



# EPS 2.0 Documentation

---

*EPS 2.0 Documentation*

*SpaceLab, Universidade Federal de Santa Catarina, Florianópolis - Brazil*



## EPS 2.0 Documentation

*November, 2020*

### Project Chief:

Eduardo Augusto Bezerra

### Authors:

André Martins Pio de Mattos

Gabriel Mariano Marcelino

Yan Castro de Azeredo

### Contributing Authors:

Leonardo Kessler Slongo

Sara Vega Martinez

Bruno Vale Barbosa Eiterer

Túlio Gomes Pereira

### Revision Control:

| Version | Author       | Changes           | Date       |
|---------|--------------|-------------------|------------|
| 0.1     | G. Marcelino | Document creation | 2020/11/05 |



© 2020 by SpaceLab. EPS 2.0 Documentation. This work is licensed under the Creative Commons Attribution-ShareAlike 4.0 International License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-sa/4.0/>.



---

## List of Figures

---

|     |  |   |
|-----|--|---|
| 1.1 | 3D view of the EPS 2.0 PCB. . . . .          | 1 |
| 3.1 | Reference diagram of the PC-104 bus. . . . . | 8 |



---

## List of Tables

---

|     |                                  |   |
|-----|----------------------------------|---|
| 3.1 | PC-104 connector pinout. . . . . | 9 |
|-----|----------------------------------|---|





---

## Nomenclature

---

|      |  |
|------|--|
| ADC  | <i>Analog to Digital Converter.</i>    |
| EPS  | <i>Electric Power System.</i>          |
| MCU  | <i>Microcontroller Unit.</i>           |
| MPPT | <i>Maximum Power Point Tracking.</i>   |
| PWM  | <i>Pulse Width Modulation.</i>         |
| RBF  | <i>Remove Before Flight.</i>           |
| RTD  | <i>Resistive Temperature Detector.</i> |



---

# Contents

---

|   |            |
|---|------------|
| <b>List of Figures</b>                          | <b>v</b>   |
| <b>List of Tables</b>                           | <b>vii</b> |
| <b>Nomenclature</b>                             | <b>ix</b>  |
| <b>1 Introduction</b>                           | <b>1</b>   |
| <b>2 System Overview</b>                        | <b>3</b>   |
| <b>3 Hardware</b>                               | <b>5</b>   |
| 3.1 MPPT Boost Converters . . . . .             | 5          |
| 3.2 Measurement Circuits . . . . .              | 5          |
| 3.2.1 Solar Panels Current . . . . .            | 5          |
| 3.2.2 Beacon Current . . . . .                  | 5          |
| 3.2.3 Solar Panels Voltage . . . . .            | 6          |
| 3.2.4 Boost Converters Output Voltage . . . . . | 6          |
| 3.2.5 Main Power Bus Voltage . . . . .          | 6          |
| 3.3 Heaters Control Circuit . . . . .           | 6          |
| 3.3.1 ADC . . . . .                             | 6          |
| 3.3.2 Heaters Drivers . . . . .                 | 6          |
| 3.4 Kill-Switches . . . . .                     | 6          |
| 3.5 Voltage Regulators . . . . .                | 7          |
| 3.6 External Connectors . . . . .               | 7          |
| 3.6.1 PC-104 . . . . .                          | 7          |
| 3.6.2 Solar Panels . . . . .                    | 7          |
| 3.6.3 Kill-Switches . . . . .                   | 7          |
| 3.6.4 Battery Charge . . . . .                  | 7          |
| 3.6.5 Remove Before Flight . . . . .            | 7          |
| 3.6.6 RTDs . . . . .                            | 7          |
| 3.6.7 Battery Module . . . . .                  | 7          |
| 3.6.8 Battery Heater . . . . .                  | 7          |
| <b>4 Firmware</b>                               | <b>11</b>  |
| <b>5 Board Assembly</b>                         | <b>13</b>  |
| <b>6 Usage Instructions</b>                     | <b>15</b>  |



# CHAPTER 1

---

## Introduction

---

The Electrical Power System (EPS) has been designed to harvest, store and distribute energy for a CubeSat. The energy harvesting system is based on solar energy conversion through six solar panels attached to the CubeSat structure. The EPS is designed to operate the solar panels at their maximum power point. The harvested solar energy is stored in the battery module connected to the EPS. The energy distribution is done by several integrated DC-DC converters. The full EPS system is composed of the solar panels, the EPS PCB and the battery module. A general view of the EPS 2.0 board can be seen in Figure 1.1.

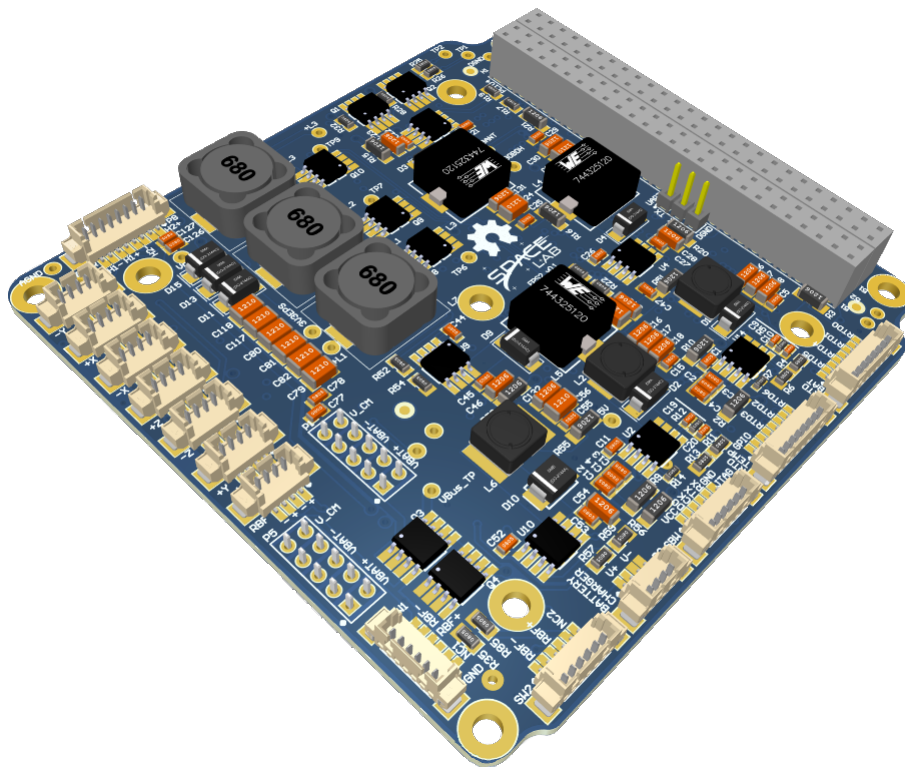


Figure 1.1: 3D view of the EPS 2.0 PCB.

The main characteristics of the EPS module are available below:

- Compatible with Gomspace Solar Panels or panel of similar characteristics.
- Compliant with CubeSat standard.

- Low power MSP430 MCU 20 MHz.
- Maximum power point tracking (MPPT).
- Overvoltage, undervoltage, overcurrent and short circuit protection for the battery module.
- Consumption measurement capability.
- Solar panels power measurement capability.
- Battery module measurements capability.
- 3.3V/1A (x1), 3.3V/2A (x2), 5V/3A (x1), 5V/5A (x2) and one battery voltage supply output pins.
- Seven temperature measurements with high accuracy.
- Low power operation capability.

[1], [2]

## CHAPTER 2

---

### System Overview

---

.





## CHAPTER 3

---

### Hardware

---

### 3.1 MPPT Boost Converters

There are three boost converters in the system, one for each couple of solar panels in parallel connection. Each one is a discrete boost with a HC9-220-R inductor, a SI4010dy mosfet as the switch and a B340LA-13-F diode. There are six GRM32ER1E226KE15L capacitors and two GRM216R71H103KA01D capacitors connected in parallel in the boost output. The output filter is the same for all the converters as their outputs are tied together. The control PWM signals are generated by the MCU at a frequency of nearly 500 kHz. Finally, the EPS PCB is provided with a LMC555 chip, which is able to generate a fixed PWM for the MPPT circuit in case of EPS MCU failures.

### 3.2 Measurement Circuits

The measurement circuits are used to generate a voltage proportional to the variable being measured, in a range accepted by the MCU internal ADC.

#### 3.2.1 Solar Panels Current

The main component of the solar panels currents measurement circuit is the MAX9934TAUA+ current sense amplifier. It generates an output current proportional to the differential input voltage. The gain is  $25 \mu\text{A/mV}$ . To make the measurements possible, the current goes through  $50 \text{ m}\Omega$ ,  $0.5 \%$  resistors, connected to the inputs of the amplifier, and the outputs are connected to  $3.3 \text{ k}\Omega$  resistors. The output voltage of the circuit is given by:

$$V_{out} = I_{sense} \cdot R_{sense} \cdot G \cdot R_{out} \quad (3.1)$$

#### 3.2.2 Beacon Current

This measurement takes place at the output of the EPS-Beacon regulator. It also uses a MAX9934TAUA+ current sense amplifier, but with a shunt resistor of  $75 \text{ m}\Omega$ ,  $0.5 \%$  and the output connected to a  $4.02 \text{ k}\Omega$  resistor.

### 3.2.3 Solar Panels Voltage

The solar panels voltage measurement circuit is composed by a voltage divider and an op-amp in a buffer configuration. The voltage divider is composed of a 93.1 kΩ resistor and an 100 kΩ resistor. The op-amp is a TLV341AIDBVR chip. The output voltage is given by:

$$V_{out} = V_{sp} \cdot \frac{R_2}{R_1 + R_2} \quad (3.2)$$

### 3.2.4 Boost Converters Output Voltage

The boost converters output voltage measurement circuit is very similar to the solar panels voltages measurement circuit, with the exception that the voltage divider is composed by a 300 kΩ resistor and an 100 kΩ resistor.

### 3.2.5 Main Power Bus Voltage

The main power bus voltage measurement circuit is identical to the boost converters output voltage measurement circuit.

## 3.3 Heaters Control Circuit

The batteries operate over a specified temperature range and need active heating to work properly in space. The heaters control circuit is composed of the heaters themselves, RTDs, an external ADC and the drivers.

### 3.3.1 ADC

The ADS1248 chip generates a precise reference current to the RTDs, and samples the voltage proportional to the temperature established over the sensors. This voltage is converted to digital data and sent to the MCU via SPI protocol.

### 3.3.2 Heaters Drivers

The drivers are chopper converters controlled by the MCU, with a PWM frequency of 50 kHz. The switches of the chopper converters are Si4010DY mosfets.

## 3.4 Kill-Switches

These switches are used to separate the solar panels and the batteries from the load during pre-flight and launch. Each one is composed of two SI4403-CDY-T1-GE3 P-channel mosfets in parallel, as a redundancy. When either the RBF is in place or the kill-switches are pressed, the mosfets disconnect the loads from the sources.

## 3.5 Voltage Regulators

To supply itself and the other modules, the EPS has 6 integrated DC-DC regulators. To supply the Beacon MCU and itself a TPS5420QDRQ1 regulator is used, with an output voltage of 3.3 V and 2 A current capability. This regulator is always on.

To power the payload, a TPS5430QDDARQ1 regulator is used. It has an output voltage of 5 V and 3 A current capability. The EPS can enable/disable this regulator.

OBDH and the main radio are powered by TPS5410QDRQ1 regulator, with an output voltage of 3.3 V and 1 A current capability. The EPS can enable/disable this regulator.

The antenna deployment system has a dedicated regulator (TPS5420QDRQ1), with 3.3 V output voltage and 2 A current capability. This regulator is always on.

Finally, each PA is powered by its own TPS54540QDDARQ1 regulator, with an output voltage of 5 V and 5 A current capability. The Beacon MCU controls its PA regulator enable/disable function and the OBDH MCU controls the main radio PA regulator enable/disable function.

## 3.6 External Connectors

The EPS module is connected to the other modules using the PC-104 bus. The solar panels, the kill-switches, the remove before flight, the RTDs, the heater, the batteries charger connector and the JTAG pins are connected using Molex PicoBlade connectors. The EPS module also has a jumper that connects the MCU VCC to the JTAG VCC and a header to debug the board via UART protocol. In the following sections each connector is detailed, with a picture showing the location on the EPS PCB and a table explaining each pin function.

### 3.6.1 PC-104

### 3.6.2 Solar Panels

### 3.6.3 Kill-Switches

### 3.6.4 Battery Charge

### 3.6.5 Remove Before Flight

### 3.6.6 RTDs

### 3.6.7 Battery Module

### 3.6.8 Battery Heater

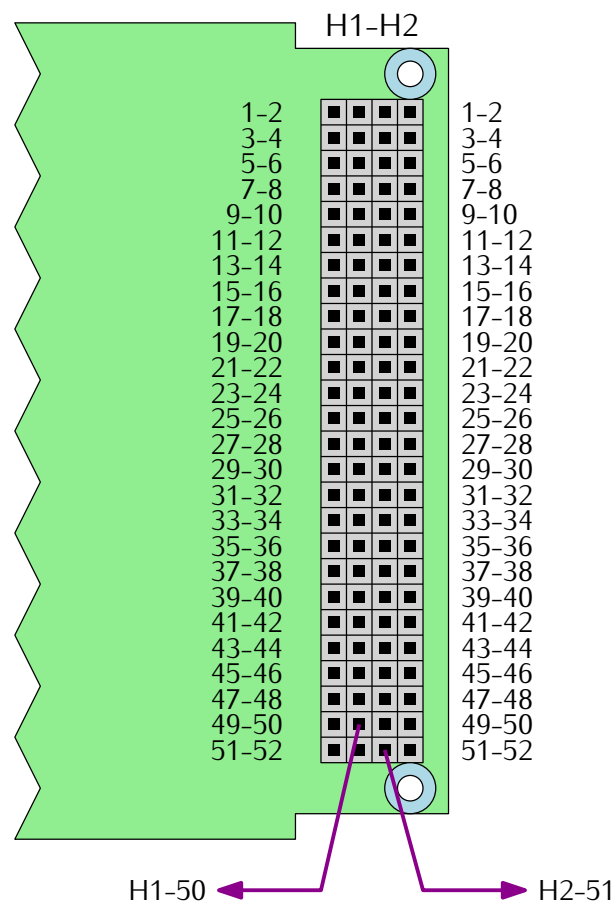


Figure 3.1: Reference diagram of the PC-104 bus.

| <i>Pin [A-B]</i> | <i>H1A</i> | <i>H1B</i> | <i>H2A</i> | <i>H2B</i> |
|------------------|------------|------------|------------|------------|
| 1-2              | -          | -          | -          | -          |
| 3-4              | -          | -          | -          | -          |
| 5-6              | -          | -          | UART_RX    | -          |
| 7-8              | -          | -          | UART_TX    | -          |
| 9-10             | -          | EN_PWR_5   | -          | -          |
| 11-12            | -          | EN_PWR_6   | -          | -          |
| 13-14            | -          | -          | -          | -          |
| 15-16            | -          | -          | -          | -          |
| 17-18            | -          | -          | -          | -          |
| 19-20            | -          | -          | -          | -          |
| 21-22            | -          | -          | -          | -          |
| 23-24            | -          | -          | -          | -          |
| 25-26            | -          | -          | PWR_4_5V   | PWR_4_5V   |
| 27-28            | -          | -          | PWR_7_3V3  | PWR_7_3V3  |
| 29-30            | GND        | GND        | GND        | GND        |
| 31-32            | GND        | GND        | GND        | GND        |
| 33-34            | -          | -          | -          | -          |
| 35-36            | -          | -          | PWR_1_3V3  | PWR_1_3V3  |
| 37-38            | -          | -          | -          | -          |
| 39-40            | -          | -          | -          | -          |
| 41-42            | -          | -          | -          | -          |
| 43-44            | -          | -          | -          | -          |
| 45-46            | PWR_2_3V3  | PWR_2_3V3  | PWR_3_BAT  | PWR_3_BAT  |
| 47-48            | PWR_4_5V   | PWR_4_5V   | -          | -          |
| 49-50            | PWR_5_5V   | PWR_5_5V   | I2C_SDA    | -          |
| 51-52            | PWR_6_6V   | PWR_6_6V   | I2C_SCL    | -          |

Table 3.1: PC-104 connector pinout.



## CHAPTER 4

---

### Firmware

---

.





## CHAPTER 5

---

### Board Assembly

---

.



## CHAPTER 6

---

### Usage Instructions

---

.



---

## Bibliography

---

- [1] SpaceLab. *Test*, July 2020. Note.
- [2] Space Technology Research Laboratory (SpaceLab). *OBDH 2.0 Documentation*, 2020. Available at <<https://github.com/spacelab-ufsc/obdh2>>.