The University of Sydney

School of Aerospace, Mechanical and Mechatronic Engineering

AERO4701 Space Engineering 3

LUNATICS

Interface Control Document

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Acronyms

ADCS Attitude Determination and Control System. 1

EPS Electronics and Power System. 1

ICD Interface Control Document. 1, 2

OBC On-Board Computer. 1

RP02W Raspberry Pi Zero 2 W. iv, 4, 5, 27, 29–31, 34

RPP2W Raspberry Pi Pico 2 W. 13, 15–18, 34

TT&C Telemetry, Tracking and Command. 1

1 Scope

The following document is the Interface Control Document (ICD) for LUNATICS-0, outlining each of the subsystems within the satellite and describing how each system interacts with each other. This document will contain a section for the Payload, Attitude Determination and Control System (ADCS), Electronics and Power System (EPS), Structures, Thermal, Telemetry, Tracking and Command (TT&C), and On-Board Computer (OBC).

For each section, a description of every part chosen to make up that system is provided, mentioning their functionality and purpose within the system. A further description of the modes that each subsystem will be have and how they interact with the overall state of the satellite with be provided. The electrical connections including pin numbers and bus protocol will also be described. Finally, figures have been included showing how the system has been mounted into the satellite's physical design in order to give an overall understanding of how the system is connected together.

2 System Overview

The physical interface bringing the overall system together is the frame of the satellite, connecting all the parts and keeping them within the internal structure of the cubesat. The PCB stack that has been designed allows the full system to operate by providing connections between each subsystem for each component to be powered and be able to send data to one another.

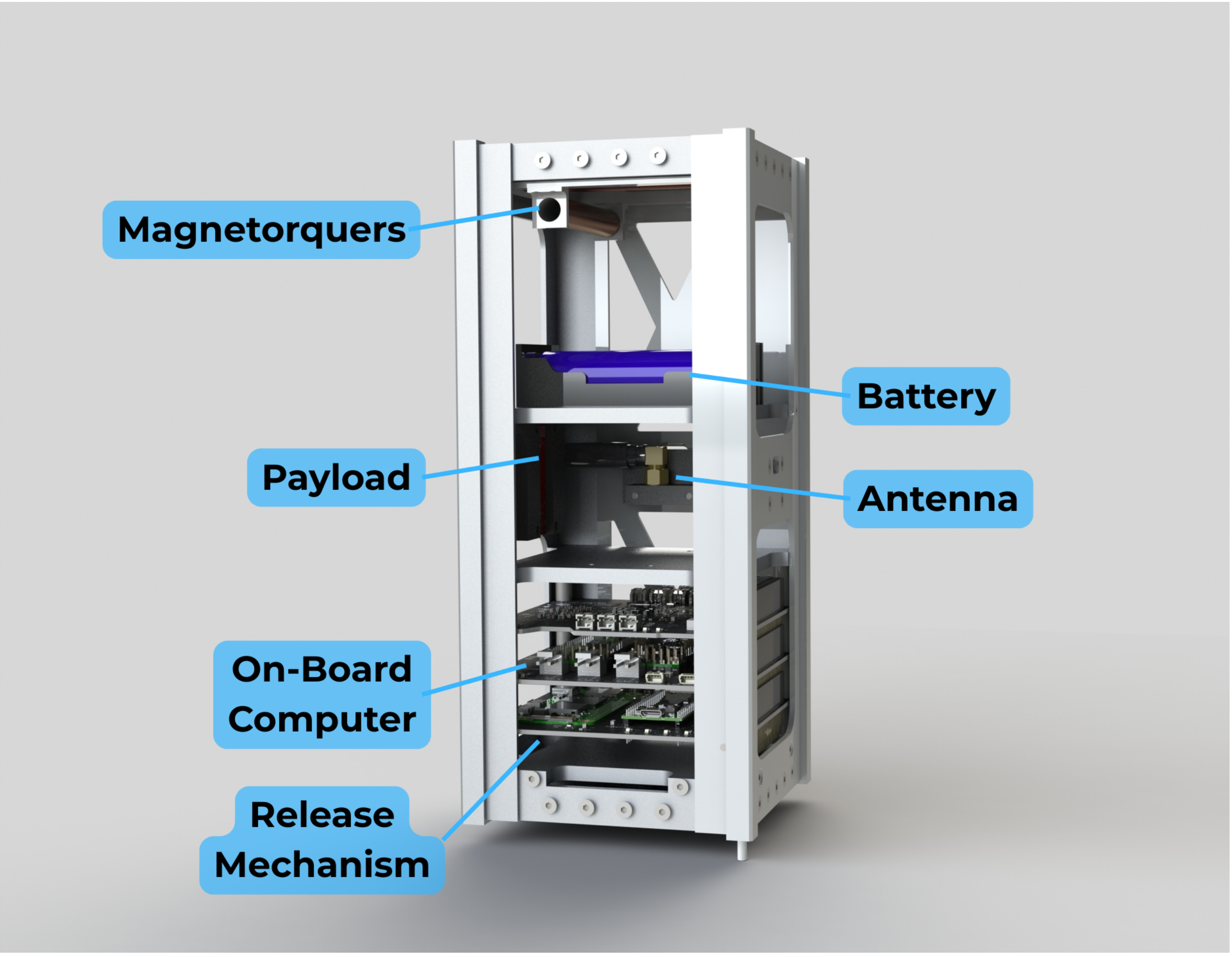


Figure 1: System Layout in Cubesat

2.1 Modes of Operation

The modes of operation for LUNATICS-0 are described in Figure 2.

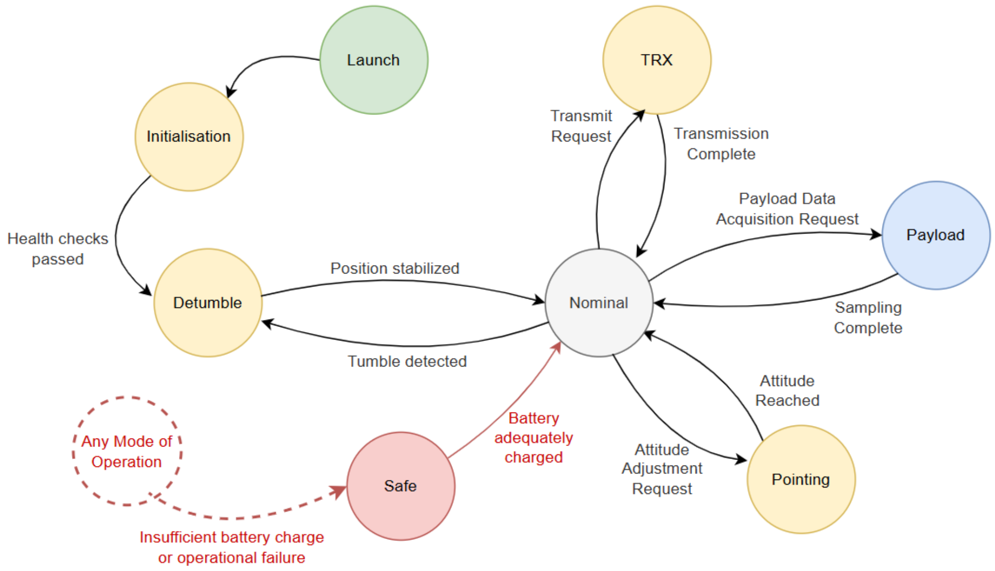


Figure 2: State Machine for LUNATICS-0

For the rest of the ICD, the states of the sub system will be compared to the overall states of the cube sat as described in the above diagram.

2.2 Electrical Interface

The main electrical interface that all subsystems share in order to connect and communicate with one another is the PCB. LUNATICS-0 will feature 3 PCB boards: OBC, EPS and ADCS. The schematic for each of these boards can be found within the Appendix.

In order to communicate across multiple levels of the PCB, a **2x20 2.54mm Pitch Male Vertical Header** on all three boards is used with the schematic shown in Figure 3.

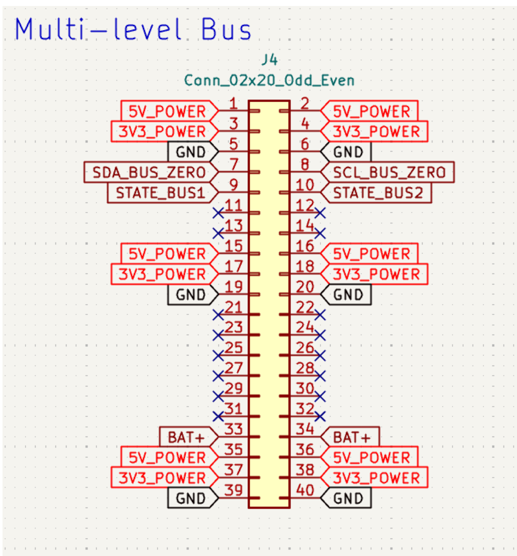


Figure 3: Schematic for the Multi Level bus, providing power and IO across all three boards

The power rails from the EPS system bring 5V and 3.3V power to all levels, allowing each component to be powered successfully. Other notable pins are described in Table 1.

Table 1: Pin connections for the Multi Level Bus

Header Pin	**Role**
7	Data line for the Zeros I2C interface. Allows Pico to send Zero attitude updates
8	Clock line for the I2C interface.
9, 10	Zero's state, being passed to the Pico
33, 34	Battery voltage, will be compared against ground

The sub-systems all share a universal ground across all electrical components, ensuring that we have the same reference for all our electronic devices. When describing pin connections, GND Plane refers to the bottom copper layer of the PCB which we have set as a universal ground.

Components external to the PCB interface to it through three types of connectors, JST VH connectors are used for the battery, the deployment switches and the magnetorquers. JST PH connectors are used for the solar panels and the thermistor. Finally, JST SH connectors are used for the spectroscopy sensor and the sun sensors.

3 Payload

The main science objective of the LUNATICS project is to record the different composition of elements within the moons atmosphere. As a proof of concept, LUNATICS-0 will orbit the Earth, and use a spectroscope in order to measure the different wavelengths of light that it receives - with different profiles corresponding to different elements.

3.1 Functional Description

3.1.1 List of Parts

The payload is made of 1 main part, the **Triad AS7265x Spectroscope Sensor** supplied by Sparkfun Electronics. This part uses three AS7265x sensors which are combined alongside a visible, UV, and IR LEDs to illuminate and test various surfaces for light spectroscopy. The AS7265x covers the measurement of light from 410nm to 940nm in 18 individual bands. The AS7265x Sensor is connected to the PCB using a **1mm Pitch, Horizontal JST SH SM04B-SRSS-TB 1x04** connector.

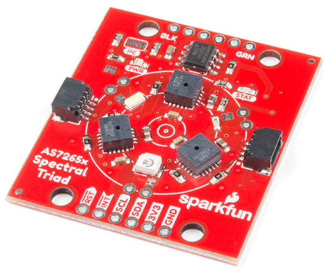


Figure 4: AS7265x part

3.1.2 Modes of Operation

The payload has two modes, either ON or OFF. In the OFF mode, no power is supplied from the ZERO meaning that no sensor data is recorded. In the ON mode, the ZERO requests data over the I2C bus and sends data from each of the 18 channels to the ZERO for it to analyse. The I2C address of the AS7265x is `0x49`.

Table 2: States of the payload corresponding to the overall state of the satellite

LUNATICS-0 Mode	Payload Mode
Launch	OFF
Initialisation	OFF
Detumble	OFF
Nominal	OFF
TRX	OFF
Payload	ON
Pointing	OFF
Safe	OFF

3.2 Electrical and Command Interface

The Payload will be interface with the RP02W and be provided with power through the PCB. As the AS7265x will be held by a custom structure so it points out of the structure, facing towards

Earth's nadir, we will be connecting it to the PCB using the connector seen in Figure 5.

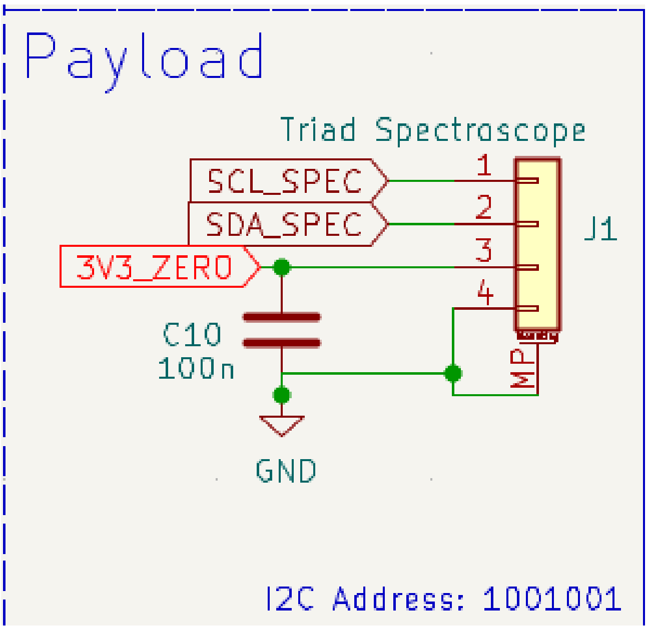


Figure 5: Schematic showing the connector that will be connected to the AS7265x

The connector has 4 pins, which includes a ground pin, two I2C pins, and a 3.3V power that comes from the Zero. The connections are as follows

Table 3: Pin connections for the payload

AS7265X Pin	RP02W Pin Number	Role
3.3V Power (Pin 3)	Pin 1	Provides power required for the AS7265x to work. When in OFF mode, this pin will be grounded.
SCL (Pin 1)	Pin 5	Clock line for the I2C interface.
SDA (Pin 2)	Pin 3	Data line for the I2C interface.
Ground (Pin 4)	GND Plane	Reference point for voltage

This allows the RP02W to interface with the payload through the I2C pins and command it to send data to the main OBC.

3.3 Structural Interface

The structure holding the payload in place can be seen in Figure 6. A small hole of 24.4mm diameter has been cutout in the face of the structures side such that the light can be received at each of the three sensors.

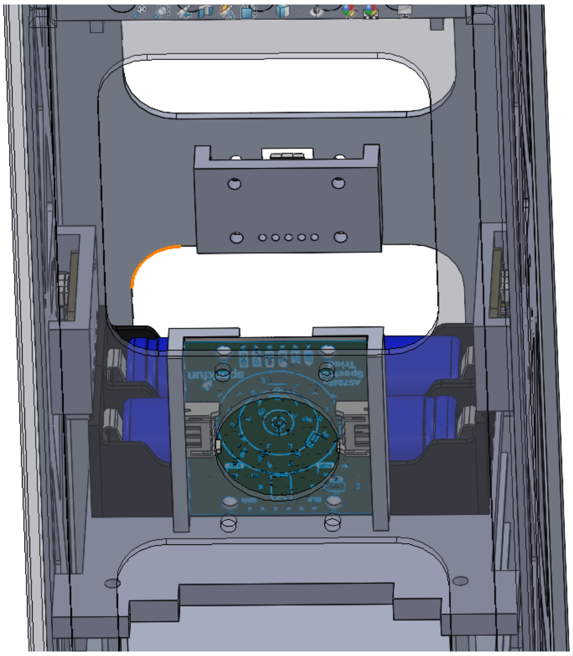


Figure 6: Structure with the AS7265x held onto the nadir-facing side

3.4 Thermal Control

The sensor has an operating temperature -40°C to 85°C. Mylar layers will be used between the internal walls ensuring that it does not obstruct the sensors functions. Kapton tape can be applied to exposed conductive parts.

4 Structures

Structures is one of the central subsystems within LUNATICS-0 as it houses all other subsystems within it and makes sure they are all protected from external loads. The structure for LUNATICS-0 is custom designed, and features housing for the PCB stack and all other peripherals.

4.1 Functional Description

4.1.1 List of Parts

All 3D printing will be done using carbon fiber nylon as the filament. The parts that need to be 3D printed include.

- 5x Sun Sensor Mounts
- 1x Antenna Mount
- 1x Spectrometer Mount
- 1x X-Axis Magnetorquer Mount
- 1x Y-Axis Magnetorquer Mount
- 1x Z-Axis Magnetorquer Mount

CNC'd Aluminium parts will be ordered using a third party provider for the following parts.

- 2x Cross Shaped Side Frame (Sides 1 and 3)
- 2x Hollow Side Frame (Sides 2 and 4)
- 1x Top End Plate
- 1x Bottom End Plate

The following fasteners will be used for the satellite.

4.1.2 Fasteners

Table 4: Fasteners required for overall assembly

Fastener	**Quantity**
M2x4mm Flat Head Socket (Countersunk) Machine Screw	4
M3x4mm Flat Head Socket (Countersunk) Machine Screw	56
M3x8mm Flat Head Socket (Countersunk) Machine Screw	24
M3x10mm Flat Head Socket (Countersunk) Machine Screw	4
M3x12mm Flat Head Socket (Countersunk) Machine Screw	4
M3x20mm Flat Head Socket (Countersunk) Machine Screw	2

Table 5: Breakdown of fasteners per sub-assembly

Sub-assembly	Fastener	Quantity
ADCS	M3x8mm Flat Head Socket (Countersunk) Machine Screw	18
	M3x20mm Flat Head Socket (Countersunk) Machine Screw	2
	M3x4mm Flat Head Socket (Countersunk) Machine Screw	8
	M3x12mm Flat Head Socket (Countersunk) Machine Screw	4
Payload	M3x10mm Flat Head Socket (Countersunk) Machine Screw	4
PCB Stack	M3x4mm Flat Head Socket (Countersunk) Machine Screw	8
	M2x4mm Flat Head Socket (Countersunk) Machine Screw	4
Top End Plate	M3x4mm Flat Head Socket (Countersunk) Machine Screw	18
Bottom End Plate	M3x4mm Flat Head Socket (Countersunk) Machine Screw	18
EPS	M3x4mm Flat Head Socket (Countersunk) Machine Screw	4
	M3x8mm Flat Head Socket (Countersunk) Machine Screw	4
Deployer	M3x8mm Flat Head Socket (Countersunk) Machine Screw	2
Total	-	94

4.2 Interfacing Description

Side Plates (LUN-P001): The main aluminium structural components of the LUNATICS-0 CubeSat consist of a base frame and four side walls, machined to meet the specifications for the CubeSat. Each side frame features pre-drilled mounting holes to interface directly with the Sun Sensor mounts or the spectrometer mount for side 4. The side plates also provide both mechanical support and thermal conduction pathways. These parts form the rigid frame of the satellite.

Top and Bottom End Plates (LUN-P002): The top and bottom end plates are CNC-machined from aluminium and are fixed to the side structures with threaded fasteners. The bottom plate includes a Sun Sensor as well as the deployment switch. The top plate provides mounting for the magnetorquer. Both end plates include tapped holes to ensure accurate subsystem installation.

Sun Sensor Mounts (LUN-P003): Five carbon fiber nylon mounts are 3D printed and attached to the outer surfaces of the CubeSat structure. These mounts interface with the sun sensors as well as each of the sides and the top and bottom plates.

Magnetorquer Mounts (LUN-P004): The three-axis magnetorquer system consists of multiple 3D printed components interfacing with the top plate. The X- and Y-axis mounts are designed to interface with the Z-axis mount, while the Z-axis mount aligns with the top end structure to ensure orthogonality.

Spectrometer Mount (LUN-P005): The spectrometer is fixed to side plate 1 using a dedicated 3D printed mount. This component interfaces both with the structural frame and the spectrometer.

Antenna Mount (LUN-P006): A 3D printed antenna mount secures the deployable antenna assembly to the CubeSat.

Solar Panel Integration Points (LUN-P007): Solar panels are attached to each of the sides on the aluminium frames. Panels are slotted and bonded using epoxy resign. Each of the fasteners used in previous sections are countersunk to allow the panels to slot on flush with the structure.

4.3 Modes of Operation

The structure has two modes of operation - REST and DEPLOYED, The resting state is when the satellite is within the launch vehicle and all electronic systems are off and the deployment switches are latched off. When the satellite is released, the deployment switches are also released, and the electronics boot up.

Table 6: LUNATICS-0 Modes of Operation

LUNATICS-0 Mode	Structure Mode
Launch	REST
Initialisation	DEPLOYED
Detumble	DEPLOYED
Nominal	DEPLOYED
TRX	DEPLOYED
Payload	DEPLOYED
Pointing	DEPLOYED
Safe	DEPLOYED

4.4 Electrical Interface

The structure does not require any electrical power. The only electrical interface are the two mechanical kill-switches, which interface with the EPS solar panel array and batteries. The switches are Single-Pole Double-Throw and are attached to the CubeSat structure.

4.5 Structural Interface

The structural system interfaces with every other part as described in the rest of the document.

4.6 Thermal Control

Titanium Dioxide Paint and Mylar layers are applied directly to the structural panels and internal mounts of the CubeSat. The insulation ensures that the structure is thermally protected from external temperature extremes, while the reflective paint ensures minimal heat absorption from the sun.

5 ADCS

There are two main functions of the ADCS system, both integral to the requirements and success of the mission. The first is ensuring that LUNATICS-0 can recover from detumbling. The second is that the payload requires that the face that it is on is *always* facing directly towards Earth.

5.1 Functional Description

The ADCS consists of a 3 axis accelerometer, 3 axis gyroscope and 3 axis magnetometer, and sun sensors. These sensors will provide measurements for the Quaternion Estimator (QUEST) and Extended Kalman Filter (EKF) to estimate the attitude of the CubeSat. Magnetorquers will be controlled by a Bdot algorithm for detumbling and a Proportional-Integral-Derivative (PID) controller for nadir pointing.

5.1.1 List of Parts

Table 7: List of Parts for ADCS

Part Name	Supplier	TRL
BNO085 9DOF IMU Fusion Breakout Board	Adafruit	5
VEML7700 Lux Sensor	Adafruit	5
Magnetorquers	In house	3
DRV8835 Dual Motor Driver Carrier	Texas Instruments	5
Raspberry Pi Pico H	Raspberry Pi	5

9 DOF IMU Fusion Breakout Board - BNO085: It includes a 3 axis accelerometer, 3 axis gyroscope and 3 axis magnetometer. The BNO085 has sensor fusion capabilities, where it can output the attitude in Euler angles and quaternions. This is connected to the PCB through 2 **2.54mm Pitch Male Headers**.

Figure 7: BNO085 9DOF IMU Fusion Breakout Board

5 x **VEML7700 Lux Sensor**: A high-accuracy ambient light sensor capable of measuring a wide range of illuminance from 0 to 120,000 lux. The VEML7700 automatically compensates for white light and infrared radiation, providing accurate lux readings across varying lighting conditions. These are connected to the PCB through 5 **1mm Pitch JST SH SM04B-SRSS-TB Connectors**.

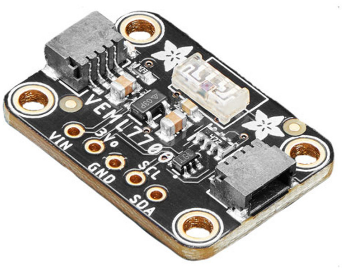


Figure 8: VEML7700 Lux Sensor

3 x **Magnetorquers**: There are 3 magnetorquers, one for each axis. The X axis magnetorquer is a rod with 200 coils, while the Y axis magnetorquer is a rod with 170 coils . The Z axis has a flat square coil with 50 coils. The coils use 0.5 mm thick enamel copper wire. They connect with the PCB through three **3.96mm Pitch, Horizontal JST VH S2P-VH Connector**. The CAD model for the custom design can be seen in Figure 9.

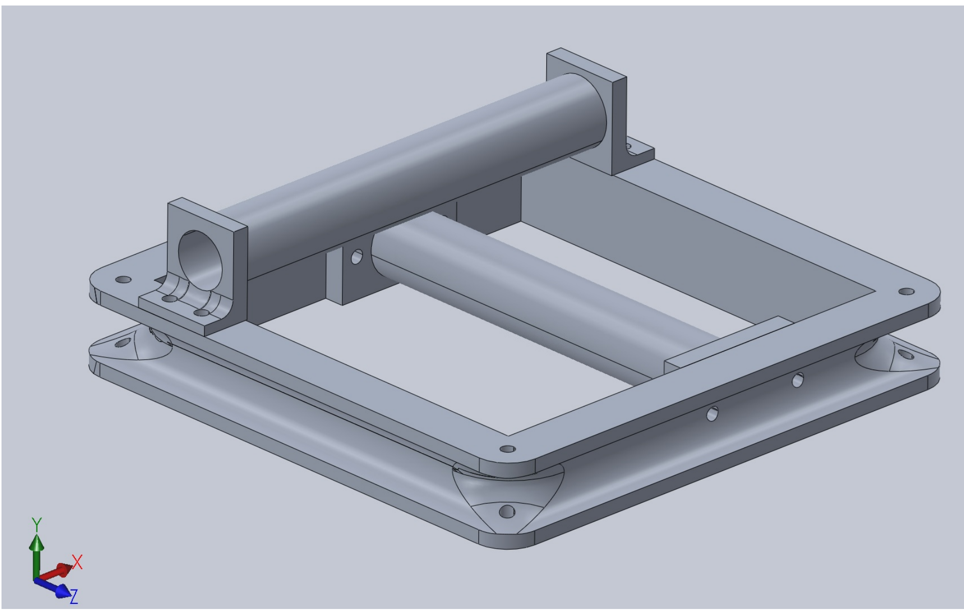


Figure 9: Magnetorquers 3D Cad Model

2 x **DRV8835 Dual Motor Driver Carrier**: This contains two H-Bridge drivers, which allow for control of the magnitude and direction of the current. It can output a maximum of 1.5A per H-bridge.

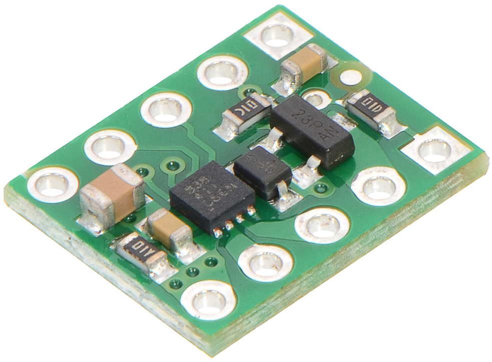


Figure 10: DRV8835 Dual Motor Driver Carrier

Raspberry Pi Pico H: It includes a RP2040 micro controller chip, with 2MB of onboard memory and 26 multi-function GPIO pins. It supports I2C, UART and SPI connections.

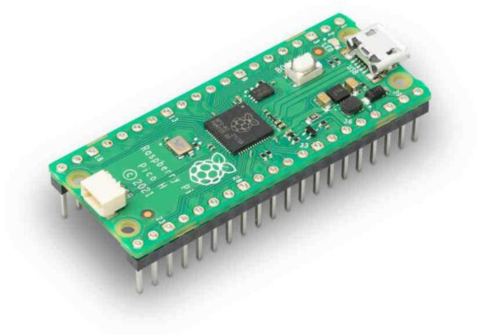


Figure 11: Raspberry Pi Pico H

5.1.2 Modes of operations

ADCS has three modes: ON, PASSIVE, OFF. In the ON mode, power is supplied to all components of the ADCS, where active attitude determination and control is occurring. In the PASSIVE mode, only the sensors will be activated and live attitude determination will still occur. Constant checks of the attitude will be conducted to ensure the satellite remains in the desired attitude. In the OFF mode, no power is supplied to any components. For Detumble mode, the Bdot algorithm will be used to control the magnetorquers to reduce slew rates within the acceptable range. For Pointing mode, the PID algorithm will be used for nadir pointing and ensuring the satellite remains within the acceptable range.

Table 8: ADCS Modes of Operation

LUNATICS-0 Mode	ADCS Mode	Control Algorithm
Launch	OFF	–
Initialisation	PASSIVE	–
Detumble	ON	Bdot
Nominal	PASSIVE	–
TRX	PASSIVE	–
Payload	PASSIVE	–
Pointing	ON	PID
Safe	OFF	–

5.2 Electrical and Command Interface

Within the ADCS subsystem, the control comes from the RPP2W, which is what each peripheral is eventually connected to. The following sub section describes how each connection is made with each component and the micro-controller. For a better understanding of the system, see the Appendix Schematic `Lunatics ADCS Board` for the full schematic for the ADCS system.

5.2.1 Micro controller

The RPP2W is used to interface with all other peripherals within the ADCS subsystem. It is a breakout board with the connections as shown in Figure 13.

The RPP2W is powered from Pin 39, connected to the 5V rail from the EPS system and the ground plane on pins 3 and 33. Key pins and their connections are described in the table below, with descriptions of the peripherals in the following sections.

Table 9: Pin connections for the Pico

RPP2W	Role
Pin 39	Connected to the 5V rail from the EPS
Pin 36	Internal step down creates a 3.3V power rail for any peripherals.
Pin 14	Watchdog to ensure reliable runtime
Pin 3, 33	GND Plane
Pin 16, 17, 19	Show which magnetorquer is being powered

Other connections that are used to interface with other ADCS peripherals and command them to perform the control algorithms are detailed in the following subsections.

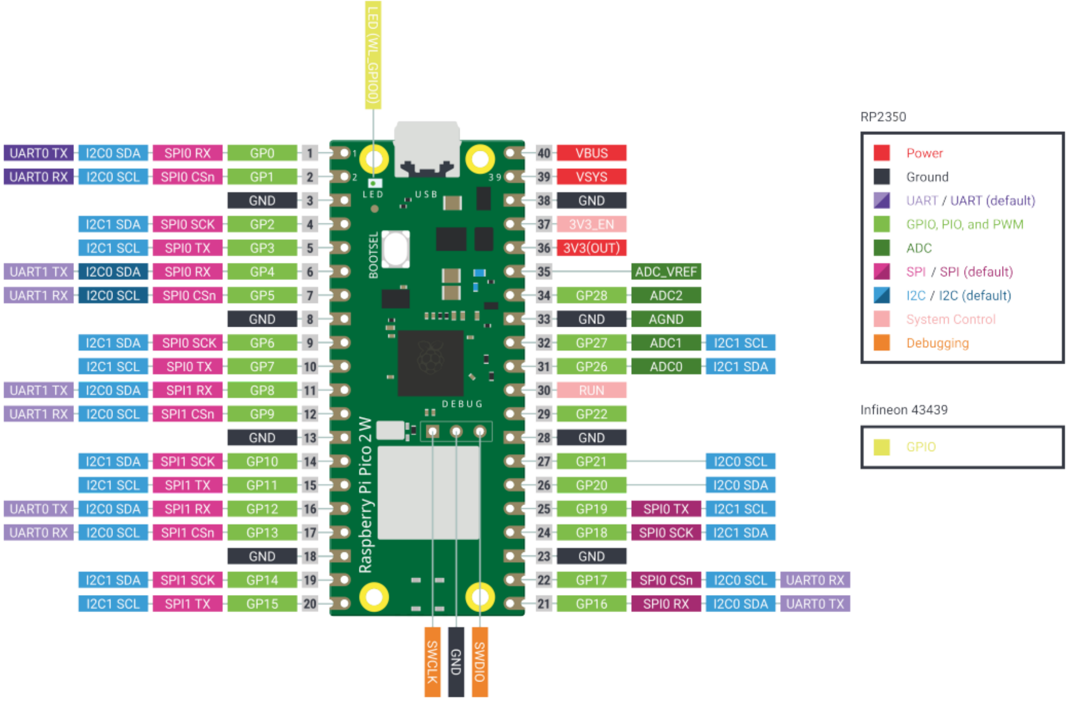


Figure 12: Raspberry Pi Pico 2 W Pinout

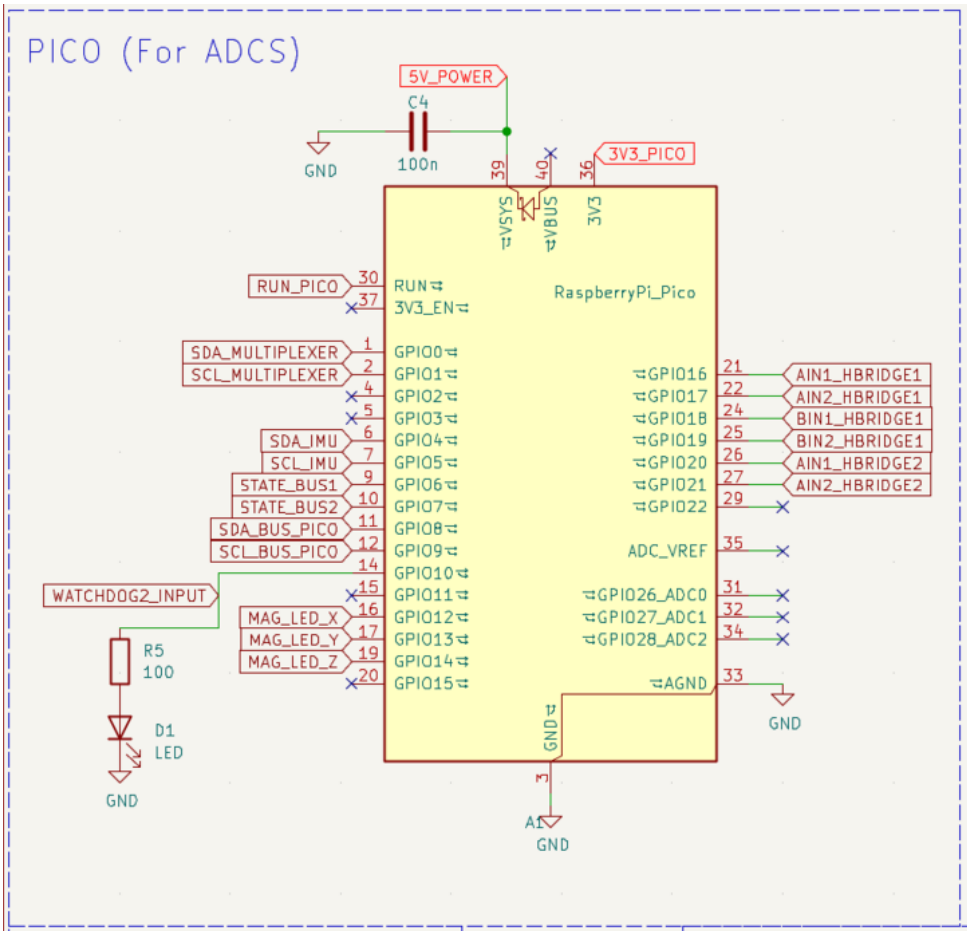


Figure 13: Schematic showing all the connections for the Raspberry Pi Pico

5.2.2 Sun Sensors

The 5 sun sensors are placed around the different faces of the structure, meaning they interface with the PCB through 5 different connectors, shown in Figure 14. Each of the sun sensors has a ground pin, 3.3V power, and a clock and data pin to interface using I2C. To note, the sensors can only use an I2C address of `0x10`, meaning that a direct connection with the bus on the RPP2W would not allow any connections to work as if a request was made to that address, they would all respond and the RPP2W could not identify which one is which. To get around this, we used a multiplexer, also shown in Figure 14, which interfaces with all the sun sensors, and connects to the RPP2W directly. This communicates over the address `0x70`, and the RPP2W can send a request for an individual sensor over this connection.

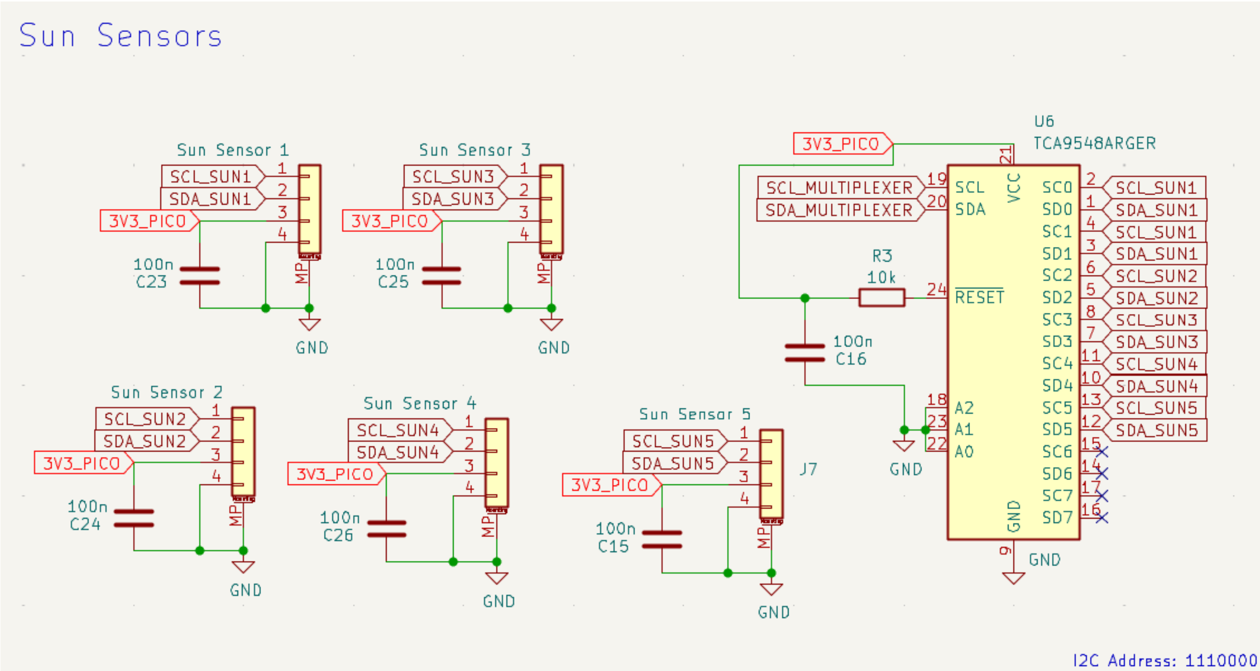


Figure 14: Schematic for the sun sensors, including connectors for each sensor and a multiplexer

Each connector has 4 pins, which includes a ground pin, two I2C pins and a 3.3V power that comes from the Pico. The connections that connect the sun sensor to the multiplexer and Pico are as follows:

Table 10: Pin connections for the sun sensors

Sun Sensor	Multiplexer	RPP2W	Role
3.3 Power	–	Pin 36	Provides power required for the sun sensors to work. When in OFF mode, this pin will be LOW.
SCL	Pin 2,4,6,8,11,13	–	Clock line for the I2C interface.
SDA	Pin 1,3,5,7,10,12	–	Data line for the I2C interface.

Furthermore, the connections that connect the multiplexer to the Pico are as follows

Table 11: Pin connections for the multiplexer

Multiplexer	**RPP2W**	**Role**
3.3 Power	Pin 36	Provides power required for the AS7265x to work. When in OFF mode, this pin will be LOW.
SCL (Pin 19)	Pin 2	Clock line for the I2C interface.
SDA (Pin 20)	Pin 1	Data line for the I2C interface.

5.2.3 IMU

The IMU is placed as a breakout board that is soldered to 2.54mm pitch male headers on the PCB. Like many of the other components, it interfaces with the RPP2W through I2C on the `0x4A` address. The schematic for the IMU is shown within Figure 15.

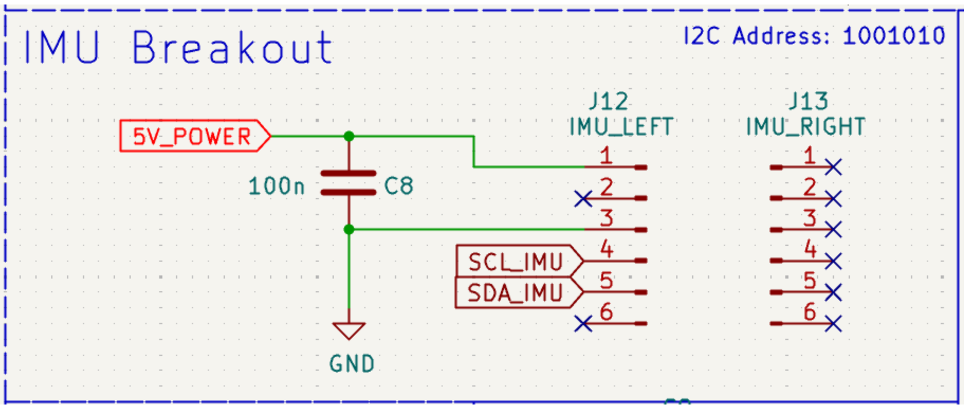


Figure 15: Schematic for the IMU

The pins that are connected from the IMU are the 5V power (Pin 1), ground (Pin 3), and the two I2C pins. The 5V power will be connected to the 5V rails from the EPS system. The connections between the IMU and RPP2W are as follows:

Table 12: Pin connections for the IMU

IMU	RPP2W	Role
SCL (Pin 4)	Pin 7	Clock line for the I2C interface.
SDA (Pin 5)	Pin 6	Data line for the I2C interface.

5.2.4 Magnetorquers

The 3 magnetorquers are connected to the two H-bridges on the PCB (shown in Figure 16, which are then connected to the RPP2W. The Pico communicates to the H-bridge with two GPIO pins (one configured to be PWM) and then changes the magnitude and direction of the current being passed through the coils of each magnetorquer accordingly. The H-Bridges are soldered onto two 1mm pitch headers for the left and the right pins.

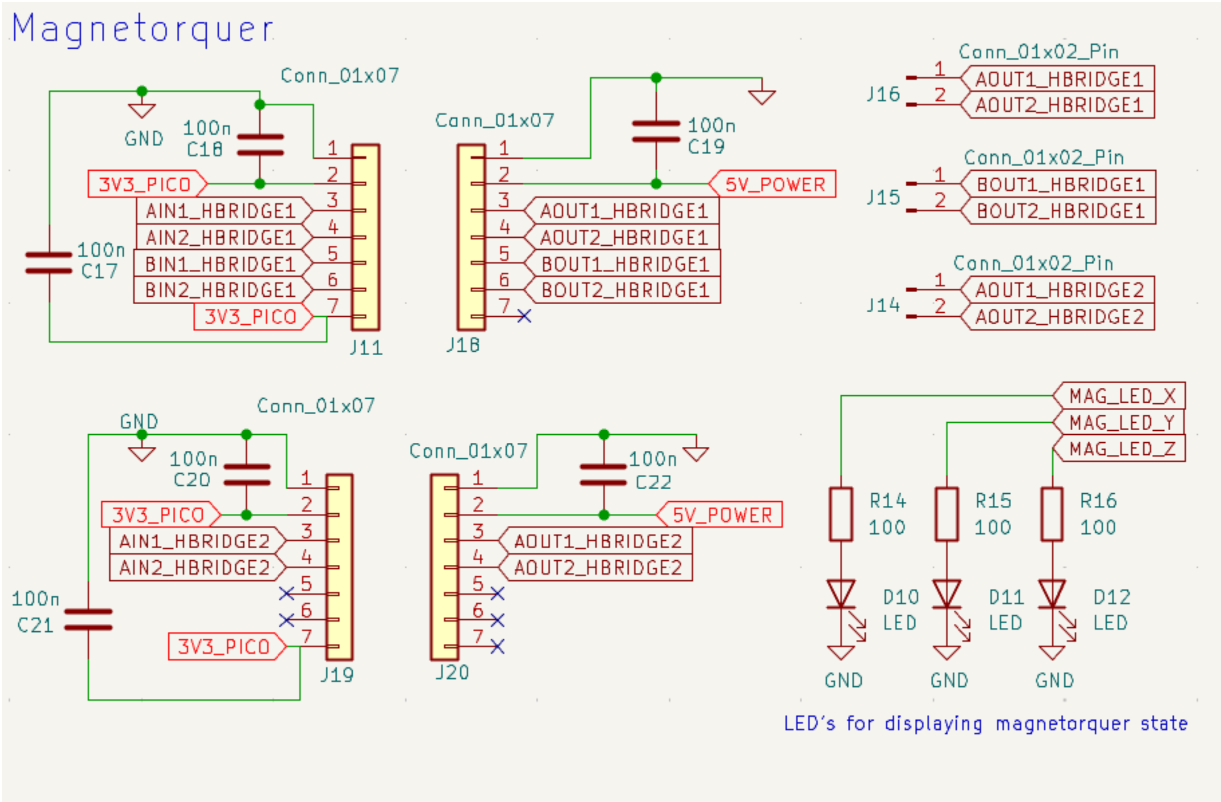


Figure 16: Magnetorquer schematic showing the H-bridges, connectors and LEDs for debugging.

Each DRV8835is a dual-hbridge meaning two are required to control the three magnetorquers we are using. To note, the 5V power for the output current comes from the 5V rail from the EPS system and is connected on pin 2 of the right header. The other pin connections are as follows:

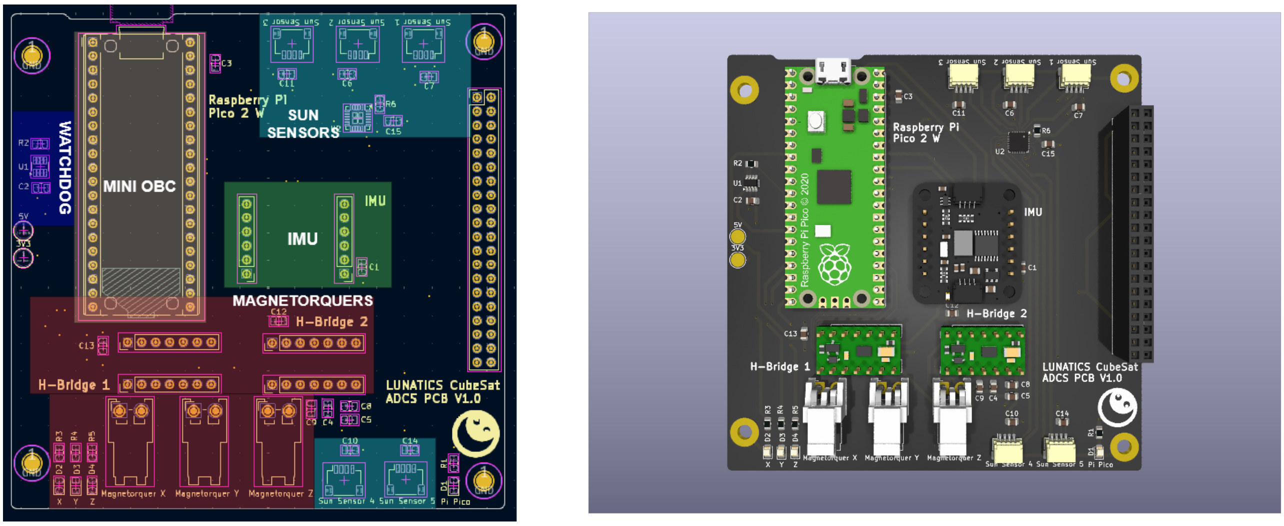
Table 13: Pin connections for each H-bridge

H-Bridge	RPP2W	Magnetorquer	Role
3.3V Power (Pin 2 left)	Pin 36	–	Logic High value.
Enable (Pin 3,5 left)	Pin 21,24,26		Controls the direction of the current
Phase (Pin 4,6 left)	Pin 22,25,27		PWM signal that controls the strength of the current
Output 1 (Pin 3,5 right)	–	Conn +	Connects to one side of the magnetorquer.
Output 2 (Pin 4,6 right)	–	Conn –	Connects to the other side of the magnetorquer, allowing current to pass through.
Mode (Pin 7 left)	Pin 6		Pulled high to use phase-enable over in-in mode.

5.3 Structural Interface

5.3.1 ADCS PCB

The ADCS PCB is the second board in the PCB stack in Figure 29 and connects to the rest of the structure as a part of that stack. A 3D render of the board can be seen in Figure 17.



(a) Footprint of the ADCS PCB (b) Render of the ACDS PCB

Figure 17: Combined view of ADCS PCB sections and render

5.3.2 Sun Sensors

The 5 sun sensors are fixed to the 5 faces and small holes are made such that the 80 degree field of view is not obstructed. The sun sensors on the top and bottom faces are offset in order to fit the magnetorquer and the PCB.

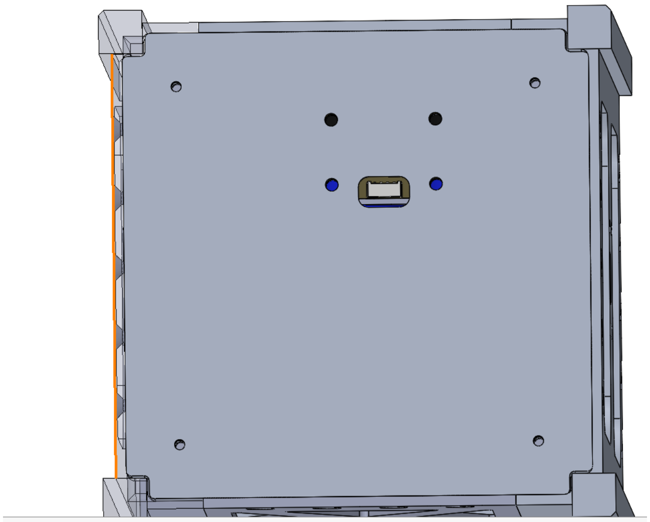


Figure 18: Sun Sensor Peek Holes

5.3.3 Magnetorquers

The magnetorquers fit in the structure at the opposite end to the PCB, seen in Figure **??**

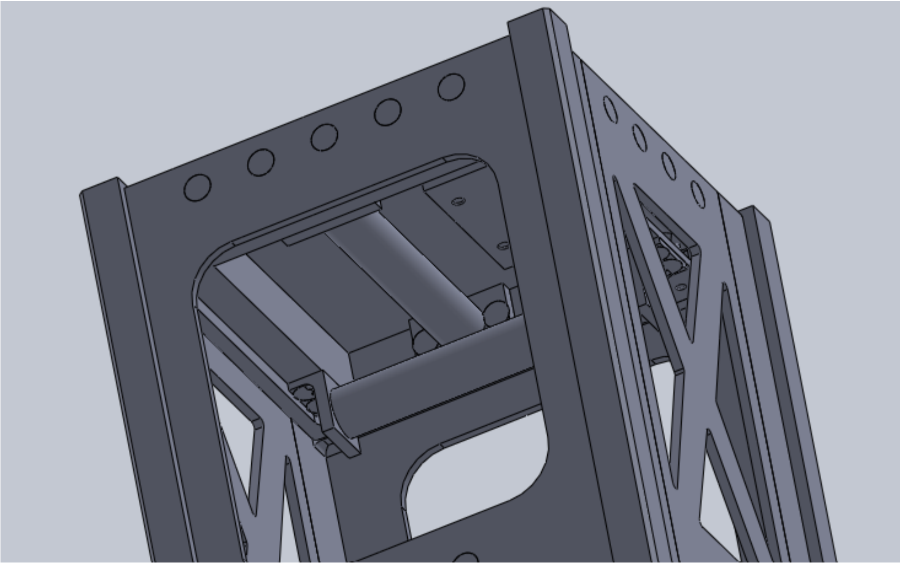


Figure 19: Showing how the magnetorquers fit in the overall structure of the

5.4 Thermal Control

The magnetorquer operates within -40°C to 85°C, while the VFMI-7700 lux sensor and ArdPilot BN0055 operate within -25°C to 80°C. For thermal control, Mylar layers provide insulation by reflecting thermal radiation, and Kapton tape provides insulation and secures materials. Together, they help maintain stable temperatures for these components.

6 EPS

The Electronics and Power System is responsible for providing stable and adequate power to all electrical components on the LUNATICs CubeSat.

6.1 Functional Description

6.1.1 List of Parts

The EPS components are listed in Table 14. The following section describes the main components and their function.

EPS Printed Circuit Board (EPS A001 EPS PCB) is our custom OCB which holds all of our EPS circuitry components including connections to other PCBs in the stack, as well as solar panels, batteries and kill switches.

18650 Batteries (EPS P002 Battery INR18650-35E) are our energy storage device for eclipse and poor sunlit conditions. The batteries supplement the solar panels when either load demand is high or power production is low. The batteries are mounted on the **Battery Holder (EPS P012 BatteryHolder)** which is located within the CubeSat chassis.

Solar Panels (EPS P003 SolarPanelSeeedStudio1W) provide power generation for the CubeSat system, providing up to 0.75 W of power in fully sunlit conditions.

Solar Charge Controller (EPS P004 SolarChargerB24650): this chip from Texas Instruments provides the core of our battery charging system, along with several resistors, capacitos and P-Channel MOSFETs.

Battery Protector (EPS P005 BatteryProtectorS82A2A): this chip from Ablic Inc. provides protection for the batteries in the case of over/under-discharge, over/under-voltage and short-circuit protection. Two N-Channel MOSFETs (EPS P011 NMOS SI2300DS) provide the switch-opening capabilities to protect the batteries.

Voltage Regulators (EPS P006 VoltageRegulatorTPS63060): this chip from Texas Instruments provides the voltage regulation capabilities of the EPS, generating regulated 3.3 V and 5 V outputs.

Current Sensors (EPS P007 CurrentSensorINA219A): this chip provides bi-directional current sensing along with an I2C interface to communicate data to our OBC.

Reverse-Polarity Protectors (EPS P008 ZenerDiode1n4733A and EPS P010 PMOS SIA459EDJ): this circuit consists of a zener diode and P-Channel MOSFET and acts to prevent the flow of current back into the solar panels

Electrical Components: the design of the EPS board involves several inductors (EPS P015-P016), capacitors (EPS P016-P022) and resistors (EPS P023-P045) to support the function of the integrated chips, decouple voltages, and provide pull-up voltages for I2C clock and data pins.

Table 14: EPS Parts List

Part ID	**Qty**	**Schem. Ref.**	**Supplier**
EPS_A001_EPS_PCB	1	_	Custom
EPS_P002_Battery INR18650-35E	2	_	Aus Batteries
EPS_P003_SolarPanelSeeedStudio1W	7	_	Core Elec
EPS_P004_SolarChargerB24650	1	U11	Mouser
EPS_P005_BatteryProtectorS82A2A	1	U3	Mouser
EPS_P006_VoltageRegulatorTPS63060	2	U1,U2	Mouser
EPS_P007_CurrentSensorINA219A	6	U4,U9,U10,U12,U13,U14	Mouser
EPS_P008_ZenerDiode1n4733A	4	D8-D11	Mouser
EPS_P009_SchottkyDiode1N5819	1	D7	Mouser
EPS_P010_PMOS_SIA459EDJ	4	Q1,Q2,Q3,Q4	Mouser
EPS_P011_NMOS_SI2300DS	4	Q5,Q6,Q7,Q8	Mouser
EPS_P012_BatteryHolder	1	_	Mouser
EPS_P013_LED_0805	4	D1,D2,D5,D6	JLCPCB
EPS_P014_Inductor_3.8uH_0805	2	L1,L2	JLCPCB
EPS_P015_Inductor_1uH_0805	1	L3	JLCPCB
EPS_P016_Capacitor_10uF_0805	18	C1,C2,C5,C6,C7,C8,C9,C10, C11,C12,C15,C16,C17, C18,C19,C20,C34,C38	JLCPCB
EPS_P017_Capacitor_0.1uF_0805	12	C3,C13,C21,C22,C23,C26,C27, C28,C29,C30,C32,C33	JLCPCB
EPS_P018_Capacitor_10pF_0805	2	C4,C14	JLCPCB
EPS_P019_Capacitor_2.2uF_0805	1	C24	JLCPCB
EPS_P020_Capacitor_1uF_0805	3	C25,C31,C37	JLCPCB
EPS_P021_Capacitor_4.7uF_0805	1	C35	JLCPCB
EPS_P022_Capacitor_22pF_0805	1	C36	JLCPCB
EPS_P023_Resistor_1.1_MR_0805	1	R1	JLCPCB
EPS_P024_Resistor_120_kR_0805	1	R2	JLCPCB
EPS_P025_Resistor_1_MR_0805	2	R3,R6	JLCPCB
EPS_P026_Resistor_680kR_0805	1	R4	JLCPCB
EPS_P027_Resistor_120kR_0805	1	R5	JLCPCB
EPS_P028_Resistor_100R_0805	2	R7,R8	JLCPCB
EPS_P029_Resistor_1_kR_0805	2	R9,R26	JLCPCB
EPS_P030_Resistor_1_mR_0805	1	R10	JLCPCB
EPS_P031_Resistor_2_R_0805	1	R11	JLCPCB
EPS_P032_Resistor_10R_0805	1	R12	JLCPCB
EPS_P033_Resistor_200_kR_0805	1	R13	JLCPCB
EPS_P034_Resistor_56_kR_0805	1	R14	JLCPCB
EPS_P035_Resistor_10_kR_0805	2	R15,R16	JLCPCB
EPS_P036_Resistor_20_mR_0805	1	R17	JLCPCB
EPS_P037_Resistor_300_kR_0805	1	R18	JLCPCB
EPS_P038_Resistor_100_kR_0805	1	R19	JLCPCB
EPS_P039_Resistor_10_R_0805	2	R20,R21	JLCPCB
EPS_P040_Resistor_100kR_0805	4	R22,R23,R24,R25	JLCPCB
EPS_P041_Resistor_260_0805	2	R27,R28	JLCPCB
EPS_P042_Resistor_3.3kR_0805	12	RPullup	JLCPCB
EPS_P043_Resistor_2mR_0805	6	RShunt	JLCPCB

6.1.2 Operational Modes

The operational mode of the EPS relies only on the mechanical kill-switches The simple operational activity of the EPS can thus be summarised as

Launch Mode: During launch, all electronic power is disabled. The kill switches are set open by the deployment mechanics which prevents power flow in and out of the solar panels and the batteries, effectively shutting down the EPS board.

Initialization Mode: During this mode, power is not enabled for 30 minutes, only after is power supplied to peripherals.

All Other Modes: In all other modes, the EPS supplies power via the 3.3 V and 5 V regulated rails to all components that draw power. In any case, it attempts to charge the batteries with any excess power produced by the solar panels. If the solar panels are not producing enough power, than the batteries will instead be drained by the system.

6.2 Electrical Interface

6.2.1 Pin Allocation

The allocation of relevant pins is shown in 15.

Table 15: EPS Pinout

Pin	Connection	Header Pin	Description
		Solar Charger (EPS P004)	
Pin 1	VIN	_	Solar input voltage
Pin 2	MPPSET	_	MPP resistor divider setting
Pin 8	SRN	_	Negative-side of charge current setting resistor
Pin 9	SRP	_	Positive-side of charge current setting resistor
		Battery Protector (EPS P005)	
Pin 6	VSS	_	Battery negative terminal
Pin 7	VC	_	Battery center terminal
Pin 8	VDD	Pin 33, 34	Battery positive terminal
		Voltage Regulators (EPS P006)	
Pin 1	L1	_	Inductor high-side
Pin 2	VIN	_	Input voltage unregulated
Pin 7	GND	Pin 19, 20	Ground
Pin 8	FB	_	Output voltage set by resistor divider
Pin 9	VOUT	Pin 3 (or 1)	3.3 V power (or 5 V)
Pin 10	L2	_	Inductor low-side
Pin 11	PGND	Pin 19, 20	Ground
		Current Sensors (EPS P007)	
Pin 1	A1	_	I2C Address pin 1
Pin 2	A0	_	I2C Address pin 0
Pin 3	SDA	Pin 7	I2C Data line
Pin 4	SCL	Pin 8	I2C Clock line
Pin 5	VS	Pin 3	3.3V power
Pin 7	IN+	_	Measurement pin positive
Pin 8	IN-	_	Measurement pin negative

6.2.2 Power

This section elucidates the power requirements for the EPS.

Solar Charge Controller (EPS P004 SolarChargerB24650): The solar charge controller receives variable power from the solar panels. This variable input voltage is used to power the IC.

Voltage Regulators (EPS P006 VoltageRegulatorTPS63060): The voltage regulators receive a variable input voltage based on the charge of the battery, from 6.6 V to 8.4 V.

Current Sensors (EPS P007 CurrentSensorINA219A): The current sensors receive regulated 3.3 V power.

6.2.3 Communication

The EPS communicates with other systems via ADC and I2C.

Current Sensors (EPS P007 CurrentSensorINA219A): This chip interfaces with the OBC via I2C communication protocol. The header pins 7 and 8 carry the data and clock signals respectively. Each current sensor is assigned a unique I2C address based on the voltage of its A0 and A1 pins, shown in Table 16.

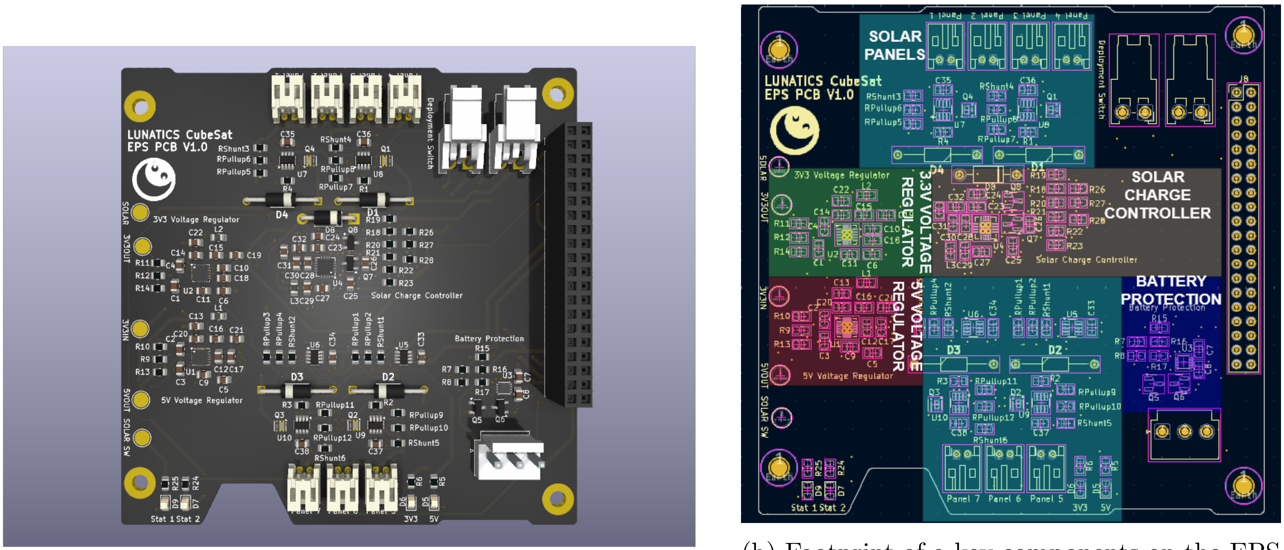
Table 16: Current Sensor I2C Addresses

Current Sensor ID	A1	A0	I2C Address
1	GND	GND	0x41
2	GND	Vs	0x42
3	GND	SDA	0x43
4	GND	SCL	0x44
5	Vs	GND	0x45
6	Vs	Vs	0x46

Battery Voltage (Header Pin 33, 34): The battery voltage is supplied via the header to the OBC. The OBC uses ADC to determine the battery voltage which is vitally important in performing state transitions.

6.3 Mechanical Interface

Most of the EPS components are mounted onto the EPS PCB, the top PCB on the stack shown in Figure 29. The solar panels are connected to the outside of the CubeSat structure while the kill-switches are mounted to the base of the CubeSat. Wires from the kill-switch terminals are connected via JST adapters to the EPS PCB.



(a) Render of the EPS PCB board

(b) Footprint of a key components on the EPS board

Figure 20: Combined view of the EPS PCB render and a component footprint

The battery fits on an internal structure in the top half of the assembly.

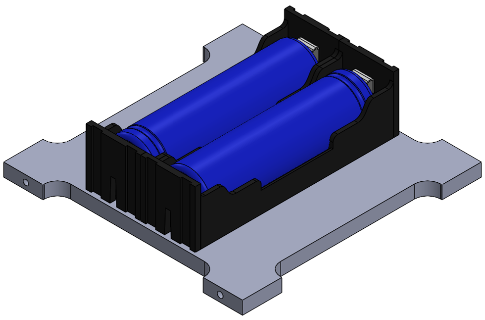


Figure 21: Assembly of the batteries and how they fit into the structure

Each of the faces is fitted with a Solar Panel, which slides into the frame as shown in 22.

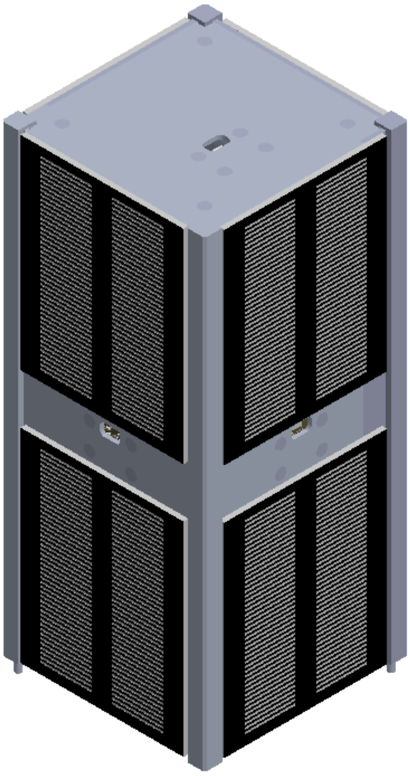


Figure 22: Solar Panels set into the structure

6.4 Thermal Control

The Electrical Power System includes several components with specific operational temperature ranges: the OBC, 1W solar panel (80×100mm), boost converter, buck converter, and current sensor all operate between -40°C and either 80°C to 125°C, while the Sony 18650 VTC6 battery functions within -20°C to 60°C. These components require thermal control to ensure reliable performance. Mylar layers provide insulation primarily by reflecting thermal radiation, while Kapton tape offers additional insulation and helps secure materials in place.

7 OBC

The OBC is responsible for maintaining the state of LUNATICS-0 and ensuring that the required peripherals are operating within each state.

7.1 Functional Description

7.1.1 List of Parts

The main OBC we are using is the **Raspberry Pi Zero 2 W (RP02W)** which is supplied by Raspberry Pi. It is a quad-core 64-bit ARM Cortex-A53 processor clocked at 1GHz and 512MB of SDRAM. We will flash the OS onto a **SanDisk 32GB High Endurance microSDHC Memory Card** which will be inserted into the OBC to allow it to run.

Figure 23: Raspberry Pi Zero 2 W

A **MAX6369–MAX6374** watchdog timer supplied by Maxim Integrated will also be implemented. This will expect a continuous high signal from the RP02W (and the **??**). If no signal is provided with a 60s buffer, then the OBC will be rebooted. The buffer is to ensure that it has time to start up and begin the signal. This is a protection for bugs and errors within each onboard computer as a result of faulty code or single upset events.

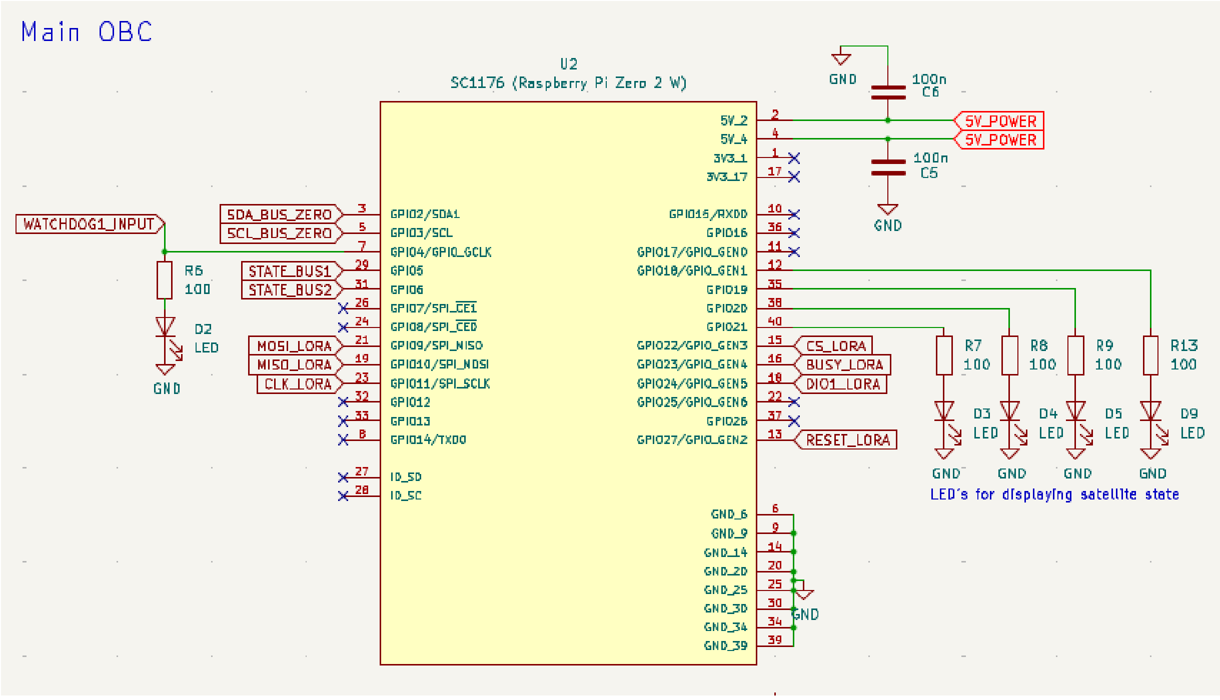
A **DS3231M MEMS Precise RTC** will be used in order to maintain reliable, accurate timings on board the OBC.

7.1.2 Modes of Operation

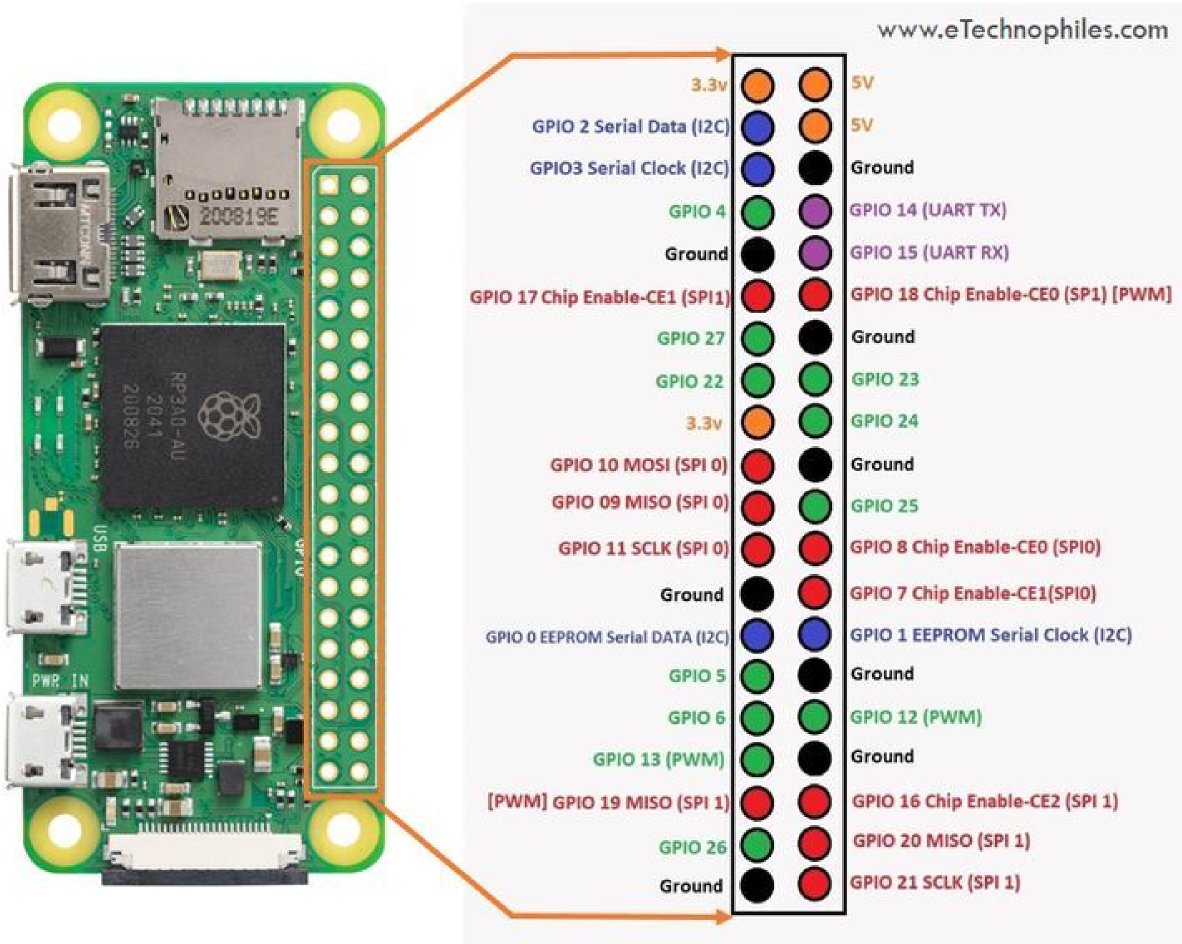
Once LUNATICS-0 has been initialised (or reset after a watchdog reset), the RP02W will be booted up and the code that the LUNATICS team have written will begin running. The Zero will be running the whole time and thus will go through every step of the state machine described in Figure 2, turning off and on components that are necessary for the next state.

7.2 Electrical and Command Interface

The RP02W is connected to other peripherals through the PCB, with the connections shown in Figure **??**.



(a) Schematic of Raspberry Pi Zero 2 W



(b) Pinout diagram of the Raspberry Pi Zero used in the design

Figure 24: Watchdog implementation and Raspberry Pi Zero pin reference

The 5V power input is provided from the 5V bus from the EPS system. Every other pin connection can be described in the following table.

Table 17: Pin connections for Zero

RP02W	Role
Pin 3	SDA Bus for I2C connections
Pin 5	SCL Bus for I2C connections
Pin 7	Watchdog
Pin 29	ADCS State Bit 1
Pin 31	ADCS State Bit 2
Pin 12	Satellite State Bit 1
Pin 35	Satellite State Bit 2
Pin 38	Satellite State Bit 3
Pin 40	Satellite State Bit 4
Pin 15	Chip Select for LoRa node
Pin 16	Indicates LoRa module is busy
Pin 18	Interrupt for LoRa Module
Pin 13	Resets the LoRa Module
Pin 21	ISO input for the LoRa Module
Pin 23	SPI clock for the LoRa Module
Pin 19	OSI output from the LoRa Module

As the I2C bus connects to a multiple addresses, Figure 25 shows the I2C bus that is used for the OBC.

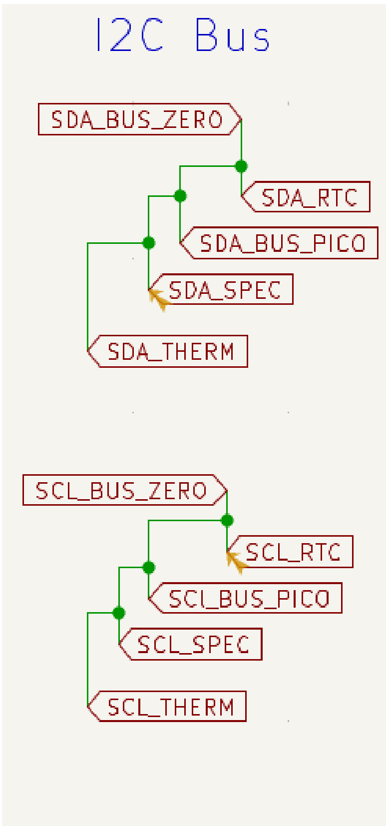


Figure 25: I2C bus for the RP02W

Furthermore, the watchdog circuit that we have included can be seen in Figure 26. It should be noted that this has been setup for both the Pico and the Zero, ensuring reliability from both our controllers. Furthermore, we have pulled all three of the selection channels to `HIGH` in order to use the longest timeout possible, 60s. This is to ensure that when booting, it has enough time to start up and begin the signal before getting reset again.

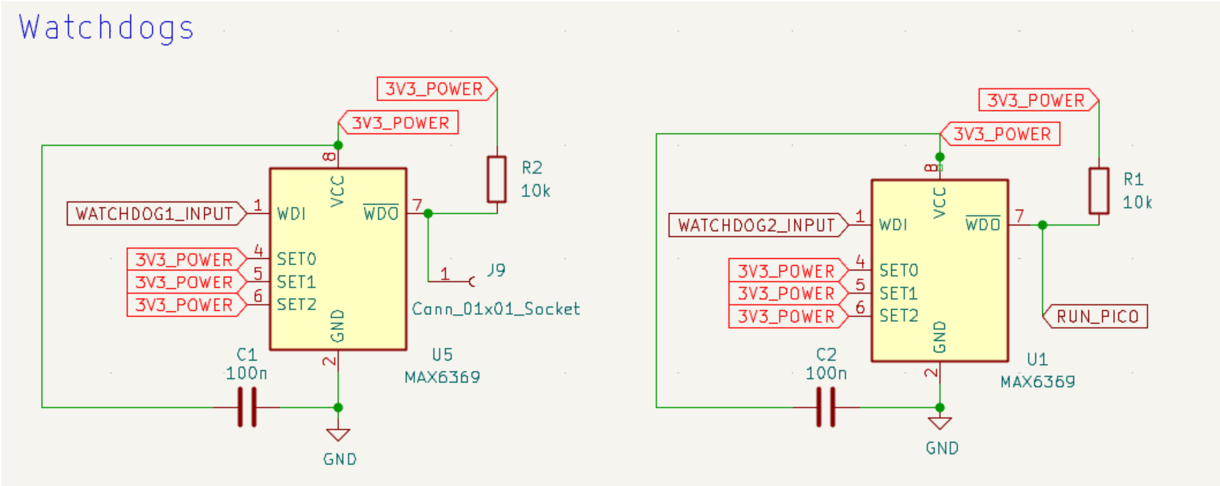


Figure 26: Schematic of the watchdogs for each of the Raspberry Pi

The pin connections are as follows:

Table 18: Pin connections for the Watchdogs

AS7265X Pin	Raspberry Pi
1	7 (Zero), 14 (Pico)

Finally, the schematic for the RTC can be seen in Figure 27.

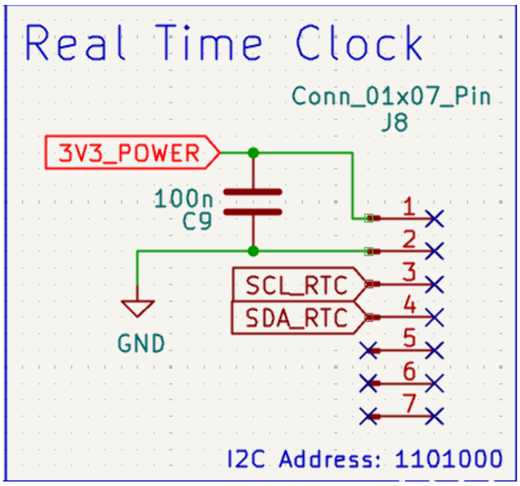


Figure 27: Schematic for the RTC

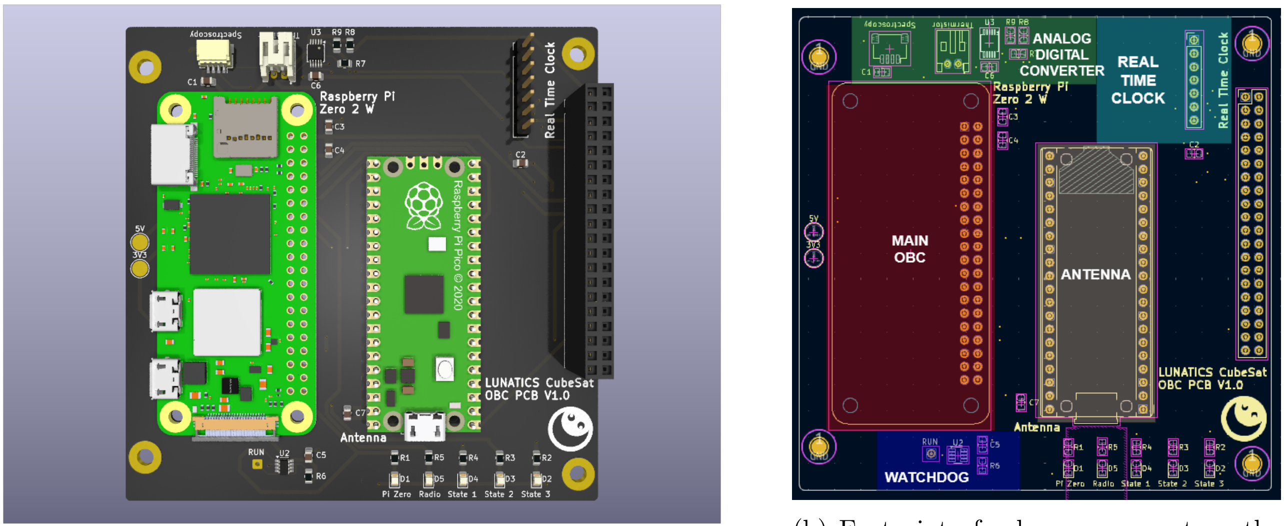
The RTC uses 3.3V of power (in Pin 1) which it draws from the 3V3 power rail, and is grounded at Pin 2. The command pins are connected to the RP02W using I2C over address `0x68` in the following configuration.

Table 19: Pin connections for the RTC

RTC	RP02W	Role
3	5	I2C Clock pin
4	3	I2C Data pin

7.3 Structural Interface

The OBC interacts with the structure of LUNATICS-0 through the OBC PCB board, the one at the bottom of the stack shown in Figure 29. A further render of the PCB Board is shown in Figure 28a with the footprint's shown for each subsection.



(a) Render of the OBC PCB board

(b) Footprint of a key component on the OBC board

Figure 28: Combined view of the OBC PCB render and a component footprint

The LUNATICS-0 PCB stack can be seen in Figure 29.

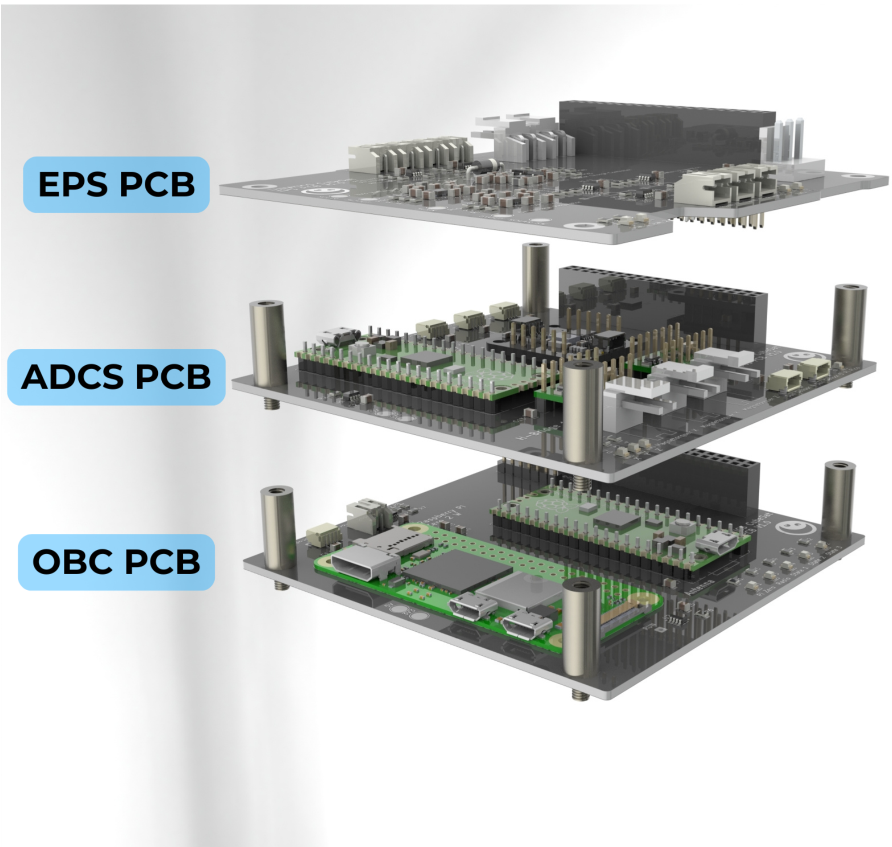


Figure 29: PCB Stack

This will be held at the bottom of our satellite and uses connectors to interface with any internal peripherals not on the board. To connect the 3 boards together and fasten them in place, screws with standoffs as specified in Figure 30 have been utilised.

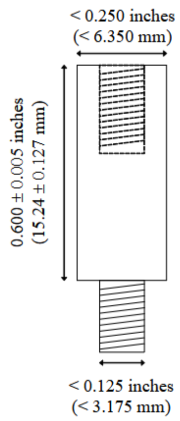


Figure 30: Standoff Specifications for the PCB stack

7.4 Thermal Control

The temperature range of the PCB is -50°C to 125°C. Like the previous subsystems, thermal control is achieved using Mylar and Kapton, where Mylar reflects radiant heat and Kapton provides insulation and structural support.

8 Communications

The communication system is responsible for two way communication between LUNATICS-0 and our ground station at The University of Sydney.

8.1 Functional Description

8.1.1 List of Parts

The part used for communications is the **SX1262 LoRa Node Module for Raspberry Pi Pico** provided by WaveShare. It is a node that nominally interfaces with a Pico and thus has an extremely small footprint. It operates at a frequency of 915MHz with a range of 902 930MHz.

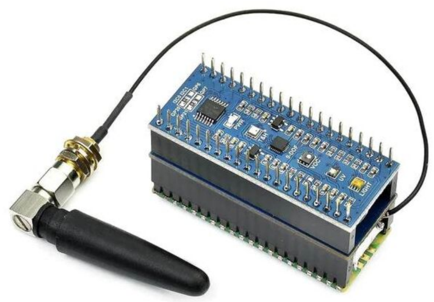


Figure 31: Nominal operation of the SX1262 Module attached to a Raspberry Pi Pico

This LoRa node acts as the modem on LUNATICS-0, and uses a **RP-SMA to uFL/u.FL/IPX/IPEX RF Adapter Cable** in order to connect to the **5cm RF SMA Duck Antenna**. Both of these are shown in Figure 31.

8.1.2 Modes of Operation

There will be two main modes of operation for the communications module. OFF when there is no communications link between the ground station and the satellite, meaning it will not be able to connect at all and thus no supplied power is needed. TRANSMIT/RECEIVE mode will be when in view of the ground station, and will be the state that sends WOD data, as well as science information. It will also receive any instructions from the ground station within this mode.

Table 20: Communications Modes of Operation

LUNATICS-0 Mode	TT&C Mode
Launch	OFF
Initialisation	OFF
Detumble	OFF
Nominal	OFF
TRX	TRANSMIT/RECEIVE
Payload	OFF
Pointing	OFF
Safe	OFF

8.2 Electrical and Control Interface

The main connection of the SX1262 Module is with the RP02W using the SPI communication protocol. Instead of normally being connected to a RPP2W, it will be a breakout board on our PCB with the connections shown in Figure 32.

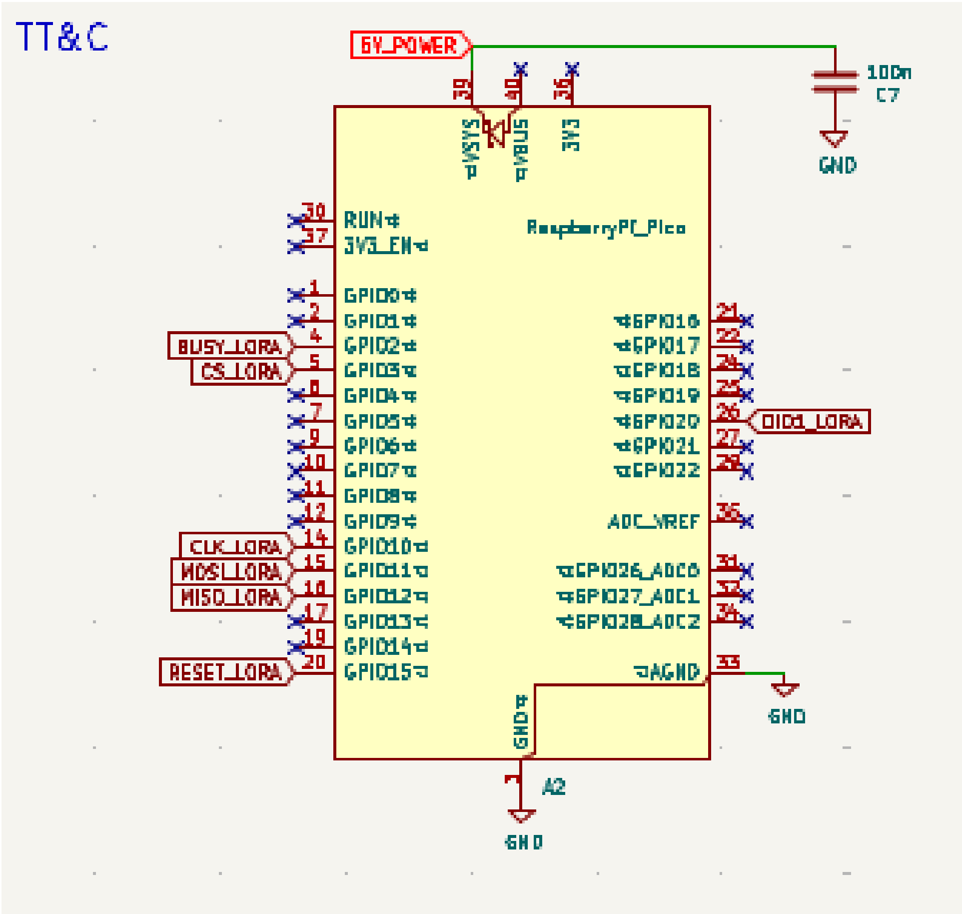


Figure 32: Schematic for the SX1262

Apart from the ground and the 5V power which will come from the 5V rail from the EPS system, the pin connections are as follows:

Table 21: Pin connections for each H-bridge

LoRa Node	**RP02W**	**Role**
Busy (Pin 4)	Pin 16	Indicates LoRa module is busy.
CS (Pin 5)	Pin 15	Chip select for SPI communication.
CLK (Pin 14)	Pin 23	Serial clock for SPI timing.
OSI (Pin 15)	Pin 21	SPI output data from RPi.
ISO (Pin 16)	Pin 19	SPI input data to RPi.
RESET (Pin 20)	Pin 13	Resets the LoRa module.
DIO (Pin 26)	Pin 18	Interrupt or digital signal line.

This allows the RP02W to request and receive transmission over the SPI bus. There are two types of transmission that the communications module will be commanded to send - the WOD data and the payload data. When receiving data, it will send the information which will be stored in a buffer and then processed on the OBC.

8.3 Structural Interface

The structural interface of LUNATICS-0 is composed of two main sections, the Modem and the antenna.

8.3.1 Modem

The modem sits on the OBC PCB and directly interfaces with it as per the schematic in Figure 32. This can

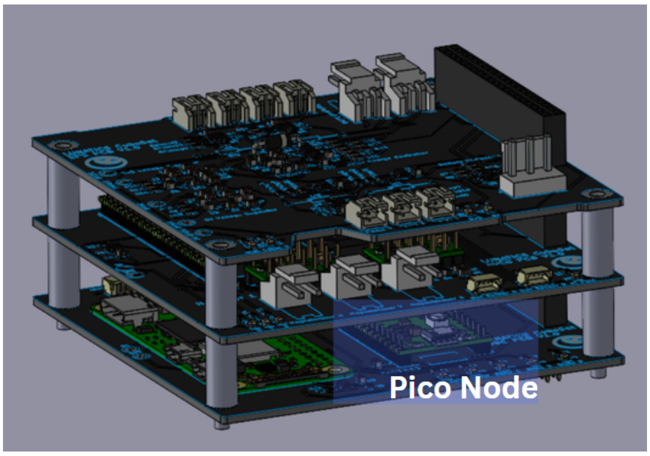


Figure 33: PCB stack showing the LoRa node on the bottom, OBC level

8.3.2 Antenna

The antenna sits held in place next to one of the sun sensors, shown in Figure 34, As this is a proof of concept, the direction and view of the antenna can be obstructed and will operate for testing.

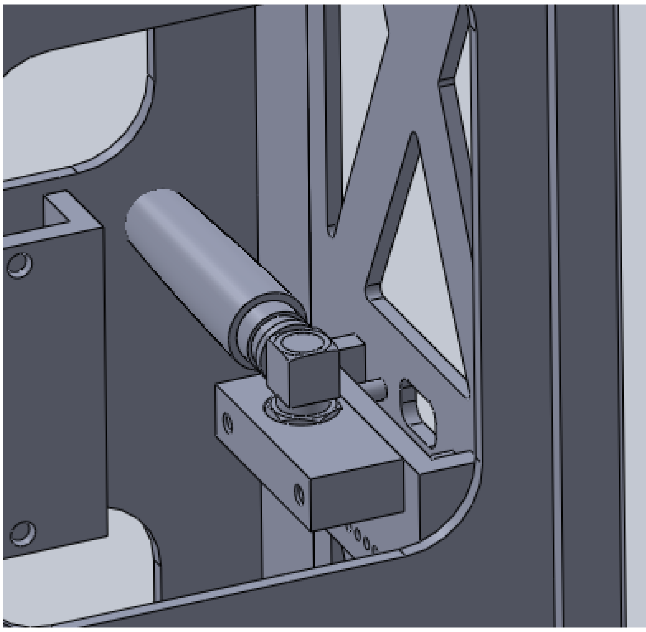


Figure 34: Structure holding the antenna in place

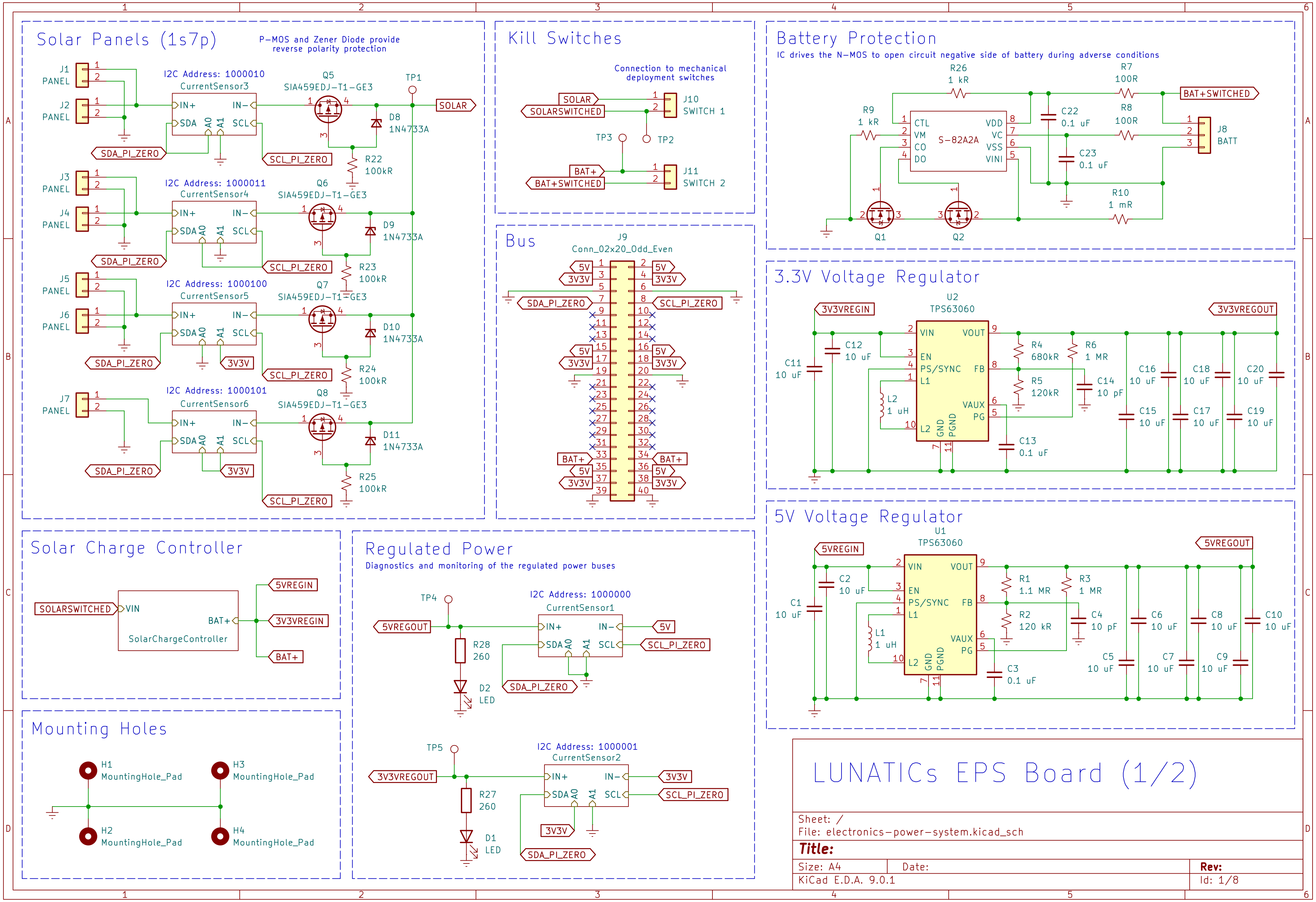
8.4 Thermal Control

The antenna operates between -40°C to 85°C while the NanoComm AX100UL modem between -30°C to 85°C. As with the previous subsystems, thermal regulation is managed using Mylar and Kapton;

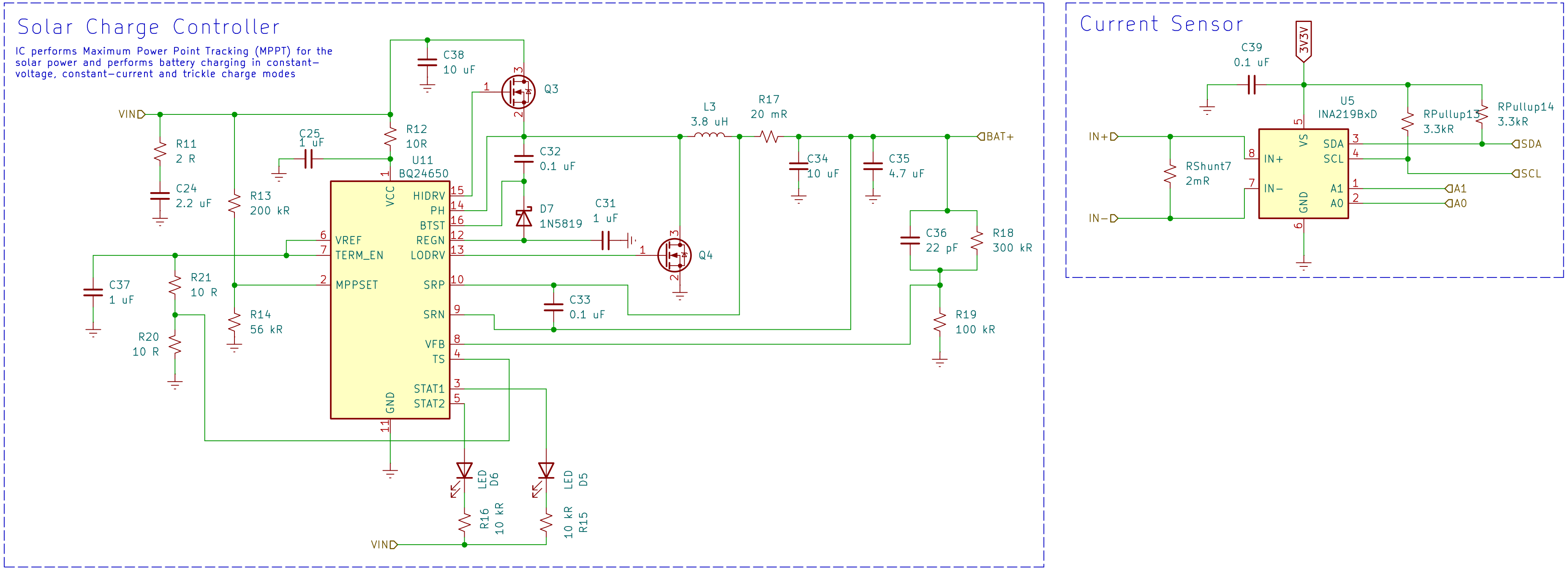
Mylar acts as an insulation, while Kapton offers both insulation and mechanical stability.

Appendix A Electrical Diagrams

A.1 Electrical Diagrams



Solar Panels (1s7p)
P-MOS and Zener Diode provide reverse polarity protection
J1 PANEL
J2 PANEL
J3 PANEL
J4 PANEL
J5 PANEL
J6 PANEL
J7 PANEL
I2C Address: 1000010
CurrentSensor3
I2C Address: 1000011
CurrentSensor4
I2C Address: 1000100
CurrentSensor5
I2C Address: 1000101
CurrentSensor6
Q5 SIA459EDJ-T1-GE3
Q6 SIA459EDJ-T1-GE3
Q7 SIA459EDJ-T1-GE3
Q8 SIA459EDJ-T1-GE3
D8 1N4733A
D9 1N4733A
D10 1N4733A
D11 1N4733A
R22 100kR
R23 100kR
R24 100kR
R25 100kR
TP1
SOLAR
SDA_PI_ZERO
SCL_PI_ZERO
3V3V
Kill Switches
Connection to mechanical deployment switches
SOLAR
SOLARSWITCHED
J10 SWITCH 1
TP3
TP2
BAT+
BAT+SWITCHED
J11 SWITCH 2
Bus
J9
Conn_02x20_Odd_Even
5V
3V3V
BAT+
Battery Protection
IC drives the N-MOS to open circuit negative side of battery during adverse conditions
R26 1 kR
R7 100R
R8 100R
R9 1 kR
R10 1 mR
C22 0.1 uF
C23 0.1 uF
S-82A2A
CTL VM CO DO VDD VC VSS VINI
J8 BATT
Q1
Q2
3.3V Voltage Regulator
U2 TPS63060
3V3VREGIN
3V3VREGOUT
VIN VOUT EN PS/SYNC FB L1 L2 VAUX PG GND PGND
C11 10 uF
C12 10 uF
R4 680kR
R6 1 MR
R5 120kR
C14 10 pF
L2 1 uH
C13 0.1 uF
C15 10 uF
C16 10 uF
C17 10 uF
C18 10 uF
C19 10 uF
C20 10 uF
5V Voltage Regulator
U1 TPS63060
5VREGIN
5VREGOUT
C1 10 uF
C2 10 uF
R1 1.1 MR
R3 1 MR
R2 120 kR
C4 10 pF
L1 1 uH
C3 0.1 uF
C5 10 uF
C6 10 uF
C7 10 uF
C8 10 uF
C9 10 uF
C10 10 uF
Solar Charge Controller
SOLARSWITCHED
VIN
BAT+
SolarChargeController
5VREGIN
3V3VREGIN
Regulated Power
Diagnostics and monitoring of the regulated power buses
TP4
5VREGOUT
R28 260
D2 LED
I2C Address: 1000000
CurrentSensor1
TP5
3V3VREGOUT
R27 260
D1 LED
I2C Address: 1000001
CurrentSensor2
Mounting Holes
H1 MountingHole_Pad
H2 MountingHole_Pad
H3 MountingHole_Pad
H4 MountingHole_Pad
LUNATICs EPS Board (1/2)
Sheet: /
File: electronics-power-system.kicad_sch
Title:
Size: A4
Date:
Rev:
KiCad E.D.A. 9.0.1
Id: 1/8

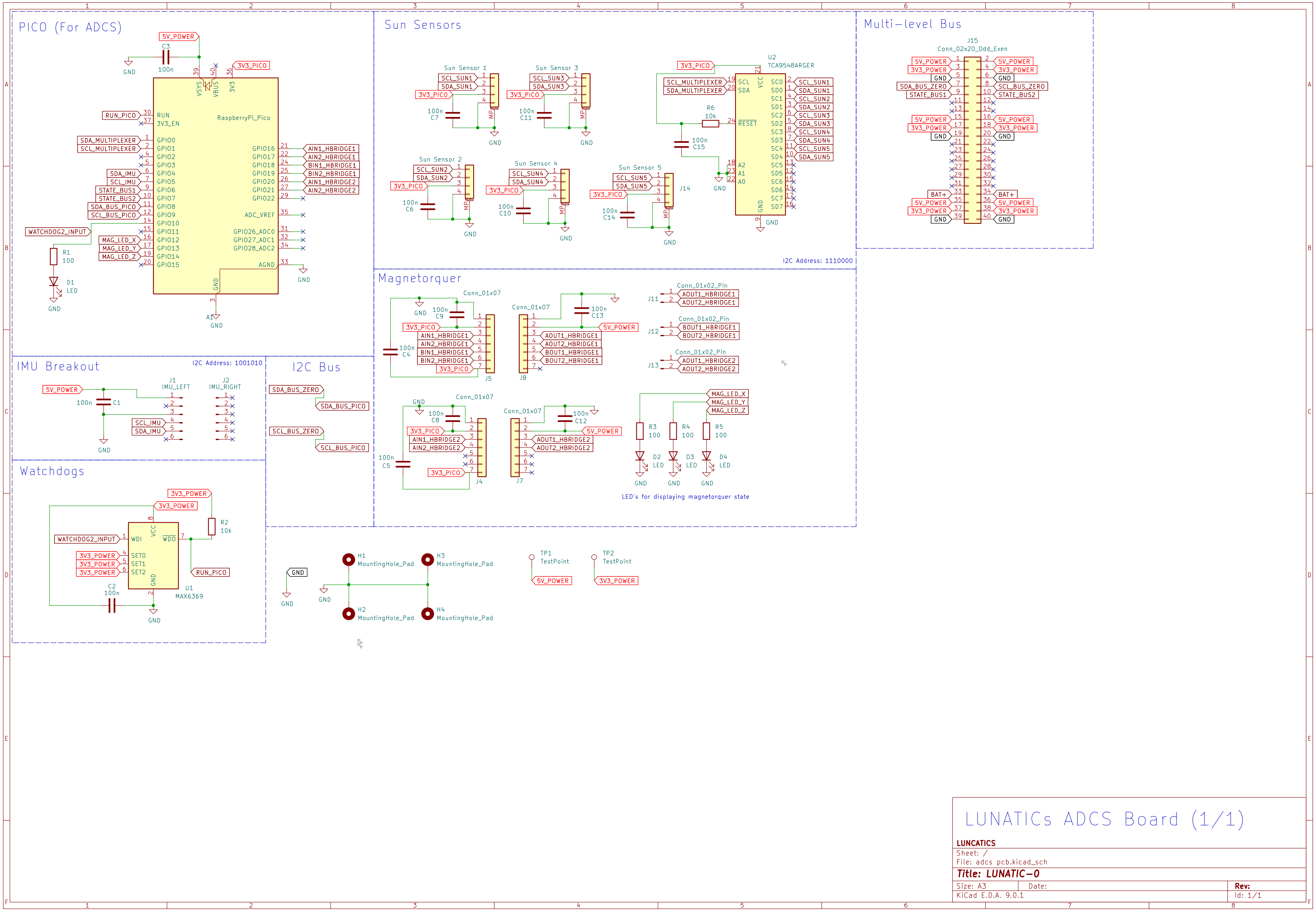


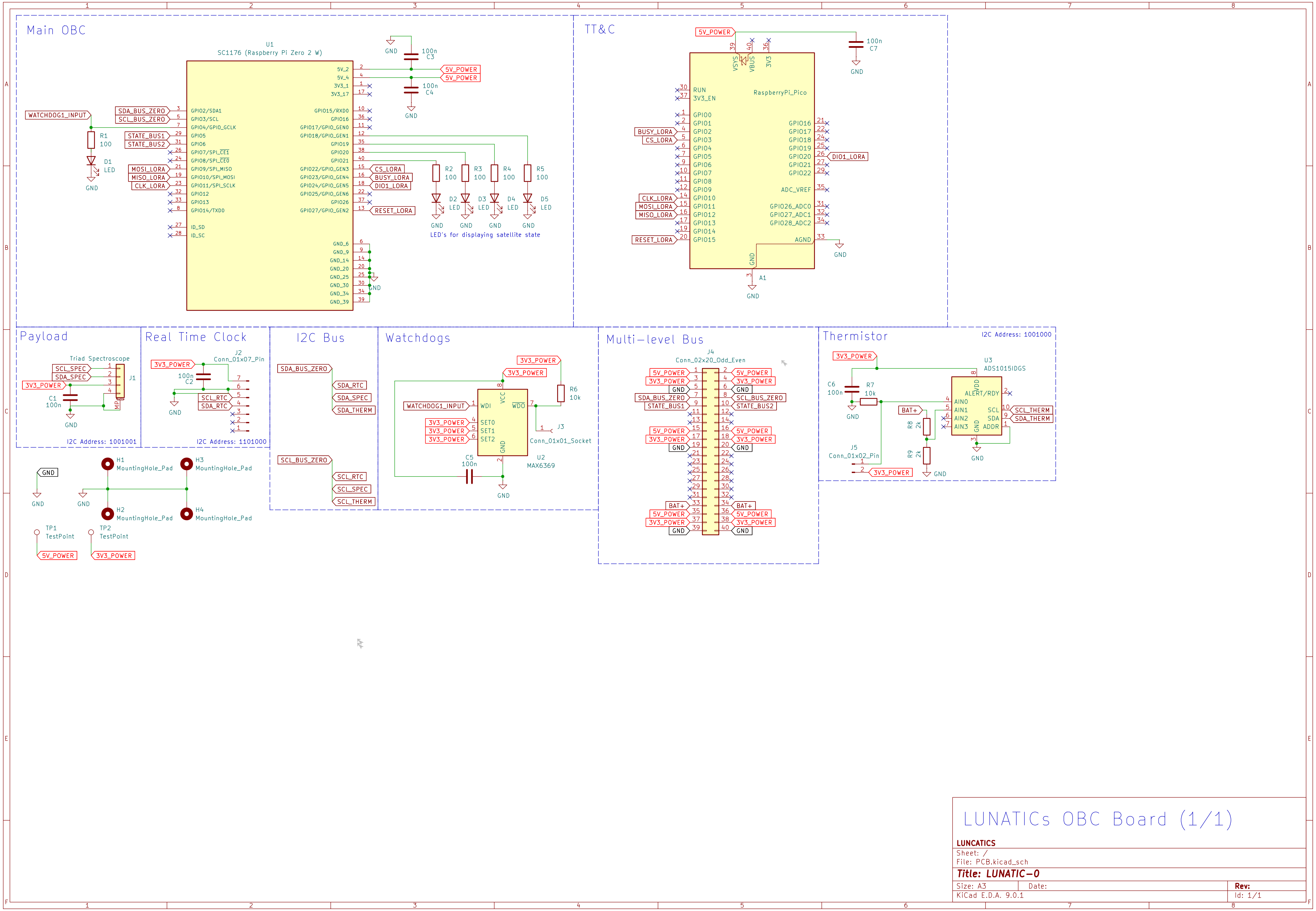
LUNATICs EPS Board (2/2)

Sheet: /SolarChargeController/
File: SolarChargeController.kicad_sch

Title:

Size: A4	Date:	**Rev:**
KiCad E.D.A. 9.0.1		Id: 5/8


PICO (For ADCS)
RaspberryPi_Pico
IMU Breakout
I2C Address: 1001010
I2C Bus
Watchdogs
MAX6369
Sun Sensors
TCA9548ARGER
I2C Address: 1110000
Magnetorquer
LED's for displaying magnetorquer state
Multi-level Bus
Conn_02x20_Odd_Even
MountingHole_Pad
TestPoint
LUNATICs ADCS Board (1/1)
LUNCATICS
Sheet: /
File: adcs pcb.kicad_sch
Title: LUNATIC-0
Size: A3
Date:
Rev:
KiCad E.D.A. 9.0.1
Id: 1/1


Main OBC
TT&C
LED's for displaying satellite state
Payload
Real Time Clock
I2C Bus
Watchdogs
Multi-level Bus
Thermistor
I2C Address: 1001001
I2C Address: 1101000
I2C Address: 1001000
LUNATICs OBC Board (1/1)
LUNCATICS
Sheet: /
File: PCB.kicad_sch
Title: LUNATIC-0
Size: A3
Date:
Rev:
KiCad E.D.A. 9.0.1
Id: 1/1