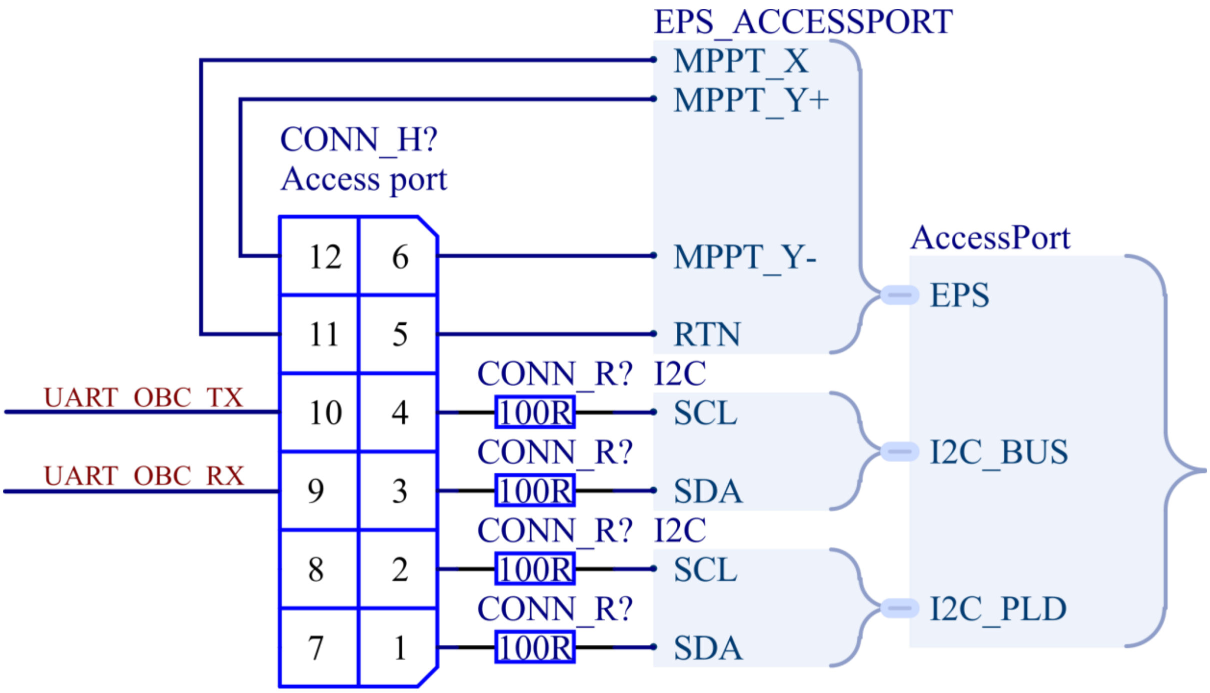

Figure 3-5 AccessPort connector

Pin	Name	Type	Voltage level	Description
1	PLD_SDA	Signal	0 – 3.3 V	I2C payload SDA line
2	PLD_SCL	Signal	0 – 3.3 V	I2C payload SCL line
3	BUS_SDA	Signal	0 – 3.3 V	I2C bus SDA line
4	BUS_SCL	Signal	0 – 3.3 V	I2C bus SCL line
5	RTN	Power return	0 V	EPS power return from MPPT
6	MPPT_Y-	Power	0 – 12 V	Power to MPPT Y- converter on EPS
9	OBC_RX	Signal	0 – 3.3 V	OBC UART_DBG RX line for testing
10	OBC_TX	Signal	0 – 3.3 V	OBC UART_DBG TX line for testing

Pin	Name	Type	Voltage level	Description
11	MPPT_X	Power	0 – 12 V	Power to MPPT X converter on EPS
12	MPPT_Y+	Power	0 – 12 V	Power to MPPT Y+ converter on EPS

Table 3-4 AccessPort connector pinout

3.4 SAIL CONNECTOR

SAIL thermal knives are connected to PLD board. It allows to read measurements (temperature, sail opened indicator), as well as passes current from EPS.

Connector is Harwin L-Tek M80-8670805. Full specification for a single connector:

Parameter	Value
Manufacturer	Harwin
Manufacturer part number	M80-8670805
Pins count	4 pins per row, double row = 8 pins
Pitch	2mm
Mounting Style	Through Hole

Table 3-5 Solar panels connector specification

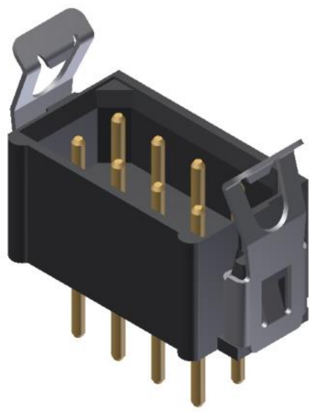

Figure 3-6 Harwin M80-8670805 CAD model

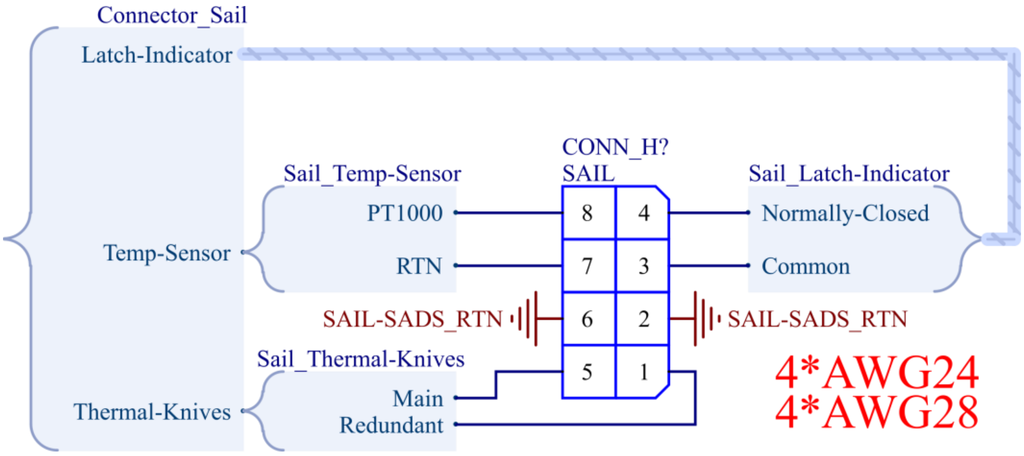

Figure 3-7 Sail connector

Pin-out definition for SAIL connector:

Pin	Name	Type	Voltage level	Description
1	Main	Power	0 – 12 V	Main thermal knife activation
5	Redundant	Power	0 – 12 V	Redundant thermal knife activation
2, 6	SAIL-SARD_RTN	Power return	0 V	Thermal knives power return
3	Common	Power	0 V	Digital ground for sail opened indicator
4	Normally-Closed	Signal digital	0 – 3.3 V	Sail opened indicator. ‘0’ – closed; ‘1’ – opened
8	PT1000	Signal analog	0 – 3.3 V	PT1000 temperature sensor ‘+’
9	PT1000	Signal analog	0 V	PT1000 temperature sensor ‘-’

Table 3-6 Sail connector pinout

3.5 Solar panels measurements connectors

Solar panels photodiodes and thermometers are connected to PLD board. The connectors are the same as SAIL connector.

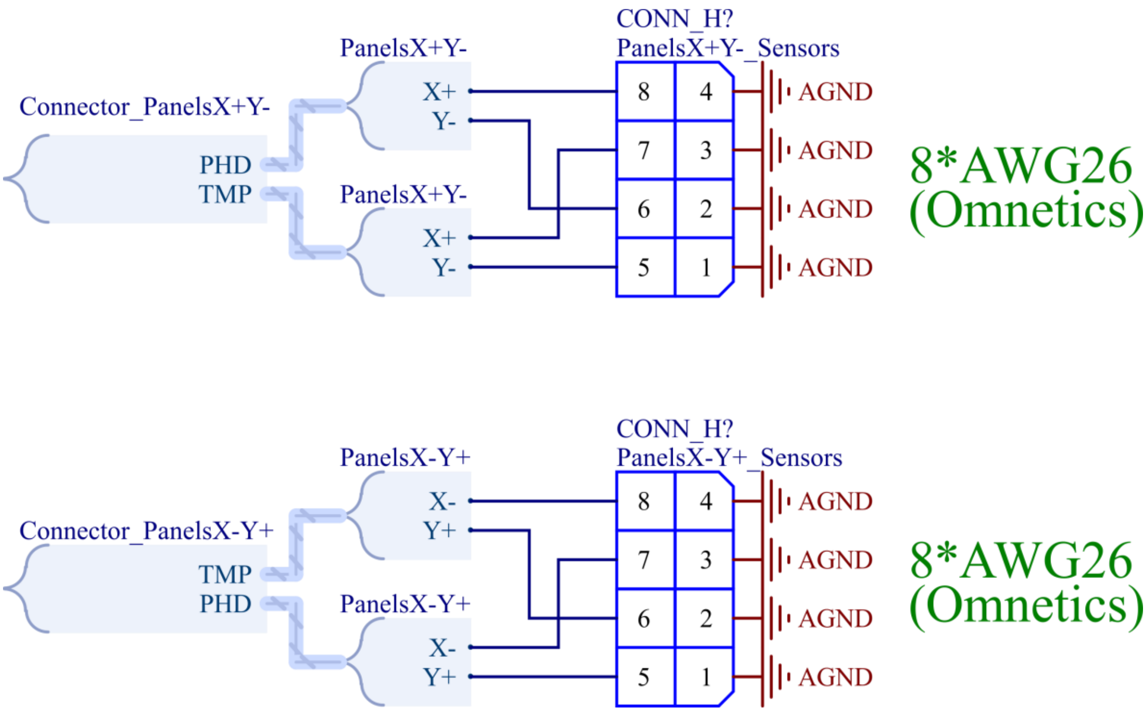

Figure 3-8 Solar panels connectors

Pin	Name	Type	Voltage level	Description
1-1, 1-2, 1-3, 1-4, 2-1, 2-2, 2-3, 2-4	AGND	Signal return	0 V	Analog ground
1-5	TMP_Y-	Signal analog	0 – 5 V	PT1000 on Y- panel
1-6	PHD_Y-	Signal analog	0 – 5 V	Photodiode on Y- panel
1-7	TMP_X+	Signal analog	0 – 5 V	PT1000 on X+ panel
1-8	PHD_X+	Signal analog	0 – 5 V	Photodiode on X+ panel
2-5	TMP_Y+	Signal analog	0 – 5 V	PT1000 on Y+ panel
2-6	PHD_Y+	Signal analog	0 – 5 V	Photodiode on Y+ panel
2-7	TMP_X-	Signal analog	0 – 5 V	PT1000 on X- panel
2-8	PHD_X-	Signal analog	0 – 5 V	Photodiode on X- panel

Table 3-7 Solar panels connector pinout

3.6 SADS THERMAL KNIVES CONNECTOR

SADS thermal knives are mounted on PLD board and connected to it via two Harwin M80-8770222 connectors.

Specification data for a single connector:

Parameter	Value
Manufacturer	Harwin
Manufacturer part number	M80-8770222
Pins count	2 pins
Pitch	2mm
Mounting Style	Through Hole

Table 3-8 Harwin M80-8770222

Figure 3-9 Harwin M80-8770222 CAD model

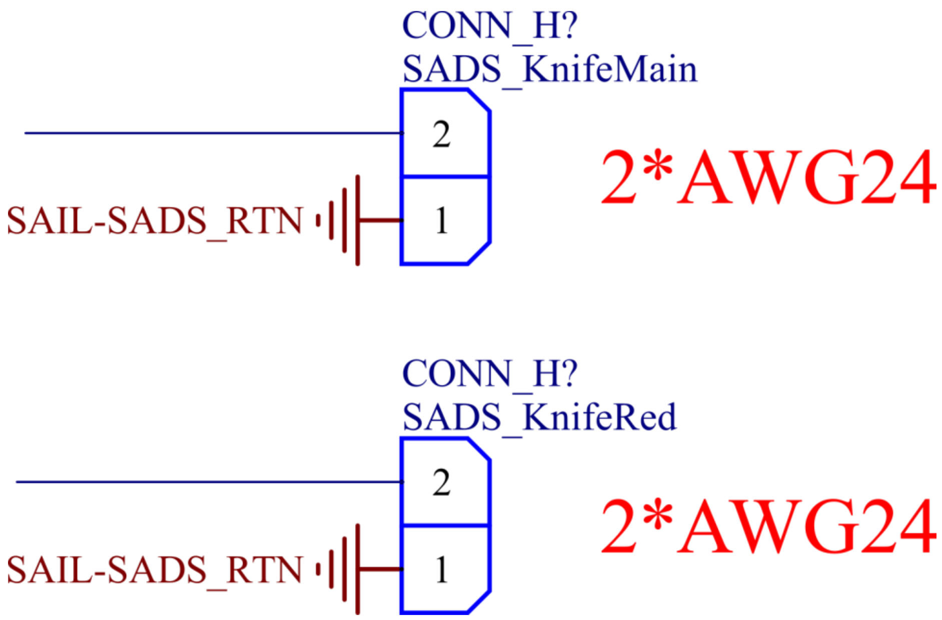

Figure 3-10 SADS connectors

Pin	Name	Type	Voltage level	Description
1-1, 1-2	SAIL-SADS_RTN	Power return	0 V	Thermal knives power return
1-2	SADS_MAIN	Power	0 – 12 V	Knife power - nominal
2-2	SADS_RED	Power	0 – 12 V	Knife power - redundant

Table 3-9 SADS connector pinout

3.7 SUNSENSOR – REFERENCE CONNECTOR

Reference SunSensor is connected to PLD board for measurements. It is connected via 3 Harwin M80-8670805 connector (same as SAIL). Naming convention is same as in SunS-ref ICD.

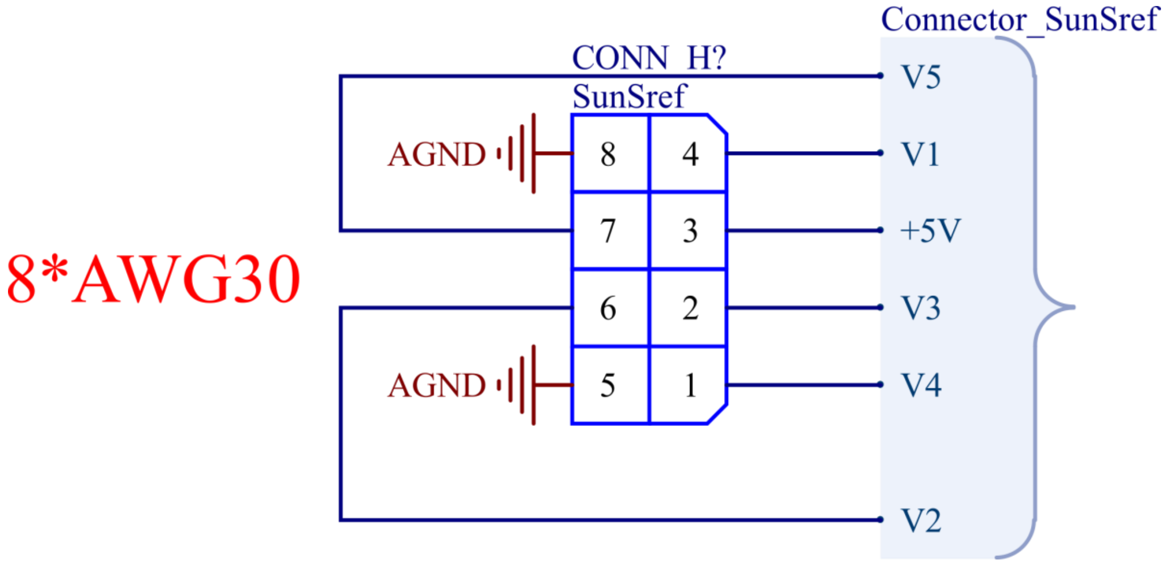

Figure 3-11 SunS-ref connector

Pin	Name	Type	Voltage level	Description
1	V4	Signal analog	0 – 5 V	V4 signal
2	V3	Signal analog	0 – 5 V	V3 signal
3	+5V	Power	0 – 5 V	Power for SunS-ref
4	V1	Signal analog	0 – 5 V	V1 signal
5, 8	AGND	Power return	0 V	Return current
6	V2	Signal analog	0 – 5 V	V2 signal
7	V5	Signal analog	0 – 5 V	V5 signal

Table 3-10 SunS-ref connector pinout

3.8 CAM CONNECTORS

Two cameras (wing & nadir) are connected to PLD board via Harwin M80-8670605 connectors. Both cameras has same connectors and pinouts.

Full specification for a single connector:

Parameter	Value
Manufacturer	Harwin
Manufacturer part number	M80-8670605
Pins count	3 pins per row, double row = 6 pins

Pitch	2mm
Mounting Style	Through Hole

Table 3-11 CAM connector specification

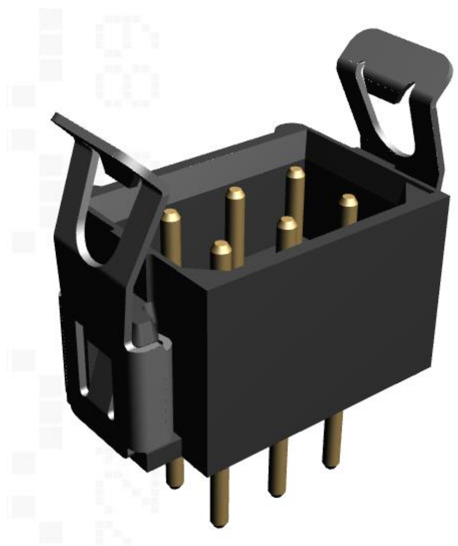

Figure 3-12 Harwin M80-8670605 CAD model

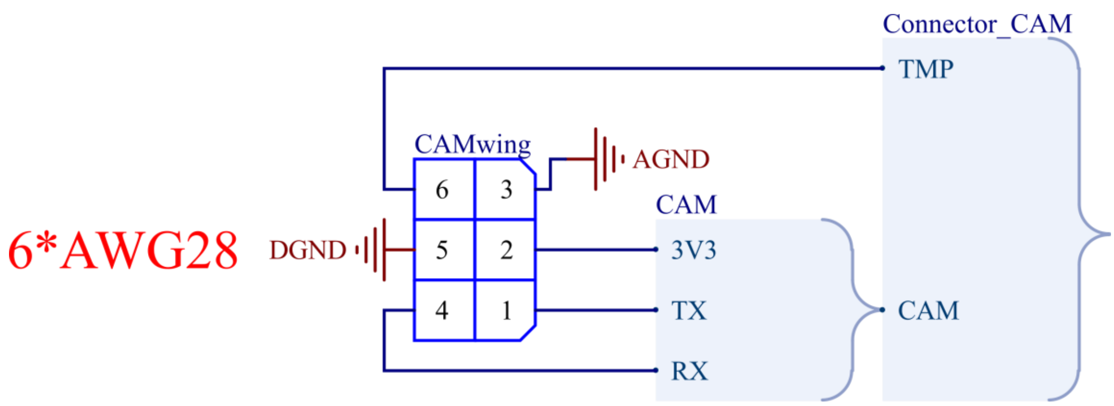

Figure 3-13 CAM connector

Pin-out definition for SAIL connector:

Pin	Name	Type	Voltage level	Description
1	TX	Signal	0 – 3.3 V	Camera TX line (to OBC RX)
2	3V3	Power	0 – 3.3 V	Power for camera
3	AGND	Signal return	0 V	Reference for temperature measurement

4	RX	Signal	0 – 3.3 V	Camera RX line (to OBC TX)
5	DGND	Power return	0 V	Power return
6	TMP	Signal analog	0 – 3.3 V	PT1000 temperature sensor

Table 3-12 CAM connector pinout

3.9 SunS connectors

Sun sensor is also connected via PLD board, which acts as a I2C repeated and connector throughput. SunS is connected with Harwin M80-8670405 connector.

Full specification for a single connector:

Parameter	Value
Manufacturer	Harwin
Manufacturer part number	M80-8670405
Pins count	2 pins per row, double row = 4 pins
Pitch	2mm
Mounting Style	Through Hole

Table 3-13 SunS connector specification

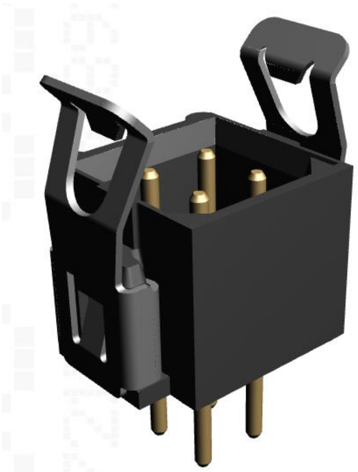

Figure 3-14 Harwin M80-8670405 CAD model

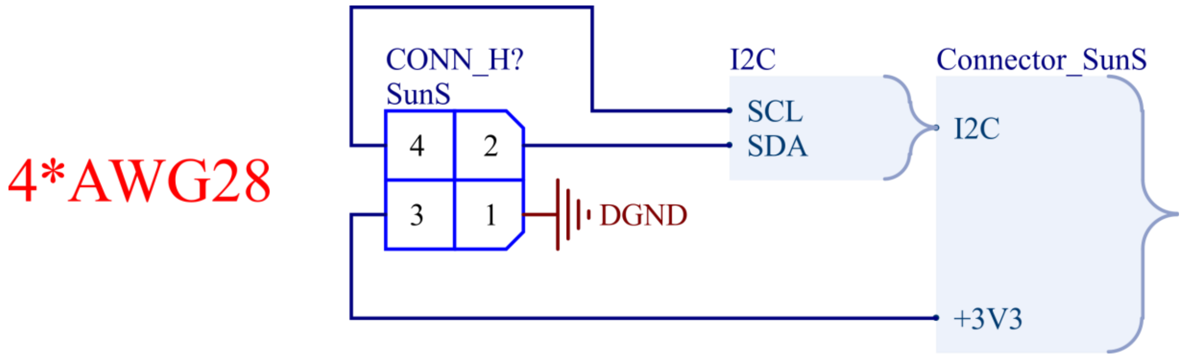

Figure 3-15 SunS connector

Pin	Name	Type	Voltage level	Description
1	DGND	Power return	0 V	Power return
2	SDA	Signal	0 – 3.3 V	I2C SDA line
3	3V3	Power	0 – 3.3 V	Power for SunS
4	SCL	Signal	0 – 3.3 V	I2C SCL line

Table 3-14 SunS connector pinout

4 ELECTRICAL CHARACTERISTICS

4.1 ESTIMATED POWER CONSUMPTION

Supply rail	Sub-circuit	Max current [mA]	Total current [mA]
SENS_5V	Flash memory	20	141
	Reference SunS	10	
	8x photodiode interfaces	40	
	ADC for photodiodes	5	
	16x thermometer interfaces	20	
	ADC for thermometers	5	
	3x gyroscopes	30	
	SAIL latch-indicator	1	
	SPI buffers and demux	10	
RadFET_3V3	[TBD]	[TBD]	[TBD]
CAMs_3V3	CAMwing	150 [TBC]	300
	CAMnadir	150 [TBC]	
OBC_3V3	SPI buffers (primary side)	10	22
	FLASH memory	20	
	FRAM memory	2	
SunS_3V3	SunS/[TBD]	[TBD]	[TBD]

Table 4-1 Estimation of current drawn

5 COMMUNICATION INTERFACES

To communicate with OBC, PLD board has I^{2}C communication interface: I2C-PLD (slave). In addition PLD board has interrupt line connected to OBC which can signal events, like acquisition completed.

5.1 I^{2}C ELECTRICAL CHARACTERISTICS

For safety reasons, I^{2}C repeater was applied.

Parameter	Value
I2C-PLD node	slave
I2C-PLD pull-up resistors (SCL and SDA)	none
I2C-PLD logic level	3.3 V
I2C-PLD series resistance (SCL and SDA)	100 Ω
I2C-PLD repeater	PCA9517A

Table 5-1 I^{2}C electrical characteristics

5.2 COMMUNICATION PROTOCOL

Communication protocol with PLD board is divided in two sections: commands & readout.

PLD 7-bit I2C address is TBD.

Basic communication scheme is as follows:

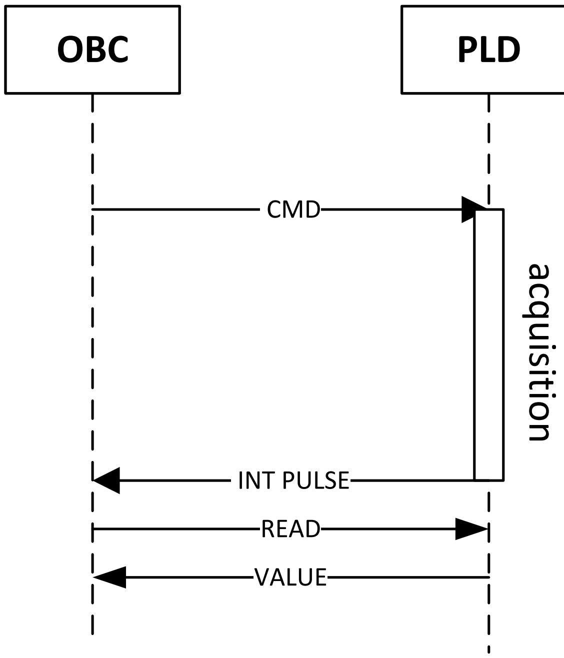

Figure 5-1 Communication scheme

PLD is requested for data acquisition (refresh). Then it performs requested action, updating local memory. Upon completion, it sets up completion flag and triggers pulse on INT line (TBD length).

After INT pulse OBC can ask PLD for particular register.

In timing graph:

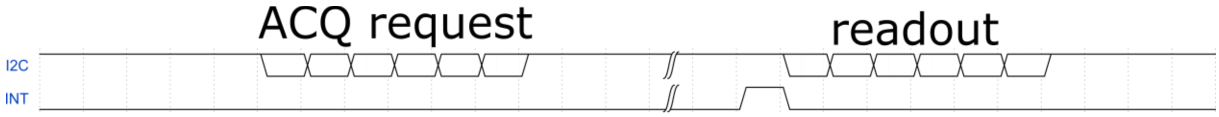

Figure 5-2 Communication scheme timing graph

First byte transmitted by master is always opcode. Most significant bit is also important:

C/D	a_6	a_5	a_4	a_3	a_2	a_1	a_0

MSB (C/D) informs if the opcode is Command ('1') or Data request ('0').

5.3 Commands

Commands are I2C transaction of 1-byte length. They are always "write" command followed by "STOP". None of command have parameters.

Most significant bit of opcode is always ‘1’ in command mode.

START (ADDR+W)	COMMAND OPCODE	STOP

After completion (defined in each command) trigger on INT line is fired.

Only one command can be active at any time. If new command arrives before previous is finished it is ignored.

5.3.1 Refresh SunS-ref

Command name	Opcode	Maximum time
Refresh SunS-ref	0x80	10 ms

This command starts acquisition of five ADC channels connected to SunS-ref.

5.3.2 Refresh PT1000 temperatures

Command name	Opcode	Maximum time
Refresh all temperatures	0x81	10 ms

This command starts acquisition of temperature channels connected to PT1000 sensors (2x CAM, SADS, SAIL, 4x solar panels).

5.3.3 Refresh Photodiodes

Command name	Opcode	Maximum time
Refresh photodiodes	0x82	10 ms

This command starts acquisition of all photodiodes channels (X+, X-, Y+, Y-).

5.3.4 Take RadFET measurement

Command name	Opcode	Maximum time
Refresh RadFET	0x83	10 s

This command will enable RadFET subsystem, measure accumulated dose and save it to memory.

5.3.5 Read housekeeping data

Command name	Opcode	Maximum time
Refresh housekeeping	0x84	10 ms

This command will measure HK data (voltages, temperatures).

5.4 DATA READOUT

When data was acquired from sensors intro internal memory it needs to be read out by OBC.

OBC requests for particular register in PLD memory (with auto-increment after each byte), the only exception is first returned byte – it contains error flag register. Second byte is requested one, and next are being read from auto-incremented address counter.

Multi-byte data are send little endian (lowest byte first).

Example data readout (data from SunS-ref):

START (Addr+W)	**0x04**	**REP-START (Addr + R)**	**Error flag**	**V1 (lower byte)**	**V1 (upper byte)**	**STOP**

To read multiple channels:

START (Addr+W)	**0x04**	**REP-START (Addr + R)**	**Error flag**	**V1 low**	**V2 up**	**V2 low**	**V2 up**	**V3 low**	**V3 high**	**V4 low**	**V5 high**	**STOP**

Data addresses are shown in Table 5-2.

Table 5-2 Data adresses table

ID	Designator	Sensor type	Data type	Length [bits]	Conversion formula	Unit (after conversion)	Accuracy
0x00							
0x01	Busy data flag	internal flag	8 flags	8	NA	NA	NA
0x02	Error flag	internal flag	TBD	TBD	NA	NA	NA
0x03							
0x04	SunS-ref-V1	SunS-ref + 12 bit ADC	uint 16-bit	12	[TBD]	V	[TBD]
0x06	SunS-ref-V2	SunS-ref + 12 bit ADC	uint 16-bit	12	[TBD]	V	[TBD]
0x08	SunS-ref-V3	SunS-ref + 12 bit ADC	uint 16-bit	12	[TBD]	V	[TBD]
0x0A	SunS-ref-V4	SunS-ref + 12 bit ADC	uint 16-bit	12	[TBD]	V	[TBD]
0x0C	SunS-ref-V5	SunS-ref + 12 bit ADC	uint 16-bit	12	[TBD]	V	[TBD]
0x0E	X+_PHD	12 bit ADC	uint 16-bit	12	[TBD]	A	[TBD]
0x10	X-_PHD	12 bit ADC	uint 16-bit	12	[TBD]	A	[TBD]
0x12	Y+_PHD	12 bit ADC	uint 16-bit	12	[TBD]	A	[TBD]
0x14	Y-_PHD	12 bit ADC	uint 16-bit	12	[TBD]	A	[TBD]
0x16	SUPPLY_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]
0x18	X+_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]
0x1A	X-_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]

ID	Designator	Sensor type	Data type	Length [bits]	Conversion formula	Unit (after conversion)	Accuracy
0x1C	Y+_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]
0x1E	Y-_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]
0x20	SADS_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]
0x22	SAIL_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]
0x24	GYRO_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]
0x26	SUPPLY_TMP	12 bit ADC	uint 16-bit	12	[TBD]	ºC	[TBD]
0x28	INT_3V3d	12 bit ADC	uint 16-bit	12	[TBD]	V	[TBD]
0x30	OBC_3V3	12 bit ADC	uint 16-bit	12	[TBD]	V	[TBD]
0x28	RADFET_TMP	24 bit ADC	uint 32-bit	24	[TBD]	ºC	[TBD]
0x2C	RADFET_VTH_1	24 bit ADC	uint 32-bit	24	[TBD]	V	[TBD]
0x30	RADFET_VTH_2	24 bit ADC	uint 32-bit	24	[TBD]	V	[TBD]
0x34	RADFET_VTH_3	24 bit ADC	uint 32-bit	24	[TBD]	V	[TBD]

5.5 DATA DESCRIPTION

5.5.1 BUSY DATA FLAGS

0	0	0	0	a_3	a_2	a_1	a_0

Reset value: 0x00

Each bit represents one measurement command.

‘1’ means that conversion is in progress. ‘0’ – PLD is not measuring anything.

After issuing any command corresponding bit is set it this register. Upon completion bit is cleared and INT pulse is triggered. If is register is not 0x00 any command from OBC will be ignored.

Bits meaning:

- a_0 – SunS-ref
- a_1 – Photodiodes
- a_2 – Temperatures
- a_3 – RadFET

5.5.2 ERROR FLAG

Reset value: 0x00

After bootup, this byte will contain error flag, if any error occurred during PLD boot-up process.

After command completion (or timeout) this byte will contain error flags corresponding to actual command.

Error codes:

Name	ERROR value
No error	0
Command rejected (busy)	1
Command undefined	2

5.5.3 Reference SunSensor

Data from reference Sun Sensor are 5 analog channels read by 12-bit ADC (ADC128).

For every channel two bytes (12 bit value coded on uint16_t) are allocated as follows:

$$ADC\ value = (a_{11}a_{10} \dots a_1 a_0)_2$$

Lower byte (eg. 0x06)								**Upper byte (eg. 0x07)**							
a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0	0	0	0	0	a_{11}	a_{10}	a_9	a_8

Reference voltage for ADC is 4.096 V, hence simple conversion formula (1 LSB is 1 mV):

$$U\ [mV] = val\ [LSB]$$

5.5.4 PT1000 Temperatures (CAM, Panels, SADS, Sail)

This values will also be converted on ground. Data format is same as for Reference SunSensor.

Resistance formula:

$$R\ [\Omega] = ADC/(1.425)$$

5.5.5 Photodiodes

Photodiodes measurements are RAW values read from ADC. They will be converted to photodiode current on ground. Data format is same as for Reference SunSensor.

Conversion formula:

$$I\ [\mu A] = val\ [LSB] - 85.3\ [uA]$$

5.5.6 RadFET

Measurement channels read from RadFET sensor are RAW reads from on-board 24-bit ADC. No conversion on PLD or OBC is performed – data will be analysed on ground. Detailed description could be found in RadFET experiment description.

Each channel looks like 32-bit register, but only 24-bits are used. Therefore, 4 channels could be compressed into 3x 32-bit register, which have to be considered.

In each 32-bit register highest byte (with highest address) will be 0x00.

6 MECHANICAL INTERFACES

6.1 PHYSICAL DIMENSIONS

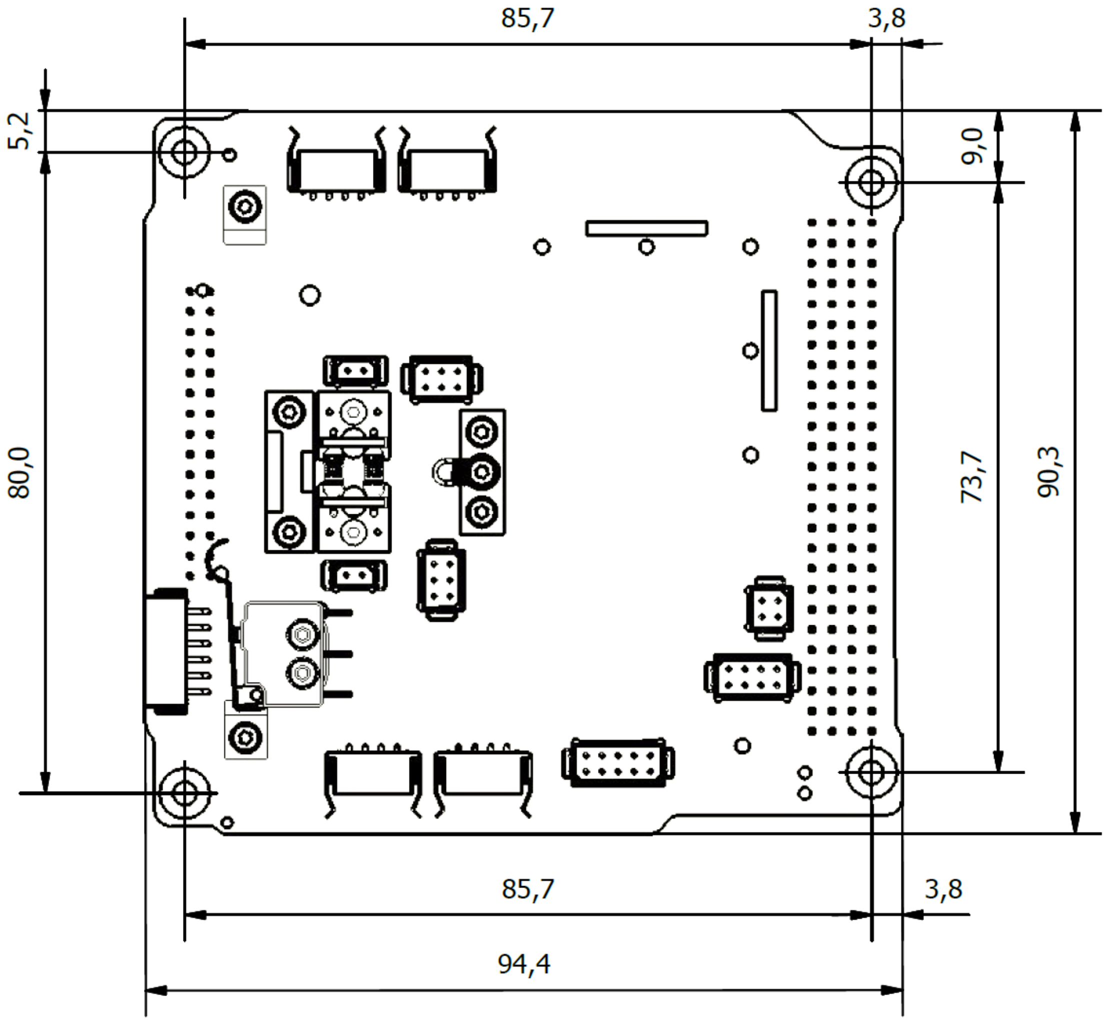

Figure 6-1 PLD drawing, top view

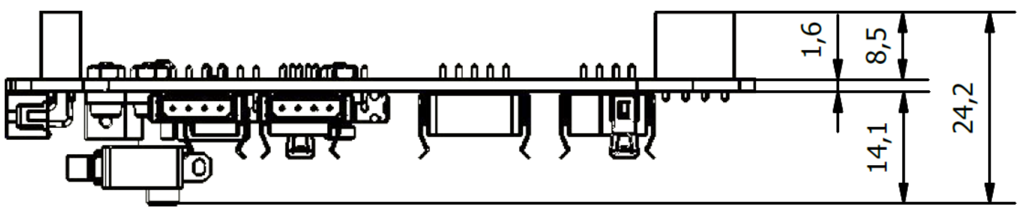

Figure 6-2 PLD drawing, top side view