Hendrik Melse

This document explains the function of the Solar Panel, its schematic level design, and its board level design

Solar Panel

Solar Panel Design

Revision: 2.1.3



Table of Contents

[1 Introduction 3](#_Toc1308010)

[1.1 Functions 3](#_Toc1308011)

[1.2 Requirements 3](#_Toc1308012)

[2 Detailed Description 4](#_Toc1308013)

[2.1 Functional Block Diagram 4](#_Toc1308014)

[2.1.1 Energy Collection 4](#_Toc1308015)

[2.1.2 Power Output 4](#_Toc1308016)

[2.1.3 Analog-to-Digital Converter 4](#_Toc1308017)

[2.1.4 Magnetorquer 4](#_Toc1308018)

[2.1.5 Connector 4](#_Toc1308019)

[2.2 Schematic 4](#_Toc1308020)

[2.2.1 Isolated Grounds 4](#_Toc1308021)

[2.2.2 Battery Charger 5](#_Toc1308022)

[2.2.3 Analog-to-Digital Converter 5](#_Toc1308023)

[2.2.4 Photodiode 5](#_Toc1308024)

[2.2.5 Thermistors 5](#_Toc1308025)

[2.2.6 Magnetorquer 6](#_Toc1308026)

[2.2.7 Voltage Reference 6](#_Toc1308027)

[2.3 Board 6](#_Toc1308028)

[2.3.1 Layout Constraints 6](#_Toc1308029)

[3 Testing 8](#_Toc1308030)

[3.1 Before First Power-On Check 8](#_Toc1308031)

[3.1.1 Test Instructions 8](#_Toc1308032)

[3.1.2 Test Data 8](#_Toc1308033)

[3.1.3 Test Notes 8](#_Toc1308034)

[3.2 Battery Chargers 8](#_Toc1308035)

[3.2.1 Output Voltage 9](#_Toc1308036)

[3.2.2 Output Efficiency 9](#_Toc1308037)

[3.2.3 Output Current Limiting 10](#_Toc1308038)

[3.3 ADC 10](#_Toc1308039)

[3.3.1 Current Monitoring 10](#_Toc1308040)

[3.3.2 Voltage Monitoring 11](#_Toc1308041)

[3.3.3 Temperature Monitoring 11](#_Toc1308042)

# Introduction

This document explains how the solar panel will fulfill the following Functions and conform to the following Requirements. This document refers to the Solar Panel version 2.0.

## Functions

The Solar Panel is responsible for the following:

* Harvest energy
* Providing power to charge the batteries located on the EPS

## Requirements

The system requirements and EPS design requirements can be found [here](https://github.com/CougsInSpace/CougSat1-Readme/blob/master/CougSat1-Requirements.pdf).

# Detailed Description

This section references the Solar Panel [schematic](https://github.com/CougsInSpace/CougSat1-Hardware/blob/master/CougSat1-PowerBoard/Documentation/SolarPanel.pdf)[[1]](#footnote-1). Page numbers will be listed and may have coordinates listed (number and letter combination found around the frame).

## Functional Block Diagram

The block diagram can be found on the first page of the schematic.

### Energy Collection

Energy is captured from the sun by the photovoltaic (PV) cells. There are two cells on each panel. Each PV cell is connected to its own battery charger with MPPT[[2]](#footnote-2).

### Power Output

Power is output via two current limited rails from the battery chargers, one from each battery charger.

### Analog-to-Digital Converter

The ADC allows the power management IC (PMIC) to monitor temperature and power at various locations on the board. Sensor locations are indicated on the block diagram.

### Magnetorquer

The magnetorquer is controlled by the Attitude and Determination Control Subsystem ([ADCS](https://github.com/CougsInSpace/CougSat1-Hardware/tree/master/CougSat1-AvionicBoard/Documentation)).

### Connector

The connector connects the solar panel to the EPS and the ADCS to the magnetorquer.

## Schematic

### Isolated Grounds

The four isolated grounds are found on page 2 of the schematic. Power ground *(PGND)* is connected to pins 6 and 7 of the connector. All other grounds are shorted to *PGND* with a resistor rated for up to . Digital ground *(DGND)* is connected to the digital components of the board. Analog ground *(AGND)* is connected to the analog components, including the ADC, its voltage reference, and the thermistors. Chassis ground *(CHASSIS)* is connected to the conductive mechanical components of the board, including the bolt holes.

### Battery Charger

Page 2 of the schematic contains the battery chargers[[3]](#footnote-3). Each battery charger has a single output, current limited to , contains MPPT technology as well as a boost converter. The batteries are capable of charging at up to , but by charging at the battery health can be preserved. The active low shutdown pin *(X\_SHUT)* is pulled up to the PV output by and resistors in series. Output voltage and current are monitored by the ADC.

### Analog-to-Digital Converter

Page 4 of the schematic contains the ADCs[[4]](#footnote-4). The ADCs have 16 single-ended inputs, or 8 differential inputs, or a combination of the two. The solar panel contains two ADCs. The ADCs’ address can be configured by selectively stuffing[[5]](#footnote-5) the resistors connected to the address pins. Each pin can be set to either high, low, or left floating. Specific addresses can be found in the [EPS design document](https://github.com/CougsInSpace/CougSat1-Hardware/blob/master/CougSat1-PowerBoard/Documentation/EPS-Design.pdf). One ADC connects to the output connector to the EPS. This ADC measures differential for each PV input, and each output. Measured as single ended is the temperature at five different locations, the outputs from each battery charger, and the reference voltage *(AVREF).* The other ADC connects to the ADCS output connector and measures the Photodiode as a single ended input.

There is a voltage divider between the ADC’s *MUXOUT* and *ADCIN* pins that cuts the voltage by 80%. Most inputs (not the temperature sensing inputs) also has a 5k series resistor to ensure that when the ADC is switched off, the ESD diodes will not short all the inputs to ground. The voltage divider and the input series resistors bring the ADC input voltage to of the true value, so that the ADC inputs will be within the range that it can measure.

### Photodiode

The photodiode[[6]](#footnote-6) can be found on page 4 of the schematic. There is one per solar panel, and it is placed in the center facing outward. This particular photodiode has a spectral sensitivity of and the expected illuminance is on the order of . This makes the maximum expected voltage drop across the load resistor about .

### Thermistors

Each solar panel contains 5 thermistors[[7]](#footnote-7). Two monitor the temperature of the battery chargers, while three monitor the temperature of the satellite in various locations on the solar panel. The thermistors use the voltage divider on the ADC as their pull down to function properly.

### Magnetorquer

The magnetorquer can be found on page 3 of the schematic. The magnetorquer is directly connected to pins 8 and 9 on the connector. These will go directly to the ADCS. The magnetorquer shall only be installed on the +Z, -Y, and -X boards, as only three axes are necessary to control the orientation of the satellite.

### Voltage Reference

The high-precision voltage reference[[8]](#footnote-8) can be found on page 2 of the schematic. This chip produces a high precision reference voltage *(AVREF)*, nominally . *AVREF* is used as the absolute voltage reference for calibrating the ADC.

## Board

The board shall be double layered with copper and ENIG finish.

### Layout Constraints

Unless specified in the following subsections, all signals shall use the default parameters specified below. Signals in the following subsections do not include their sense signals unless specified. Trace width can be broken if a trace needs to bottleneck down to a pin, the bottleneck shall be minimized.

Trace width:

Vias: , unlimited count

Separation:

Length: unlimited

Devices with specific placement and Routing considerations are called out in the schematic, see “CAD Note”

#### I2C – I2C\_[SDA, SCL]

Length: Each node shall be length matched

Stubs: <

#### Solar Panel Outputs – PV\_IIN\_P-[A:B] , PV\_IIN\_P-[A:B] , PGND

PGND applies between the solar panel and the output connector

Trace width:

#### MPPT Inputs – MPPT\_LX-[A:B] , PGND

PGND applies between the battery charger and the output connector. This includes the input capacitors.

Trace Width:

#### Power Outputs – MPPT\_VOUT-[A:B] , VOUT-[A:B], PGND

PGND applies between the battery charger and the output connector. This includes the output capacitors.

Trace width:

#### Magnetorquer Inputs – MAGNETORQUER\_[P, N]

Trace width:

# Testing

All tests shall be performed at room temperature and not under vacuum unless otherwise specified. If any modifications are performed, take note. Include enough information to understand circuit behavior and for others to replicate the results. Include any software written to execute the test and link it in the test notes section. Save all software, waveforms, etc. in a subfolder of the board’s test folder for each test. All tests shall be performed prior to attaching the solar cells to the solar panel.

* Waveforms shall be captured whenever appropriate.
* Have the event take fill the screen (for fast events, zoom in, for slow events, zoom out)
* Label each channel accurately
* Only have bandwidth limiting if necessary for the test (this applies to the oscilloscope and probe settings)
* If ringing or overshoot occurs, use a ground spring or differential probe

Results location: <https://github.com/CougsInSpace/CougSat1-Hardware/tree/master/CougSat1-PowerBoard/Testing/SolarPanel.2.0>

Common test instructions can be found on the [wiki](https://cis.vcea.wsu.edu/wiki/index.php/Cougs_in_Space_Wiki).

## Before First Power-On Check

**Test Configuration: Charles**

This test is required to be executed before batteries are attached and before any external power is applied to the Solar Panel.

### Test Instructions

Measure the resistance of various points in reference to PGND located at the output connector.

### Test Data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Node | Resistance |  | Node | Resistance |
| I2C\_SDA\_PMIC |  |  | VOUT-A |  |
| I2C\_SCL\_PMIC | Overload |  | VOUT-B |  |
| I2C\_SDA\_ADCS | Overload |  | AVDD |  |
| I2C\_SCL\_ADCS | Overload |  | AVREF |  |
| PV\_IIN\_P-A |  |  | 3.3V |  |
| PV\_IIN\_P-B |  |  |  |  |

## Battery Chargers

**Results: Pass / Fail**

**Test Configuration: Charles**

This test evaluates the Battery Charger.

### Output Voltage

#### Test Instructions

Attach a battery charged to to the output. Apply at the solar cell output and wait until the current into the battery drops below . Measure the final battery voltage. Adjust the voltage divider (R109, R105, R120, R126) as necessary.

#### Test Data

|  |  |  |
| --- | --- | --- |
| Apply to PV\_IIN\_P-A and measure the final battery voltage on VOUT-A. | | |
| Measured Voltage VOUT-A | Passing Criteria | Pass / Fail |
|  |  | Pass |

|  |  |  |
| --- | --- | --- |
| Apply to PV\_IIN\_P-B and measure the final battery voltage on VOUT-B. | | |
| Measured Voltage VOUT-B | Passing Criteria | Pass / Fail |
|  |  |  |

#### Test Notes

Added resistor to low side of voltage divider on VOUT-A (R105)

Added resistor to low side of voltage divider on VOUT-B (R126)

### Output Current Limiting

#### Test Instructions

Attach a battery discharged to to the output before executing this test. Apply at the solar panel output. Measure the current to the battery.

#### Test Data

|  |  |  |  |
| --- | --- | --- | --- |
| Attach a dead battery to the output and measure the current to it. | | | |
| Output | Current | Passing Criteria | Pass / Fail |
| VOUT-A |  |  | Pass` |
| VOUT-B |  |  | Pass |

#### Test Notes

Delete me if no notes are required.

### Output Efficiency

#### Test Instructions

Apply at the solar cell outputs. Attach a battery charged to . Measure the efficiency of the Battery Chargers at battery voltage increments of from to .

Note: , measure the power across the input and output current shunt resistors.

#### Test Data

|  |  |  |
| --- | --- | --- |
| Measure the efficiency of Battery Charger A at outputs from to . | | |
| Attach a graph of the data | Passing Criteria | Pass / Fail |
|  |  |  |

#### Test Notes

Delete me if no notes are required.

## ADC

**Results: Pass / Fail**

**Test Configuration: Charles**

### Current Monitoring

#### Test Instructions

Connect the EPS to the Solar Panel with a cable connecting only I2C, GND, and 3.3V. Apply to the solar panel outputs before executing this test. Attach a battery to the output and compare the measured voltages across the shunt resistor from the EPS and a DMM.

Note:

#### Test Data

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Apply at the solar panel output and measure the voltage across the shunt resistor. | | | | | |
| Signal | EPS voltage | DMM voltage | Error | Passing Criteria | Pass / Fail |
| VOUT-A |  |  |  |  |  |

#### Test Notes

Test was not completed because it was determined that the ADCs are not sufficient for our purposes.

### Voltage Monitoring

#### Test Instructions

Connect the EPS to the Solar Panel with a cable connecting only I2C, GND, and 3.3V. Charge or discharge the batteries to , and apply to the solar panel outputs before executing this test. Apply a resistive load to the solar panel output and compare the output voltages measured by the EPS and a DMM.

Note:

#### Test Data

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Apply a resistive load to VOUT-A and measure the voltage at various signals. | | | | | |
| Signal | EPS Voltage | DMM Voltage | Error | Passing Criteria | Pass / Fail |
| VOUT-A |  |  |  |  |  |
| VOUT-B |  |  |  |  |  |

#### Test Notes

Test was not completed because it was determined that the ADCs are not sufficient for our purposes.

### Temperature Monitoring

#### Test Instructions

Connect the EPS to the Solar Panel and charge or discharge the batteries to before executing this test. Compare the temperature measured by the EPS and a thermometer at the following thermistors:

* FRONT\_TOP
* MPPT-A

Note:

#### Test Data

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Compare the temperature measured by the EPS and a thermometer | | | | | |
| Sensor | EPS Temperature | Thermometer  Temperature | Error | Passing Criteria | Pass / Fail |
| TEMP\_BACK |  |  |  |  | Pass |
| MPPT-A |  |  |  |  | Pass |

#### Test Notes

Delete me if no notes are required

## Solar Cell

**Results: Pass / Fail**

**Test configuration: Charles**

### Output Voltage Under Solar Power

#### Test Instructions

Perform solar cell tests only after all other tests have been completed. Attach one solar cell to the solar panel. Measure the output voltage under no load using both the weed lamp and the sun on a clear day at or near solar noon.

#### Test Data

|  |  |  |  |
| --- | --- | --- | --- |
| Measure the output voltage under no load | | | |
| Test Condition | Output Voltage | Passing Criteria | Pass / Fail |
| Weed Lamp |  |  | Pass |
| Sun |  |  |  |

### Output Power

#### Test Instructions

Attach a battery to the power output. Measure the power input into the battery using the weed lamp and the sun on a clear day at or near solar noon.

#### Test Data

|  |  |  |  |
| --- | --- | --- | --- |
| Measure the output power into a battery | | | |
| Test Condition | Output Power | Passing Criteria | Pass / Fail |
| Weed Lamp |  |  | Pass |
| Sun |  |  |  |

1. <https://github.com/CougsInSpace/CougSat1-Hardware/blob/master/CougSat1-PowerBoard/Documentation/SolarPanel.pdf> [↑](#footnote-ref-1)
2. Maximum Power Point Tracking adjusts the output voltage and current to maximize the power harvested from the solar cells [↑](#footnote-ref-2)
3. [SPV1040](https://github.com/CougsInSpace/Resources/blob/master/SupplierDocuments/ST/SPV1040.pdf) [↑](#footnote-ref-3)
4. [LTC2499](https://github.com/CougsInSpace/Resources/blob/master/SupplierDocuments/Linear/LTC2499_I2CADC-8DifferentialInputs.pdf) [↑](#footnote-ref-4)
5. Stuffing refers to populating a component during assembly [↑](#footnote-ref-5)
6. [SFH 2430](https://github.com/CougsInSpace/Resources/blob/master/SupplierDocuments/OSRAM/SFH%202430_Photodiode.pdf) [↑](#footnote-ref-6)
7. [NTCS0603E3](https://github.com/CougsInSpace/Resources/blob/master/SupplierDocuments/Vishay/NTCS0603E3...T_NTCThermistorSMD.pdf) [↑](#footnote-ref-7)
8. [MCP1501](https://github.com/CougsInSpace/Resources/blob/master/SupplierDocuments/Microchip/MCP1501_HighPrecisionVoltageReference.pdf) [↑](#footnote-ref-8)