EPS USER MANUAL

Electrical Power System (EPS)

ELECTRICAL POWER SYSTEM (EPS) USER MANUAL

This user manual is specially designed to detail the EnduroSat Electrical Power System (EPS) description, functions and features.

Please read this manual before unpacking and using the EPS to ensure safe and proper use.

Figure 1 - EPS module

1 CHANGE LOG

Date	Version	Note
03/08/2016	Rev 1.0	
13/04/2017	Rev 1.1	Battery EOC changed to 4.1V, minor changes in the block diagram
12/01/2018	Rev 1.2	Minor changes in text and diagrams

2 ACRONYMS LIST

BCR	Battery Charger Regulator
EOC	End of Charge
EPS	Electrical Power System
ESD	Electrostatic Discharge
I2C	Inter Integrated Circuit
Li-Po	Lithium Polymer Battery
LUP	Latch-up Protected
MPPT	Maximum Power Point Tracking
PCM	Protection Circuit Module
RBF	Remove Before Flight
UART	Universal asynchronous receiver/transmitter
USB	Universal Serial Bus
LDO	Low Dropout Regulator
MCU	Microcontroller

3 HIGHLIGHTED FEATURES

- ✓ 3 Photovoltaic input channels with independent control and monitoring;
- ✓ Input voltage (per input channel): 0.5 - 5.5 V;
- ✓ Input current (per input channel): up to 1.8 A;
- ✓ BCR efficiency: up to 95%;
- ✓ Battery pack power: 10.4 Wh;
- ✓ Battery pack voltage: 3.3 - 4.2 V;
- ✓ Stackable battery packs: up to 8A;
- ✓ Output power buses: 3.3V, 5V, BCR ($5V_{max}$) and battery raw
- ✓ Two Latch-up protected outputs
- ✓ Interfaces: UART, I2C, USB;
- ✓ Remove before flight switch;
- ✓ Six outputs for shutdown/reset of other modules;
- ✓ USB debug & battery charger;
- ✓ Weight: 198g including 1 battery pack and 278g including 2 battery pack;

4 SYSTEM DESCRIPTION

The power module is most suitable for 1U, 1.5U and 2U CubeSat Satellites. It comes with integrated one or two Li-Po battery packs encapsulated inside the aluminum box. Capacity of one battery pack is 10.4 Wh, which adds up to 20.8 Wh with 2 stacked battery packs. There are three photovoltaic input channels for supplying the power from each axis of solar panels. Each channel consists of two connectors (see paragraph 6.4) that are intended for opposite solar panels in order to maintain the input parameters within the maximum ratings of the module. Observe the maximum input ratings in all cases (especially if deployable solar panels are used).

There are three independent channels for control and monitoring of the solar panels on each axis. They have the following features:

- Precision current and voltage measurement;
- Overcurrent protection;
- Overvoltage protection;
- Overtemperature protection;
- ESD protection;
- Solar panels reverse-insertion protection – turns off the corresponding channel;
- Every solar panel channel supports safe shutdown in case of a problem (optional).

The photovoltaic power convertors can handle input voltage up to 5.5V and the current maximum threshold for overcurrent protection can be set up to 1.8A (hardware customizable). The operating temperature range is from -40°C to +150°C and overtemperature threshold is set to be +155°C (the module will turn off if threshold is reached and restart automatically when the temperature decreases to +130°C). The efficiency of the step-up convertors is up to 95%.

The step-up convertor turns OFF if the input voltage is lower than 0.27V (under voltage lockout) and restarts when the voltage exceeds 0.34V. A hysteresis is implemented to avoid unpredictable ON-OFF switching. However the minimum input voltage threshold for boosting is 0.5V.

The step-up convertors work at 100kHz fixed frequency. The duty cycle is controlled by MPPT algorithm. Boosted output voltage can be accessed through PC/104 connector for additional functionality such as charging of another battery pack, super capacitors, etc.

Battery charger features operation in both linear and quasi-pulse modes. The advantage of the quasi-pulse charging method is that it allows the energy harvested by not well illuminated solar cells to be maximized. Programmable charge current: 230mA / 460mA for slow charge and fast charge respectively (hardware customizable up to 1A); Hardware and Software monitoring and control.

In the standard configuration, the EPS with one battery pack has 2 Li-Po batteries connected in parallel. There is hardware and firmware battery protection. Each battery has its own Overcurrent, Overcharge and Overdischarge protections ensured by integrated protection circuit module (PCM). Special firmware algorithm is implemented for protection of the batteries from short circuit, deep discharge and overheating (figure 2).

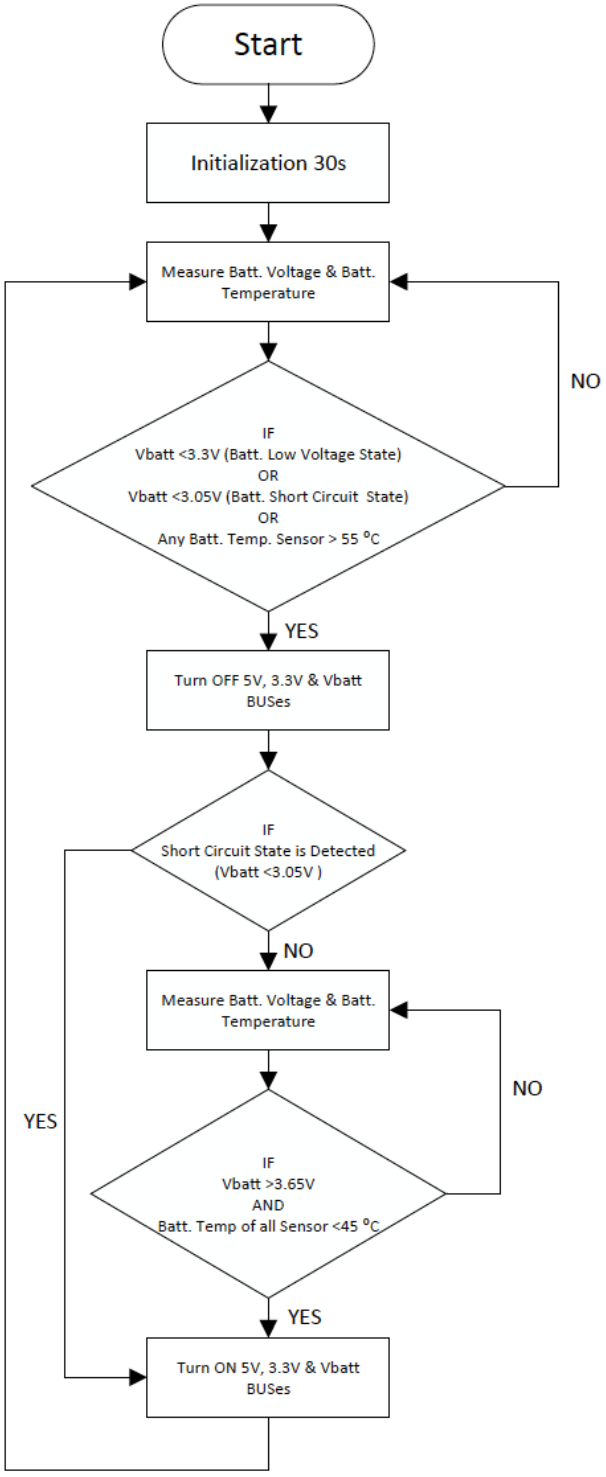


Figure 2 – Algorithm for protection of the batteries from short circuit, deep discharge and overheating.

Each battery pack has three independent heaters to prevent charging under 0 ºC. Special algorithm optimizes heater power consumption in relation to the temperature (figure 3).

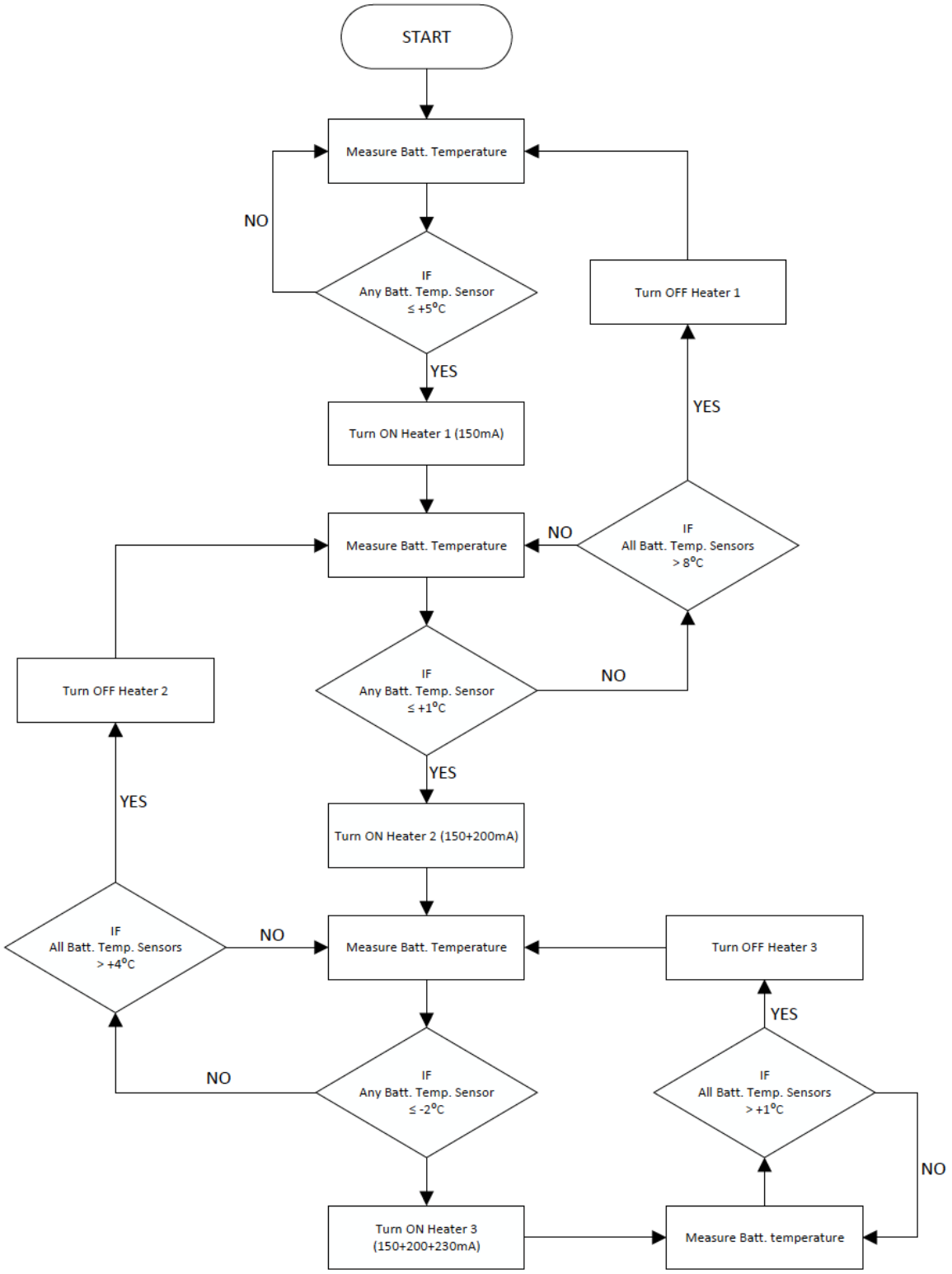


Figure 3 - Algorithm for the optimization of the heater power consumption

The two deployment switch connectors are located at two opposite corners of the CubeSat structure in accordance with CubeSat Design Specification. A remove-before-flight (RBF) connector is also available. When the RBF pin is plugged in or both deployment switches are pressed, the module is inactive. In order to activate the module it is necessary that RBF pin is unplugged and at least one deployment switch is released.

The deployment switches and RBF disconnect the batteries from the power buses and thereby turn off the system and stop all power consumption. Once the module is turned on, the self-locking functionality is activated and the power supply cannot be stopped by the deployment switches or remove before flight pin anymore. For ground test purposes the self-lock functionality can be stopped through the PC software via the USB cable provided.

The incoming power along with the energy stored in the batteries is used to feed all main buses: 3.3V@3A, 5V@2.5A and Vbatt@4A (specifications for Power System with 1 Battery Pack). Both DC-DC converters are synchronized with the same working frequency.

There are two Latch-up protected (LUP) outputs - one connected to the 5V BUS (H1-48) and one to the 3.3V BUS (H1-51). The set fault current threshold is 2A for both LUPs. If fault current threshold is reached the LUP disconnects its output. Auto retry mechanism is implemented - every 15ms LUPs check if the fault current is below fault threshold in order for normal operation to continue. The fault current can be monitored by status flag.

There is a built-in firmware for monitoring and control, which can display the following parameters:

- ✓ Solar panels voltages and currents;
- ✓ BCR voltage (H2-41/42/43/44);
- ✓ Output power buses current consumptions (5V BUS, 3.3V BUS, Battery BUS and BCR BUS);
- ✓ Battery pack(s) voltage, current and temperature;
- ✓ External temperature sensors;
- ✓ Critical state flags – power cycle; low voltage states, short circuit states, over temperature states, minimum and maximum reached temperatures of each battery;
- ✓ Status of output power buses, charging and deployment switches Self-lock.

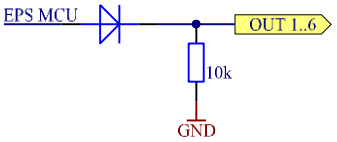
The firmware provides control over the following features:

- ✓ Deployment switches Self-lock;
- ✓ Battery BUS;
- ✓ BCR Bus;
- ✓ 3.3V & 5V Buses;
- ✓ Battery Normal / Fast Charge;
- ✓ Six general purpose outputs
- ✓ Battery heaters

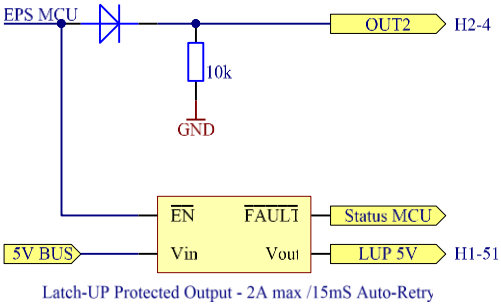
The EPS measures current of each solar panel and voltage of opposite panels on each axis. Stabilized voltage from the three photovoltaic step-up convertors is also monitored – BCR Voltage. Power Module measures the current consumption through all buses – 5V, 3.3V, Battery Raw and BCR Out. When the

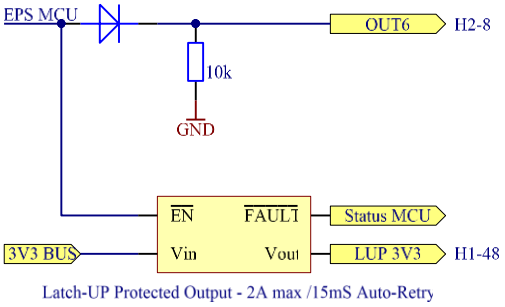
5V & 3.3V BUS is within 5% of the regulation voltages status flag is provided. The instant, minimum and maximum temperature of every battery cell is monitored. Up to three external temperature sensors can be connected to the module for thermal measurement of user defined critical places inside the satellite.

The EPS Module has six general purpose outputs. Every output can be switched between 2.4V and Ground. All outputs are protected with diodes and 10k pull-down resistors, which enable other modules to control them at the same time. Diode OR gate can be realized.



Output 2 and 6 have double usage - they can be used as general purpose outputs or to control the LUPs. Both LUPs work with inverted logic - when the corresponding Output is set to ground level, LUP is turned ON.





5 BLOCK DIAGRAM

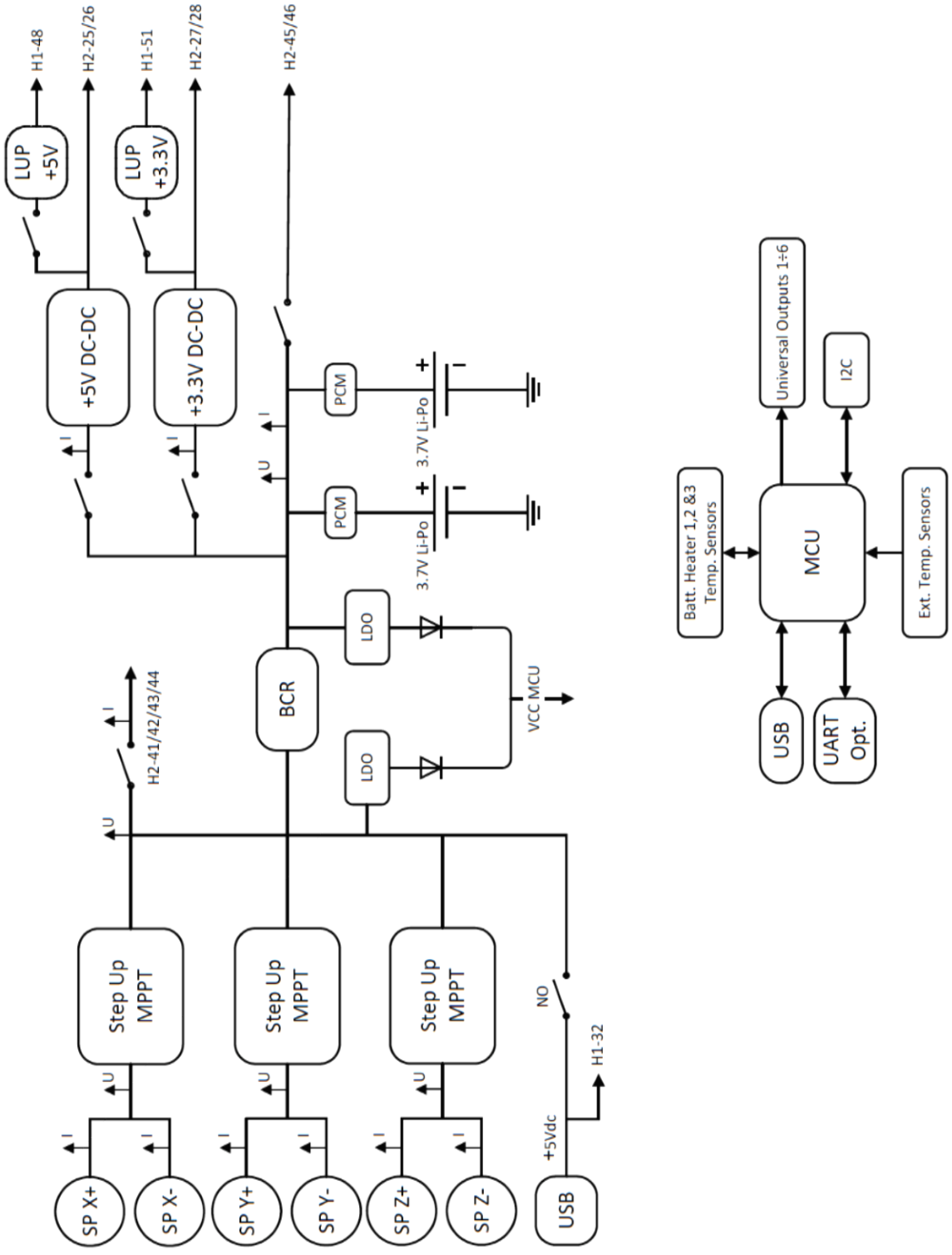


Figure 4 – Block diagram

6 CONNECTOR PINOUT

6.1 Connectors Location

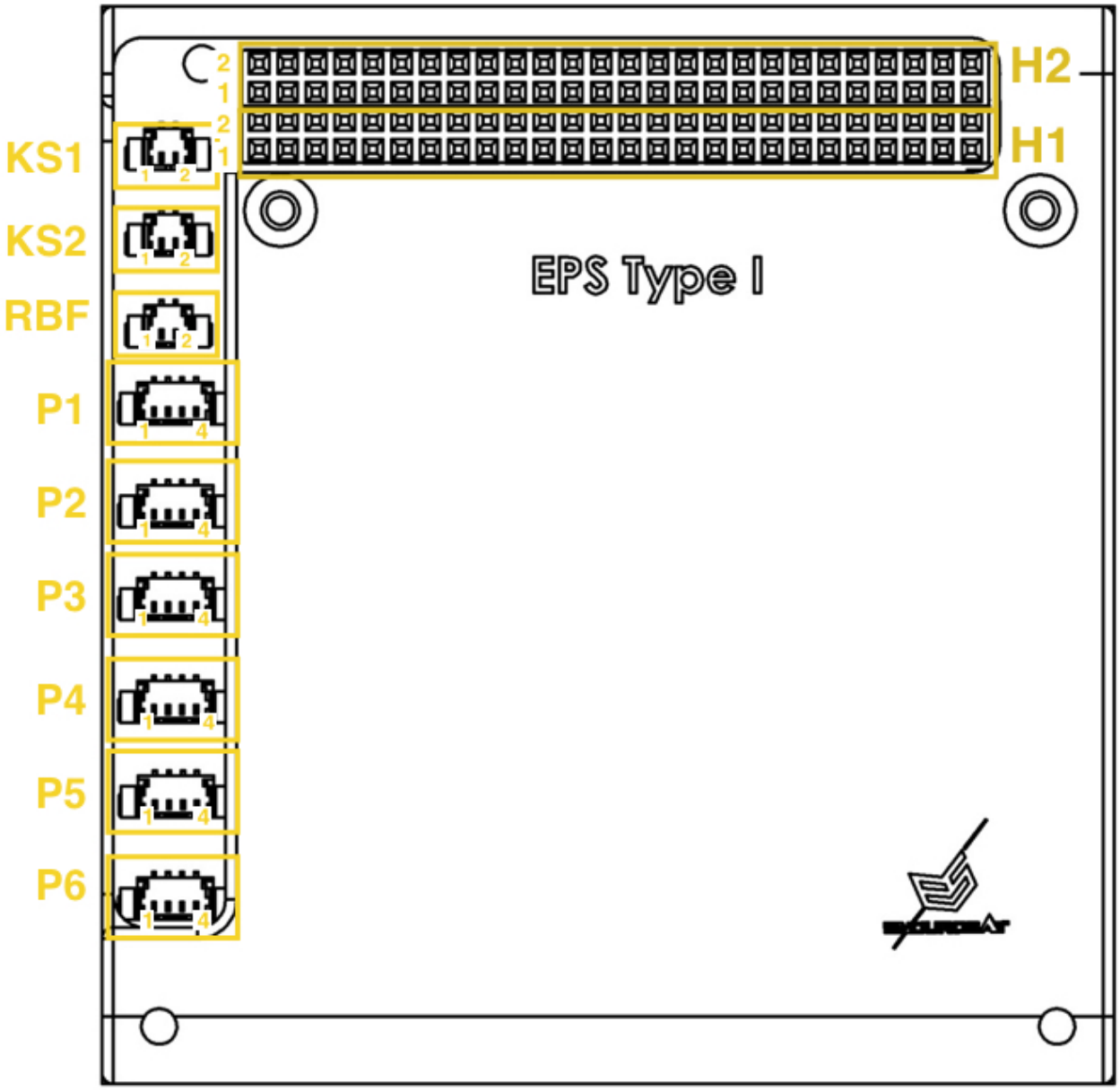


Figure 5 - Connectors location and pinout

6.2 H1 - Stack Connector

Pin	Mnemonic
H1-32	5VUSB
H1-33	UART RX*
H1-35	UART TX*
H1-41	I2C SDA
H1-43	I2C CLK
H1-48	LUP2 5V
H1-51	LUP1 3.3V

* (Optional – Hardware Customizable)

6.3 H2 - Stack Connector

Pin	Mnemonic
H2-3	OUT1
H2-4	OUT2
H2-5	OUT3
H2-6	OUT4
H2-7	OUT5
H2-8	OUT6
H2-25	5V BUS
H2-26	5V BUS
H2-27	3.3V BUS
H2-28	3.3V BUS
H2-29	GND
H2-30	GND
H2-31	GND
H2-32	GND
H2-41	BCR Out
H2-42	BCR Out
H2-43	BCR Out
H2-44	BCR Out
H2-45	VBATT BUS
H2-46	VBATT BUS

6.4 P1 to P6 - Solar Panel Input connector

The solar panel input connectors from P1 to P6 are 4 pins MOLEX Picoblade 53398-0471. By default, they are set in the following configuration:

P1 → X-

P2 → X+

P3 → Y-

P4 → Y+

P5 → Z-

P6 → Z+

This configuration can be modified, taking in account that the pairs: P1 and P2; P3 and P4; P5 and P6 should be connected to solar panels on opposite sides of the same axis.

The pinout is the same for all 6 connectors:

Pin	Mnemonic	Description
1	-	Negative
2	-	Negative
3	+	Positive
4	+	Positive

6.5 KS1 and KS2 – Deployment switches

KS1 and KS2 are respectively deployment switch 1 and deployment switch 2 connectors. Both are 2 pins MOLEX Picoblade 53398-0271 connectors.

6.6 RBF – Remove before flight

RBF is the remove before flight connector - 2 pins MOLEX Picoblade 53398-0271

7 ELECTRICAL CHARACTERISTICS

Parameter	Unit	Condition	Min	Typ	Max
Battery Capacity					
Capacity	mAh	EPS with 1 battery pack	2640	2800	
	mAh	EPS with 2 battery packs	5280	5600	
	Wh	EPS with 1 battery pack		10.4	
	Wh	EPS with 2 battery packs		20.8	
Battery Charger					
EOC voltage	V		4.08	4.1	4.12
Charge current	mA	Fast Charge Mode (by default)	430	460	490
	mA	Slow Charge Mode	215	230	245
Battery Discharge					
Over Discharge Detection	V	Limited by PCM	2.24	2.3	2.36
Over Current Detection	mA	EPS with 1 battery pack (limited by PCM)		4000	9000 (8 to 16ms)
	mA	EPS with 2 battery packs (limited by PCM)		8000	16000 (8 to 16ms)
Exp. Cycle Life	mAh	Discharge @ 0.5/1C, 23 ±2ºC;	500 Cycles ≥ 2196 mAh		
Unregulated Battery Bus					
Output voltage	V	Firmware defined	3.3		4.24
Output current	mA	EPS with 1 battery pack (limited by PCM)		4000	9000 (8 to 16ms)
	mA	EPS with 2 battery packs (limited by PCM)		8000	16000 (8 to 16ms)
+5 V Bus					
Output voltage	V		4.88	5	5.15
Output current	mA	EPS with 1 battery pack			2500
Operating frequency	kHz		380	390	400
Efficiency		V_{batt} = 3.8; I_{5VBUS} = 2A	88%	89%	90%
+3.3 V Bus					
Output voltage	V		3.3	3.38	3.45
Output current	mA				3000
Operating frequency	kHz		380	390	400

Efficiency		V_{batt} = 4V; $I_{3.3VBUS}$ = 2A	79%	80%	81%
Module Consumption					
Power Consumption	mW	Normal Operation. LUP5V & LUP3V3 are OFF		75	
	mW	Low Voltage or High Temperature State. All Buses are OFF		43	
Current Consumption	mA	Batt. Low State @3.3V		13	
	mA	Normal Operation @3.7V		20	
	mA	LUP3V3 & LUP5V	3.9		5
	mA	Heater 1		150	
	mA	Heater 2		200	
	mA	Heater 3		230	
Fault Current Threshold (auto retry every 15ms)	A	LUP3V3 & LUP5V	1.75		2.2
Solar Panels Input					
Voltage	V	@25ºC	0	4.66	5.5
Current	mA	@25ºC		517	1800
Power	W	@25ºC		2.6	

8 MECHANICAL DRAWING

The following pictures show the external dimensions of the EPS subsystem. The EPS, as already mentioned, has 2 configurations: EPS with one battery pack and with two. The bottom lid of the module could be with an opening, which is designed to accommodate the RF connector of EnduroSat S-Band Patch Antenna. The top view is the same for both configurations.

All dimensions are in mm.

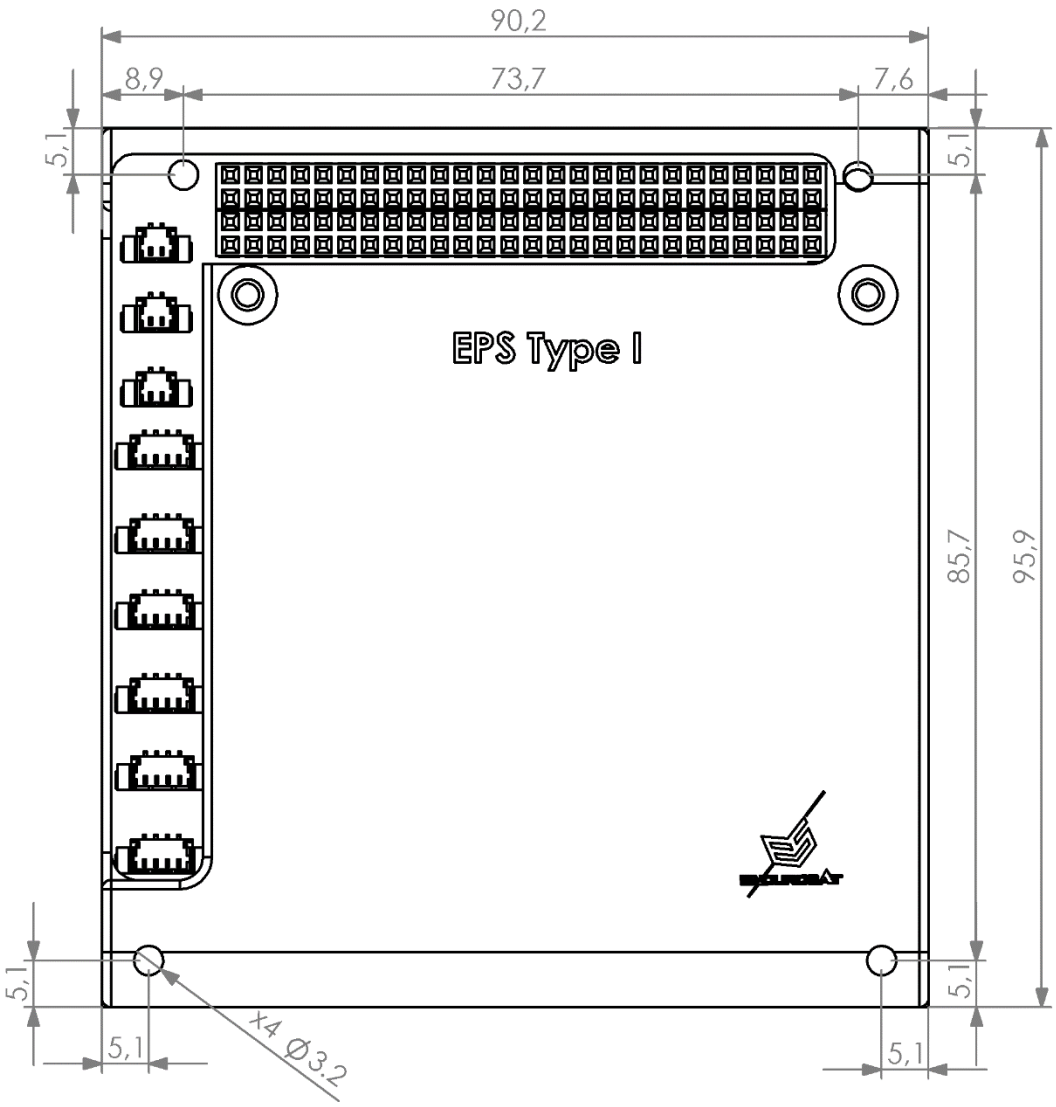


Figure 6 – EPS top view

The bottom part of the EPS box has 2 configurations. One has opening as shown in figure 7 and figure 9 to accommodate cables and connectors for the EnduroSat S-band patch antenna. The second configuration is without opening as shown in figure 8 and figure 10.

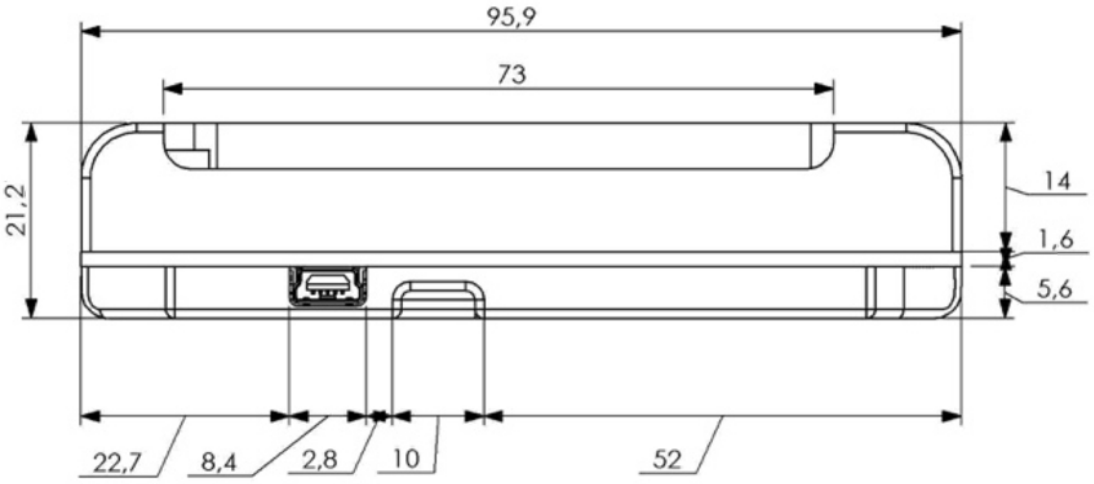


Figure 7 – EPS with 1 battery pack – side view

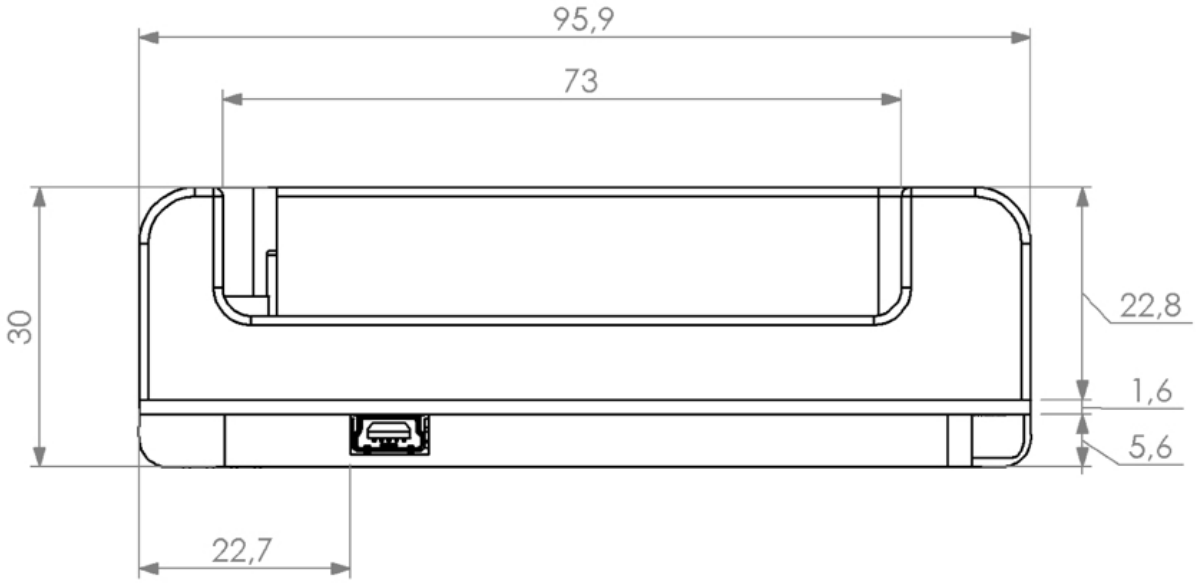


Figure 8 – EPS with 2 battery packs – side view

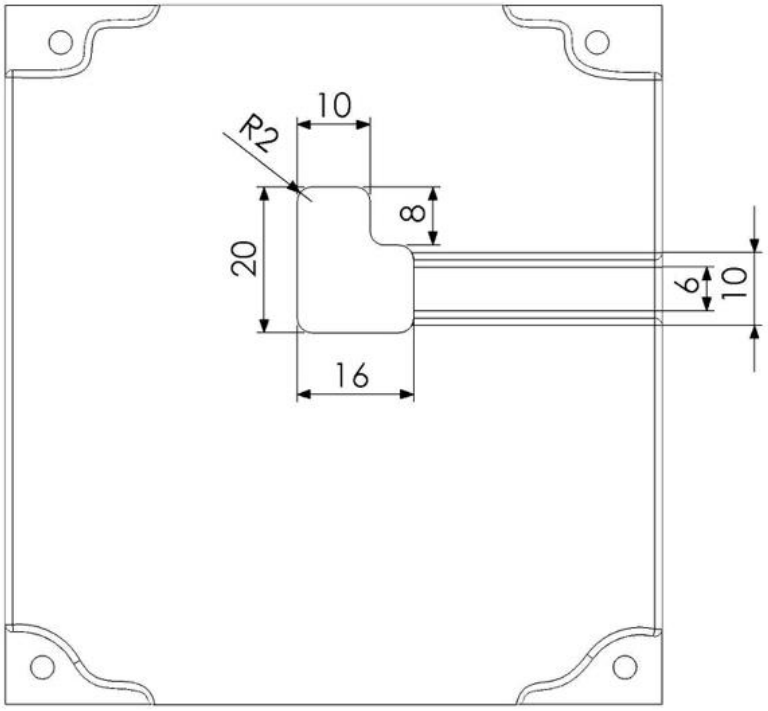


Figure 9 - EPS - bottom view with opening

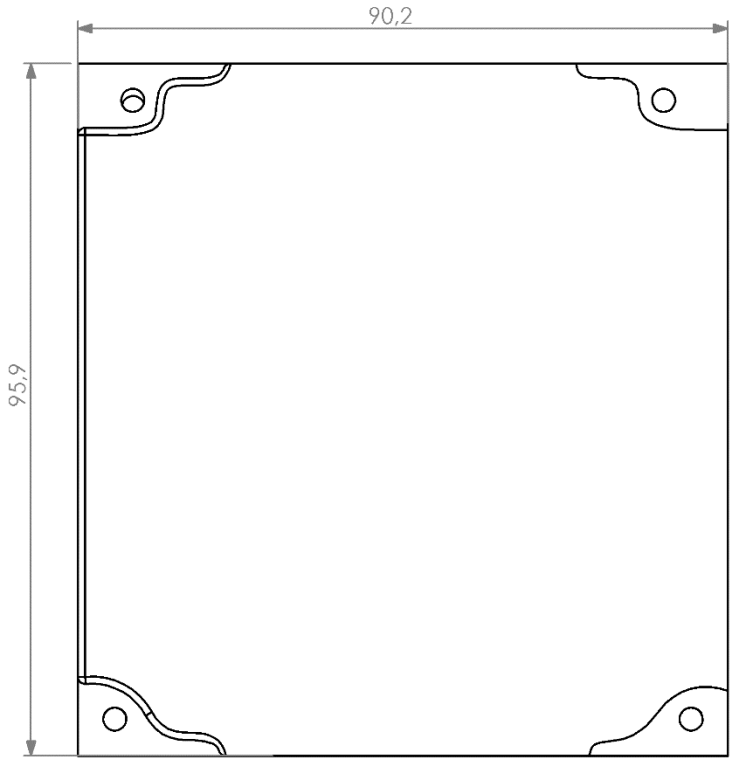


Figure 10 - EPS - bottom view without opening

9 ENVINRONMENTAL AND MECHANICAL TEST

A full campaign of tests at qualification level was performed on the qualification engineering model Qualification tests level and duration follow the ESA standard ECSS-E-ST-10-03C and GEVS: GSFC-STD-7000A. Tests performed:

- Thermal Cycling
- Thermal Vacuum
- Random Vibration
- Sine Vibration
- Shock Test

Test report can be provided upon request.

10 HANDLING AND STORAGE

Particular attention shall be paid to the avoidance of damage to the EPS during handling, storage and preservation. The handling of the EPS module should be performed in compliance with the following instructions:

- Handle using PVC, latex, cotton (lint free) or nylon gloves.
- The environment where EPS module will be handled shall meet the requirements for a class 100,000 environment, free of contaminants such dust, oil, grease, fumes and smoke from any source.
- Store in such a manner as to preclude stress and prevent damage.
- To prevent the deterioration, the power module must be stored in a controlled environment, i.e. the temperature and humidity levels shall be maintained in the proper ranges:
    - Ideal storage temperature range: 15ºC to 27ºC
    - Ideal storage humidity range: 30% to 60% relative humidity (RH)

11 WARNINGS

This product uses semiconductors that can be damaged by electrostatic discharge (ESD). Observe precautions for Handling

Sensitive Electronic device. Do not ship or store near strong electrostatic, electromagnetic, magnetic or radioactive fields.

LITHIUM ION RECHARGEABLE BATTERY
Caution! May explode if disposed in fire

- Do not incinerate or place near an open flame
- Do not drop, crush, puncture or disassemble battery
- Do not short terminal
- Do not expose to temperature above 140°F/60°C
- Do not replace by a battery other than that specified by manufacturer