CUBESPACE

Interface Control Document

CubeADCS

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Revision History

Version	Author(s)	Date	Description
1.00	C.J. Groenewald, C. Leibbrandt	14/12/2022	First formal release
1.01	C. Leibbrandt	17/01/2023	Correcting minor errors
1.02	L. Hobson, C. Leibbrandt, J. Miller, F. Louw	14/05/2024	Correcting wheel pyramid mounting dimensions Changed title of reference document [2] from "ADCS HW config and options" to "Client Mission Overview" Added CW0017 details Added details for Backplane and DM variants Updated Table 9 with new options Changed max VBAT from 18 V to 17.6 V in Table 9 to account for CubeWheel VBAT range Updated detail for CubeADCS communication interfaces and backup power
1.03	F. Louw, N. Roets	26/03/2025	Common ICD changes implemented. Updated list of Reference Documents. Removed sections on sensors and actuators that are covered in the individual ICD documents for those products. Added additional VBAT pin option on PC104 pinout. Updated CubeConnect section for Backplane variant. Added warnings for externally supplied 3.3V levels for CubeMag deployments. Updated CoM and MoI info Removed detail from "Environmental Qualification" chapter, these details are contained in Reference Document [RD4] Minor updates, clarifications and removal of redundant info. Updated renders to Surtec.
1.04	F. Louw	13/08/2025	Added detail of V_{Bat} Bypass PCB option. Changed internal CubeTorquers in 3U-Stack from CR0003 to CR0004. Updated images of Backplane variant to the updated CubeConnect PCB. Added detail of maximum harness lengths and bending radii. Renamed Demo model to Development model.
1.05	N. Roets, M. du Plessis, F. Louw	20/02/2026	Reworded for clarity maximum harness lengths and warnings. Included reference to [RD16] Temperature Ranges and Limits.

Reference Documents

The following documents are referenced in this document.

[RD1]	CS-DEV.PD.CA-01	CubeADCS Product Description Ver.1.03 or later
[RD2]	CS-DEV.FOR.TPL-02	Client Mission Overview Ver.2.02 or later
[RD3]	CS-DEV.UM.CA-01	CubeADCS User Manual Ver.1.10 or later
[RD4]	CS-DEV.ETP.CA-01	General Environmental Test Plan Ver.1.05 or later
[RD5]	CS-DEV.ICD.CW-01	CubeWheel NanoSat Range ICD Ver.1.03 or later
[RD6]	CS-DEV.ICD.CW-02	CubeWheel SmallSat Range ICD Ver. C or later
[RD7]	CS-DEV.ICD.CR-01	CubeTorquer ICD Ver.1.01 or later
[RD8]	CS-DEV.ICD.CM-01	CubeMag ICD Ver.1.04 or later
[RD9]	CS-DEV.ICD.CS-M2.1E4.5	CubeSense Sun ICD Ver.1.02 or later
[RD10]	CS-DEV.ICD.CI-M2.1E1.3	CubeSense Earth ICD Ver.1.02 or later
[RD11]	CS-DEV.ICD.CT-M2.1E5.3	CubeStar ICD Ver.1.01 or later
[RD12]	CS-DEV.FRM.CA-01	CubeProduct Firmware Reference Manual Ver 7.02 or later
[RD13]	CS-DEV.MNL.CM.M2.1E4.2-02	CubeMag Gen 2 Deployment Priming Manual Ver.2.00 or later
[RD14]	CS-DEV.ICD.CG-M2.0E1.0	CubeAuriga ICD Ver.1.01 or later
[RD15]	CS-DEV.ICD.CNo-M2.0E1.3	CubeNode ICD Ver. 1.00 or later
[RD16]	CS-DEV.TN.CA-04	Thermal Ranges and Limits, Ver. 1.00 or later

List of Acronyms/Abbreviations

ADCS	Attitude Determination and Control System
ASGP4	Augmented Simplified General Perturbations 4
AWG	American Wire Gauge
CAN	Controller Area Network
COM	Center Of Mass
CSS	Coarse Sun Sensor
DM	Development Model
ECEF	Earth-Centered, Earth-Fixed coordinate system
EM	Engineering Model
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPS	Electronic Power Supply
FDIR	Fault Detection, Isolation, and Recovery
FM	Flight Model
GNSS	Global Navigation Satellite System
I^2C	Inter-Integrated Circuit
IMU	Inertial Measurement Unit
MCU	Microcontroller Unit
MOI	Moment Of Inertia
OBC	On-board Computer
PCB	Printed Circuit Board
PPS	1 Pulse Per Second
RTC	Real-Time Clock
SGP4	Simplified General Perturbations 4
SMPS	Switched Mode Power Supply
SPI	Serial Peripheral Interface
SRAM	Static Random-Access Memory
TLE	Two-Line Element
UART	Universal Asynchronous Receiver/Transmitter

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1. Introduction

The purpose of this document is to provide information on how to correctly interface with CubeADCS. This includes communications, power requirements, mechanical mounting and axes definitions, as well as guidelines on EMI/EMC compatibility. It is assumed that the reader is already familiar with the relevant product description document [RD1]. Details regarding environmental qualification, and a declared materials list, are available to clients upon request.

CubeSpace cannot guarantee nominal operation of CubeADCS if the specifications provided in this document are not adhered to.

Please see the respective ICD documentation of individual CubeSpace sensor and actuator products for important mounting and integration information.

CubeADCS itself is an assembly. This version of the ICD applies to the sub-products and hardware versions described in Table 1.

Table 1: Document Applicability

CubeProduct	Version	Notes
CubeDoor PC104	M0.0E1.3	--
CubeDoor Backplane	M0.0E3.1	--
CubeComputer	M2.2E5.4	This revision contains updated CoM and MoI information due to larger IMU
CubeConnect PC104	M0.0E1.1	--
CubeConnect Backplane	M0.0E3.0	--
Coarse Sun Sensors	M0.0E1.0	--
VBat Bypass (PC104, Top / Bottom Mount)	M0.0E1.0	--
VBat Bypass (PC104, Midstack Mount)	M0.0E1.0	--
VBat Bypass (Backplane)	M0.0E1.0	--

2. CubeADCS Variants

CubeSpace currently has four main variants of the CubeADCS as standard offerings. This document will reference some aspects like headers, which are different between these variants, and so they are briefly discussed below.

2.1 PC104 Variants

The first main variant is shown in Figure 1 and is suitable for integration in a PC104-type stack. In this case, all sensors and actuators are mounted external to the CubeADCS. This PC104 variant is suited to satellites larger than 6U, although this does not exclude it from being used in smaller satellites as well.

Figure 1: PC104 Variant of CubeADCS

CubeSpace also offers a PC104 variant where CubeWheels and CubeTorquers are mounted internal to a CubeADCS mechanical enclosure. These are called CubeADCS 3U and 6U Stacks.

A CubeADCS 3U Stack is shown in Figure 2 with the following reaction wheels and magnetorquer rods internal to the enclosure:

- Magnetorquer rods: 2x CR0004 (X- and Y-axis) and 1x CR0002 (Z-axis)
- Reaction wheels: 3x CW0017

See the individual ICD documents [RD5] and [RD7] for more information on these actuators.

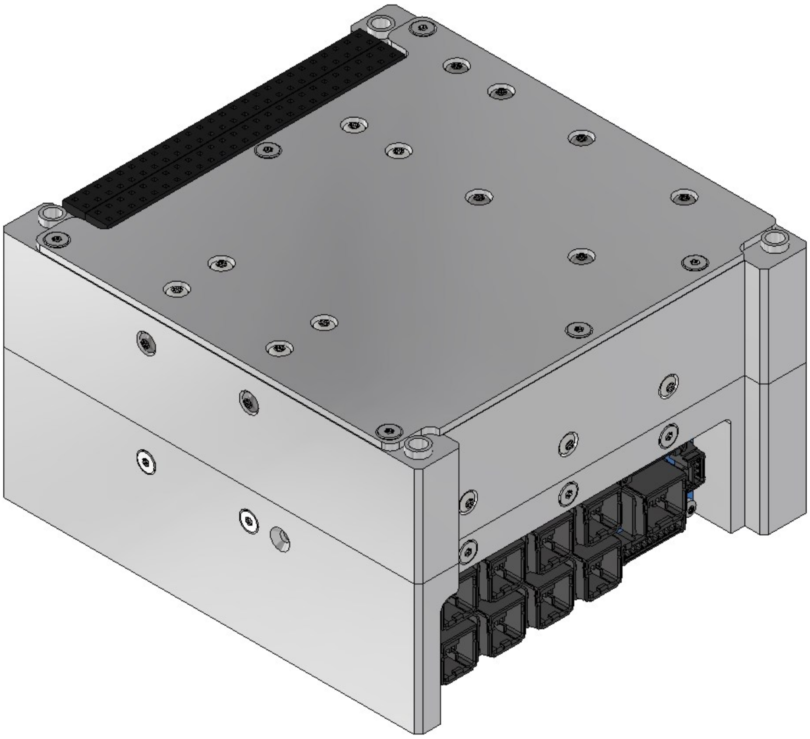

Figure 2: PC104 Variant of CubeADCS for 3U and Smaller Satellites

A CubeADCS 6U Stack is shown in Figure 3 with the following reaction wheels and magnetorquer rods internal to the enclosure:

- Magnetorquer rods: 3x CR0004
- Reaction wheels: 3x CW0057

See the individual ICD documents [RD5] and [RD7] for more information on these actuators.

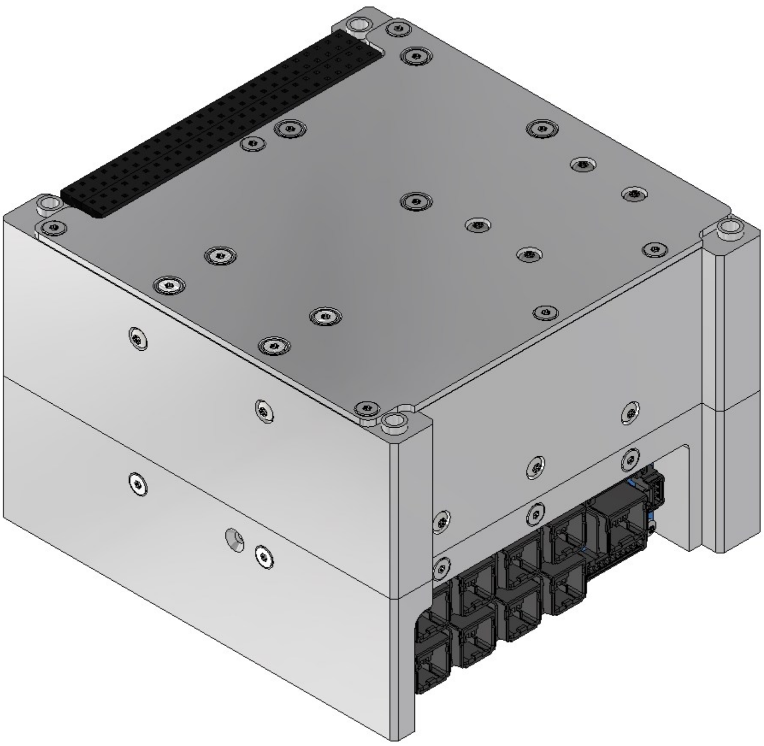

Figure 3: PC104 Variant of CubeADCS for 3U to 6U Satellites

2.2 Backplane Variant

The second main variant is shown in Figure 4 and is suitable if a different form factor is required. This Backplane variant does not have internal actuators, like the PC104 variants that are shown in Figure 2 and Figure 3. The remaining differences between the PC104 and Backplane variants are purely of a mechanical nature.

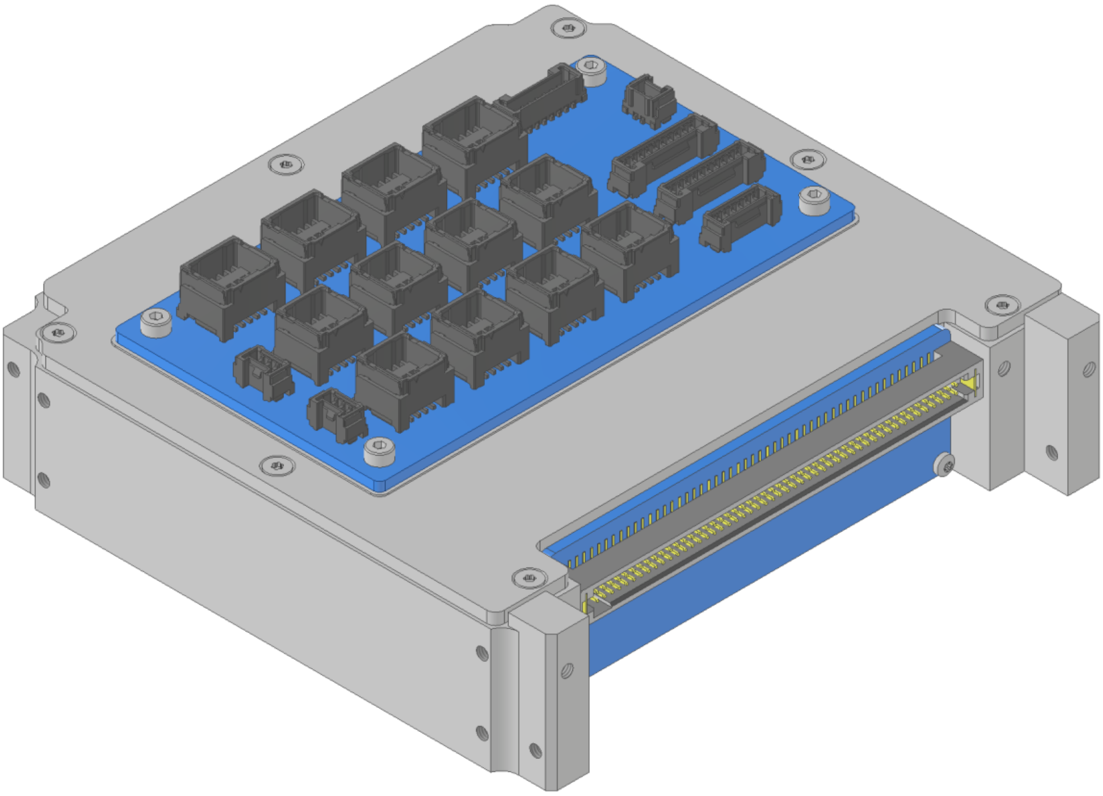

Figure 4: Backplane Variant of CubeADCS Core

2.3 Development Model

The third variant is similar to the PC104 variant shown in Figure 1. However, it does not include a functional CubeConnect (discussed in Section 3.9) for plugging in any sensors or actuators, nor does it include the high-accuracy IMU usually included with other engineering and flight models. It still includes the secondary (redundant) IMU sensor, so it is still able to measure rotation around all three of the X, Y, and Z axis.

These cost-saving measures still allows prospective clients to start developing the software interface between the OBC and CubeADCS and is otherwise ideally suited for evaluating most functions of the CubeADCS. This variant is shown in Figure 5. Note the absence of connectors on the CubeConnect board.

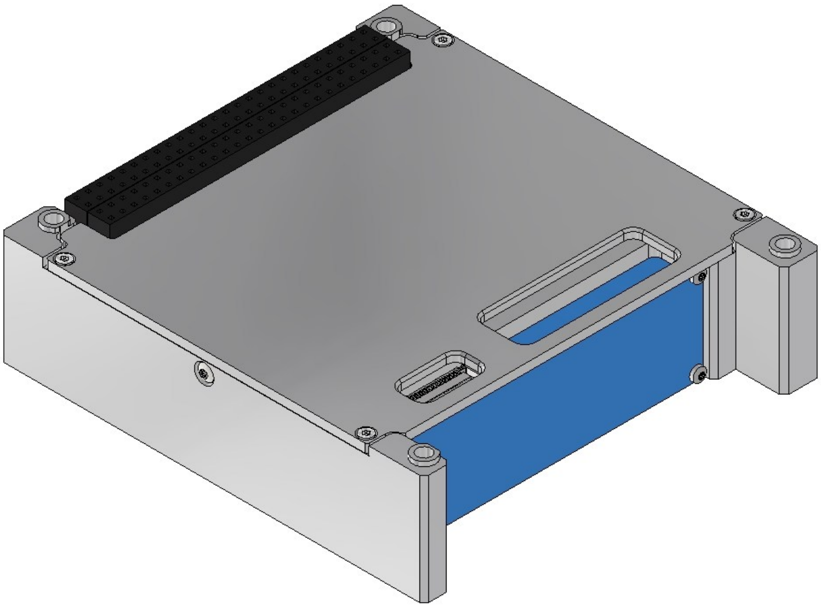

Figure 5: Development Model (DM) Variant of CubeADCS Core

2.4 Summary of CubeADCS Variants

Table 2: Summary of CubeADCS Variants

Variant	Satellite Size	Internal CubeTorquers	Internal CubeWheels	Main IMU	CubeDoor	CubeConnect
PC104	Any	None	None	Fitted	PC104	Fully functional
PC104, 3U-stack	3U and smaller	2x CR0004 (X- and Y-Axis) 1x CR0002 (Z-Axis)	3x CW0017	Fitted	PC104	Fully functional
PC104, 6U-stack	3U – 6U and smaller	3x CR0004	3x CW0057	Fitted	PC104	Fully functional
Backplane	Any	None	None	Fitted	Customized Backplane or harness	Fully functional
Development Model (DM)	None: Only for development and HIL simulations	None	None	Not fitted	PC104	Non-functional: No connectors populated.

2.5 V_{Bat} Bypass CubeDoor PCB

The standard CubeADCS Core is designed to internally route power to CubeSpace reaction wheels up to and including CW0167. For larger reaction wheels, i.e. CW0500 and upwards, a “V_{Bat} Bypass” version of the CubeDoor interface PCB is used to route V_{Bat} and GND connections around the CubeADCS Core, directly to the wheels. In this case each reaction wheel harness has two connections to CubeADCS Core: one for high-power V_{Bat} and GND to the motor (Section 3.9.8), the other services all other logic and control signals as usual.

This section presents the different V_{Bat} Bypass CubeDoor options available to suite different mounting configurations of CubeADCS Core. The V_{Bat} Bypass CubeDoor is not applicable to CubeADCS Development models or integrated 3U- and 6U-stacks.

Dimensions for each configuration can be found in Section 9, and 3D CAD files are available from CubeSpace.

2.5.1 V_{Bat} Bypass CubeDoor PCB for CubeADCS Core, PC104

For the case where the CubeADCS Core is mounted at the top of the PC104 stack, the V_{Bat} Bypass Top-Mount variant is recommended: the reaction wheel power harnesses are routed over the top of the CubeADCS Core and do not interfere with the rest of the PC104 stack below the CubeADCS Core. This option makes further plugging into the PC104 stack from the top impossible.

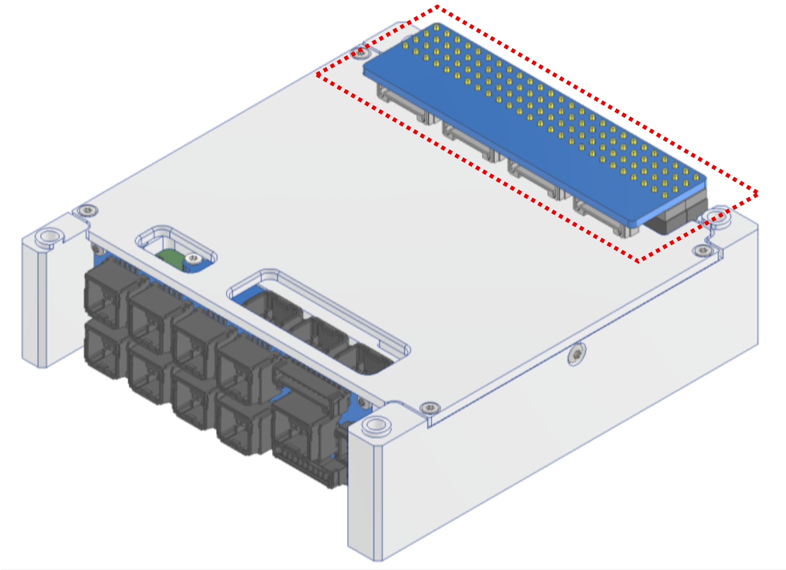

Figure 6: V_{Bat} Bypass Top-Mount variant for CubeADCS Core PC104

For the case where the CubeADCS Core is mounted at the bottom of the PC104 stack, the V_{Bat} Bypass Bottom-Mount variant is recommended: the reaction wheel power harnesses are routed under the bottom of the CubeADCS Core. This option makes further plugging into the PC104 stack from the bottom impossible.

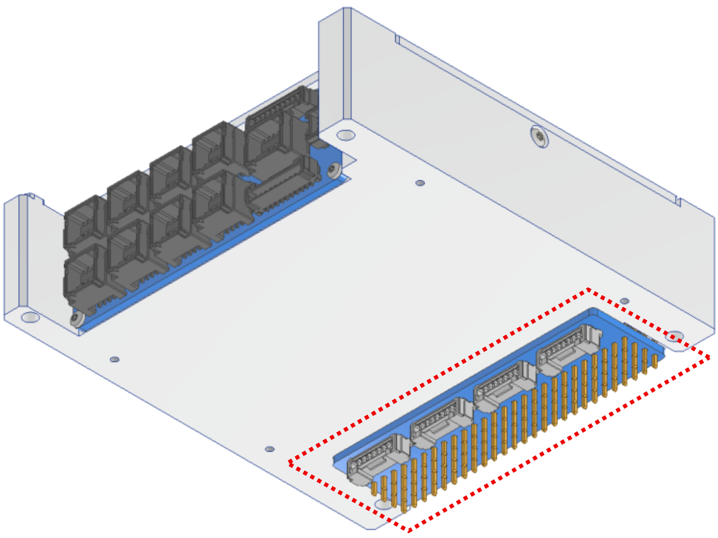

Figure 7: V_{Bat} Bypass Bottom-Mount variant for CubeADCS Core PC104

Alternatively, for other PC104 stack cases, a V_{Bat} Bypass Midstack-Mount variant may be used, with either upward-facing headers (Figure 8) or downward-facing headers (Figure 9). The reaction wheel power harnesses may now be routed around, under or over the CubeADCS Core. In this case, all PC104 pins are still accessible from both the top and bottom.

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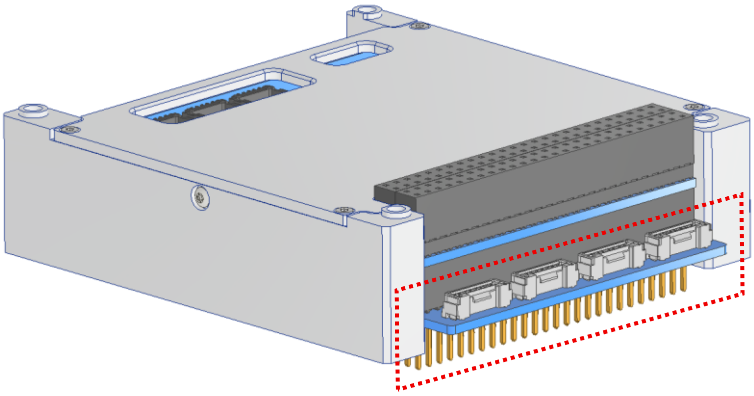

Figure 8: V_{Bat} Bypass Midstack-Mount variant (upward-facing headers) for CubeADCS Core PC104

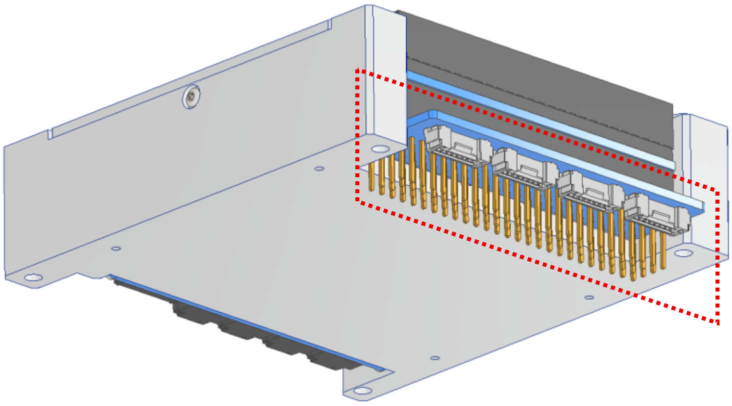

Figure 9: V_{Bat} Bypass Midstack-Mount variant (downward-facing headers) for CubeADCS Core PC104

2.5.2 V_{Bat} Bypass CubeDoor PCB for CubeADCS Core Backplane Variant

The Backplane variant of CubeADCS Core is not stackable like the PC104 variants. Therefore, the CubeDoor V_{Bat} Bypass option only has a single configuration, shown in Figure 10, below. All headers are still on the same face of CubeADCS Core in this configuration.

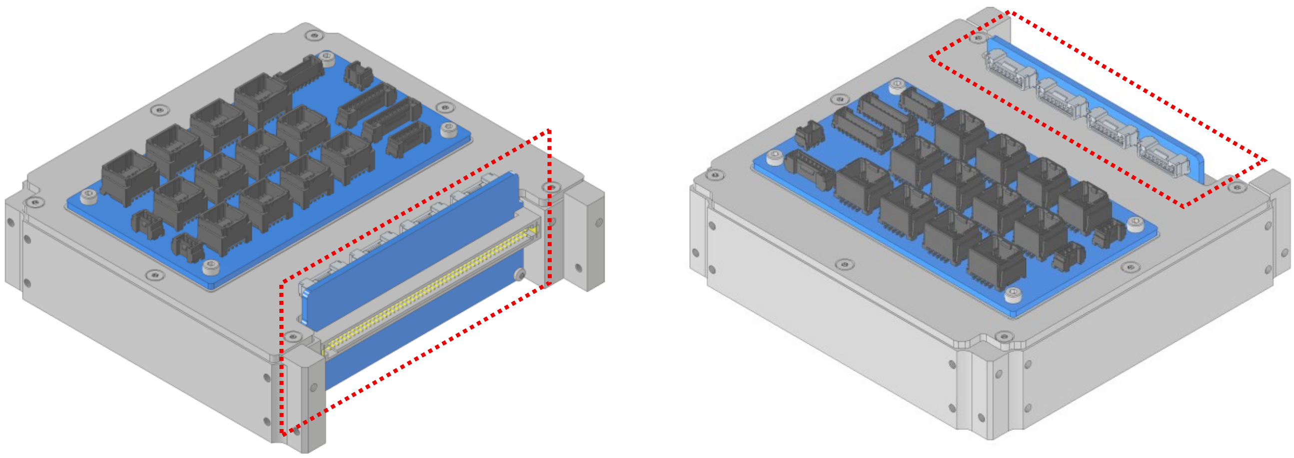

Figure 10: Two perspectives of the V_{Bat} Bypass option for CubeADCS Core Backplane

3. Electrical Interface

3.1 Communication Interfaces

3.1.1 CAN Characteristics

Table 3: CAN Bus Characteristics

Parameter	Value
Supported CAN Standard	V2.0B
Supported Bit Rate	1 Mbit/s
Supported Protocols	CubeSpace CAN Protocol, CubeSat Space Protocol (CSP)
Default CAN Address	4 (configurable)
CAN Termination	120 Ω (optional)

3.1.2 UART and RS422/RS485 Characteristics

Table 4: UART and RS422/RS485 Characteristics

Parameter	Value
Maximum Supported Baud Rate	921600 (configurable)
Data Bits	8
Parity	None
Stop Bits	1
Default RS485 Address	1 (optional and configurable)
RS485 / RS422 Termination	120 Ω (optional)

3.1.3 I²C Characteristics

Table 5: I²C Characteristics

Parameter	Value
Baud Rate	100 kHz
Clock Stretching	Required
Default I²C Address	0x53 (configurable)
I²C Pull-Up Resistors	3 kΩ (optional)
I²C Bus Voltage Level	3.3 V (default), 5 V, or externally supplied (optional)

Any combination of the communication interfaces can be used simultaneously, but RS422 and RS485 are mutually exclusive. If RS485 is selected in [RD2], RS422 will not be available for use. It is recommended that at least CAN and UART is connected from the OBC to CubeADCS.

3.2 GNSS

Most satellite missions that require accurate pointing capabilities, will require exact positional data at regular intervals. A GNSS module (not supplied by CubeSpace) provides this functionality, with time synchronization made possible with the PPS output of the GNSS (discussed in Section 3.3). Note that some missions might not require that GNSS is included in the satellite, and the specific options need to be specified in [RD2].

3.2.1 GNSS data transmission over telecommand

This is the default case and gives the most freedom to the client over which specific GNSS model is used. In this case, the data output of GNSS module is not directly connected to the CubeADCS, but only to the client OBC. The client procures, owns, powers, and configures the GNSS, and CubeADCS's associated GNSS pins can be left unconnected. The GNSS data is transmitted from the OBC to CubeADCS over telecommand on any communication interface discussed in Section 3.1, on the condition that it conforms to the required data structure containing the ECEF position and velocity vectors, and happens once per second, at a latency of less than 100 milliseconds from being output by the GNSS module.

3.2.2 Legacy option: Direct connection between GNSS module and CubeADCS

A second option is to have the GNSS's data output directly connected to CubeADCS's OBC interface. This option was used in previous missions but is a complicated solution and has been deprecated in favour of the preferred solution discussed in Section 3.2.1. **The direct CubeADCS-GNSS connection is no longer maintained and is not recommended for use.** Please contact CubeSpace if this option is required for a mission.

With this legacy option, a direct connection potentially lightens the computational load on the client OBC since periodic transmissions of the GNSS data over telecommand is not required. The OBC can still obtain the GNSS data from CubeADCS via a telemetry request. Only certain GNSS modules and protocols are supported (see "GNSS interface health check" in [RD3]). The client is required to procure, own, power, and configure the GNSS module.

Note that CubeADCS's GNSS interface will always be in receive mode and never transmit any data to the GNSS module. The data interface from the GNSS module to CubeADCS can be over either UART or RS485 (also see Section 3.4).

- With UART, only the RX line (CubeADCS input) is connected to the GNSS data output line, the TX line (CubeADCS output) is left unconnected.
- With RS485, the CubeADCS's GNSS interface is always in receive mode.

3.3 PPS

Accurate time synchronization with the GNSS data is performed by means of the PPS output of the GNSS module. This signal is normally supplied on one of the pins of the CubeADCS-OBC interface as a single-ended CMOS level signal, or a differentially signalled pin pair with RS485 or LVDS signal levels. CubeADCS is configured to buffer and propagate the PPS signal to other sensors or actuators that require it, such as third-party star trackers, on the PPS output pins as discussed in Section 3.9.6. There is not a strict requirement on the client to provide the PPS signal as differentially signalled, although this is supported by CubeADCS.

3.4 Buffering and Passive Component Values

The communication interfaces of CubeADCS are buffered for signal conditioning and protection purposes. To assist the client in verifying hardware interfacing, additional details are given in the table below.

Table 6: Communication Interfaces Buffering and Filtering Characteristics

Interface	Transceiver / Buffer	Filtering / Passive Components
CAN	SN65HVD233-EP	Optional 120 Ω termination Minimal RC and common-mode current filtering
UART	SN74LVC2G17MDCKREP	Minimal RC filtering (15 Ω, 1 nF) on TX and RX lines 100 kΩ pull-up to 3.3V on RX (CubeADCS input) line
RS422 (dual differential pair, full duplex capable)	SN65HVD33MDREP	Optional 120 Ω termination on each pair
RS485 (single differential pair, half duplex)	SN65HVD33MDREP, A/B and Y/Z pins passively connected	Optional 120 Ω termination
I^2C	PCA9512ADP,118	Optional 3 kΩ pull-ups to 3.3V on SDA and SCL lines
GNSS (Legacy option; UART) RX (CubeADCS input) line only, TX line not connected	SN74LVC2G17MDCKREP	Minimal RC filtering (15 Ω, 1 nF) and 100 kΩ pull-up to 3.3V
GNSS (Legacy option; RS485)	SN55HVD75DRBREP	Optional 120 Ω termination
PPS (differential input option)	SN65HVD33MDREP	Optional 120 Ω termination
PPS (single-ended input option)	SN74LVC1G17MDCKREP	None

For resistors in Table 6 which are specified as optional, clients can select (in [RD2]) to have these items removed to ensure good interoperability between OBC and CubeADCS. The specific values of these passive components are generally not selectable by clients.

3.4.1 Legacy PPS Input Buffer IC

An earlier revision of CubeADCS used the Texas Instruments SN65LVDM179D for the differential PPS input buffer. This hardware revision has been phased out due to incompatibility with RS485 signal levels.

3.5 Boot Line

CubeADCS implements a boot line for accessing the MCU's low-level ROM bootloader. The boot line must be driven or pulled high by the client OBC prior to power-on, to access the ROM bootloader. It is used by CubeSpace to initially flash the CubeSpace software bootloader to the MCU, thereafter the software bootloader is used for uploading flight software. The software bootloader that runs on the CubeComputer inside CubeADCS can update itself as well. However, it is recommended to connect the Boot line from the OBC to CubeADCS, along with the UART interface, as a recovery method. More detail is given in the Bootloader section in [RD3].

It is strongly advised to connect the Boot line, and UART interface, from the OBC to CubeADCS.

3.6 Internal CAN Interface

A second CAN interface exist on CubeADCS, used to communicate to sensor and actuator products connected to the CubeConnect board (discussed in Section 3.9). This second CAN interface is thus internal to the CubeADCS/Sensor/Actuator ecosystem and is not meant to be used by clients. However, it can still be exposed to the client OBC, as shown in Table 9 and Table 11, where it is referred to as CAN1. This can assist in running diagnosis procedures, or as an alternative way to program the CubeSpace Software Bootloader when UART is not available. It is however not a strict requirement to expose this internal CAN interface to the OBC.

Although clients can select to remove the 120 Ω termination resistor on the CAN interface to the OBC, removal of the second (internal) CAN interface termination is not left as a configurable option to clients, since it has been selected to provide good interoperability within the CubeADCS/Sensor/Actuator ecosystem. Note that the termination of the internal CAN interface is 120 Ω on CubeADCS, and 2 kΩ on CubeSpace Sensor and Actuators products, with the intention of not overloading the differential lines of the internal CAN bus with too many 120 Ω -terminated devices, the number of which is not known in advance for each client order.

3.7 Power Interface

3.7.1 Power Supply

CubeADCS has three internal power domains: 5V, 3.3V, and V_{Bat}. Clients can select in [RD2] between three different configurations, discussed below.

The first option is to only supply satellite- or EPS battery voltage to CubeADCS. In this case, CubeADCS makes use of switched mode power supplies (SMPS) to regulate its internal 5V and 3.3V power domains (while passing through the battery voltage to the CubeWheel actuators if they are present in the system). This is shown in Figure 11.

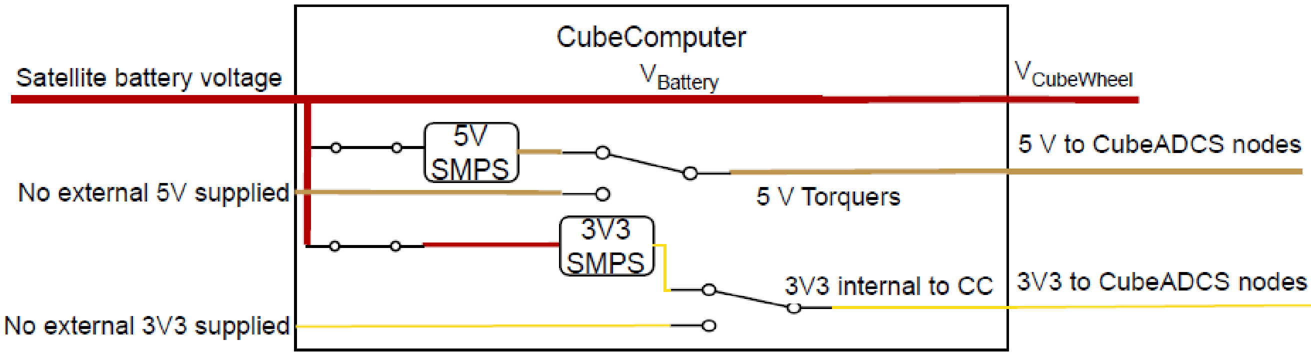

Figure 11: CubeADCS Internal Voltage Regulation from Battery Input

Note that this (Figure 11) is the preferred choice for supplying power, as the current draw through the CubeADCS is the lowest in this case, also resulting in the fewest losses. The 5V and 3.3V regulators are fully qualified for spaceflight.

The second option is to supply all voltage domains with the appropriate regulated voltage from the satellite EPS. This will require more connections than the first option. This option will also disconnect and isolate the switched mode power supply circuit from the CubeADCS. This is shown in Figure 12.

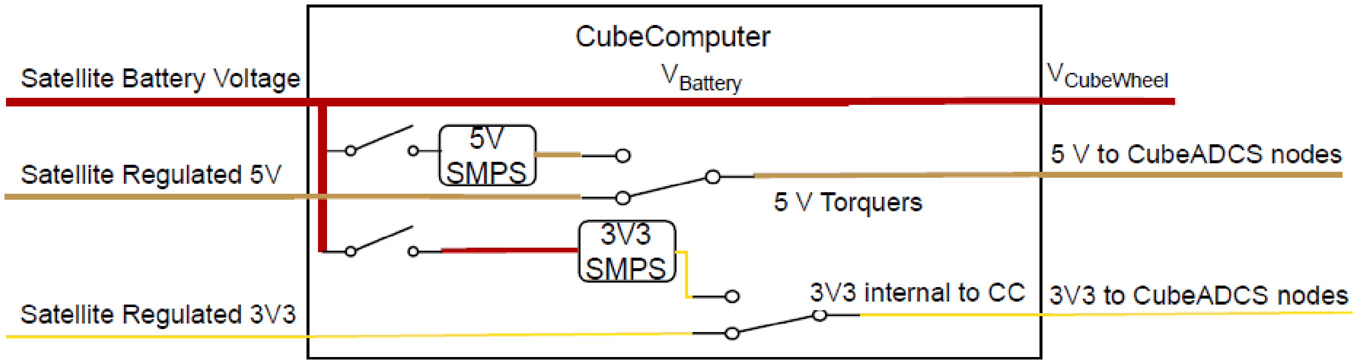

Figure 12: CubeADCS External Regulation from EPS Input

A third option is to supply battery voltage and regulated 3.3V only. This might be an attractive option to the user which can control the 3.3V line from the EPS. This will allow the user to power down CubeADCS by turning off the 3.3V rail from the EPS. This is shown in Figure 13. Note an Enable line is also available to perform this task (see Section 3.7.2)

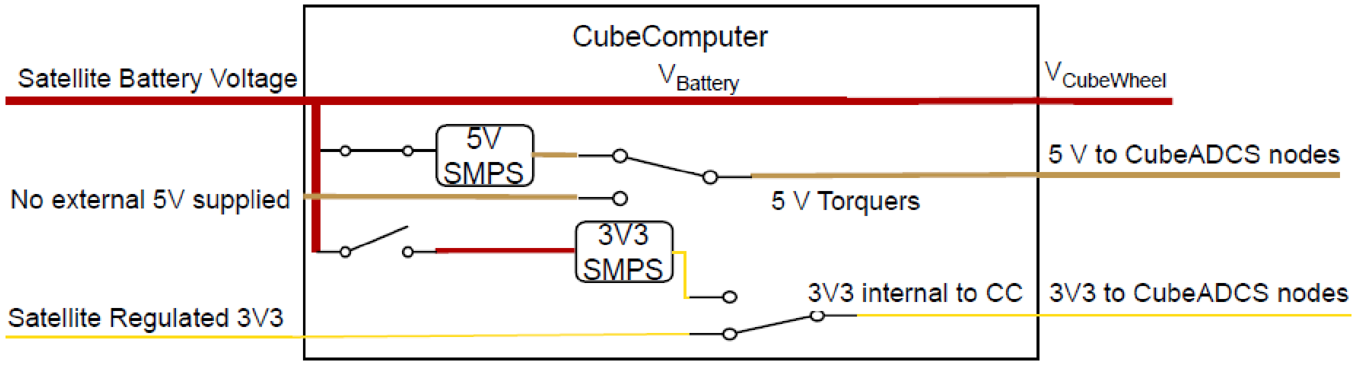

Figure 13: CubeADCS Battery Voltage and Regulated 3V3 Input

See notes under Table 9 and Table 11. CubeWheels CW0017, CW0057, and CW0162, and thus the associated RWL pyramids, and CubeADCS variants for 3U- (Figure 2) and 6U- satellites (Figure 3), are not tolerant of V_{Bat} voltages above 17.6 V. CubeWheels CW0500 and CW1200 will shut down at V_{Bat} voltages above 24.0V. Otherwise, the battery voltage can be as high as 36.0V. Refer to [RD5] and [RD6] to ensure the maximum V_{Bat} specifications for different CubeWheel variants are adhered to.

If the 3.3V voltage rail is supplied externally, it is important to not supply a voltage lower than 3.30V, which would be too low to deploy a CubeMag Deployable. It is strongly advised that the client perform deployment tests of a CubeMag Deployable plugged into the CubeADCS, with power supplied as eventually intended. CubeMag repriming kits are included in every shipment that contains a CubeMag Deployable, with repriming instructions discussed in [RD13]. CubeMag Deployable has a deployment current of roughly 0.9 A for about 2 seconds, drawn from the 3.3 V rail. The deployment circuitry has a trip current set to 1.7 A.

CubeADCS's 5 V rail is mainly used for driving Magnetorquers such as CubeTorquers. Certain third-party products could also be supplied from the 5 V rail.

Typical power consumption characteristics of CubeADCS's 3.3 V domain itself, whether supplied externally or regulated on-board, is given in the following table.

Table 7: Power Consumption on 3.3 V Line

Parameter	Value	Notes
Average current	67 mA	Default (single-ended) PPS output Main and Redundant IMUs powered on.
Average power	220 mW	
Max current	85 mA	Differential PPS output with 120 Ω termination Main and Redundant IMUs powered on.
Max power	281 mW	
Inrush current	190 mA	
Inrush current duration	1.6 s	

The orbit average power consumption of the complete ADCS system will depend on the sensor and actuator suite used, as well as the manoeuvres performed by the satellite and the satellite's size. The power consumption of the reaction wheels and magnetorquers will greatly depend on the following factors (amongst others):

- Satellite size
- Wheel configuration
- ADCS mode
- Pointing performed during orbit

Also refer to the relevant ICD documentation for power consumption of different sensor and actuator products. Total expected system power consumption can be estimated and provided with an ADCS mission simulation report.

Individual connected sensor or actuator products can be powered on and off by way of telecommands from the client OBC to CubeADCS. When powering on connected devices, CubeADCS implements a staggered power on strategy, allowing inrush current as experienced by the satellite EPS to be minimised / staggered over time.

3.7.2 Enable Line

CubeADCS implements an externally controlled enable line to power on the device's 3.3 V power switch (discussed in Section 3.7.3), as well as the 3.3 V and 5 V SMPS regulators if used. The enable line is active-high and should be controlled by the client OBC.

The enable line is internally pulled high to V_{Bat} with a 100 kΩ resistor. For some mission configurations, V_{Bat} might not directly be connected to the CubeADCS, in such a case it is implied that 5V will be supplied, and the enable line will then instead be pulled high to 5V with the 100 kΩ resistor. Due to the internal pull-up resistor, CubeADCS is powered on by default, and the enable line can thus be configured in [RD2] to be an unconnected input. If the enable line is externally pulled low or driven to GND, CubeADCS, and thus all connected sensor and actuator products, will be powered down.

3.7.3 3.3 V Power Switch

CubeADCS implements an input power switch that is enabled by pulling or driving the enable line high. The power switch also provides a current limit to protect against severe latch-up events. The trip current is set to 3 Ampere of total current consumption on the 3.3 V supply for the entire ADCS system (CubeADCS and all connected sensor and actuator products). Under- and overvoltage protection is also implemented, with a range of 2.5 V – 4.0 V depending on thermal conditions.

If the 3.3 V power switch turned off due to an over- or undervoltage or overcurrent condition, it can only be reenabled by toggling of the CubeADCS Enable line to low and high again, or otherwise power cycling the entire 3V3 rail, whether supplied externally or regulated internally from V_{Bat}.

3.7.4 CubeComputer RTC and Backup Power

The CubeADCS makes use of an onboard real-time clock (RTC) for its event log functionality. The RTC requires power to be supplied on the internal V_{Backup} rail. By default, this V_{Backup} rail is supplied from the CubeADCS's 5 V rail. This is the most simplistic option, and the V_{Backup} pin on the CubeADCS-OBC interface can be left unconnected in this case. CubeADCS stores a bit of backup power in a bank of ceramic capacitors to run the RTC during short interruptions in power.

A client can also select in [RD2] to supply the V_{Backup} rail externally. The main advantage of this option is that the RTC can be kept running when everything else is switched off for longer periods, meaning that all logs will have correct timestamps immediately after power-on, which might be a valuable feature (for example when filtering logs by timestamp). The V_{Backup} rail also powers the MCU's backup registers, which hold information about the most recent error codes, if any. This is foreseen to only be of high importance if an issue develops which results in endless boot loops.

The RTC needs to be set by a telecommand from the OBC after power-on, otherwise the log timestamps will be inaccurate. Otherwise, if a GNSS module is directly connected to the GNSS UART or GNSS RS485 input (see Section 3.2.2), CubeADCS will automatically be updated with the latest UTC information as it gets transmitted by the GNSS.

If supplied externally, the V_{Backup} pin draws approximately 1.0 mA – 1.5 mA over the entire 17.6 V range.

3.7.5 Client OBC Power Protection Requirements

Power protection on CubeADCS is included as deemed necessary. CubeADCS implements voltage and current monitoring of the different voltage domains and subsystems. To allow for wide operating conditions, further hardware protection circuitry limits are left wide on purpose, with the client EPS/OBC ultimately being responsible for voltage and current protection if required.

Note that there is no protection against overvoltage on the externally supplied V_{Bat} and 5 V input lines. A voltage input above 38 V on the V_{Bat} line will cause damage to CubeADCS, and potentially to other products lower in the connection chain as well. Also note that certain CubeWheel products are **not tolerant of V_{Bat} voltages above 17.6 V**, including those used in CubeADCS variants for 3U- and 6U-satellites. Some other CubeWheel variants will shut down at battery voltages above 24.0 V. See [RD5] and [RD6] for correct maximum input voltage specifications for different reaction wheel variants.

CubeADCS contains sensitive circuitry that requires the following to be adhered to if power is supplied externally:

- If the 3.3 V power is supplied externally, do not supply lower than **3.30 V** or higher than **3.45 V**.
- If the 5 V power is supplied externally, do not supply a voltage higher than **5.25 V**.

3.7.6 Power and Signal Ground

CubeADCS does not have separate power and signal ground, all circuits share the same ground.

3.8 Header Pinout and Electrical Characteristics: CubeDoor

The main interface header from the client OBC and EPS to CubeADCS, is referred to as CubeDoor.

3.8.1 PC104 and Development Model Variants

For these CubeADCS offerings, the CubeDoor is implemented in a PC104 header format and indicated in Figure 14, with some pin numbers also shown.

Devices can be mated to and from both the bottom and top of the CubeADCS core as required, header details are given in Table 8. The CubeDoor for the PC104 3U- and 6U-variants are slightly taller but are otherwise equivalent.

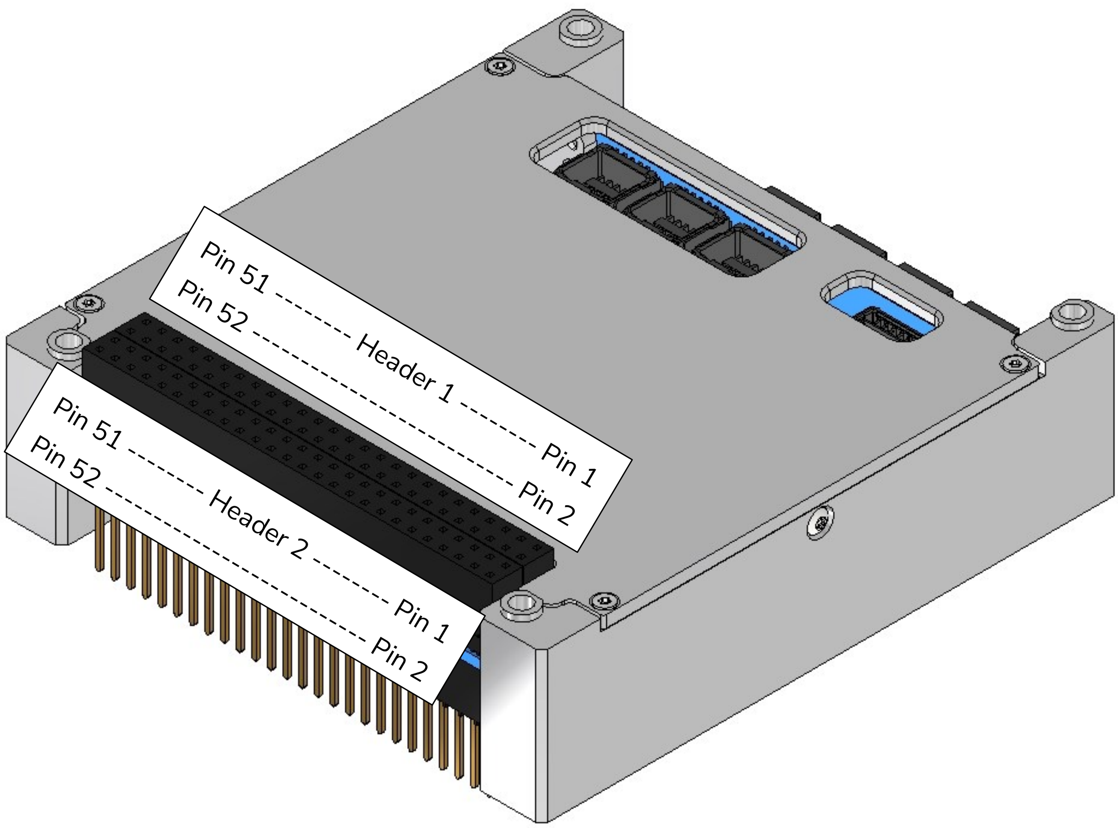

Figure 14: CubeADCS Core, PC104 Variant, Showing CubeDoor Header

Table 9 shows the pin-out of the PC104 interface to the CubeADCS. Default pin numbers are shown but are finalised by clients as required in [RD2].

Table 8: PC104 Header Details

Part	Description	Part Number
Top Header Mating	Samtec	ESQ-126-13-G-D
Bottom Header Mating	Samtec	SSQ-126-03-G-D

Table 9: PC104 Header Pinout and Electrical Characteristics

Pin Options	Default Pin	Pin Name	Pin Description	IO Type	Voltage Range [V]
H1: 1	H1-1	CAN 2 L	CubeADCS-OBC CAN Bus Low	Bidirectional	0 to 3.4
H1: 3	H1-3	CAN 2 H	CubeADCS-OBC CAN Bus High	Bidirectional	0 to 3.4
H1: 2, 5	NC	CAN 1 L	Sensor/Actuator Nodes CAN Bus Low	Bidirectional	0 to 3.4
H1: 4, 7	NC	CAN 1 H	Sensor/Actuator Nodes CAN Bus High	Bidirectional	0 to 3.4
H1: 41	H1-41	I2C_SDA	I^2C Data	Bidirectional	0 to 3.4
H1: 43	H1-43	I2C_SCL	I^2C Clock	Input	0 to 3.4
H1: 17, 18, 19, 20 H2: 21, 22	H1-20	UART_1_RX	UART data receive line	Input	0 to 3.4
	H1-19	UART_1_TX	UART data transmit line	Output	0 to 3.4
H1: 33, 35, 39, 40	H1-39	Legacy GNSS Data Interface: UART or RS485	UART data receive line (default), or RS485 B (bidirectional)	Input	0 to 3.4
	NC		UART data transmit line (default, NC), or RS485 A (bidirectional)	Output	0 to 3.4
H1: 9, 11, 13, 15	H1-9	RS422 (Cannot be used along with RS485)	RS422 data receive line high	Input	0 to 3.4
	H1-11		RS422 data receive line low	Input	0 to 3.4
	H1-13		RS422 data transmit line high	Output	0 to 3.4
	H1-15		RS422 data transmit line low	Output	0 to 3.4
	NC	RS485 (Cannot be used with RS422)	RS485 A	Bidirectional	0 to 3.4
	NC		RS485 B	Bidirectional	0 to 3.4
H1: 8, 10	NC	PPS (Differential option)	PPS input line high	Input	0 to 3.4
	NC		PPS input line low	Input	0 to 3.4
H1: 2, 8, 10, 14, 16	14	PPS (CMOS option)	PPS input line (single-ended)	Input	0 to 3.4
H2: 19, 20	H2-20	Boot	Toggle ROM bootloader on startup	Input	0 to 3.4
H2: 12, 17, 18	H2-18	Enable	Toggle power on	Input	0 to 17.6
H2: 29, 30, 32	Always connected	GND	Power and signal ground	Power	0
H2: 45 and 46, and/or H2: 48	H2-45, H2-46	V_{Bat}	Battery supply voltage input	Power	8 to 17.6 ***see note**
H1: 47, 49, 51 H2: 25, 26	H2-25, H2-26	5V	5V supply voltage input	Power	5 to 5.25
H1: 48, 50, 52 H2: 27, 28	H2-27, H2-28	3V3	3V3 supply voltage input	Power	3.3 to 3.4
H2: 41	NC	I2C_Bus_Ext	Custom I^2C bus voltage input	Power	2.7 to 5.0
H2: 42	NC	VBackup	RTC and Backup registers supply voltage input	Power	3.2 to 17.6

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See all warnings and notes in Sections 3.7.1 and 3.7.5 to ensure minimum and maximum voltage levels are adhered to. Systems making use of CubeWheels connected to CubeADCS, have certain maximum V_{Bat} voltage levels that must not be exceeded.

Pin H1-2 can be set up to be a single-ended PPS input pin, or a CAN1 communication pin, but not both. It can also be left unconnected. As discussed in Section 3.6, CAN1 is the internal interface used for communication between CubeADCS and the connected sensors and actuators and is not strictly required to be connected on the CubeDoor.

3.8.2 Backplane Variant

For this variant of CubeADCS, the CubeDoor is implemented with the connector in Table 10 that is suitable for plugging into a satellite backplane or connecting over a harness. This is indicated in Figure 15, with some pin numbers also shown.

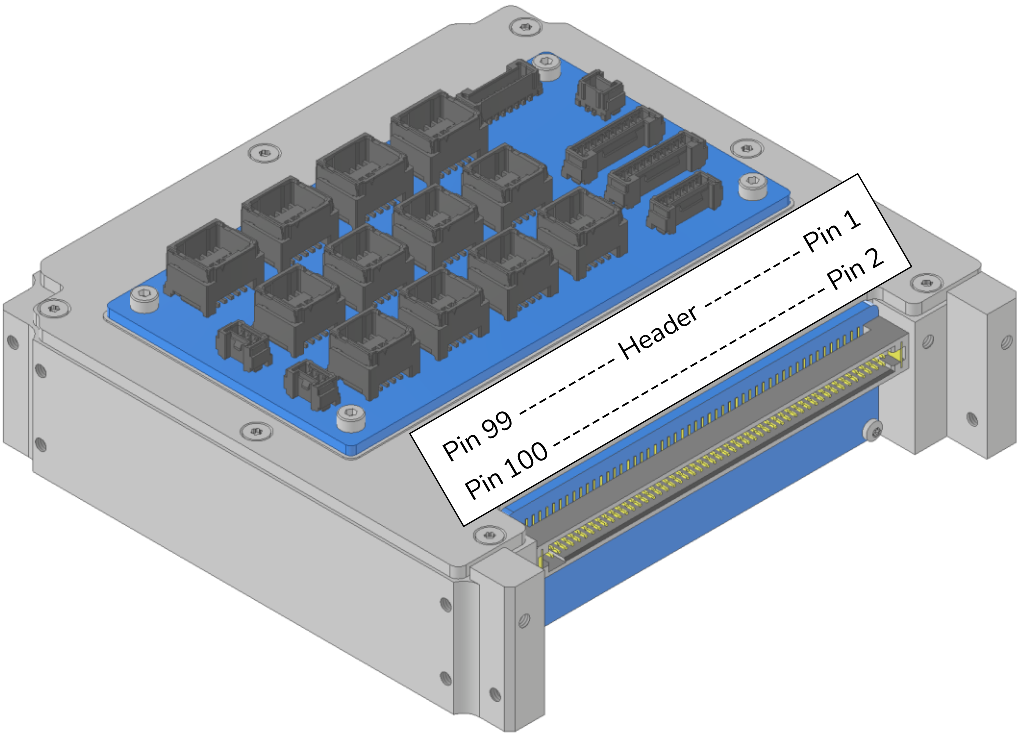


Figure 15: CubeADCS Core, Backplane Variant, Showing CubeDoor Header

Table 11 shows the pin-out of the Backplane interface to the CubeADCS. Default pin numbers are shown but are finalised by clients as required in [RD2].

Table 10: Backplane Variant Header Details

Part	Description	Part Number
Header	100 Pin Samtec	TFM-150-03-L-D-WT

Table 11: Backplane Header Pinout and Electrical Characteristics

Pin Options	Default Pin	Pin Name	Pin Description	IO Type	Voltage Range [V]
77	77	CAN 2 L	CubeADCS-OBC CAN Bus Low	Bidirectional	0 to 3.4
78	78	CAN 2 H	CubeADCS-OBC CAN Bus High	Bidirectional	0 to 3.4
20	NC	CAN 1 L	Sensor/Actuator Nodes CAN Bus Low	Bidirectional	0 to 3.4
18	NC	CAN 1 H	Sensor/Actuator Nodes CAN Bus High	Bidirectional	0 to 3.4
74	74	I2C_SDA	I^2C Data	Bidirectional	0 to 3.4
73	73	I2C_SCL	I^2C Clock	Input	0 to 3.4
61, 62, 81, 82	62	UART_1_RX	UART data receive line	Input	0 to 3.4
	82	UART_1_TX	UART data transmit line	Output	0 to 3.4
69, 70	69	Legacy GNSS Data Interface: UART or RS485	UART data receive line (default), or RS485 B (bidirectional)	Input	0 to 3.4
	NC		UART data transmit line (default, NC), or RS485 A (bidirectional)	Output	0 to 3.4
86, 88, 90, 92	86	RS422 (Cannot be used along with RS485)	RS422 data receive line high	Input	0 to 3.4
	88		RS422 data receive line low	Input	0 to 3.4
	90		RS422 data transmit line high	Output	0 to 3.4
	82		RS422 data transmit line low	Output	0 to 3.4
	NC	RS485 (Cannot be used with RS422)	RS485 A	Bidirectional	0 to 3.4
	NC		RS485 B	Bidirectional	0 to 3.4
49, 50	49	PPS (Differential option)	PPS input line high	Input	0 to 3.4
	50		PPS input line low	Input	0 to 3.4
49, 50, 57, 58	NC	PPS (CMOS option)	PPS input line (single-ended)	Input	0 to 3.4
97, 98	98	Boot	Toggle ROM bootloader on startup	Input	0 to 3.4
95, 96	96	Enable	Toggle power on	Input	0 to 17.6
5, 6, 7, 8, 13, 14, 19, 21, 22, 23, 25, 27, 31, 33, 35, 39, 43, 47, 48, 51, 52, 55, 56, 65, 75, 76	Always connected	GND	Power and signal ground	Power	0
9, 10, 11, 12, 53, 54	53, 54	V_{Bat}	Battery supply voltage input	Power	8 to 17.6 ***see note**
40, 41, 44, 45	40	5V	5V supply voltage input	Power	5 to 5.25
24, 26, 28, 32, 34, 36	24	3V3	3V3 supply voltage input	Power	3.3 to 3.4
64	NC	I2C_Bus_Ext	Custom I^2C bus voltage input	Power	2.7 to 5.0
66	NC	VBackup	RTC and Backup registers supply voltage input	Power	3.2 to 17.6

All notes and warnings from Section 3.8.1 is also applicable to the CubeDoor of the Backplane variant CubeADCS.

3.8.3 Custom CubeDoor Design

The external connector interface can be customised based on customer needs if the described standard options will not suffice. The type of connector, the pin-out of the connector, and even the shape of the interface PCB can be customised to fit any satellite bus. Note that this will carry additional costs and lead times. Contact CubeSpace for more information. Terms and conditions apply.

3.9 Header Pinout and Electrical Characteristics: CubeConnect

CubeConnect is part of the CubeADCS core and serves as the interface PCB to connect the various sensors and actuators.

3.9.1 Variants

The CubeConnect PCB for the Development Model shown in Figure 5 is not functional and does not contain any headers. The rest of Section 3.9 is not applicable to the Development Model.

The CubeConnect PCB for the remaining PC104 variants is shown in Figure 16 and Figure 17. It can also be seen on the back of CubeADCS in Figure 1, Figure 2, and Figure 3.

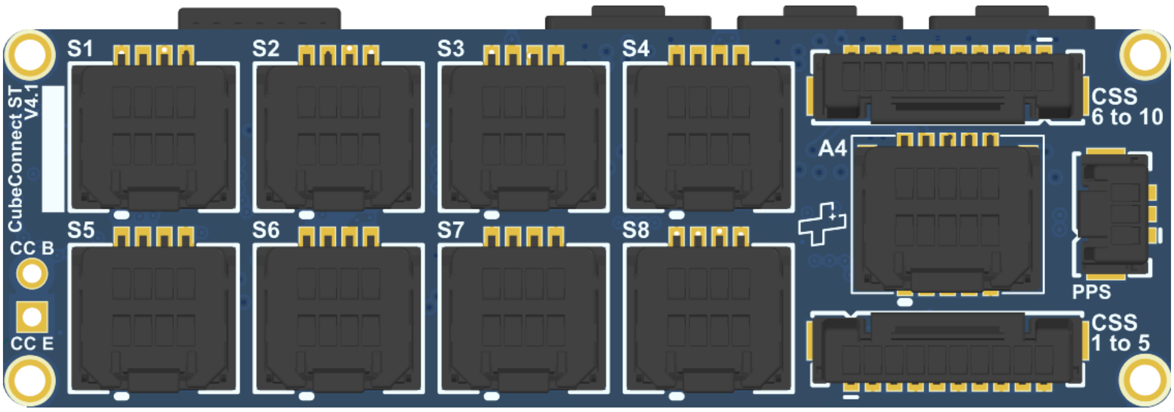


Figure 16: CubeConnect PCB (PC104 Variants) – Exterior (Front) View

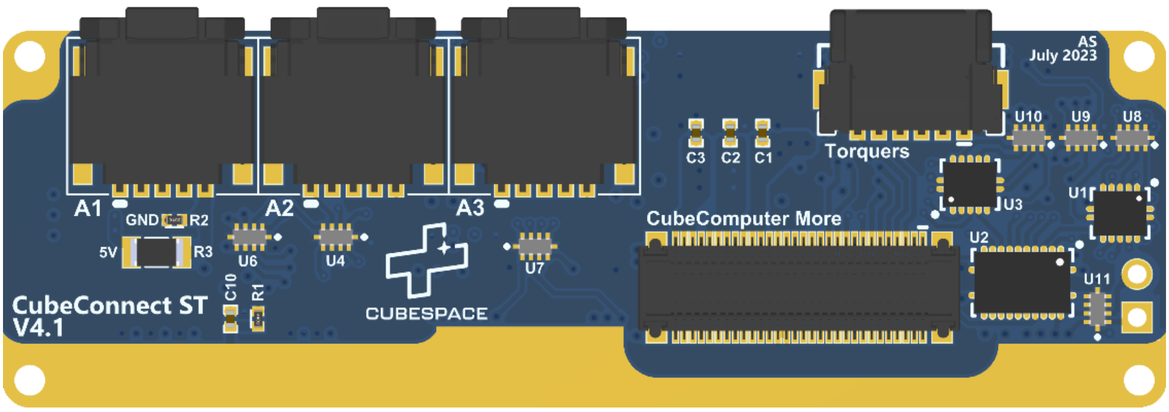


Figure 17: CubeConnect PCB (PC104 Variants) – Interior (Back) View

The CubeConnect PCB for the Backplane variant is shown in Figure 18. It can also be seen on the top of CubeADCS in Figure 4.

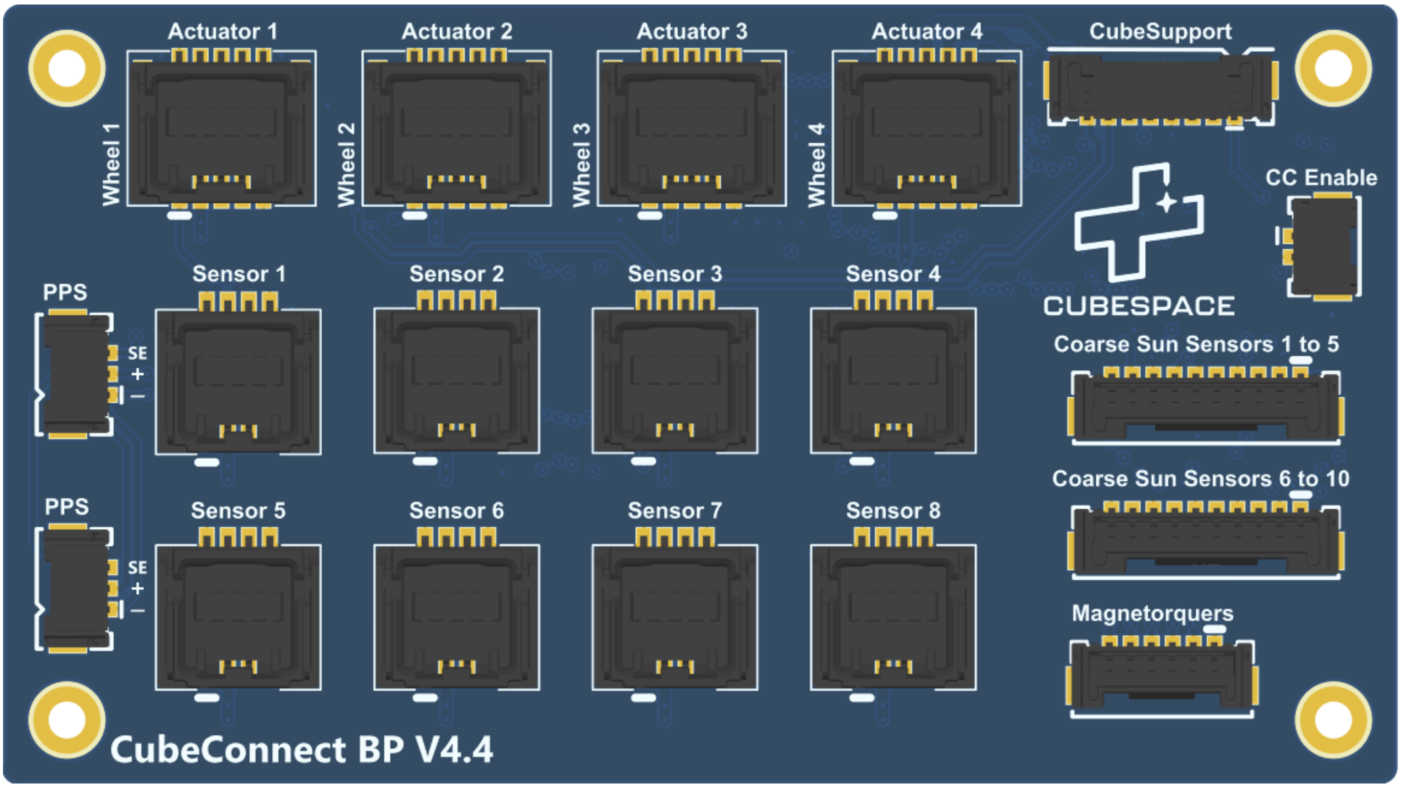


Figure 18: CubeConnect PCB (Backplane Variant) – Top View

Externally available connections include a Magnetorquer header, eight Sensor headers, four Actuator headers, PPS headers with configurable PPS output signals potentially required by CubeNode(s), and two headers for coarse sun sensor photodiodes, each capable of interfacing with five photodiodes (Coarse Sun Sensors) for a total of 10. For the 3U- and 6U variants of CubeADCS, the Magnetorquer header and the first three Actuator headers are not externally accessible, as they are already used to connect to internal actuators. Note that depending on the client needs, a fourth reaction wheel is not always required.

The eight Sensor headers on CubeConnect are identical, and sensor harnesses can therefore be connected to any sensor header based on customer needs. Similarly, the four Actuator headers are also identical. The difference between a Sensor and Actuator header are two additional pins that carries VBAT and an additional GND connection, so harnessing might potentially be manufactured to allow a sensor to plug into an actuator header.

Note that although UART and I2C pins are available and functional on sensors and actuators within the CubeSpace product range, the CubeADCS communicates to these products over CAN. Thus, the ports on the CubeConnect and the harnesses between CubeConnect and these CubeSpace products, do not carry these UART or I2C signals.

An example of a client sensor configuration for a PC104 CubeADCS is shown in Figure 19.

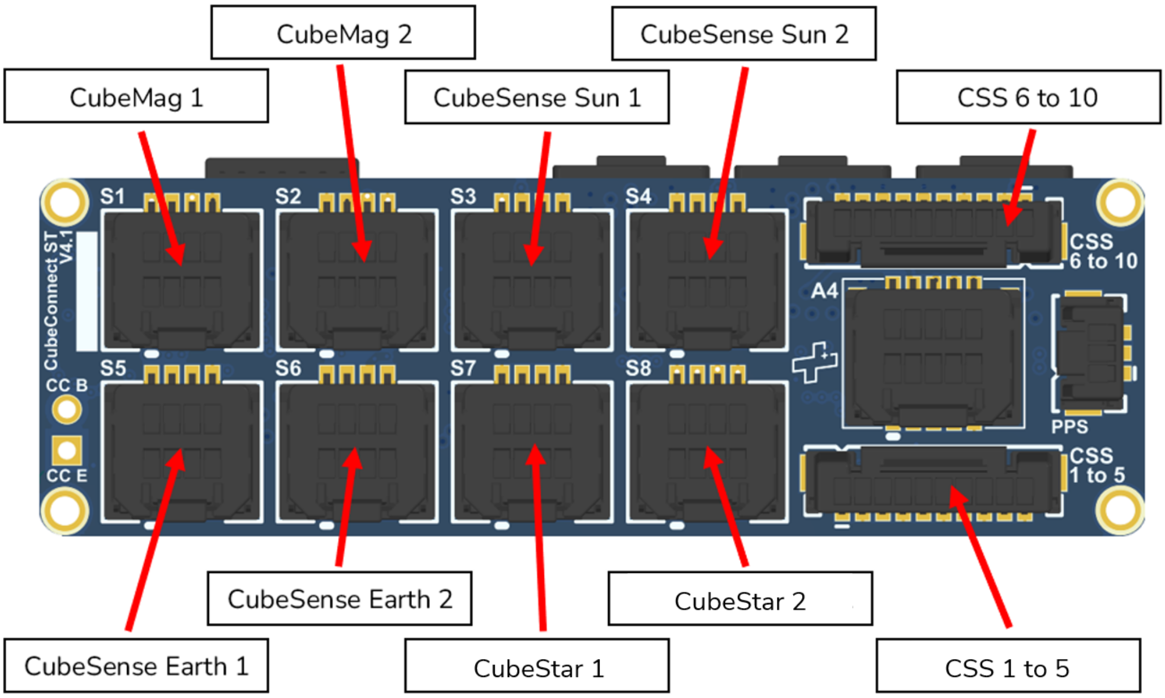


Figure 19: Example Configuration of External Sensors Connected to a PC104 Variant of CubeConnect

For the PC104 variants, CubeConnect also contains additional actuator headers that are located internally to the CubeADCS Core, as shown in Figure 20. These are usually used to connect CubeWheels and CubeTorquers. For the CubeADCS Core Stack for use in 3U and 6U satellites (Figure 2 and Figure 3), these headers are located internally to the CubeADCS Core Stack and will therefore not be accessible. Figure 20 shows the configuration where all actuators are mounted externally, i.e., somewhere in the satellite but not part of the CubeADCS core stack.

Figure 20: CubeADCS Core (PC104 Variants): CubeConnect Actuator Headers Available to the Outside of Housing

The sensor- and actuator headers mentioned earlier in this section are described in further detail in the following sub-sections.

3.9.2 Magnetorquer Header

The CubeConnect supports the connection of three CubeTorquers. The three CubeTorquers are all connected to a single wire harness which connects to a single header on CubeConnect. The location of this header on the two CubeConnect variants is shown in Figure 21 and Figure 22. The header details are provided in Table 12 and Table 13.

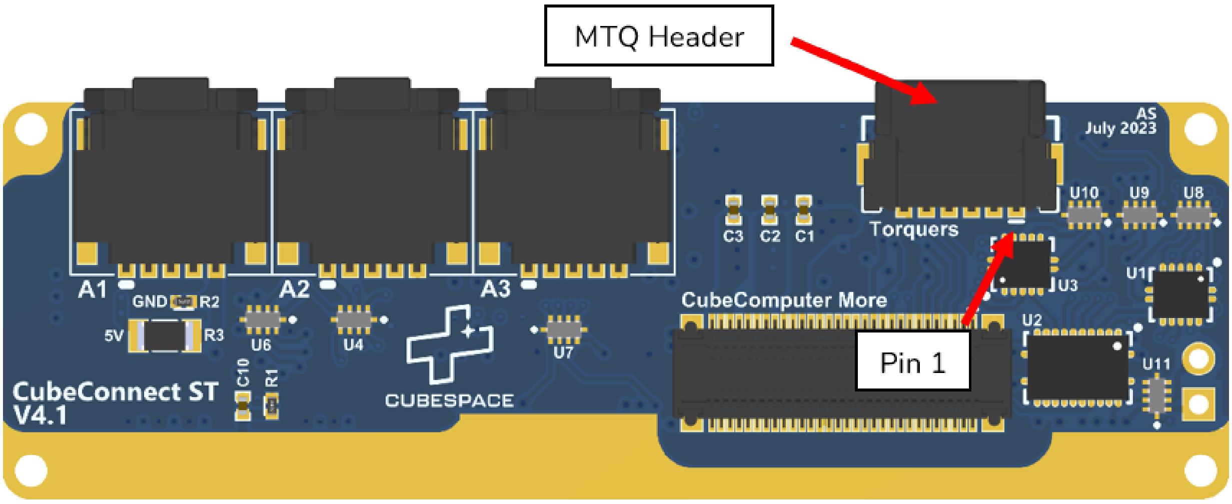


Figure 21: CubeConnect PCB, PC104 Variants (Back View) - Magnetorquer Header

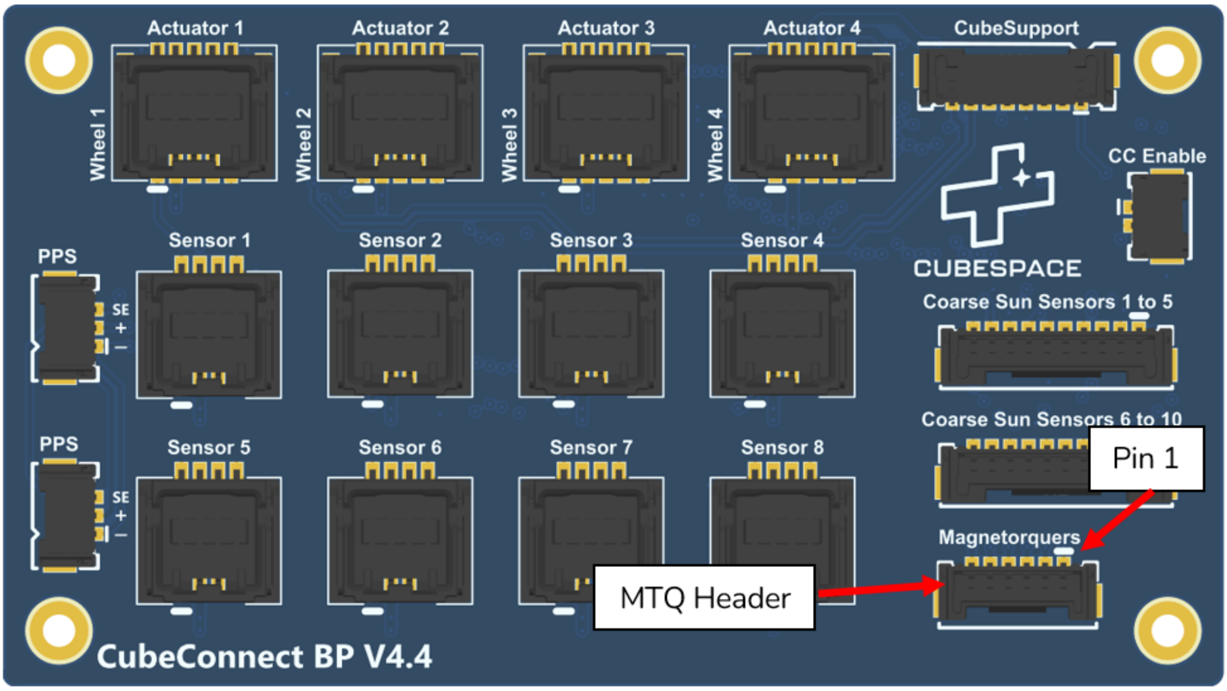


Figure 22: CubeConnect PCB, Backplane Variant - Magnetorquer Header

Table 12: Magnetorquer Header Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5055680671 or 5055670671
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5055650601
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 13: Magnetorquer Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	T1+	PWM-driven H-Bridge output for CubeTorquer 1 pin 1 (V+)	Output	0 to 5.1
2	T1-	PWM-driven H-Bridge output for CubeTorquer 1 pin 1 (V-)	Output	0 to 5.1
3	T2+	PWM-driven H-Bridge output for CubeTorquer 2 pin 1 (V+)	Output	0 to 5.1
4	T2-	PWM-driven H-Bridge output for CubeTorquer 2 pin 1 (V-)	Output	0 to 5.1
5	T3+	PWM-driven H-Bridge output for CubeTorquer 3 pin 1 (V+)	Output	0 to 5.1
6	T3-	PWM-driven H-Bridge output for CubeTorquer 3 pin 1 (V-)	Output	0 to 5.1

The voltage levels output by the magnetorquer driving circuitry depends on the powering option specified in Section 3.7.1. The source of the 5V power could be either the output voltage of the internal 5 V regulator shown as in Figure 11, and controlled to be no more than 5.25V (5.0 V typical), or alternatively the externally supplied 5 V input shown in Figure 12, required to be no more than 5.25 V.

3.9.3 Actuator Headers

Unlike the Sensor headers, the Actuator headers carry V_{Bat} for products that require it, usually actuators like the CubeWheel. Four CubeWheels can be connected to CubeConnect simultaneously. For the PC104 variants, it has been shown in Figure 20 how three Actuator headers are located on the back side of the CubeConnect, with a fourth one located on the front. The Pin 1 indicators for the Actuator headers are shown in Figure 23, Figure 24, and Figure 25. Note that Pin 2 is physically located across from Pin 1 and not next to Pin 1.

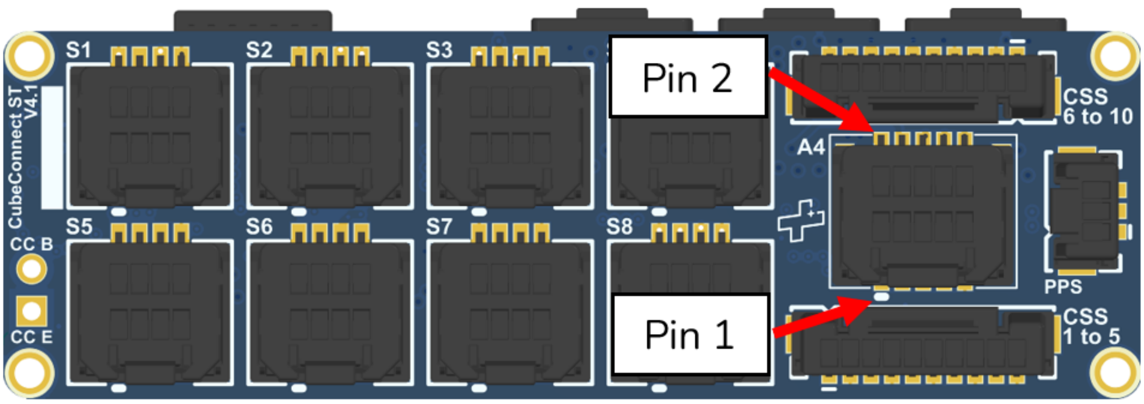


Figure 23: CubeConnect (PC104 Variants) – Pin 1 Indicated for Actuator 4

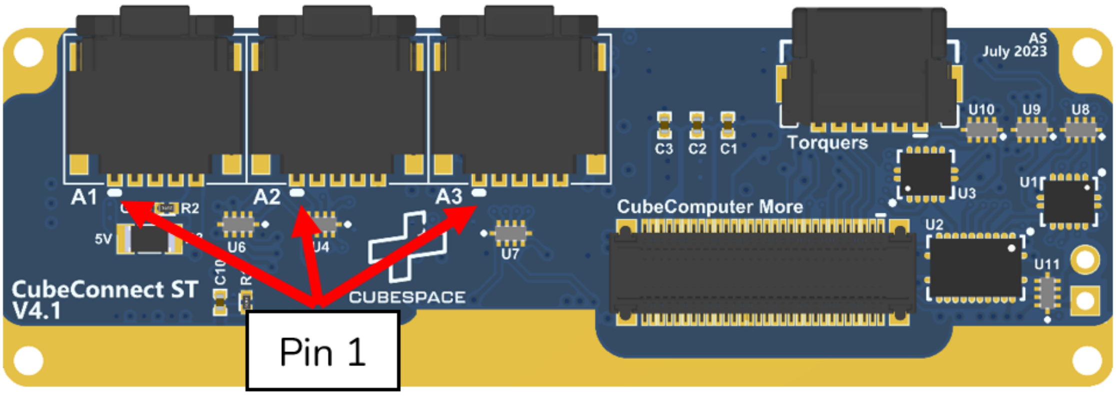


Figure 24: CubeConnect (PC104 Variants) – Pin 1 Indicated for Actuators 1-3

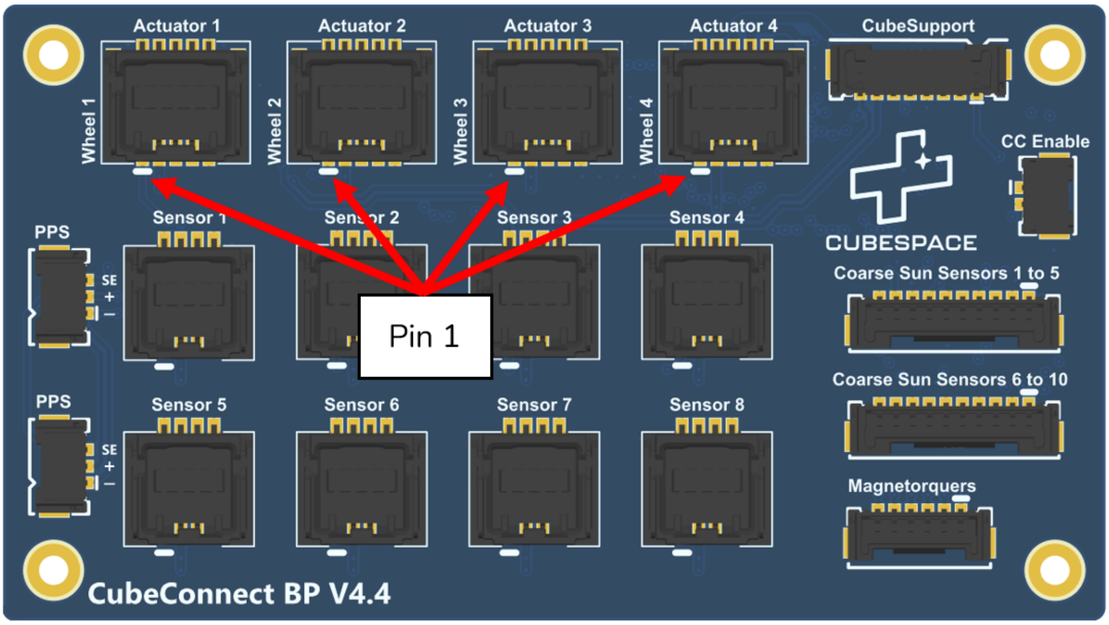


Figure 25: CubeConnect (Backplane Variant) - Pin 1 Indicated for Actuators 1-4

The header details are provided in Table 14 and Table 15 below.

Table 14: Actuator Header Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5054331071 or 5054481071
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5054321001
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 15: Actuator Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	Enable	Toggle connected device power	Output	0 to 3.4
2	GND	Power and signal ground	Power	0
3	3V3	Supply voltage output	Power	3.3 to 3.4
4	Boot	Toggle connected device ROM bootloader on startup	Output	0 to 3.4
5	CAN1 H	High level CAN bus line	Bidirectional	0 to 3.4
6	5V	Supply voltage output	Power	5.0 to 5.1
7	CAN1 L	Low level CAN bus line	Bidirectional	0 to 3.4
8	V_{Bat}	Supply voltage output	Power	V_{Bat}
9	GND	Power and signal ground	Power	0
10	GND	Power and signal ground	Power	0

Note: Although the CAN pins are +5V/-5V-tolerant, all CubeSpace products run on 3.3 V logic and the voltage levels that will be output on these pins are thus also 0 V - 3.3 V.

3.9.4 Sensor Headers

CubeConnect has eight Sensor headers. The Pin 1 indicators for these headers are shown in Figure 26 and Figure 27. Note that Pin 2 is physically located across from Pin 1 and not next to Pin 1.

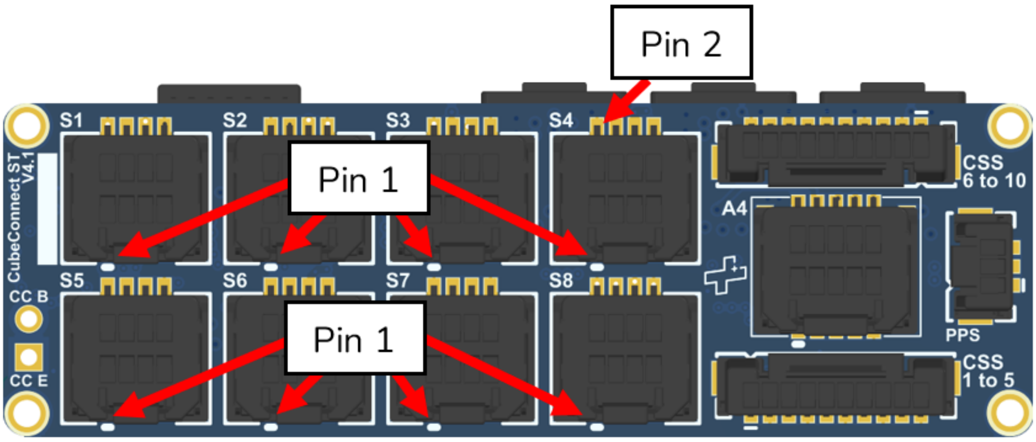


Figure 26: CubeConnect (PC104 Variants) - Pin 1 Indicated for Sensors 1-8

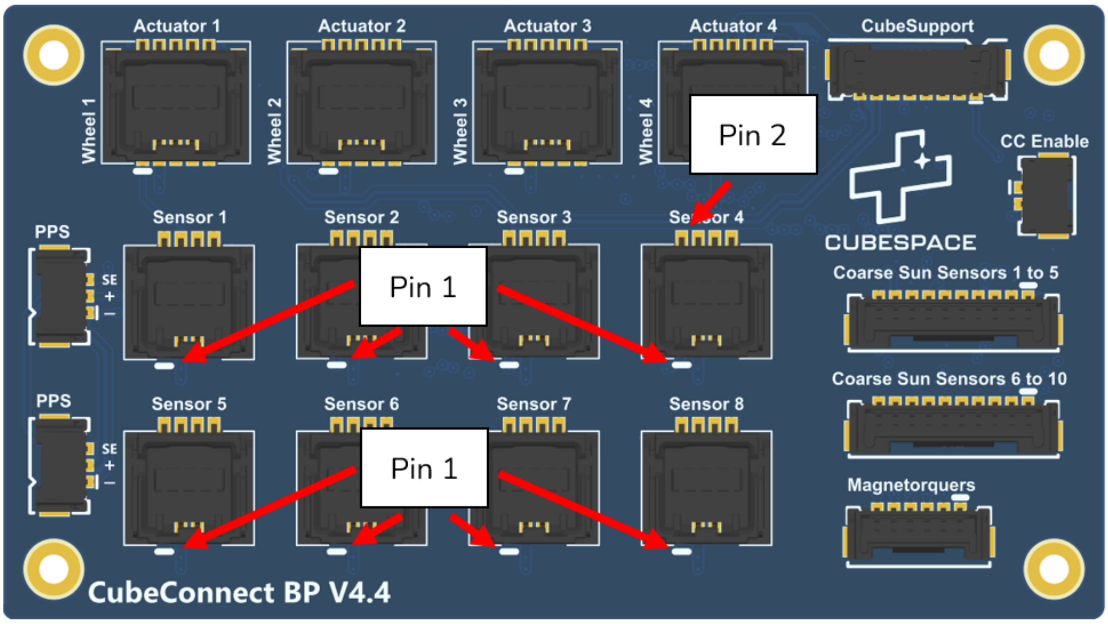


Figure 27: CubeConnect (Backplane Variant) - Pin 1 Indicated for Sensors 1-8

The header details are provided in Table 16 and Table 17 below.

Table 16: Sensor Header Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5054330871
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5054320801
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 17: Sensor Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	Enable	Toggle connected device power	Output	0 to 3.4
2	GND	Power and signal ground	Power	0
3	3V3	Supply voltage output	Power	3.3 to 3.4
4	Boot	Toggle connected device ROM bootloader on startup	Output	0 to 3.4
5	CAN1 H	High level CAN bus line	Bidirectional	0 to 3.4
6	5V	Supply voltage output	Power	5.0 to 5.1
7	CAN1 L	Low level CAN bus line	Bidirectional	0 to 3.4
8	GND	Power and signal ground	Power	0

3.9.5 Coarse Sun Sensor Headers

CubeConnect has two headers to connect the 10 Coarse Sun Sensors (photodiodes) to CubeADCS, as shown in Figure 28 and Figure 29.

The Coarse Sun Sensor photodiodes is also discussed in some more detail in [RD3]. The Coarse Sun Sensor photodiodes supplied by CubeSpace are SLCD-61N8 from Advanced Photonix.

Each photodiode has a Cathode and Anode and needs to be connected to the correct corresponding pin. The Anode is grounded, and the Cathode is connected to a sensing circuit.

The header details are provided in Table 18 and Table 19 below.

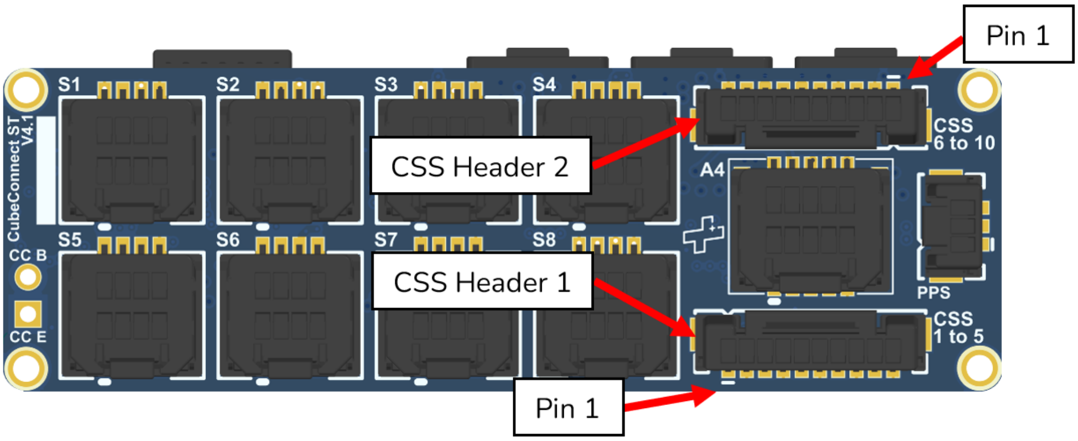


Figure 28: CubeConnect PCB (PC104 Variants) – Coarse Sun Sensors Headers

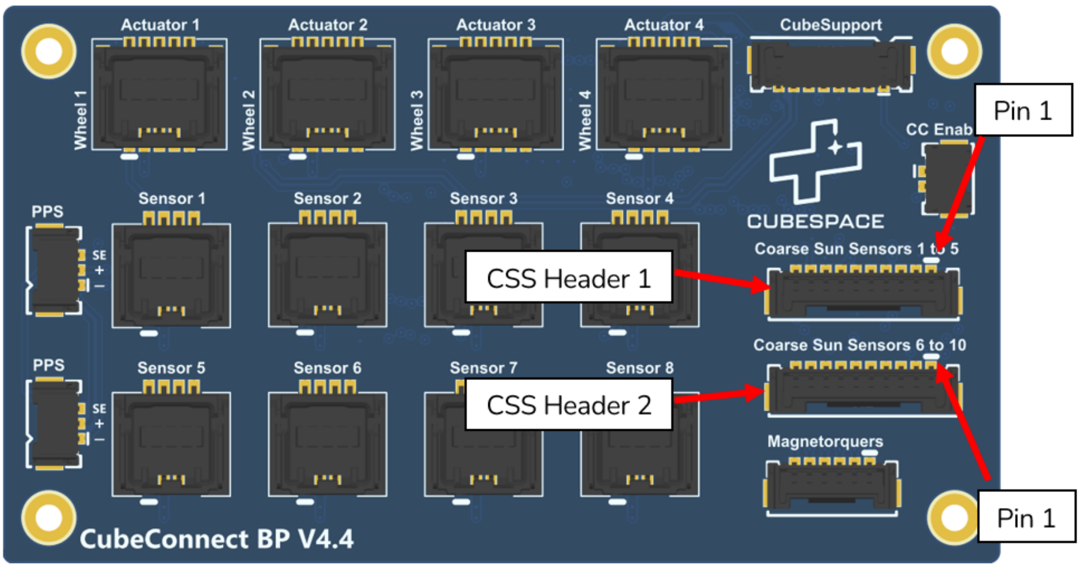


Figure 29: CubeConnect PCB (Backplane Variant) - Coarse Sun Sensors Headers

Table 18: Coarse Sun Sensor Header Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5055681081
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5055651001
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 19: Coarse Sun Sensor Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	Cathode	Cathode, Photodiode 1 or 6	Input	0 to -3.4
2	GND	Anode, Photodiode 1 or 6	Power	0
3	Cathode	Cathode, Photodiode 2 or 7	Input	0 to -3.4
4	GND	Anode, Photodiode 2 or 7	Power	0
5	Cathode	Cathode, Photodiode 3 or 8	Input	0 to -3.4
6	GND	Anode, Photodiode 3 or 8	Power	0
7	Cathode	Cathode, Photodiode 4 or 9	Input	0 to -3.4
8	GND	Anode, Photodiode 4 or 9	Power	0
9	Cathode	Cathode, Photodiode 5 or 10	Input	0 to -3.4
10	GND	Anode, Photodiode 5 or 10	Power	0

3.9.6 PPS headers

For some sensors, a one-pulse-per-second (PPS) signal might be required for time synchronization purposes. CubeSpace supplies this signal on one or more of the pins on the PPS headers shown in Figure 30 and Figure 31.

The nature of this signal is either of a single-ended CMOS nature, or differentially signalled. The exact configuration requirements of these pins and associated harness or harnesses, is determined by CubeSpace and is expected to remain internal to the CubeSpace sensors ecosystem, so only general specifications are given in Table 20 and Table 21.

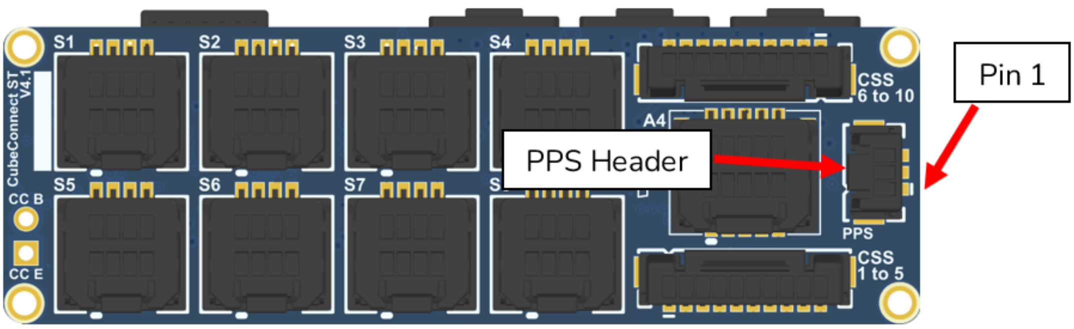


Figure 30: CubeConnect PCB (PC104 Variants) – PPS Header

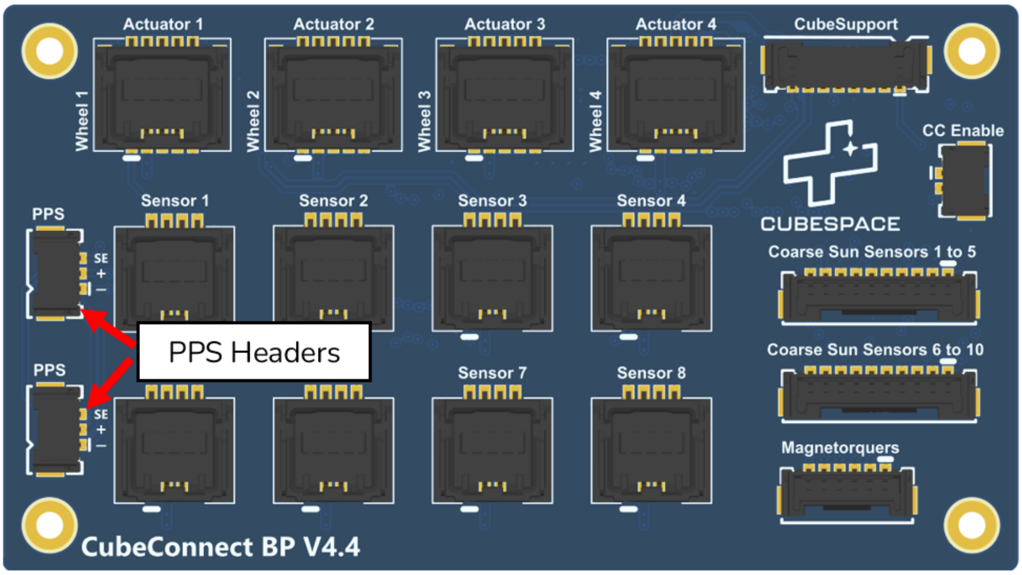


Figure 31: CubeConnect PCB (Backplane Variant) - PPS Headers

Table 20: PPS Header Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5055680371 or 5055680271
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5055650301 or 5055650201
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 21: PPS Header Pinout and Electrical Characteristics

CubeADCS Variant	Pin #	Pin Description	IO Type	Voltage Range [V]
PC104	Pin 1	PPS_N or Single-ended	Output (Single-ended CMOS Or Differentially signalled)	0 to 3.4
	Pin 2	PPS_P or Single-ended		0 to 3.4
	Pin 3	PPS output (Single-ended)	Output (Single-ended CMOS)	0 to 3.4
Backplane (see note below this table)	Pin 1: -	PPS_N or Single-ended	Output (Single-ended CMOS Or Differentially signalled)	0 to 3.4
	Pin 2: +	PPS_P or Single-ended		0 to 3.
	Pin 3: SE	PPS output (Single-ended)	Output (Single-ended CMOS)	0 to 3.4

Note: Previous revisions of the Backplane variant, uses a CubeConnect board of which the two PPS headers are a two-pin type. These pins are PPS_P and PPS_N, indicated on the top silkscreen, with Pin 3 (SE) being omitted. These two pins could also be configured to be single-ended outputs, depending on the system. This older revision of the CubeConnect can be identified by the words “CubeConnect OC V4.3” applied to the top silkscreen.

3.9.7 Ground Support Headers

Additional connection points are provided on the CubeConnect board to assist ground testing tasks in case a client selected to not have these pins connected on the CubeDoor board. For the CubeADCS PC104 variants, additional connection points for the Boot line (section 3.5) and Enable line (section 3.7.2) are indicated in Figure 32.

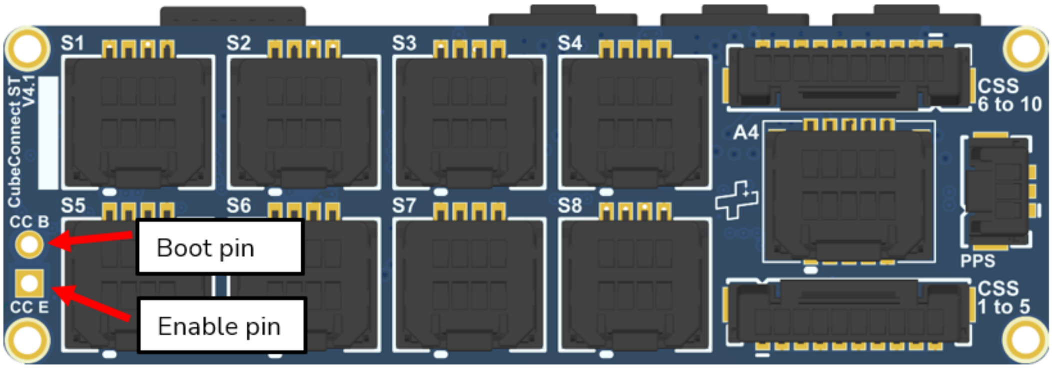


Figure 32: CubeConnect PCB (PC104 Variants) – Additional Boot and Enable Connection Points

For the CubeADCS Backplane variant, two headers are indicated in Figure 33 and detailed in the tables that follow.

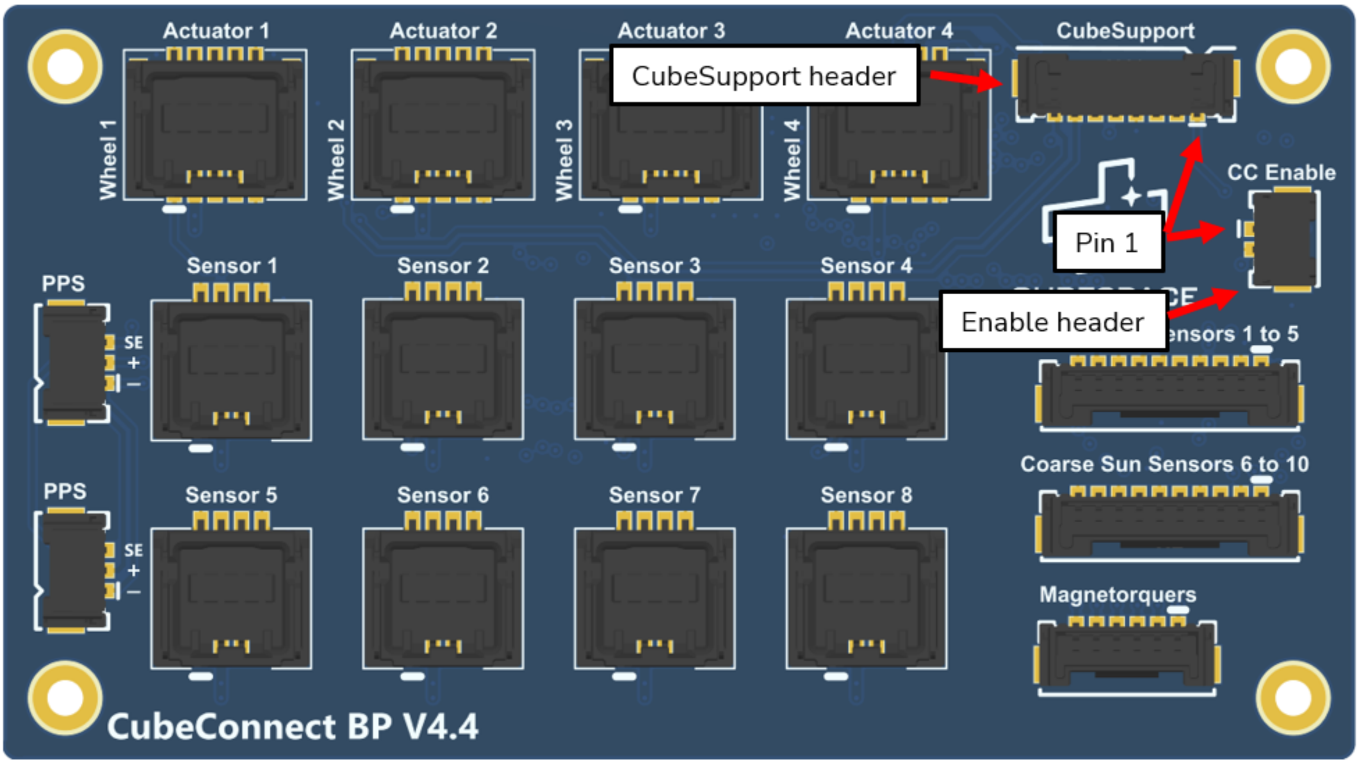


Figure 33: CubeConnect PCB (Backplane Variant) – Ground Support Headers

Table 22: CubeConnect PCB (Backplane Variant)Header Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5055680871
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5055650801
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 23: CubeConnect PCB (Backplane Variant) Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	Boot	Toggle connected device ROM bootloader on startup	Input	0 to 3.4
2	UART Tx	UART data transmit line	Output	0 to 3.4
3	UART Rx	UART data receive line	Input	0 to 3.4
4	GND	Power and signal ground	Power	0
5	CAN1 H	High level CAN bus line	Bidirectional	0 to 3.4
6	CAN1 L	Low level CAN bus line	Bidirectional	0 to 3.4
7	NC	Reserved	None	0
8	NC	Reserved	None	0

Table 24: Enable Header Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5055680271
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5055650201
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 25: Enable Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	Enable	Toggle connected device power	Input	0 to 3.4
2	GND	Power and signal ground	Power	0

3.9.8 V_{Bat} Bypass CubeDoor PCB Headers

In cases where the Reaction Wheel power is supplied from a V_{Bat} Bypass board (see Section 2.5), refer to the following figures and tables. Note that the pinout detail of the PC104 and Backplane interface connector headers (Section 3.8) remain unchanged.

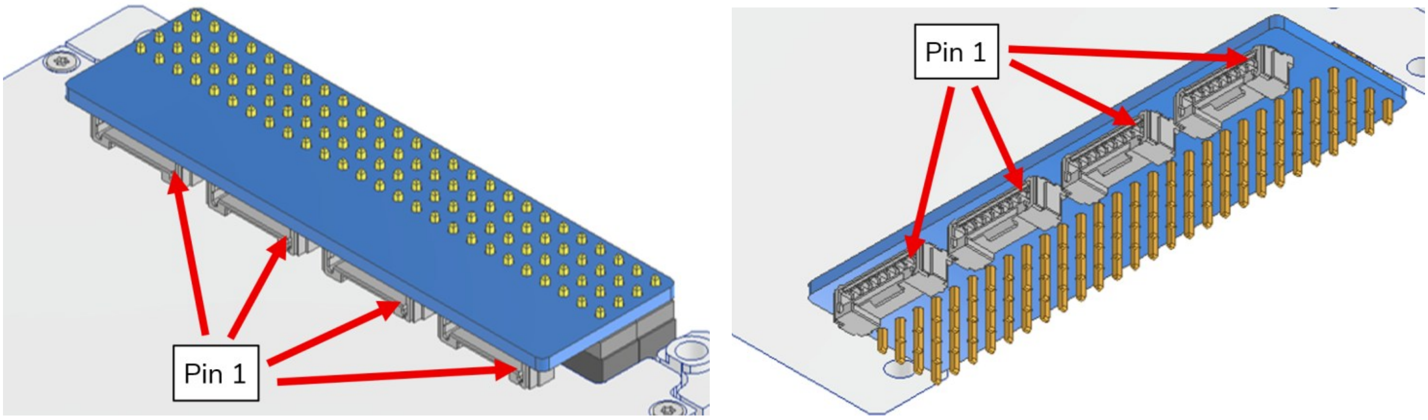
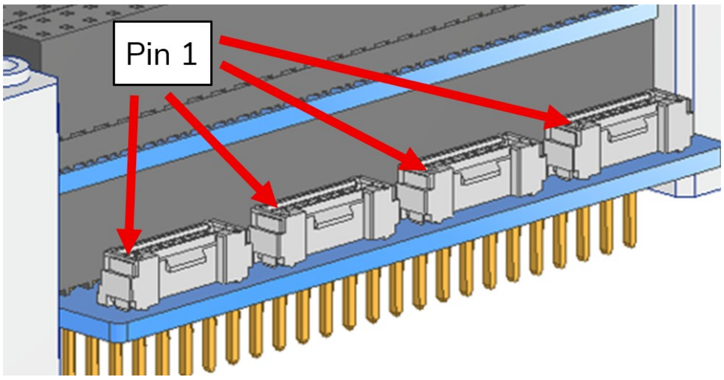


Figure 34: V_{Bat} Bypass CubeDoor PCB (PC104 Variants, Top- and Bottom-Mount) – Reaction Wheel Power Headers



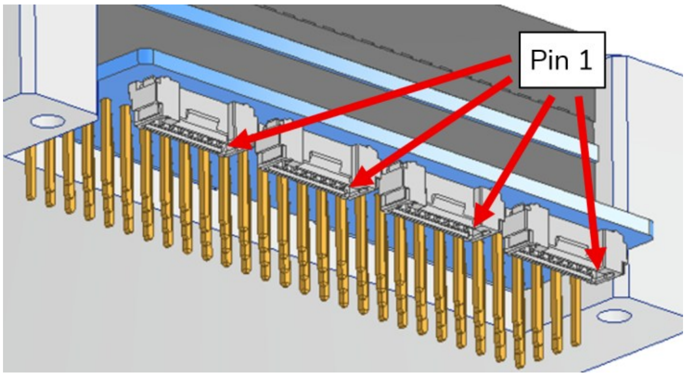


Figure 35: V_{Bat} Bypass CubeDoor PCB (PC104 Variants, Midstack-Mount) – Reaction Wheel Power Headers

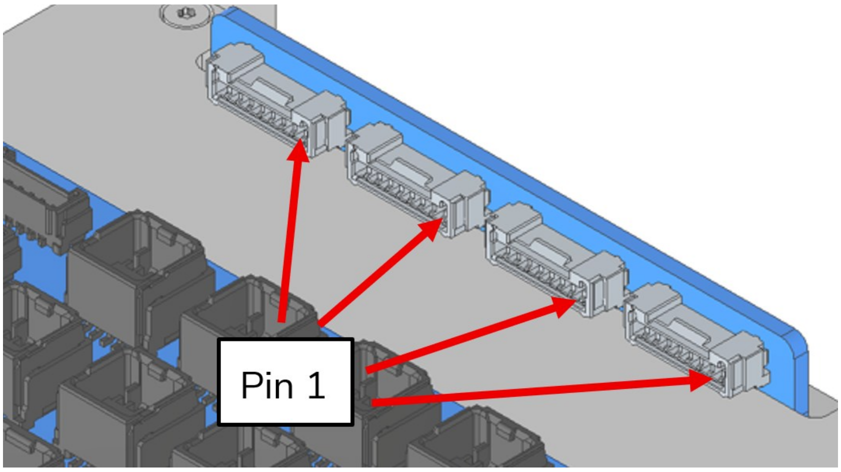


Figure 36: V_{Bat} Bypass CubeDoor PCB (Backplane Variant) – Reaction Wheel Power Headers

Table 26: V_{Bat} Bypass Individual Header Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5055680871
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5055650801
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 27: V_{Bat} Bypass Individual Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	GND	Power and signal ground	Power	0
2	GND	Power and signal ground	Power	0
3	GND	Power and signal ground	Power	0
4	GND	Power and signal ground	Power	0
5	GND	Power and signal ground	Power	0
6	GND	Power and signal ground	Power	0
7	V_{Bat}	Supply voltage output	Power	V_{Bat}
8	V_{Bat}	Supply voltage output	Power	V_{Bat}

3.10 Harness Details

CubeADCS connects to sensor and actuator products through wire harnesses, for which the required lengths can be specified in [RD2] during order placement. CubeSpace supplies pre-built harnesses ranging from 150mm to 800mm in length, in predetermined increments. Custom lengths up to 2m may be supplied by special arrangement, carrying additional lead time and cost.

Harness lengths longer than 800mm have shown unsafe voltage changes over the 3.3V and GND wires depending on the bundle architecture. If harness lengths over 800mm are needed, please contact CubeSpace.

CubeSpace supplies both GSE test harnesses and FM harnesses. FM harnesses use different colour wires twisted in pairs and braided to form the final harness, as shown in Figure 37. The FM harnesses have a PTFE insulation which is low-outgassing, safe for space-flight and vacuum operations.

CubeSpace GSE test harnesses with all-black insulation, or without twisted pairs and braiding, are not safe for spaceflight or for use in a vacuum.

The Molex Micro-Lock Plus 1.25mm Pitch connectors are rated for a maximum of thirty (30) mating cycles only. Care must be taken with flight harnesses to not exceed this threshold. Please contact CubeSpace to order additional harnesses if required.

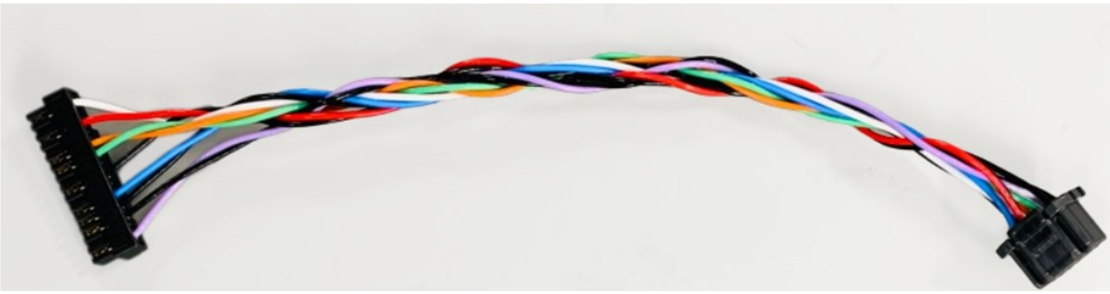


Figure 37: Flight Harness Example

General harness details are described in Table 28 below, where “Housing 1” mates with CubeConnect on CubeADCS Core, and “Housing 2” mates with the sensor or actuator header (discussed separately in their respective ICD documents).

Table 28: Harness Details

Harness	Housing 1 Mass (mg)	Terminal 1 Mass (mg)	No. Wires	Wire Gauge (AWG)	Wire Mass (g/m)	Terminal 2 Mass (mg)	Housing 2 Mass (mg)
CubeTorquer	138.021	35.434	6	28	1.4	7.04	16
Actuator	261.67	35.434	10	26	1.96	35.434	263.5
Sensor	229.64	35.434	8	26	1.96	35.434	198.8
CSS	198.816	35.434	10	26	1.96	9.8	52.2

For a PC104 3U- and 6U-Core stack variant CubeADCS, FM harnessing for three internal CubeWheels and CubeTorquers is housed within the enclosure.

During satellite assembly and integration, take note of the minimum bending radius of the harnesses of 16mm. This was determined by referring to IPC-610-A.

4. Mechanical Interface

CubeADCS is fully enclosed in an aluminium enclosure (6082-T6), treated with a chromate conversion coating.

The dimensions given in this chapter are indicative only. The mechanical CAD files with the latest dimensions are supplied to customers and must be used for final design and fitment verification.

4.1 Standard PC104 CubeADCS Core

4.1.1 Outer Dimensions

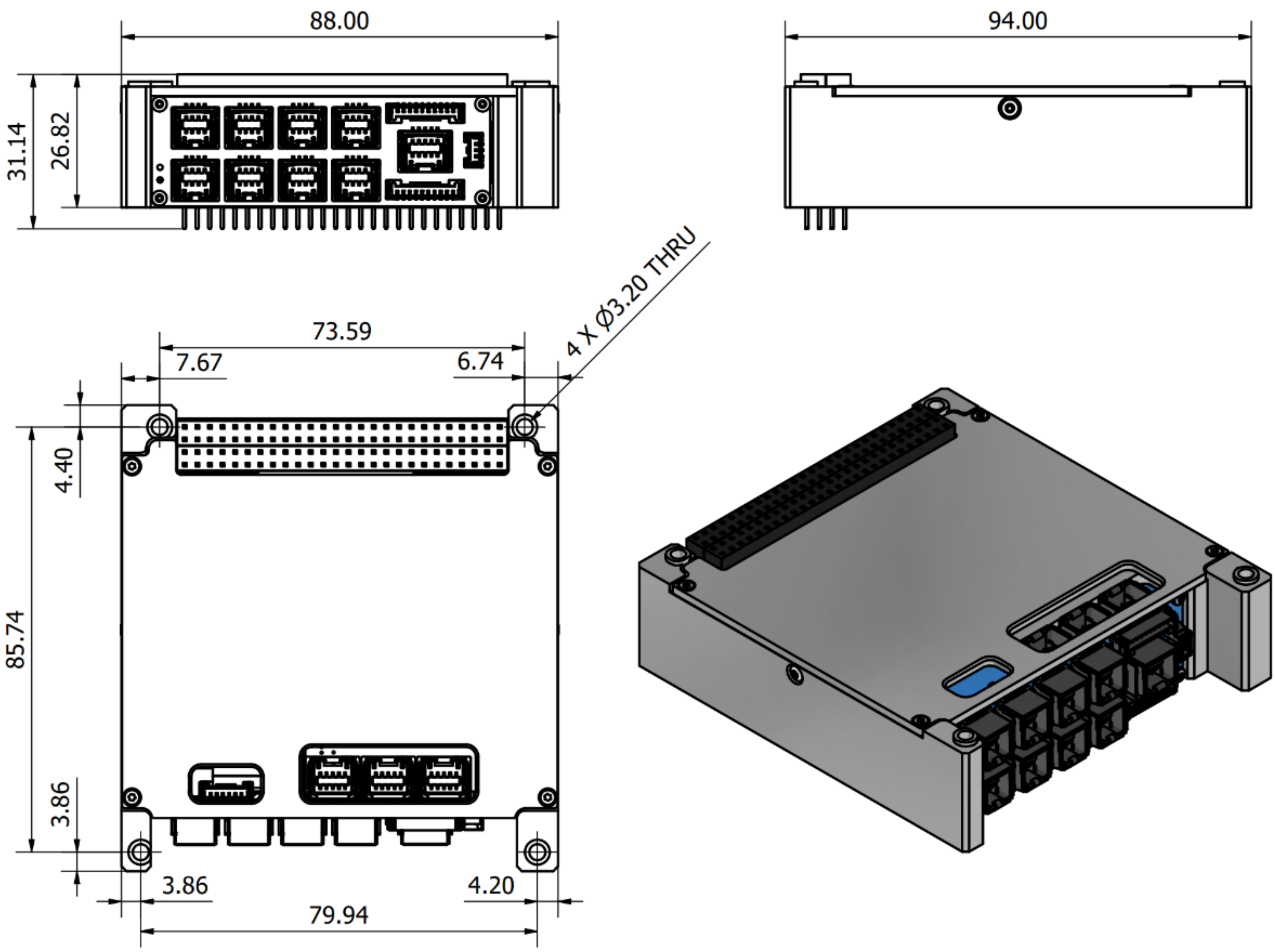


Figure 38: Indicative Dimensions of the Standard PC104 CubeADCS Core

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See Section 9 for dimensions of the PC104 CubeADCS Core with the V_{Bat} Bypass boards as discussed in Section 2.5.

4.1.2 Mounting Definition

The Standard PC104 CubeADCS Core is reliant on the use of four mounting rails. The stack will slide into the rails through the four ⌀3.20mm mounting holes dimensioned in Figure 38. It is possible to connect the CubeADCS to a PC104 header from the top and / or bottom. It will be the client's responsibility to secure the CubeADCS in its final position.

4.1.3 Mass, CoM and Inertia

Table 29: Mass Details

Variant/Model	Mass	Notes
Standard PC104 CubeADCS Core	250 g	Does not include any sensors, actuators, or harnessing

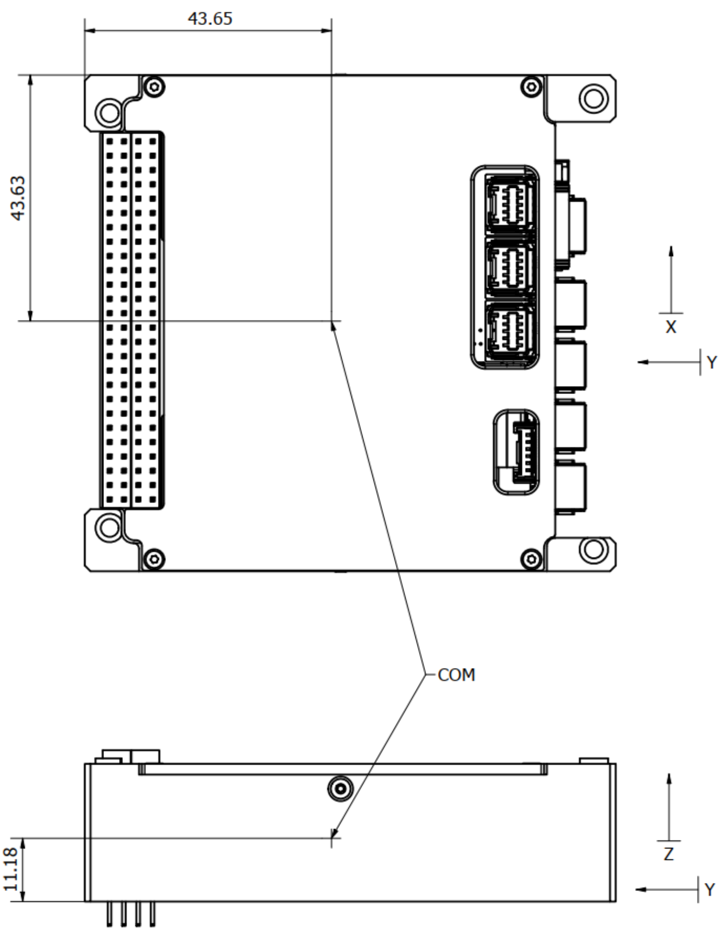

Figure 39: CoM Position of the Standard PC104 CubeADCS Core

The moments of inertia of the Standard PC104 CubeADCS Core about its CoM are presented in Table 30, using the coordinate system definition shown in Figure 39. The indicated coordinate system is used by the CubeComputer's Main and Redundant IMUs.

Table 30: Moments of Inertia of the Standard PC104 CubeADCS Core

Axis	Value [gmm²]
Ixx	137980 ± 15 %
Iyy	138660 ± 15 %
Izz	249794 ± 15 %

4.2 Standard PC104 CubeADCS Core Stack For Satellites Up To 3U

4.2.1 Outer Dimensions

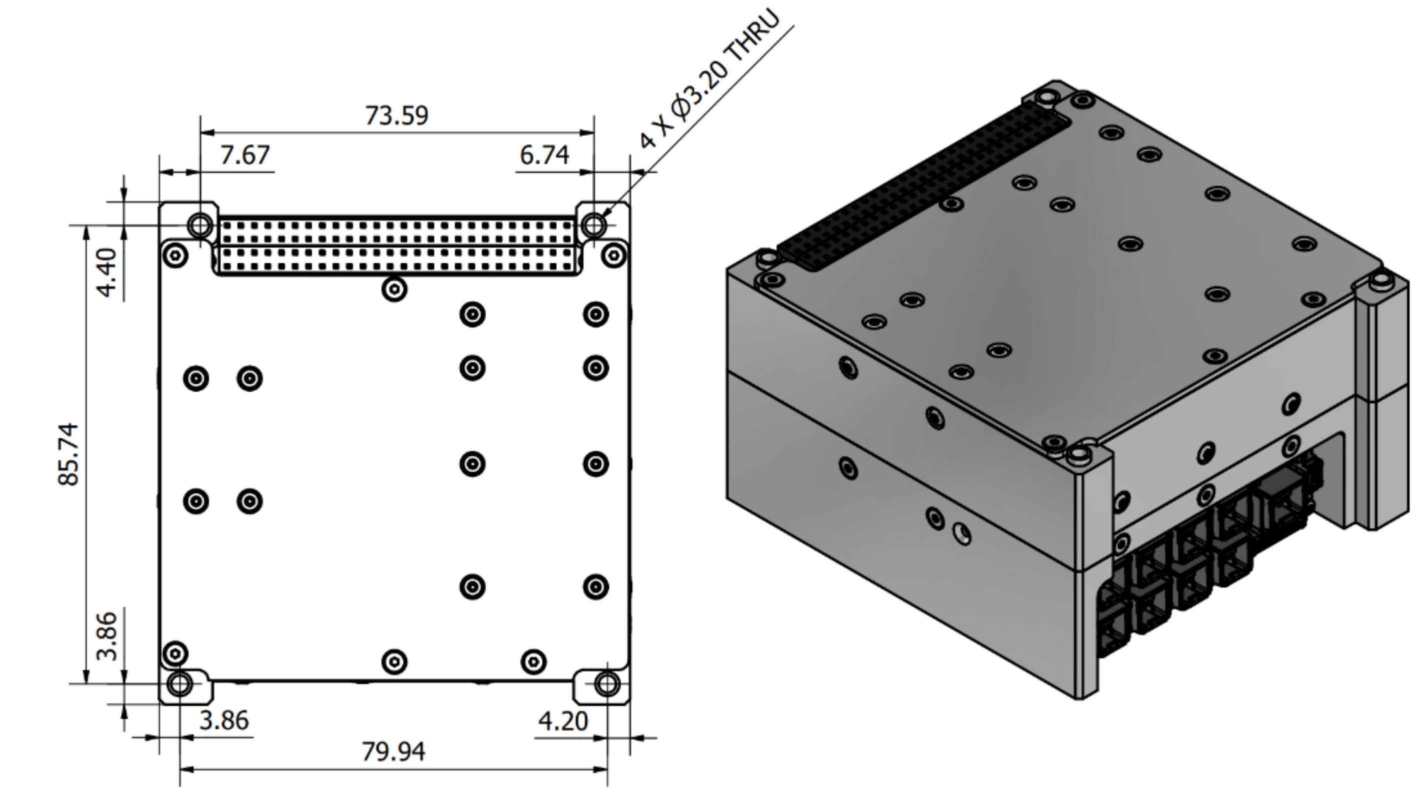

Figure 40: Indicative Dimensions of the PC104 CubeADCS Core Stack for 3U Satellites

4.2.2 Mounting Definition

The PC104 CubeADCS Core Stack for 3U and smaller satellites is reliant on the use of four mounting rails. The stack will slide into the rails through the four ⌀3.20mm mounting holes dimensioned in Figure 40. It is possible to connect the CubeADCS to a PC104 header from the top and / or bottom. It will be the client's responsibility to secure the CubeADCS in its final position.

4.2.3 Mass, CoM and Inertia

Table 31: Mass Details

Variant/Model	Mass	Notes
PC104 variant of CubeADCS for 3U and smaller	575 g	Including internal actuators and harnessing

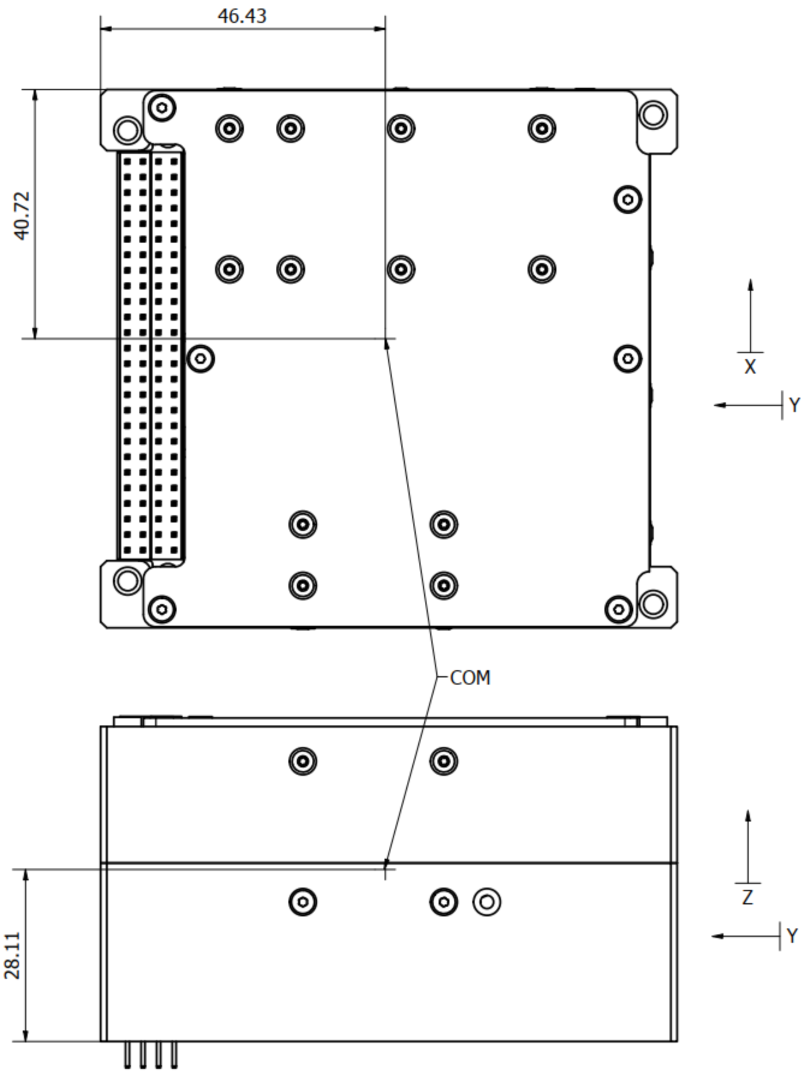

Figure 41: CoM Position of the PC104 CubeADCS Core Stack for 3U Satellites

The moments of inertia of the PC104 CubeADCS Core Stack for 3U about its CoM are presented in Table 32, using the coordinate system definition shown in Figure 41. The indicated coordinate system is used by the CubeComputer's Main and Redundant IMUs.

Table 32: Moments of Inertia of the PC104 CubeADCS Core Stack for 3U Satellites

Axis	Value [gmm²]
I_{xx}	510256 ± 15 %
I_{yy}	520558 ± 15 %
I_{zz}	764877 ± 15 %

4.3 Standard PC104 CubeADCS Core Stack for Satellite Sizes Between 3U and 6U

4.3.1 Outer Dimensions

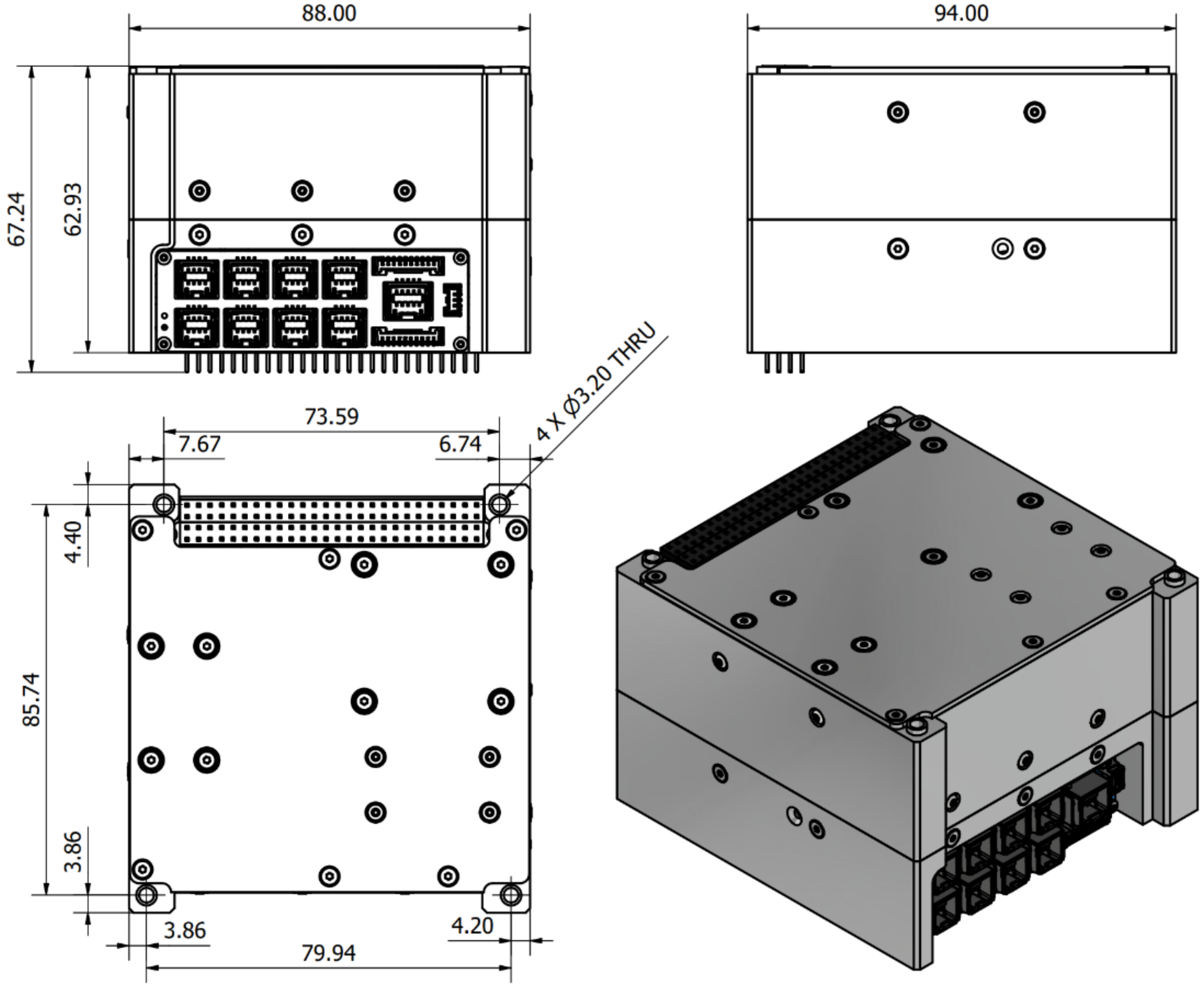

Figure 42: Indicative Dimensions of the PC104 CubeADCS Core Stack for 3U to 6U Satellites

4.3.2 Mounting Definition

The PC104 CubeADCS Core Stack for 3U to 6U satellites is reliant on the use of four mounting rails. The stack will slide into the rails through the four ⌀3.20mm mounting holes dimensioned in Figure 42. It is possible to connect the CubeADCS to a PC104 header from the top and / or bottom. It will be the client's responsibility to secure the CubeADCS in its final position.

4.3.3 Mass, CoM and Inertia

Table 33: Mass Details

Variant/Model	Mass	Notes
PC104 variant of CubeADCS for 3U to 6U	743 g	Including internal actuators and harnessing.

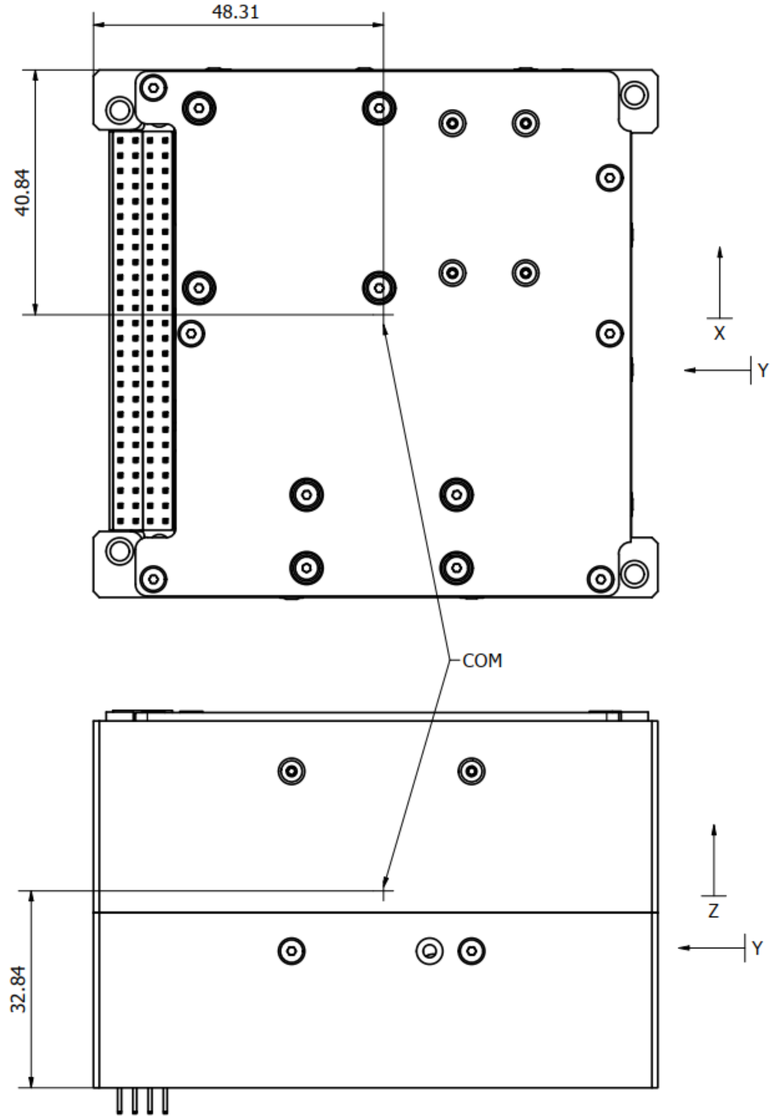

Figure 43: CoM Position of the PC104 CubeADCS Core Stack for 3U to 6U Satellites

The moments of inertia of the PC104 CubeADCS Core Stack for 3U to 6U satellites about its CoM are presented in Table 32, using the coordinate system definition shown in Figure 43. The indicated coordinate system is used by the CubeComputer's Main and Redundant IMUs.

Table 34: Moments of Inertia of the PC104 CubeADCS Core Stack for 3U to 6U Satellites

Axis	Value [gmm²]
I_{xx}	610768 ± 15 %
I_{yy}	690045 ± 15 %
I_{zz}	907014 ± 15 %

4.4 Backplane CubeADCS Core

4.4.1 Outer Dimensions

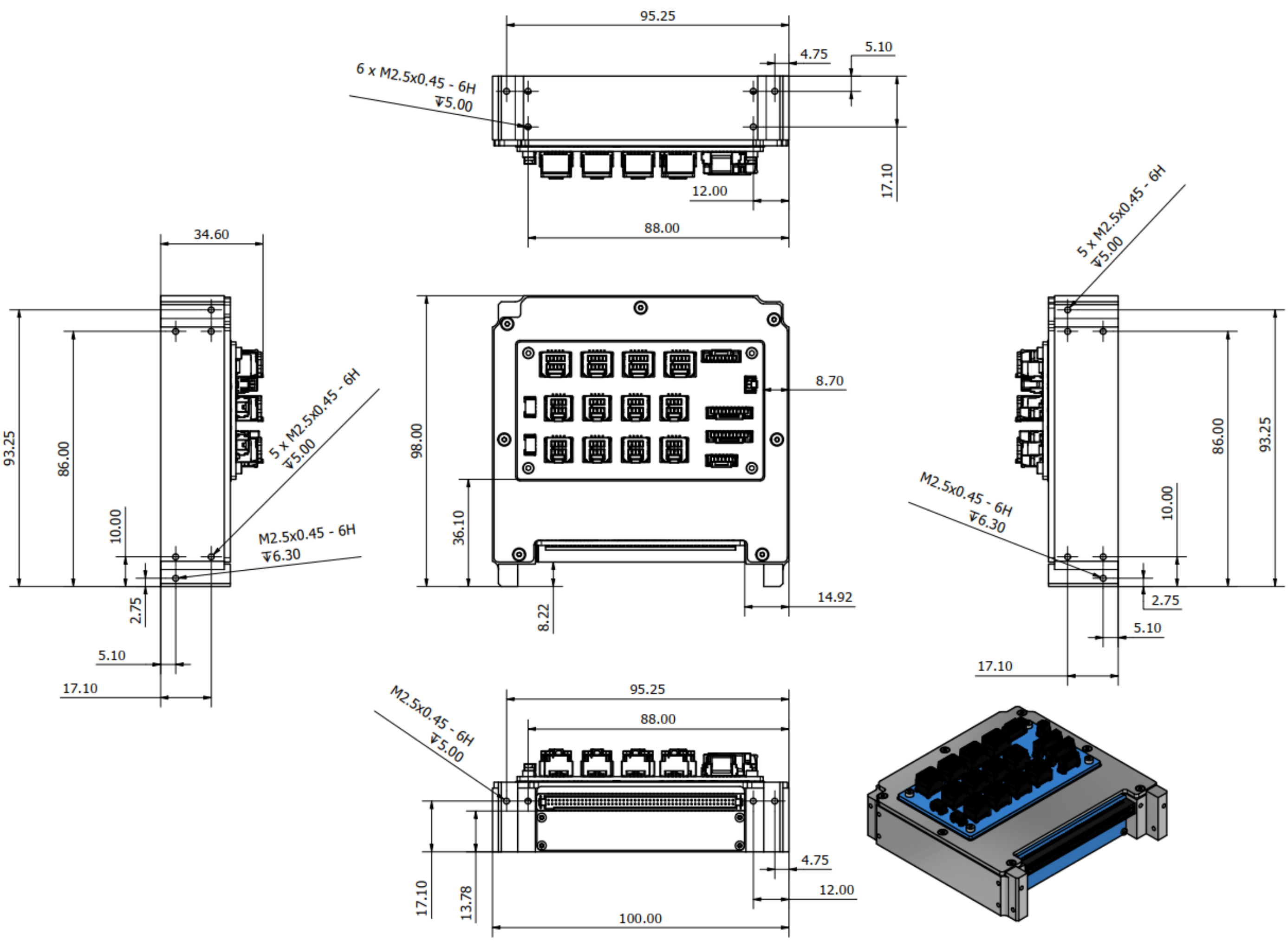

Figure 44: Indicative Dimensions of the Backplane CubeADCS Core

See Section 9 for dimensions of the Backplane variant CubeADCS Core with the V_{Bat} Bypass board as discussed in Section 2.5.

4.4.2 Mounting Definition

The Backplane CubeADCS Core is mounted in place utilising up to 22 x M2.5 mounting screws, the positions of which is indicated in Figure 44. The screw holes for these have a depth as indicated in Figure 44. It will be the client's responsibility to secure the CubeADCS in its final position.

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4.4.3 Mass, CoM and Inertia

Table 35: Mass Details

Variant/Model	Mass	Notes
Backplane variant of CubeADCS	260 g	Does not include any sensors, actuators, or harnessing

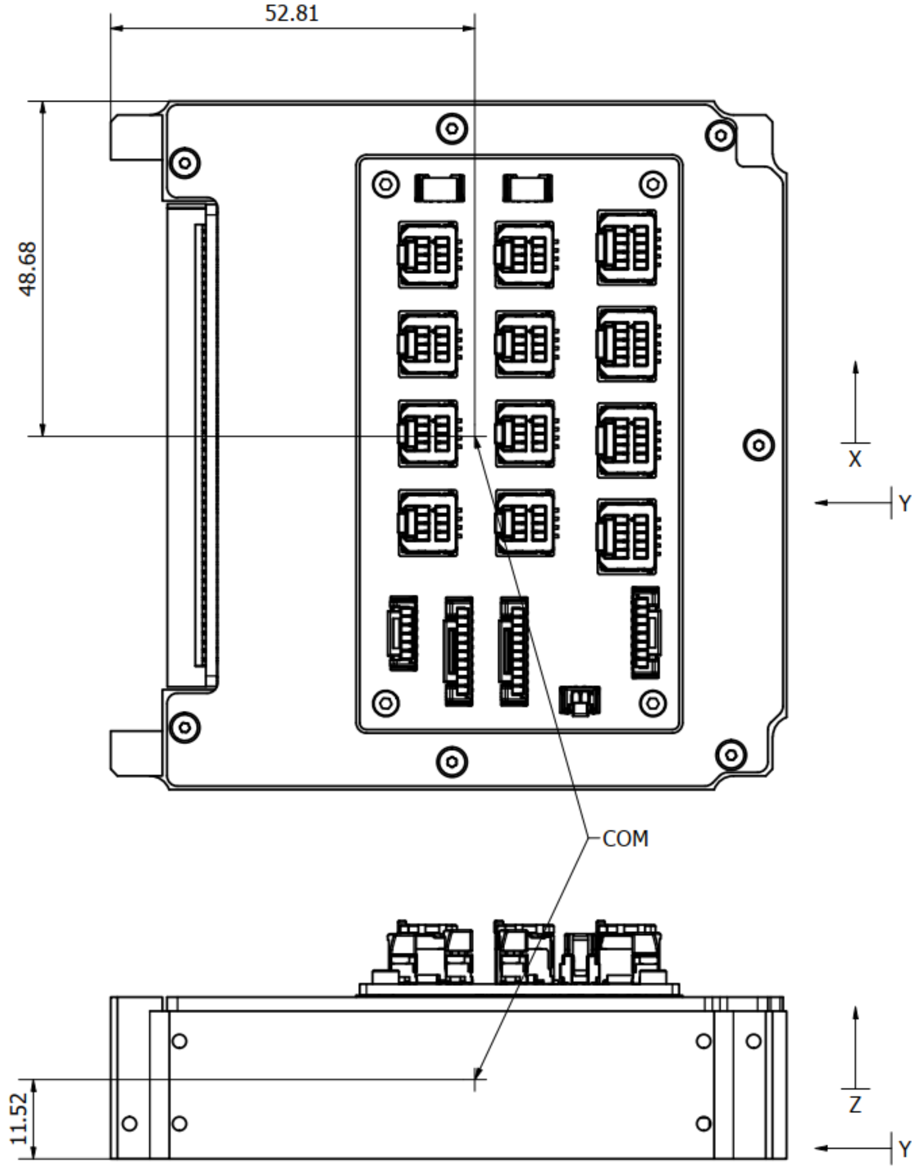

Figure 45: CoM Position of the Backplane CubeADCS Core

The moments of inertia of the Backplane variant of CubeADCS about its CoM are presented in Table 36, using the coordinate system definition shown in Figure 45. The indicated coordinate system is used by the CubeComputer's Main and Redundant IMUs.

Table 36: Moments of Inertia of the Backplane CubeADCS Core

Axis	Value [gmm²]
I_{xx}	154203 ± 15 %
I_{yy}	157328 ± 15 %
I_{zz}	280716 ± 15 %

4.5 Coarse Sun Sensors

The Coarse Sun Sensors (CSS) should be mounted on the external surfaces of the satellite panels. It is necessary to ensure that these sensors are not shadowed by other deployable structures. Up to ten Coarse Sun Sensors can be supplied by CubeSpace. Placement of the sensors is at the client's discretion, typically one sensor must be placed on each of the six external surfaces of the satellite. The four extra photodiodes can be placed on any faces, bearing in mind that shadowing is to be minimised.

Ensure that the photodiodes are kept clear of epoxy or glue.

If solar panels already have photodiodes mounted on them, contact the CubeSpace team to discuss the possibility of pairing them with the CubeADCS. CubeSpace makes use of the SLCD-61N8 planar photodiodes from "Silonex inc."/"Advanced Photonix". Any photodiodes with the same specifications should work with the CubeADCS.

4.5.1 Outer Dimensions

Indicative dimensions of a Coarse Sun Sensor without a harness are shown in Figure 46.

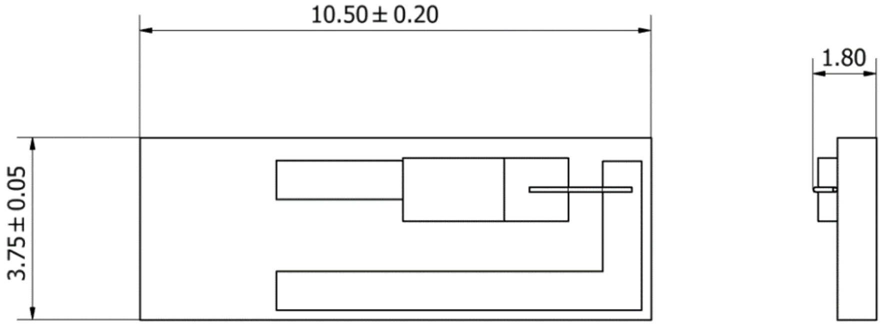

Figure 46: Indicative Dimensions of a Coarse Sun Sensor

4.5.2 Mounting Definition

The CSSs do not have mounting holes – they should be attached to the satellite body using epoxy as shown in Figure 47.

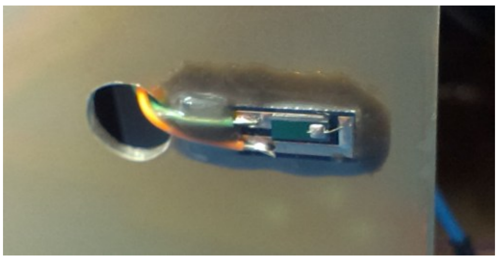

Figure 47: Coarse Sun Sensor Epoxied to Satellite Body

4.5.3 Mass, COM and Inertia

The mass of a CSS is considered negligible.

4.5.4 Electrical Interface

The CSS are provided with harnesses which contains in line 2-pin Molex PicoBlade headers. The length of the standard harness is 50 mm.

Figure 48: Single Coarse Sun Sensor PCB and Wire Harness

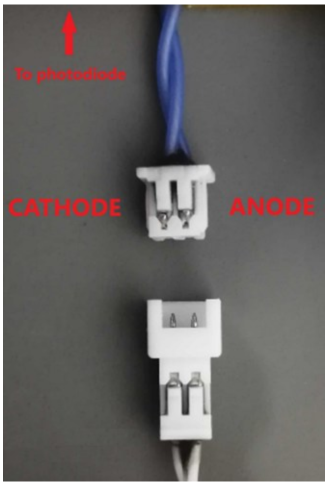

Figure 49: Coarse Sun Sensor In-line Harness Pins

Table 37: Course Sun Sensor Header Part Details

Part	Description	Part Number
Header	Molex PicoBlade	510210200
Mating Housing	Molex PicoBlade Male Connector Housing	510470200
Housing Terminal	Molex PicoBlade Male Crimp Terminal	501258000

Table 38: Actuator Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	GND	Anode	Input	0
2	V_{out}	Cathode	Output	0 to -3.4

5. Environmental Interface

For Handling and Storage conditions, and Operating and Non-Operating temperature limits, refer to [RD16].

6. Software Interface

Each CubeProduct is accompanied by a user manual [RD3] that provides detail regarding simple telemetry exchanges using ground support equipment. For further information regarding software interfacing and control, please refer to the firmware reference manual [RD12].

7. Timing, synchronization, and location data

The CubeADCS CubeComputer has a real-time clock (RTC) which is used to keep track of the current time. There are two methods with which the time of the CubeADCS can be synchronised:

1. The OBC can set the current RTC time via telecommand
2. A compatible GNSS receiver of which the UART output is routed to the CubeComputer can supply current time as output message (using one of the supported protocols). Please refer to Section 3.2.2.

In both cases it is also possible to perform fine time synchronization using a Pulse Per Second (PPS) signal. Such a signal would typically originate from a GNSS receiver. Where a PPS signal is present, time can be synchronized to within 1ms accuracy.

For missions with tight pointing requirements, precise location data is required. Where GNSS reception is not always available, the algorithms running on the CubeADCS CubeComputer offers the option of using an SGP4 or ASGP4 propagator, which uses a combination of Two-Line Elements (TLEs) and GNSS data. Location propagation does not require constant GNSS updating, but the frequency of the updates will impact accuracy.

Table 39: Location Propagation Accuracy

Propagation Method	Accuracy	Notes
SGP4	1km	Requires TLEs to be updated at least once per orbit
ASGP4	100m	Requires TLEs to be updated at least once per orbit Will decay towards 1000m if not updated frequently
GNSS data	10m	Must be updated at 1 Hz

8. EMI / EMC

8.1 Potential RF Emitter List

Table 40: Potential Emitters

Component	Type	Frequency / Bit Rate	Frequency Stability (ppm)
5V SMPS	PWM	1.1 MHz	± 1 %
3V3 SMPS	PWM	1.1 MHz	± 1 %
MCU	Crystal	24 MHz	± 50
MCU RTC	Crystal	32.768 kHz	± 10
MCU PLL and peripherals	PLL	48 MHz	± 50
OBC CAN	CAN	1 Mb/s	± 50
OBC CAN (Controller)	SPI	6 MHz	± 50
OBC CAN (Controller Clock)	Crystal	20 MHz	± 50
OBC UART	UART	921600 baud	± 1 %
OBC RS422 / RS485	UART	921600 baud	± 1 %
OBC I^2C	I^2C	100 kb/s	± 1 %
GNSS UART	UART	115200 baud	± 1 %
FRAM	SPI	12 MHz	± 50
MCU-FPGA	Parallel	4 Mb/s	± 50
NAND Flash	QSPI	4.8 MHz	± 50
Redundant IMU	I^2C	100 kb/s	± 1 %
ADC, Main IMU	SPI	1.5 MHz	± 50

8.2 EMI / EMC Cleanliness

8.2.1 Grounding

The enclosure and mechanical parts of CubeADCS are connected to the power and signal ground through a filter designed to minimise EMI, as illustrated by Figure 50. The user can ground the enclosures of the CubeADCS Core and the sensor and actuator nodes if desired.

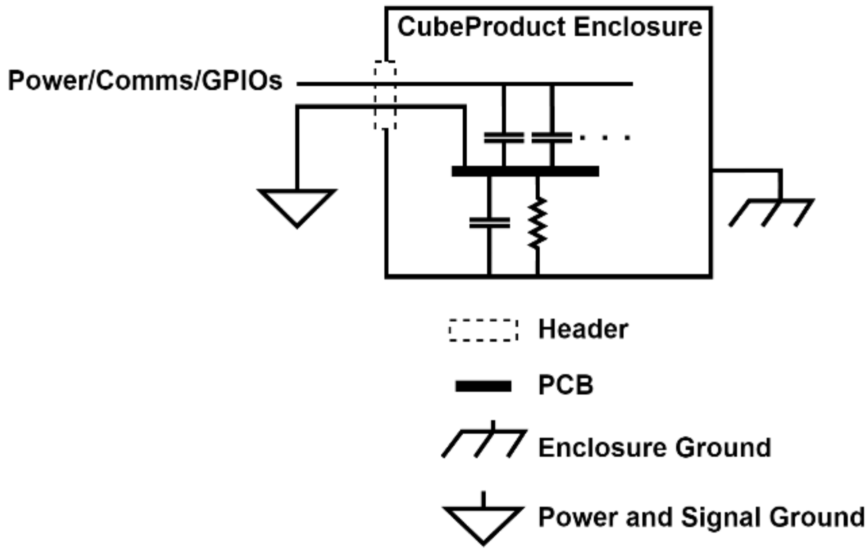

Figure 50: Generic Grounding Diagram

The enclosure's RC filter design consists of a high value resistor in parallel with a low ESL capacitor. This dissipates high frequency noise to ground and also conducts static buildup away from the enclosure. The commonly used alternative method where the enclosures are directly connected to the ground introduces the risk that shorts may occur during satellite integration.

In some cases a customer might require the enclosures of the various CubeProducts to be completely isolated from the system ground by removing the EMI filters completely. In such a case, it should be specified as a custom option using [RD2] during order placement.

8.2.2 Shielding

Shielding of CubeADCS electronics is accomplished by the mechanical enclosure as a Faraday cage. The enclosure makes contact to the chassis ground trace on each PCB. This chassis trace is connected to the PCB power and signal ground through the filter discussed in section 8.2.1.

8.2.3 Filtering and Suppression

The following noise filtering strategies are implemented on CubeADCS:

- All pins that are externally exposed through headers are filtered by way of a 100pF decoupling capacitor to signal ground as shown in Figure 50.
- Further passive RC filtering of the communication interfaces from the OBC is discussed in Table 6.
- LC filtering is implemented on the 5 V and 3.3 V power supply pins of the CubeConnect board, for powering external sensor and actuator products (see Table 15 and Table 17).
- Minimal RC and common-mode current filtering is implemented on both the CubeADCS-OBC CAN interface, and the CubeADCS's internal CAN interface to external sensor and actuator products (see Table 15 and Table 17) to minimize spurious frequencies above 1 MHz.
- The Boot- and Enable lines from CubeADCS to external sensor and actuator products (see Table 15 and Table 17) employ LC filtering on the CubeConnect PCB.
- A pre-filter is in place for the satellite battery supply to CubeADCS. This ensures that noise on this power rail will be minimized before entering CubeADCS and will also minimize noise (generated by CubeADCS) emitted onto the power rail.

9. Appendix A: Details of the V_{Bat} Bypass CubeDoor PCB

This appendix contains specifics regarding the V_{Bat} Bypass solution discussed in Section 2.5.

The dimensions given in this appendix are indicative only. The mechanical CAD files with the latest dimensions are supplied to customers and must be used for final design and fitment verification.

9.1 Dimensions of CubeADCS Core PC104 with the Top-Mount V_{Bat} Bypass CubeDoor

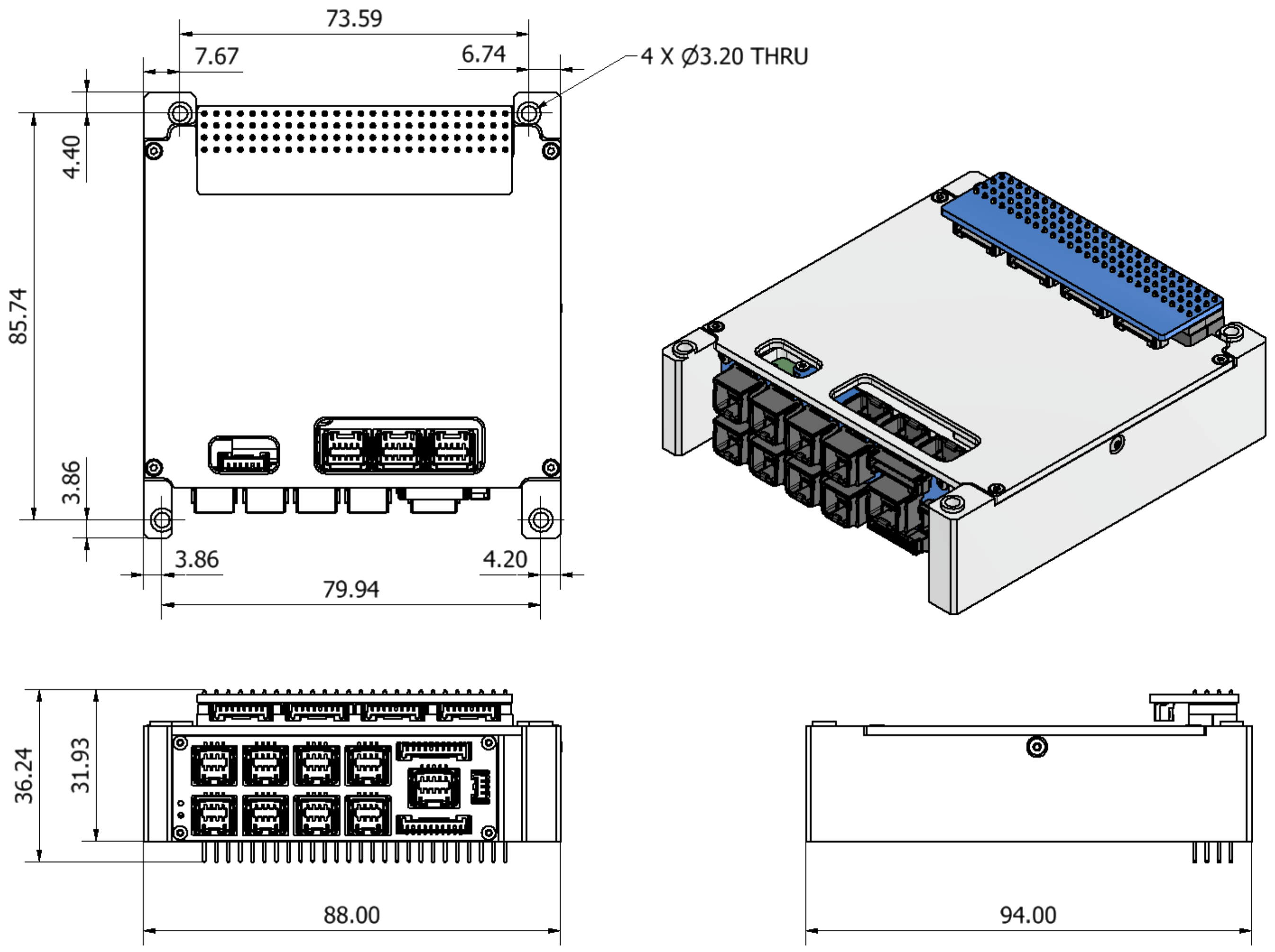

Figure 51: Indicative Dimensions of CubeADCS Core PC104 with the Top-Mount V_{Bat} Bypass CubeDoor PCB

9.2 Dimensions of CubeADCS Core PC104 with the Bottom-Mount V_{Bat} Bypass CubeDoor

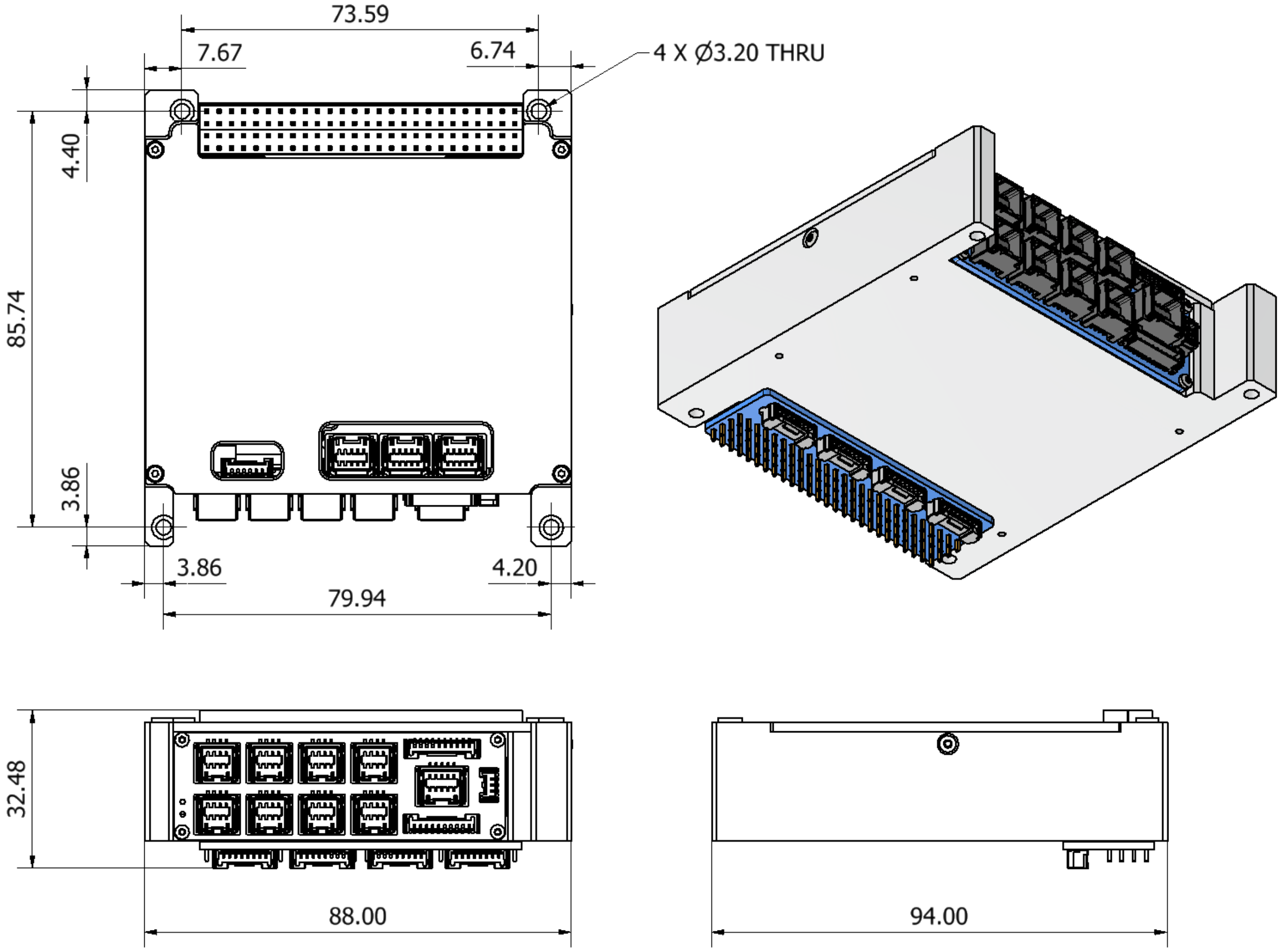

Figure 52: Indicative Dimensions of CubeADCS Core PC104 with the Bottom-Mount V_{Bat} Bypass CubeDoor PCB

9.3 Dimensions of CubeADCS Core PC104 with the Midstack-Mount V_{Bat} Bypass CubeDoor with Upward-facing Headers

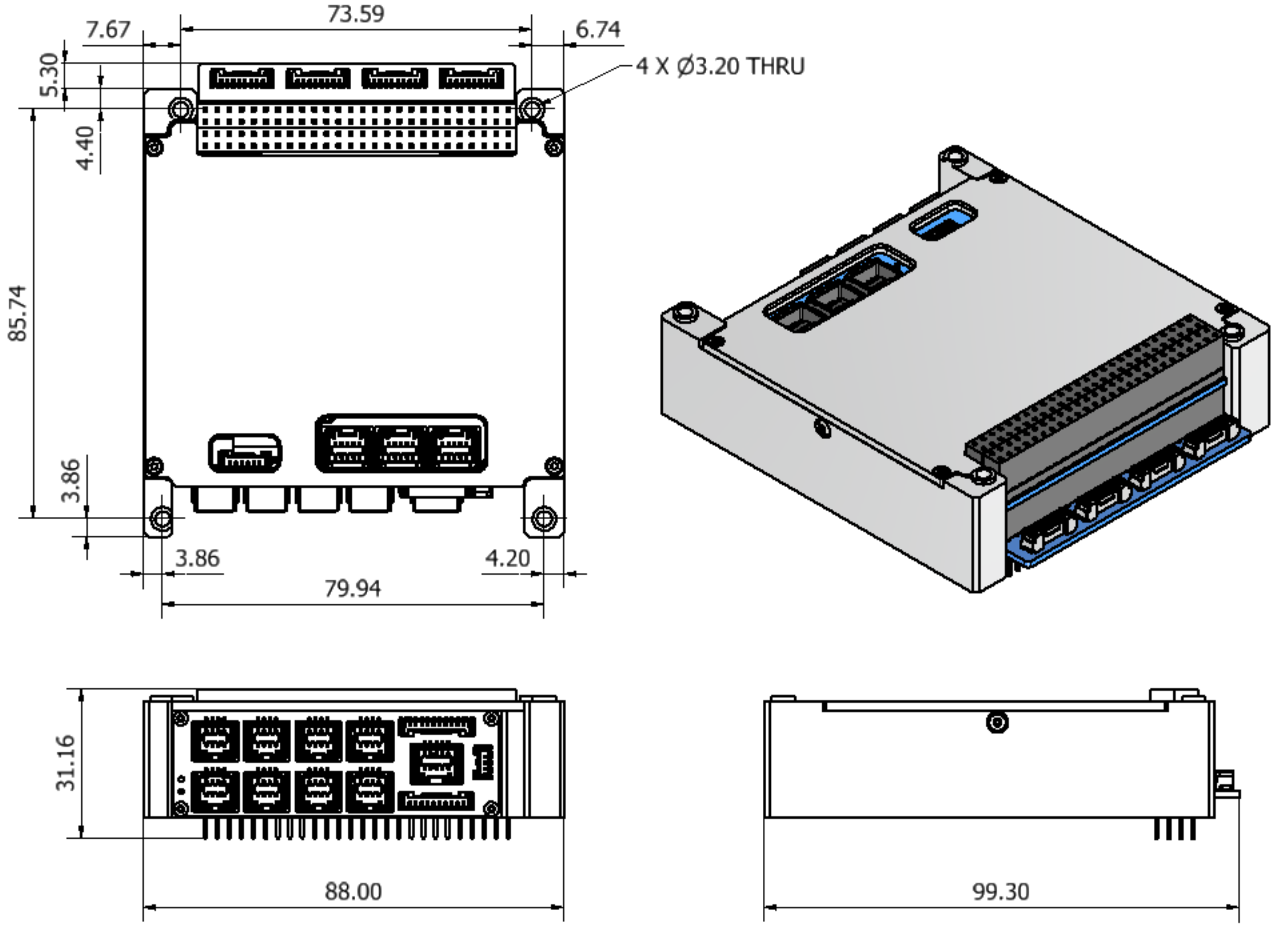

Figure 53: Indicative Dimensions of CubeADCS Core PC104 with the Midstack-Mount V_{Bat} Bypass CubeDoor PCB with Upward-facing Headers

9.4 Dimensions of CubeADCS Core PC104 with the Midstack-Mount V_{Bat} Bypass CubeDoor with Downward-facing Headers

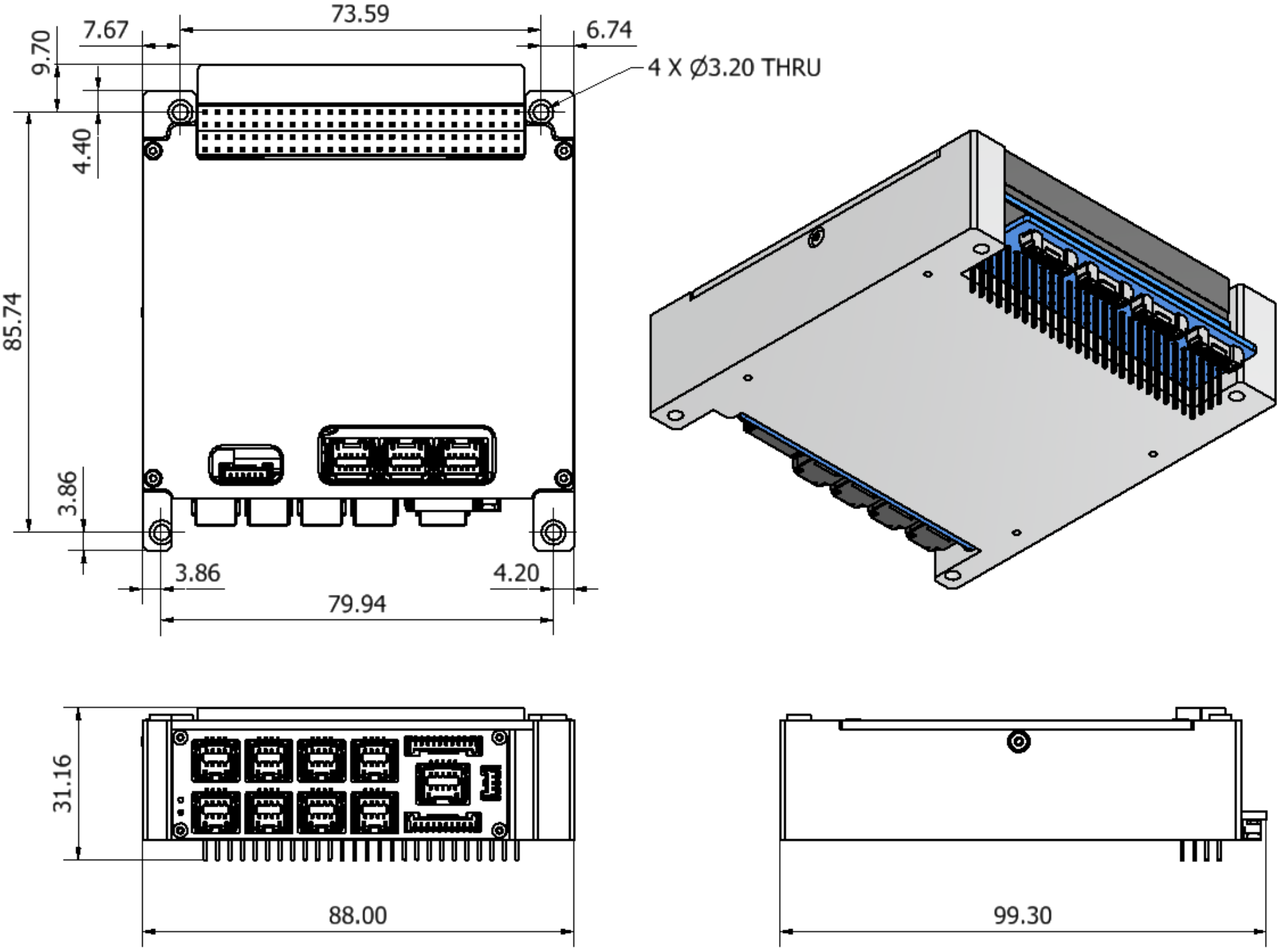

Figure 54: Indicative Dimensions of CubeADCS Core PC104 with the Midstack-Mount V_{Bat} Bypass CubeDoor PCB with Downward-facing Headers

9.5 Dimensions of CubeADCS Core Backplane with the V_{Bat} Bypass CubeDoor

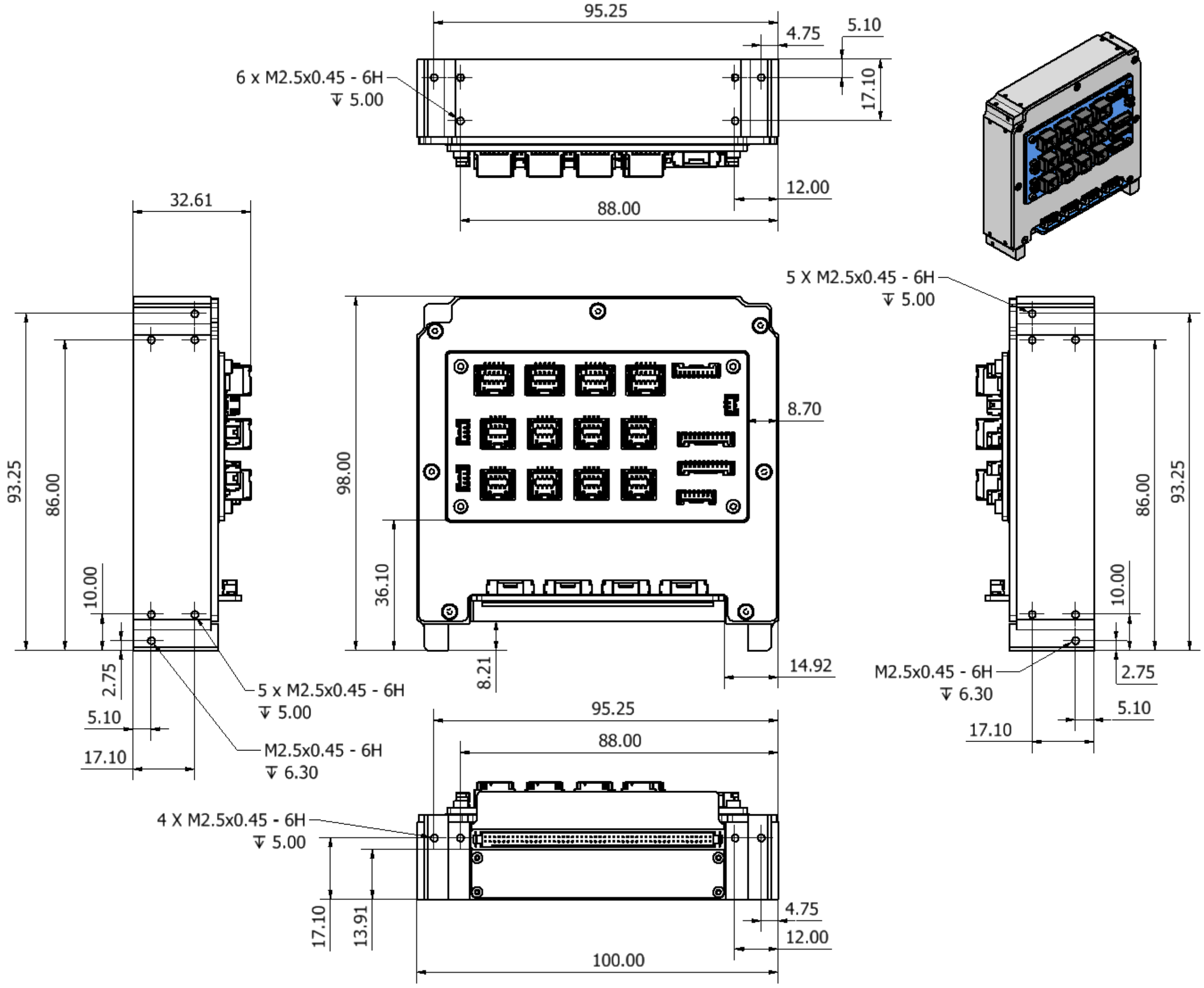

Figure 55: Indicative Dimensions of CubeADCS Core Backplane with the V_{Bat} Bypass CubeDoor PCB

9.6 Header and Pinout Description for All V_{Bat} Bypass CubeDoor PCB Variants

The following figures present header details for the different V_{Bat} Bypass board variants, with Pin 1 of each header indicated. Although the headers are labelled for Reaction Wheel 1-4, any reaction wheel can be plugged into any header, as is most convenient to the user. The header part and pinout details for all variants are provided in

See all warnings and notes in Sections 3.7.1 and 3.7.5 to ensure minimum and maximum voltage levels are adhered to. Systems making use of CubeWheels connected to CubeADCS, have certain maximum V_{Bat} voltage levels that must not be exceeded.

Table 41 and Table 42 below.

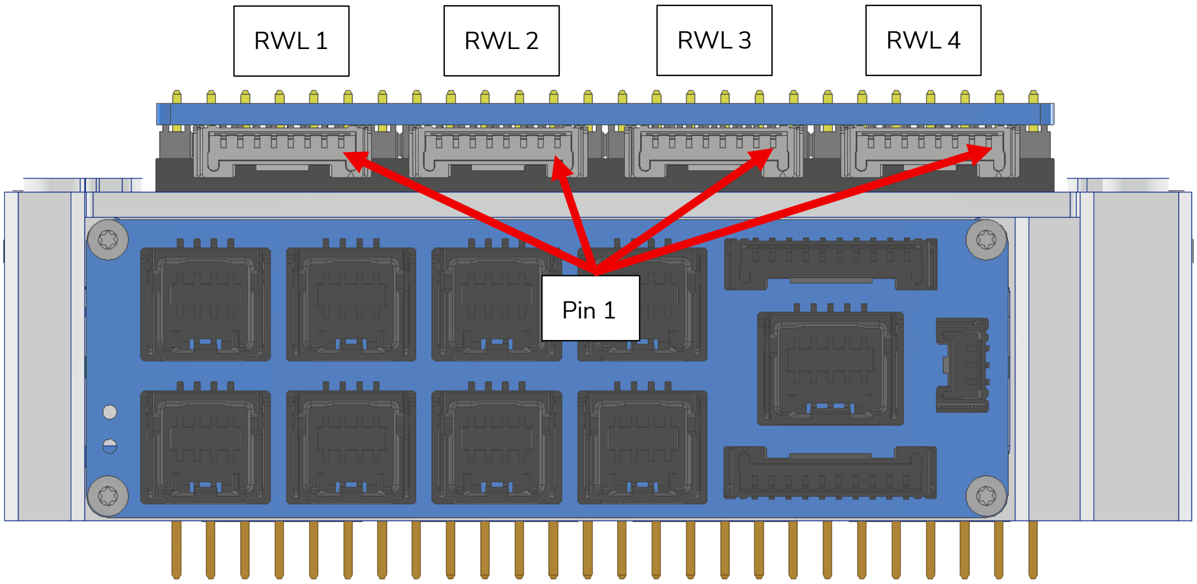

Figure 56: V_{Bat} Bypass PCB, Reaction Wheel Headers (PC104, Top-Mount Variant)

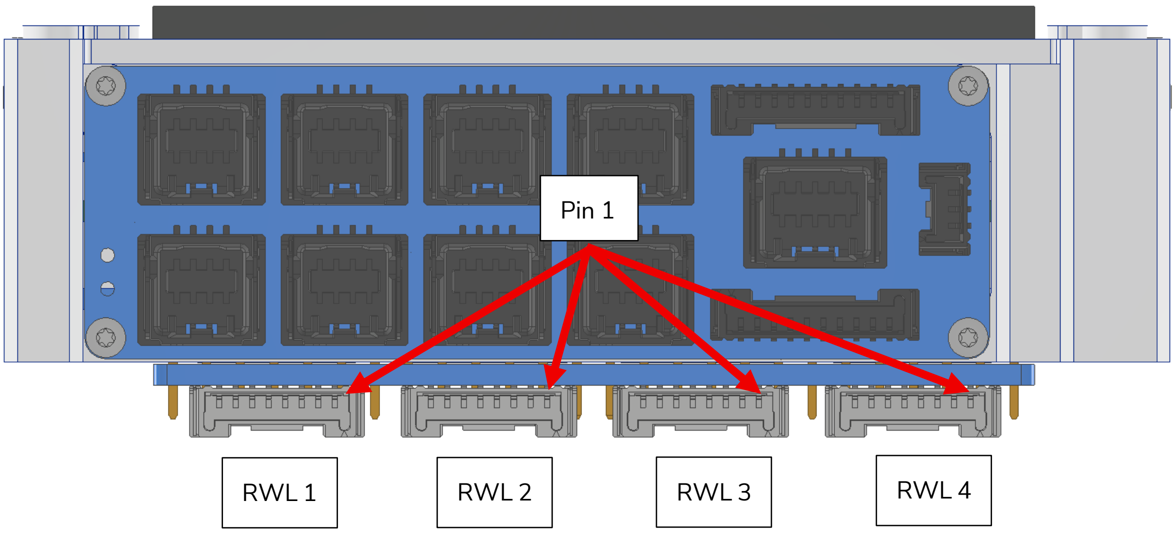

Figure 57: V_{Bat} Bypass PCB, Reaction Wheel Headers (PC104, Bottom-Mount Variant)

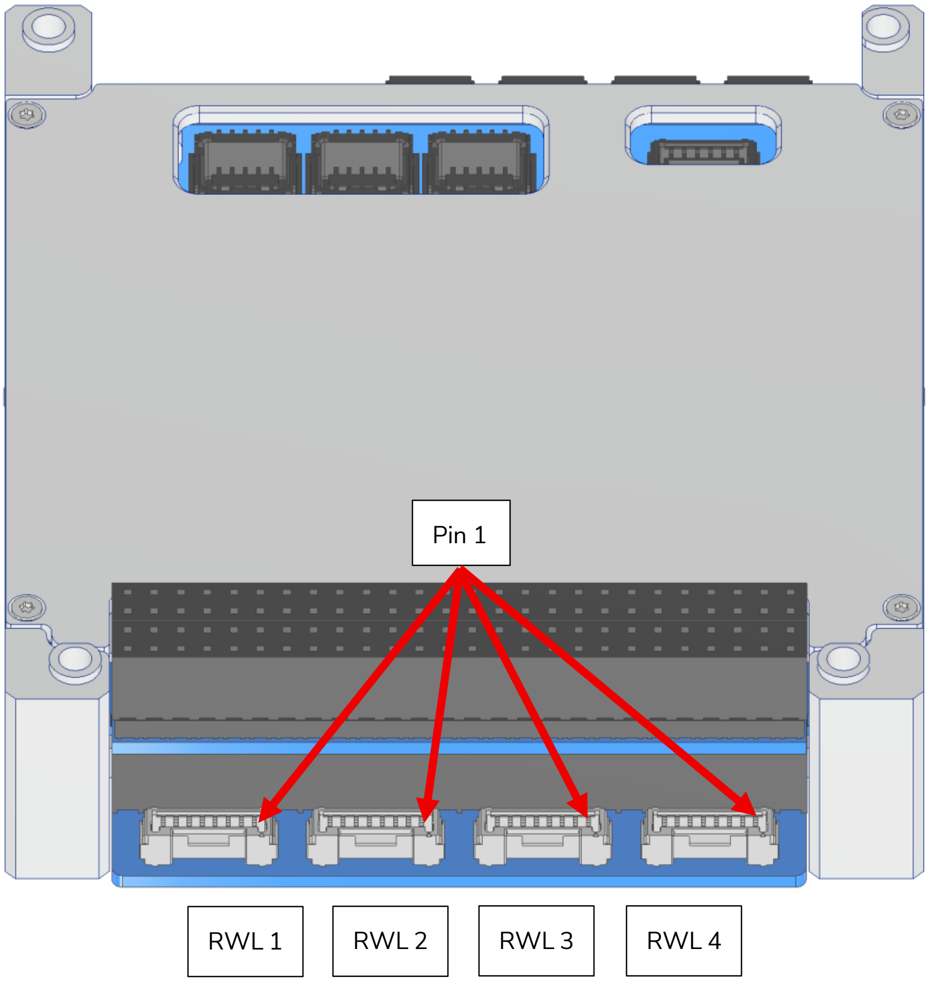

Figure 58: V_{Bat} Bypass PCB, Reaction Wheel Headers (PC104, Midstack-Mount Upward-Facing Headers Variant) – Top View

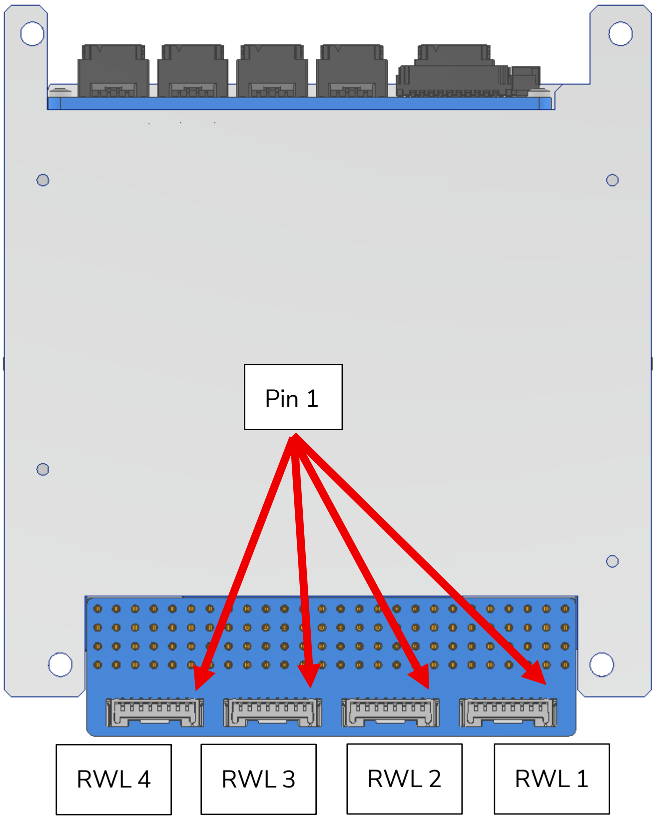

Figure 59: V_{Bat} Bypass PCB, Reaction Wheel Headers (PC104, Midstack-Mount Downward-Facing Headers Variant) – Bottom View

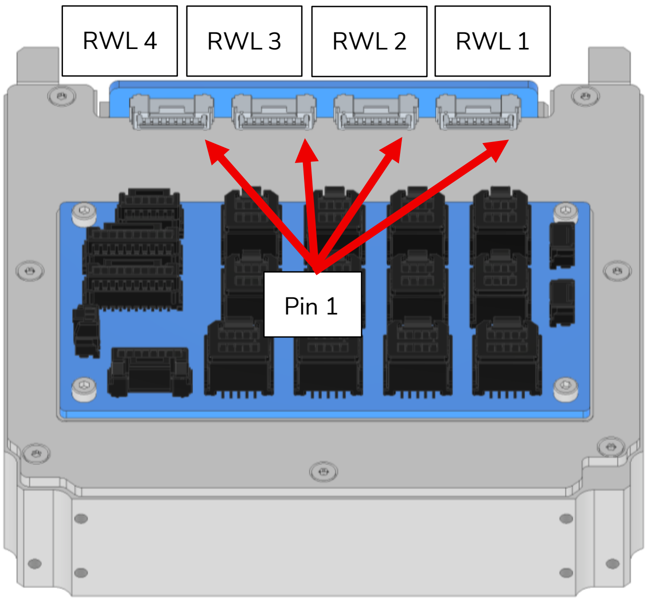

Figure 60: V_{Bat} Bypass PCB, Reaction Wheel Headers (Backplane Variant)

See all warnings and notes in Sections 3.7.1 and 3.7.5 to ensure minimum and maximum voltage levels are adhered to. Systems making use of CubeWheels connected to CubeADCS, have certain maximum V_{Bat} voltage levels that must not be exceeded.

Table 41: V_{Bat} Bypass PCB Header Part Details

Part	Description	Part Number
Header	Molex Micro-Lock Plus	5055670881 (PC104 Top- or Bottom-Mounted) 5055680871 (Backplane or PC104 Midstack-Mounted)
Mating Housing	Molex Micro-Lock Plus Receptacle Crimp Housing	5055650801
Housing Terminal	Molex Micro-Lock Female Crimp Terminal	5054311100

Table 42: V_{Bat} Bypass PCB Header Pinout and Electrical Characteristics

Pin #	Pin Name	Pin Description	IO Type	Voltage Range [V]
1	GND	Power and signal ground	Power	0
2	GND	Power and signal ground	Power	0
3	GND	Power and signal ground	Power	0
4	GND	Power and signal ground	Power	0
5	GND	Power and signal ground	Power	0
6	GND	Power and signal ground	Power	0
7	V_{Bat}	Supply voltage output	Power	V_{Bat}
8	V_{Bat}	Supply voltage output	Power	V_{Bat}

9.7 Reaction Wheel Harnesses for V_{Bat} Bypass CubeDoor Variants

For CubeADCS solutions using the V_{Bat} Bypass CubeDoor variants, each reaction wheel harness has two connections to CubeADCS Core. The high-power V_{Bat} and GND connector goes to the V_{Bat} Bypass CubeDoor connector, and the other connector which services all other logic and control signals, connects to the standard CubeConnect header as usual. The two connectors are different from one another and cannot be plugged into the wrong header.

The photographs below demonstrate how reaction wheels CW0500 (and larger) are plugged into a PC104 (Figure 61) and Backplane (Figure 62) CubeADCS Core with the V_{Bat} Bypass CubeDoor PCB. The same connection principle applies for Bottom-Mount and Midstack-Mount variants, although not specifically shown.

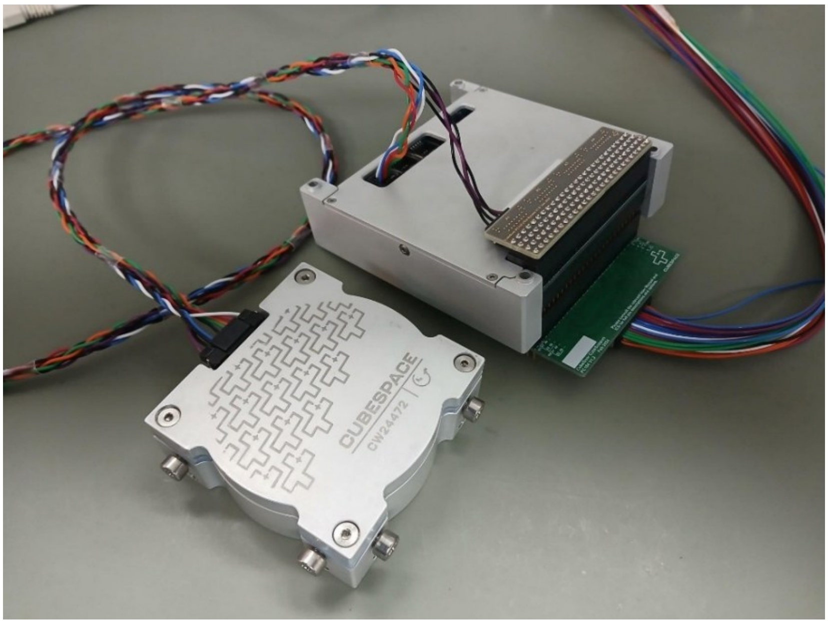

Figure 61: Single CW0500 reaction wheel plugged into CubeADCS Core PC104 with a Top-Mount V_{Bat} Bypass CubeDoor PCB

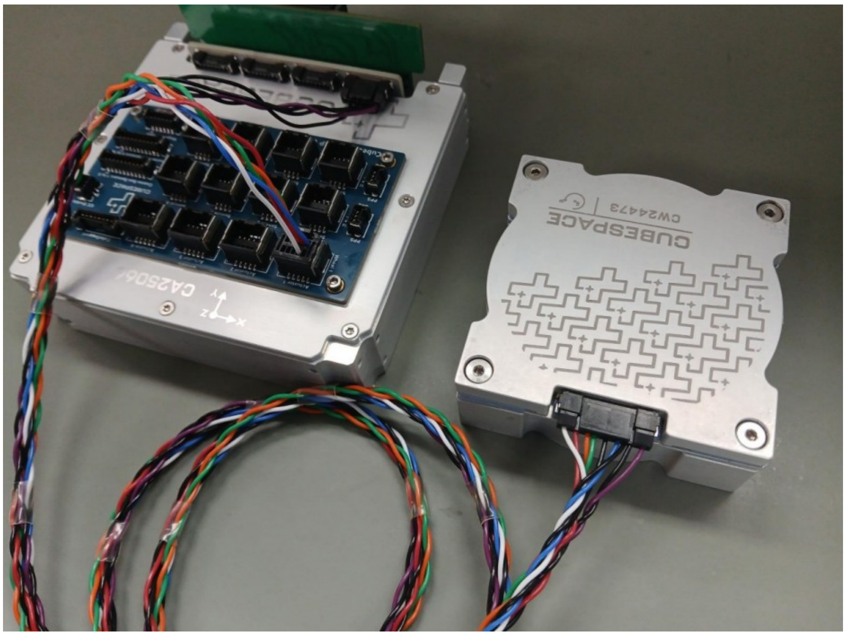

Figure 62: Single CW0500 reaction wheel plugged into CubeADCS Core Backplane with a V_{Bat} Bypass CubeDoor PCB

10. Appendix B: Fastener Torque Specifications

When integrating CubeSpace products into a satellite structure, the following fastener torque levels are recommended.

Table 43: Recommended Torque Specifications for Various Size Fasteners

Bolt Size	Tightening Torque: Into Bare Aluminium (6082-T6)		Tightening Torque: Using Helicoil Inserts	
	Nm	cN.m	Nm	cN.m
M1.4	0.089	9	-	-
M1.6	0.13	13	0.14	14
M2	0.26	26	0.37	37
M2.5	0.51	51	0.76	76
M3	0.87	87	1.36	136
M4	2.07	207	3.16	316
M5	4.05	405	6.39	639
M6	7.00	700	10.85	1085

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