SLB-EPS2-DOC-v0.1

EPS 2.0 Documentation

EPS 2.0 Documentation
SpaceLab, Universidade Federal de Santa Catarina, Florianópolis - Brazil

November 2020

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

List of Figures

List of Tables

Nomenclature

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

Contents

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.

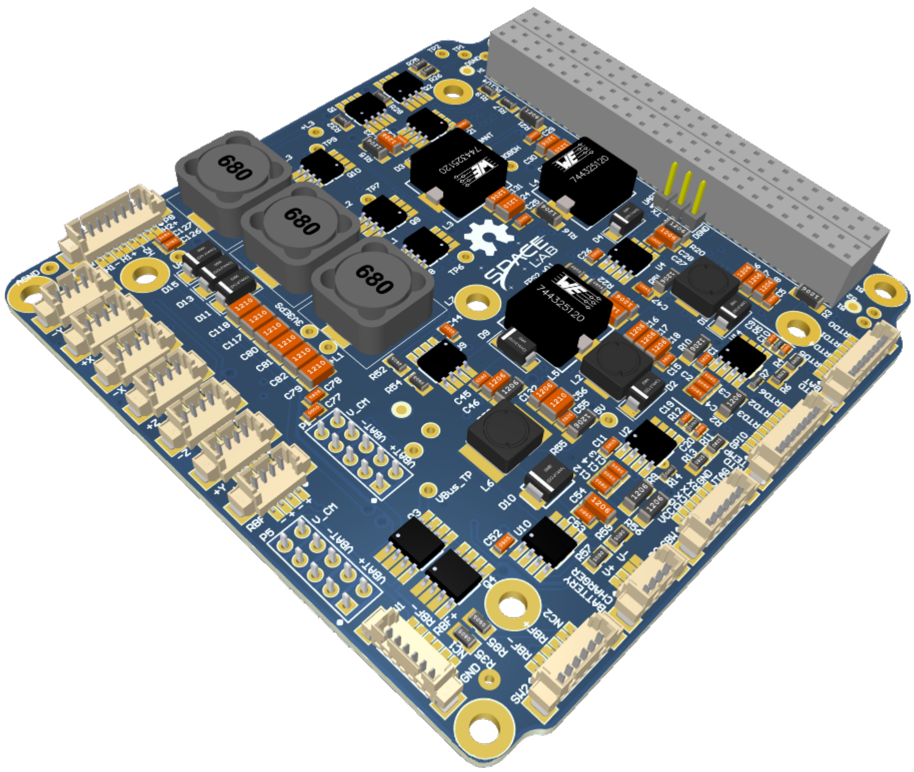

Figure 1.1: 3D view of the EPS 2.0 PCB.

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 μA/mV. To make the measurements possible, the current goes through 50 mΩ, 0.5 % resistors, connected to the inputs of the amplifier, and the outputs are connected to 3.3 kΩ resistors. The output voltage of the circuit is given by:

$$V_{out} = I_{sense} \cdot R_{sense} \cdot G \cdot R_{out} \tag{3.1}$$

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 mΩ, 0.5 % and the output connected to a 4.02 kΩ 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:

$$V_{out} = V_{sp} \cdot \frac{R_2}{R_1 + R_2} \tag{3.2}$$

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 and 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 capabiity. 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

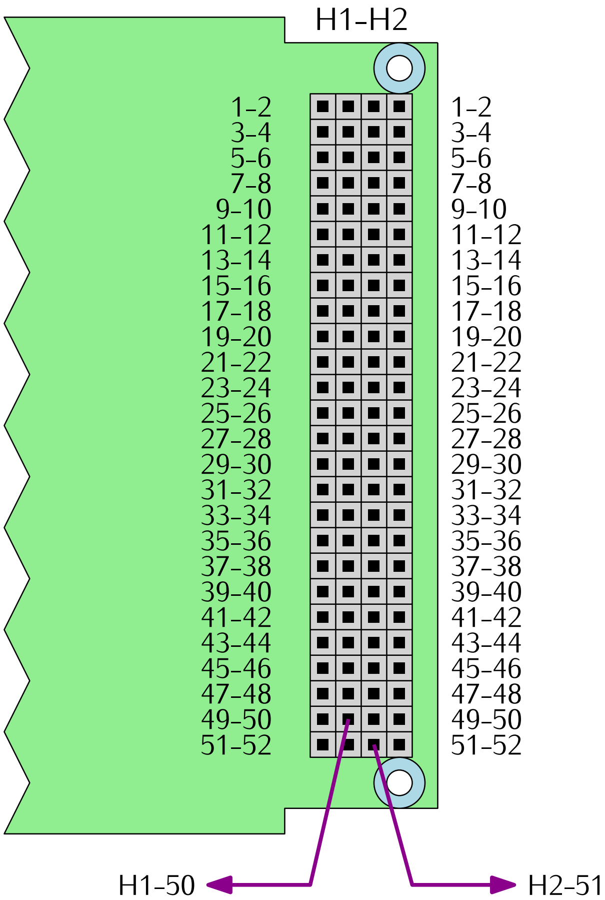

Figure 3.1: Reference diagram of the PC-104 bus.

Pin [A-B]	*H1A*	*H1B*	*H2A*	*H2B*
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.

Signal	Pin(s)	Description
GND	H1-29, H1-30, H1-31, H1-32, H2-29, H2-30, H2-31, H2-32	Ground reference
PWR_1_3V3	H2-35, H2-36	Power bus 1, 3.3 V, 2 A max.
PWR_2_3V3	H1-45, H1-46	Power bus 2, 3.3 V, 1 A max.
PWR_3_BAT	H2-45, H2-46	Power bus 3, battery terminals (+)
PWR_4_5V	H1-47, H1-48, H2-25, H2-26	Power bus 4, 5 V, 3 A max.
PWR_5_5V	H1-49, H1-50	Power bus 5, 5 V, 5 A max.
PWR_6_6V	H1-51, H1-52	Power bus 6, 6 V, 5 A max.
PWR_7_3V3	H2-27, H2-28	Power bus 7, 3.3 V, 2 A max.
I2C_SDA	H2-49	Primary communication bus (data signal)
I2C_SCL	H2-51	Primary communication bus (clock signal)
UART_RX	H2-5	Secondary communication bus (RX)
UART_TX	H2-7	Secondary communication bus (TX)
EN_PWR_5	H1-10	Enable signal of the power bus 5
EN_PWR_6	H1-12	Enable signal of the power bus 6

Table 3.2: PC-104 bus signal description.

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>.