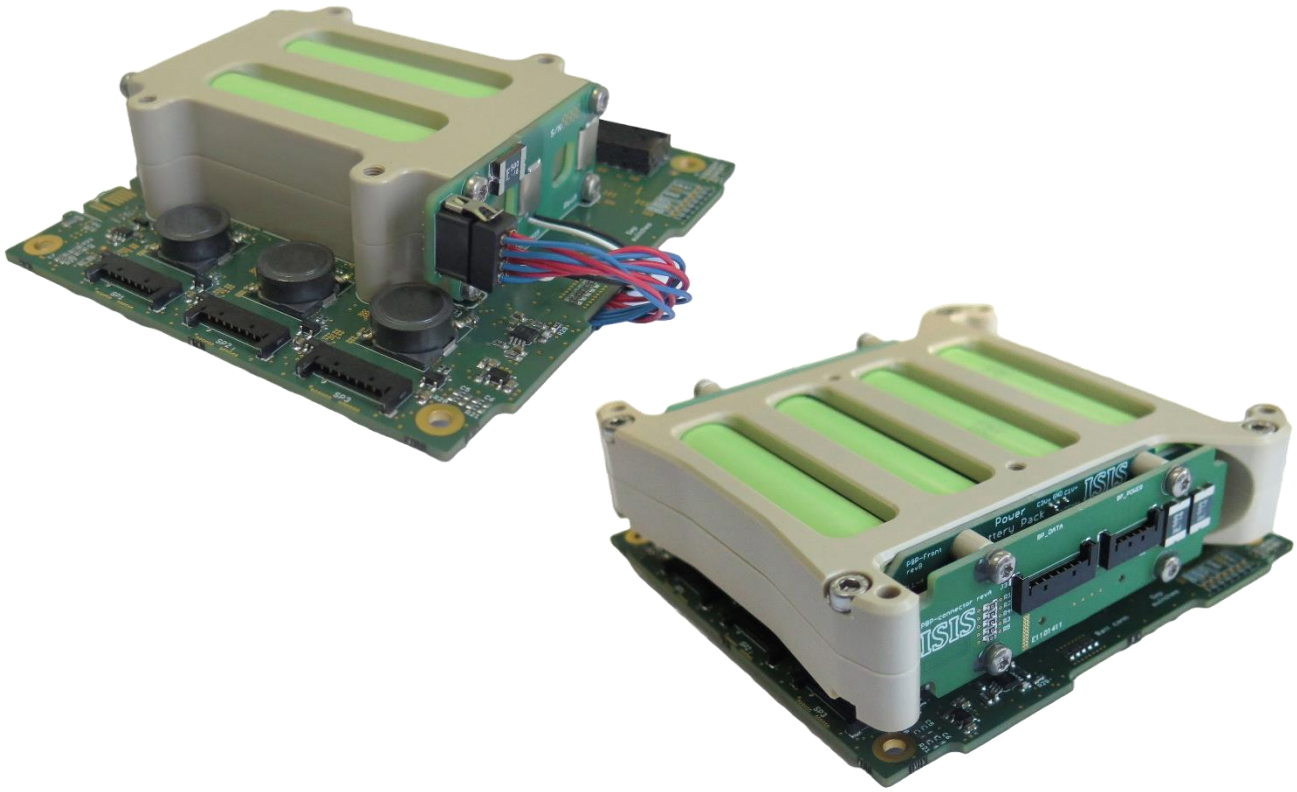

ISISPACE Compact EPS 2

ICEPS2 Datasheet

ISIS-ICEPS2-DSH-0001, Version 1.2, Released 2024-07-26

Compact Electrical Power System suitable for up to 3U XL CubeSat missions.

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Applications

The ICEPS2 is a compact power solution, which follows a PC104 form factor, tailored for 1U-3U sized platforms and LEO missions. Available in three configurations, which can supply from 28.2Wh to 57.6Wh.

General Description

The ISISPACE Compact Electrical Power System 2 (ICEPS2) is the second-generation compact power system for nanosatellites. It is an off-the-shelf Electrical Power System (EPS) available in three standard configurations (Type A/B/C), ideal for powering 1U – 3U CubeSats. ICEPS2 can interface with and regulate solar panel and battery power, providing stable power to the payload. Equipped with an integrated autonomous battery heater, hardware-based Maximum Power Point Tracking (MPPT), it boasts up to 5 solar panel arrays and 6 output voltage domains, including 3.3V and 5V regulated buses, as well as an unregulated bus.

Optional Features

- Battery configurations:
  - 2S1P (2 series) Power Battery Pack (PBP): 7.2V and 4A or 28.8Wh
  - 4S1P (4 series) Power Battery Pack (PBP): 14.4V and 4A or 57.6Wh
- Customisable output voltage of output channels
  through mountable add-on DaughterBoard.
  - including boost voltage levels
- Cells can be certified to meet requirements for use from the ISS, MOQ applies.

Key Product Features

Battery and Solar Panel Interface

- 3 independent MPPT controller with possible extension to 5, if needed
- 3 output Rails (including regulated 3.3V, 5V and unregulated battery voltage) with possible extension to 6, if needed
- Battery charge and discharge protection
- Automatic integrated battery heater and thermostat control
- Low side and high side inhibit switches for possible fully redundant separation switch configuration

Software Interface

- MCU independent housekeeping Telemetry of battery
- FRAM-based MCUs for improved radiation tolerance
- Low-power MCUs for control and Telemetry (TLM)
- I2C Watchdog (stack reset on comms failure)
- GaN-FETs implemented for improved power conversion efficiency and performance
- Complete output bus protection including short circuit and backflow protection

Flight heritage and quality assurance

- Design based on heritage from ICEPS1 design flown on PEASSS CubeSat (2016).
- ICEPS2, second generation, flown on the Hiber 1,2 CubeSats (2018)
- Qualification Thermal Testing, -40 to +80 ºC
- Design qualification load Static +10.8 [g], three axes
- Sine and Random Vibration ASAP5 Qualification Levels
- IPC-A-610 Class 3 PCB, flight units thermally acceptance tested
- PBP-4S1P has deployment heritage from ISS.
- Contact ISISPACE if you are in need of more detailed heritage information.

Related Products

The ICEPS2 belongs to the ISISPACE EPS family of products, including IMEPS2 and IMEPS3 for larger missions. Other related products are listed below:

- **IMEPS2** – Modular EPS for 3U-12U Platforms
- **IMEPS3** – High-Power Modular EPS for CubeSats above 12U, and MicroSats.
- **EPS EGSE** – EGSE for Interfacing with ISISPACE EPS units
- **ISPA** – ISISPACE Solar Panels

Ordering information

- STEP Files available on Website.
- ICDs can be shared on request.
- User Manuals are shared upon purchase.
- EGSE and Stack Frames sold separately.
- Please contact sales@isispace.nl for ordering information.

Disclaimer

The contents of this document are subject to the relevant provisions in the contract concluded between the parties. ISISPACE Group (“ISISPACE”) shall not be liable, in full or in part, for any damage arising out from the application or use of any product or circuit described herein, in case such application or use are carried out in a manner not in line with the instructions and warranties provided in the User Manual, Safety Manual, product information sheets or any other document provided by ISISPACE upon the delivery of the product (“Documents”). Further, ISISPACE shall not be liable for any damage caused by any use which exceeds the function(s) of the product, or does not conform to such function(s) as described in the Documents. ISISPACE shall not be liable for any damage arising from a use which is not carried out in a manner conforming to acceptable practices in the aerospace industry.

ISISPACE warrants that the product is supplied after relevant tests had shown the product is in good order and functioning, as far as these tests may indicate and predict product functionality.

System Description

The ICEPS2 hardware is divided in three distinct Sub-Systems:

1. Power Battery pack ***(PBP)***: Either a two-cell (PBP-2S1P) or a four-cell (PBP-4S1P) battery pack
2. Power Integrated Unit mainboard ***(PIU)***
3. Power Integrated Unit DaughterBoard ***(PIU-DB)***

The electronics on the different PIU and PIU-DB boards can be separated in three types:

1. ***Power Conditioning Unit (PCU***): This includes all electronics interfacing with the solar panels. The electronics are divided over the PIU and PIU-DB.
2. ***Power Battery Unit (PBU)***: This includes all electronics interfacing with the battery pack and is located solely on the PIU board.
3. ***Power Distribution Unit (PDU)***: This includes all electronics interfacing with the satellite and microcontroller. The electronics are divided over the PIU and PIU-DB.

Complete Power System Overview

The diagram below illustrates a complete ICEPS2 implementation within a reference satellite system.

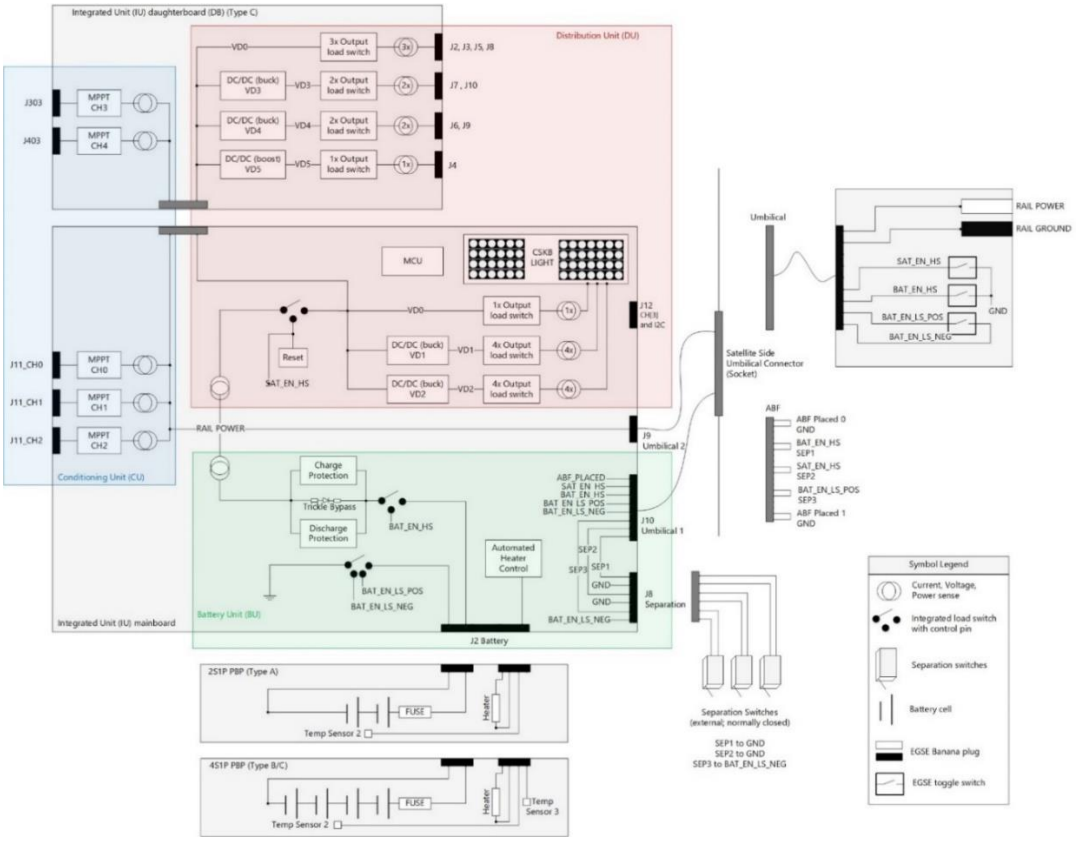


Figure 1 ICEPS2 General block diagram

Power Battery Unit

The PBU allows connecting a battery pack to the internal voltage RAIL. The functionality of the battery unit consists of:

- Back-to-back (B2B) protection MOSFETs inhibit if the battery is attached to the RAIL
- Optional third low side separation switch places single MOSFET on the low side to block discharge return currents into the battery when actively inhibited.
- Charge load switch for charge current limiting, with under and overvoltage lockout
- Trickle charge bypass diode to resuscitate batteries that have dropped to voltages below the charge undervoltage lockout threshold
- Battery pack heater load switch that attaches to and enables the battery pack heater.
- Voltage, current and power sensing of input and output Rail
- If the low side switch is present (three separation switches), independent high and low side inhibit enable control. A special circuit mechanism introduces a dependency that only allows the high side to connect once the low side is connected. This ensures a proper ground connection is available before the high side connects. It also protects the non-B2B low side switch from charge currents.
- If the options for three separation switches are selected: a Remove Before Flight (RBF) circuit allows overriding the inhibit control, fixing it in inhibited state
- Discharge load switch for active discharge current limiting
- Surge protection using TVS protection diodes

The PIU microcontroller collects housekeeping (HK) telemetry (TLM) and controls the battery heating. The battery unit electronics, other than the heater load switch, is fully autonomous and does not depend on a functioning microcontroller.

Power Conditioning Unit

The PCU provides three channels, each consisting of a maximum power point tracker (MPPT) that takes power from attached solar panels and regulates that to a fixed voltage on the shared output RAIL. The DaughterBoard provides two additional channels. The MPPT on each channel ensures maximum power is extracted from the panels under varying illumination and temperature conditions. The conditioning unit regulates to a fixed voltage on its output that is equal to the maximum battery voltage level.

The functionality of a MPPT channel consists of:

- a boost regulator with true maximum power point tracking using the perturb and observe algorithm.
- voltage, current and power sensing on MPPT input and output.
- an output ideal diode protecting against current backflow from the RAIL.

The MPPT channel electronics are fully autonomous and do not depend on a functioning MCU. This autonomy improves reliability through the redundancy provided by the parallel MPPT channels. During eclipse (no power on MPPT inputs), the conditioning units will be deactivated, limiting power drain on the battery powered platform. In this case, there will also be no MPPT telemetry available.

Power Distribution Unit

The PDU distributes power, taken from RAIL_PWR and splits that into several output bus channels. There are several output channels that provide buck regulated voltages. Apart from the regulated channels, there is also one channel that passes RAIL voltage directly. Additional channels (including unregulated and boost voltage) are available on the DaughterBoard. All channels have load switches, which are controlled by the PIU microcontroller.

DaughterBoard

The PIU DaughterBoard offers:

- Two additional solar MPPT chains
- Three more voltage domains (VD3, VD4, VD5)
  - VD3 and VD4 are buck voltage
  - VD5 is boosted voltage
- Eight more output bus channels (three on VD0, two on VD3, two on VD4 and one on VD5)

All housekeeping data of the DaughterBoard will be collected by the PIU (mainboard) microcontroller.

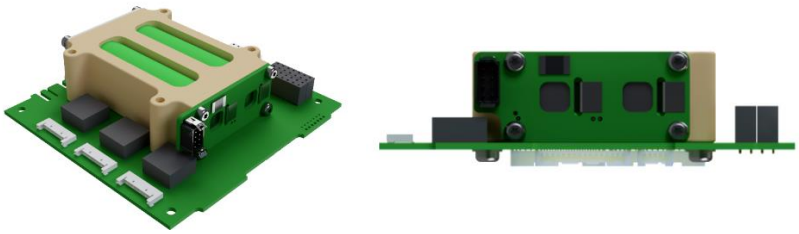
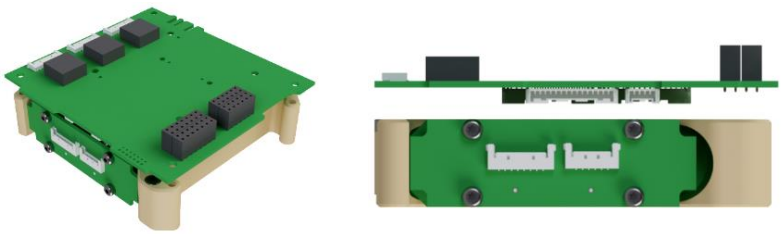
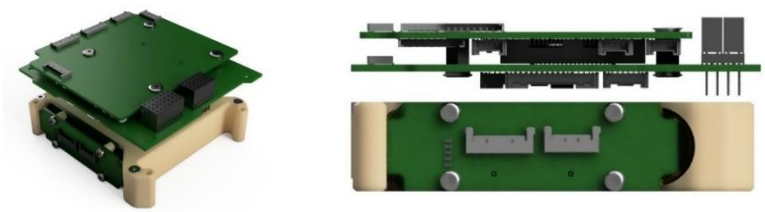
ICEPS Types

The PIU mainboard interfaces with a Battery Pack and can additionally be combined with the PIU-DB. Due to the mounting of the PBP-2S1P battery pack directly onto the PIU mainboard PCB, the PBP-2S1P cannot be used in conjunction with the DaughterBoard.

Therefore, the following standard types are available:

- Type A: PIU + PBP-2S1P. The battery pack is mounted directly on top of the IU mainboard. The centre of mass of the assembly is close to the geometrical centre of the board.
- Type B: PIU + PBP-4S1P. The battery pack can be mounted anywhere in the stack.
- Type C: PIU + PBP-4S1P + PIU-DB. The battery pack can be mounted anywhere in the stack. The daughterboard provides additional solar panel input channels and several regulated voltages and output channels on point-to-point connectors.

Table 1 ICEPS2 Type configuration

Type A	
Elements: 1. PIU mainboard 2. PBP-2S1P	
Type B	
Elements: 1. PIU mainboard 2. PBP-4S1P	
Type C	
Elements: 1. PIU mainboard 2. PBP-4S1P 3. PIU Daughter Board	

Electrical Specification

Table 2 ICEPS Specification

Parameter				Min	Typ	Max	Unit
Environmental Characteristics							
Without battery[1]	Operational temperature			-40		+85	°C
	Storage temperature			-50		+65	°C
	Storage lifetime (at relative humidity < 60 %)				12		months
With battery	Operational temperature[2] (heaters disabled)	charge		+10		+45	°C
		charge up to 800 mA		0		+45	°C
		discharge		-20		+60	°C
	Storage condition[3] (at relative humidity < 60 % and 30% state of charge)	up to 1 month		-20		+50	°C
		up to 3 months		-20		+40	°C
		up to 1 year		-20		+20	°C
Battery holding charge[4]		-20°C to +20°C			6-8	12	months
Electrical Characteristics							
Static (Idle) consumption					93		mW
(Power) Distribution Unit	Maximum input current PDU section			4.01	4.35	4.68	A
	VD0	Number of output channels	Type A and B	1			-
			Type C	1+3			
		Output voltage[5]		Battery Voltage			V
		Output max. current per channel on PIU		2.75	3.01	3.30	A
		Output max. current per channel on PIU-DB (Type C)		3.0	3.3	3.6	A
	VD1	Number of output channels		4			-
		Output voltage unloaded		4.91	4.99	5.07	V
		Output max. current per channel		2.75	3.01	3.30	A
		Output max. current total for voltage domain[6]		4			A
	VD2	Number of output channels		4			-
		Output voltage unloaded		3.26	3.33	3.41	V
		Output max. current per channel		2.75	3.01	3.30	A
		Output max. current total for voltage domain[6]		4			A
	VD3 (Type C only)	Number of output channels		2			-
		Output voltage default		4.91	4.99	5.07	V

[1] Estimate from design evaluation.
[2] Operational temperature can be extended by use of the EPS battery heaters. Additional testing is recommended to verify the battery can be kept within specified operating conditions within the target satellite configuration and environment.
[3] Battery aging reduces total capacity. Recoverable battery capacity is ≥ 80% under specified storage conditions. Reduce battery state of charge to ~30% before long-term storage to reduce aging effects. Storage is preferably done in a protected container that can withstand leakage of electrolyte and thermal runaway conditions.
[4] Estimated by analysis, intermediate check would be recommended when exceeding 8 months.
[5] Battery voltage range.
[6] Peak currents up to 6 A possible for a short duration on either VD1 or VD2 and VD3 or VD4.

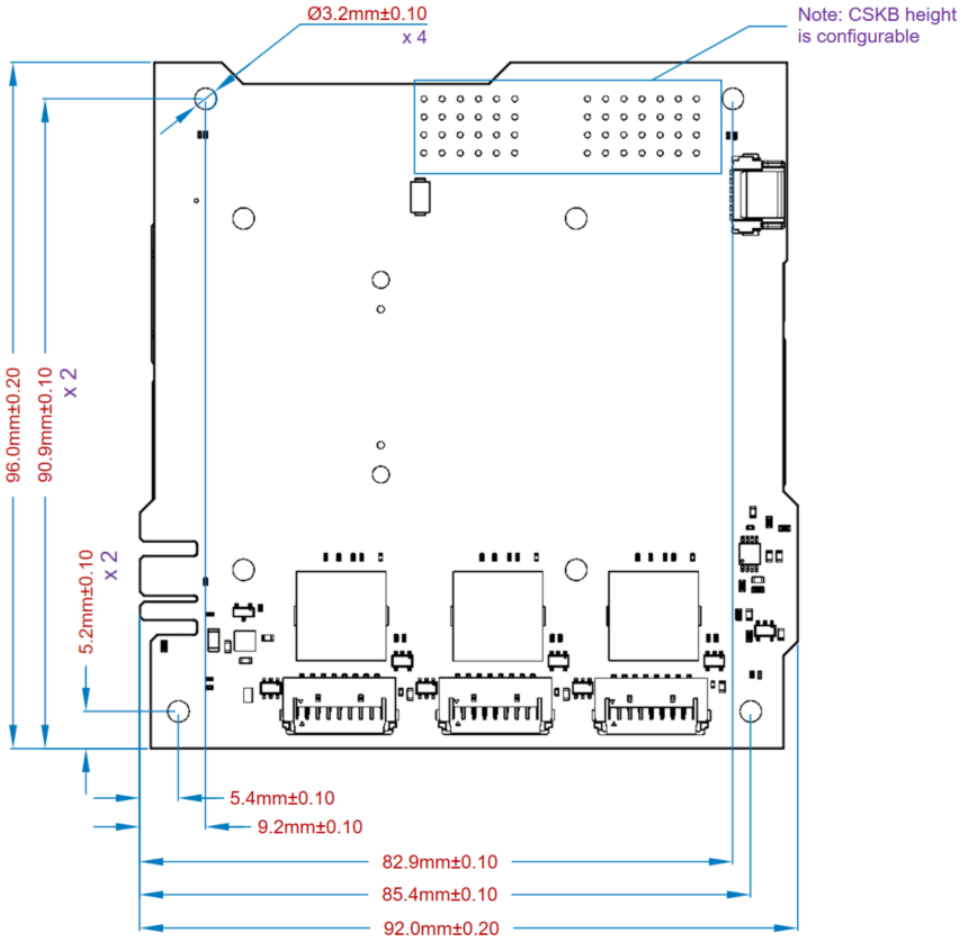
Parameter					Min	Typ	Max	Unit
		Custom output voltage range[7]			2.8		12.0[8]	V
		Output max. current per channel			3.0	3.3	3.6	A
		Output max. current total for voltage domain[6]			4			A
	VD4 (Type C only)	Number of output channels				2		-
		Output voltage default			3.26	3.33	3.41	V
		Custom output voltage range[7]			2.8		12.0[8]	V
		Output max. current per channel			3.0	3.3	3.6	A
		Output max. current total for voltage domain[6]			4			A
	VD5 (Type C only)	Number of output channels				1		-
		Output voltage default			27.4	28.2	29.0	V
		Custom output voltage range[7, 9]			V_{bat}[10]	28.2	32.1	V
		Output max. current			1.4	1.5	1.6	A
Condition Unit (Solar interface)	Number of MPPTs inputs			Type A and B	3	3		-
				Type C	3+2	3+2		
	Maximum input voltage MPPT						15.0	V
	Functional voltage range for MPPT[11, 12]			Type A	3.5		7.5	V
				Type B and C	3.5		13.0	
	Input current per channel[13,14]						2	A
Battery Unit	Cell[15]	Voltage (absolute maximum)			2.5	3.6	4.0	V
		Nominal Capacity				3.2		Ah
	Pack[15]	Configuration		Type A	2 in series			-
				Type B and C	4 in series			
	Battery charge	over voltage limits	Vth rising	Type A		8.27		V
			Vth falling			7.68		V
		under voltage limits[16]	Vth rising			4.20		V
			Vth falling			3.91		V
	Battery discharge	under voltage limits	Vth rising			5.82		V
			Vth falling			5.41		V
	Battery charge	over voltage limits	Vth rising	Type B and C		16.27		V
			Vth falling			15.13		
		under voltage limits[16]	Vth rising			8.42		V
			Vth falling			7.82		
	Battery discharge	under voltage limits	Vth rising			11.88		V
			Vth falling			11.04		

[7] Custom output voltage possible, additional costs apply.
[8] Requires a higher battery voltage
[9] If a voltage > Vbat and < 2 x Vbat is required outside 28V – 32.1V range, contact ISIS.
[10] Maximum battery voltage
[11] If one channel input voltage is above 3.5V on other channels 2.0V is sufficient.
[12] If input voltage is above functional MPPT range but below absolute maximum input voltage, no power point tracking with boost regulation is performed. SPA power will be allowed to pass to RAIL without regulation.
[13] If a higher current limit is required, please contact ISIS.
[14] Not enforced in hardware. Hardware limit set to 2.5A.
[15] Specification of default 18650 cells. Alternative 18650 cells can be provided upon request. Contact ISIS.
[16] Trickle bypass path included for reviving cells that are below charge under voltage limit. Current: ~8mA.

Parameter				Min	Typ	Max	Unit
	Operating Voltage (software limits)[17]		Type A	6.0			V
			Type B and C	12.0			
	Battery charge current			1.60	1.78	1.96	A
	Battery discharge current			4.0	4.45	4.9	A
	Trickle charge path	Blocking Diode V_f (at 10mA)				0.75	V
		Series Resistance R			2		kΩ
	Maximum battery heater current allowed by load switch			0.80	1.00	1.20	A
EGSE	Maximum input voltage		Type A			8	V
			Type B and C			16	V
Physical characteristics							
Mass			Type A	179	184	189	gram
			Type B	305	310	315	
			Type C	355	360	365	
Volume (excluding CSKB)	IU mainboard + 2 cell BP		Type A	96 x 92 x 26.5			mm^3
	IU mainboard		Type B	96 x 92 x 11.3			
	IU mainboard + DaughterBoard		Type C	96 x 92 x 16			
	4 cell BP		Type B and C	94 x 89 x 21.0			
Digital characteristics							
I^2C Specifications							
Bus logic low-level input voltage				0		1	V DC
Bus logic high-level voltage				2.3		3.3	V DC
Supported I^2C modes		Standard-mode				100	kbit/sec
		Fast-mode				400	
Supported address types				7 bits			-
I^2C node type				Slave only			-
I^2C general call supported				No			-

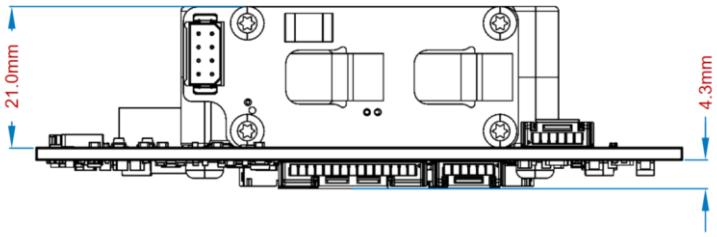
[17] Software limits turn off the satellite when the lower voltage level is reached, to limit the depth of discharge to acceptable levels. Deep discharge causes accelerated degradation of the battery, reducing lifetime and increasing risk of sudden failure. If different levels are required, contact ISIS.

Mechanical Specification



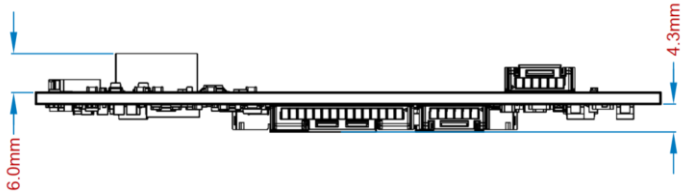
Type A

PIU + PBP-2S1P



Type B

PIU, excl PBP-4S1P



Type C

PIU + PIUDB, excl PBP-4S1P