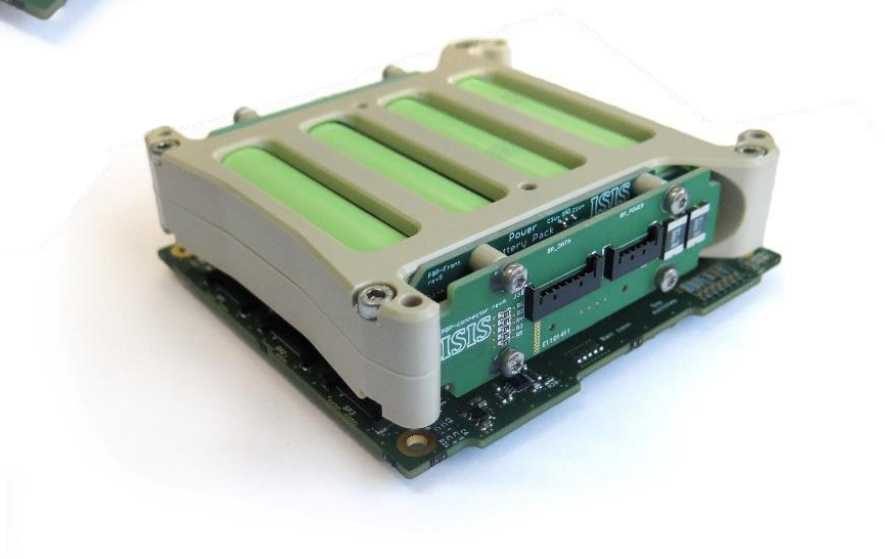

# ICEPS2

# ICEPS2 Datasheet

ISIS-ICEPS2-DSH-0001, version 1.0

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

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## Applications

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

## General description

The ISIS Compact Electrical Power System 2 (ICEPS2) is the second-generation compact power system for nanosatellites. It is an off-the-shelf Electrical Power System available in three standard configurations (Type A/B/C), ideal for powering 1U – 3U Cubesats. The system leverages wide bandgap semiconductor technologies, implementing GaN-FETs to improve solar power conversion efficiency and performance. It is equipped with an integrated heater, hardware-based Maximum Power Point Tracking (MPPT) and hardware voltage and over-current protection. The ICEPS2 provides 3.3V and 5V regulated buses, as well as an unregulated bus. An add-on daughterboard allows additional configurations to suitably power the system and payload instruments.

## Product features

- Communication over I2C
- FRAM-based MCUs for improved radiation tolerance
- Low (idle) power consumption, dedicated emergency low power mode for EPS survivability
- Easy to disconnect battery harness
- Hardware over-current protection
- Hardware supervisor including watchdog
- Low-power MCU for control and Telemetry (TLM)
- $I^2C$ Watchdog (stack reset on comms failure)
- Hardware based maximum power point tracking
- GaN-FETs implemented for improved power conversion efficiency and performance
- Automatic integrated battery heater control

## Optional features

- Optional battery capacities:
  - 2S1P (2 series) Power Battery Pack (PBP): 7.2V and 4A or 28.8W
  - 4S1P (4 series) Power Battery Pack (PBP): 14.4V and 4A or 57.6W
- Customizable voltage output channels through mountable add-on daughterboard, including boost voltage.

## Compatibility

- Interoperable with ISIS Solar Panels, On-Board Computer (iOBC) and Antenna System (AntS)
- Compliant to CubeSat standard.

## Flight heritage and quality assurance

- Design based on heritage from PEASSS Cubesat (2016).

- Second generation improvements 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.
- Flight units thermally acceptance tested for workmanship.
- IPC-A-610 Class 3 PCB, flight units thermally acceptance tested.

## Ordering information

Please contact sales@isispace.nl for ordering information

## System Description

The ICEPS2 hardware is divided in three parts:

1. Power Battery pack (PBP). This is either a two-cell (PBP-2S1P) or a four-cell (PBP-4S1P) battery pack.
2. Power Integrated Unit mainboard (PIU)
3. Power Integrated Unit Daughter Board (PIU-DB)

The electronics on the PIU and PIU-DB can also be separated in three sections:

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

## Block Diagram[1]

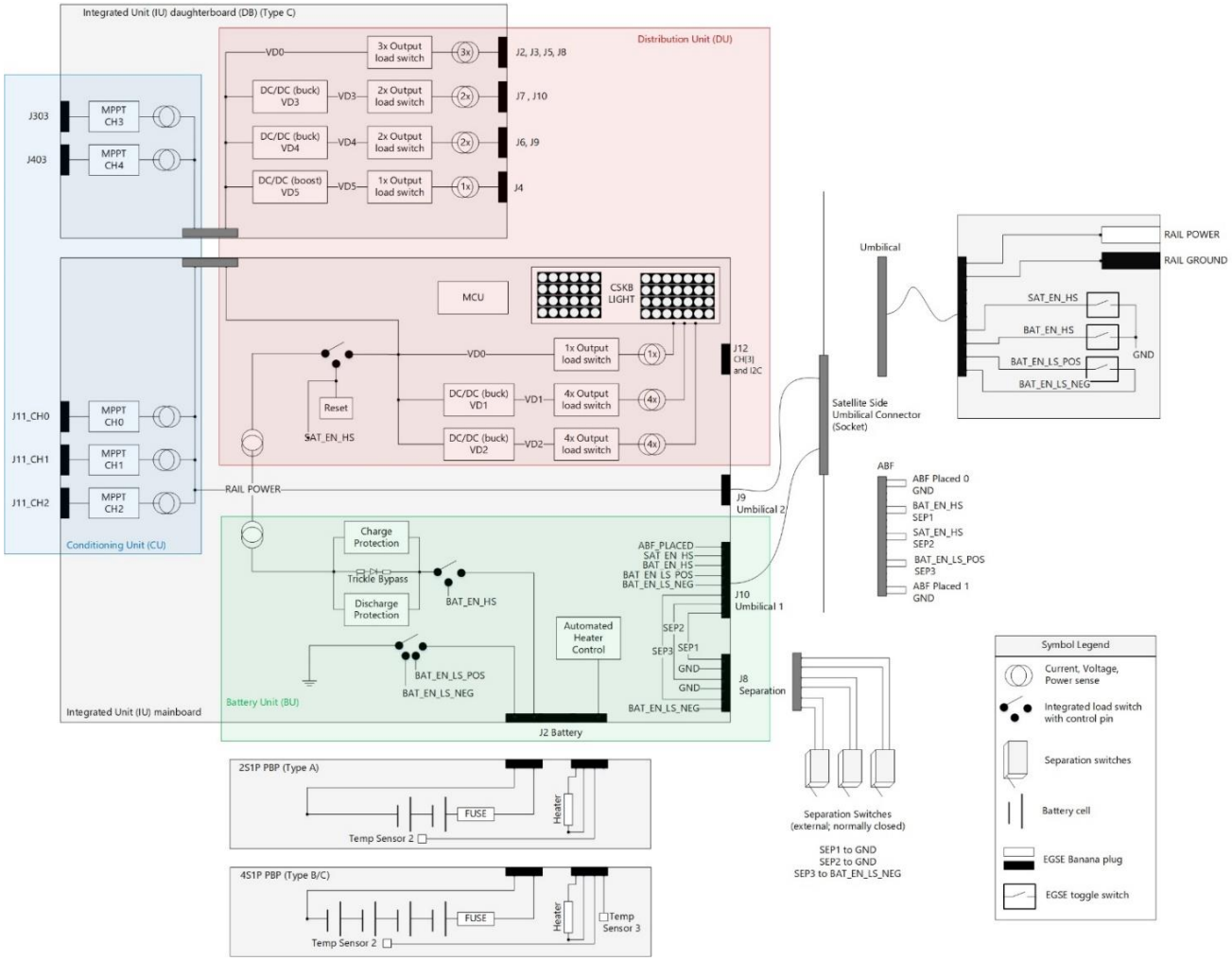



Figure 1 ICEPS2 General block diagram

[1] Several other variations of the indicated seperation switch configuration are supported, see Option Sheet

## Power Battery Unit

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

- a back-to-back (B2B) MOSFET high-side inhibit controlling whether the battery is attached to the RAIL.
- If the options for three separation switches is seletcted in the option sheet: a single MOSFET low side inhibit blocks discharge return currents into the battery when inhibiting.
- If the low side switch is present (three separation switches), independent high and low side inhibit enable controls. 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 is selected: a Remove Before Flight (RBF) circuit allows overriding the inhibit control, fixing it in inhibited state.
- a discharge load switch provides discharge current limiting.
- a charge load switch provides charge current limiting, under and overvoltage lockout.
- a trickle charge bypass diode allows resuscitating batteries that have dropped to voltages below the charge undervoltage lockout threshold.
- a heater load switch, which gets attached to the battery pack heater.
- voltage, current and power sensing
- voltage 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. An additional two channels are available on the daughterboard. 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 completely powered down, 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.

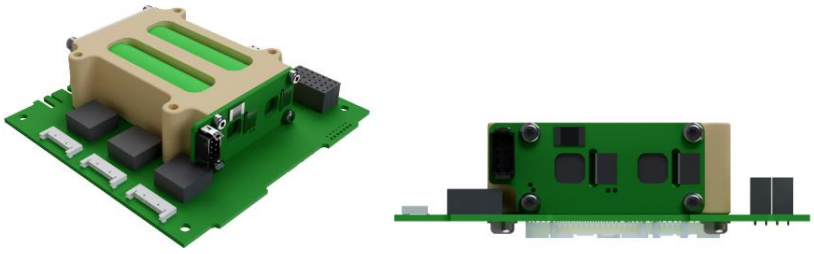
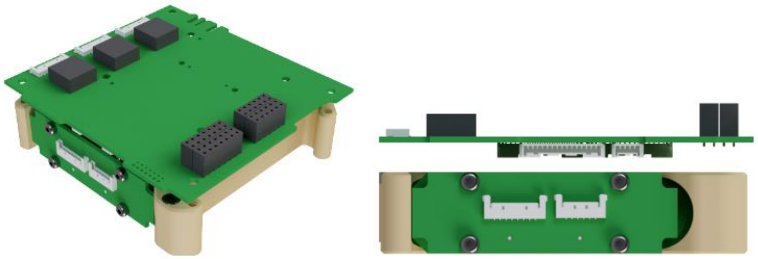
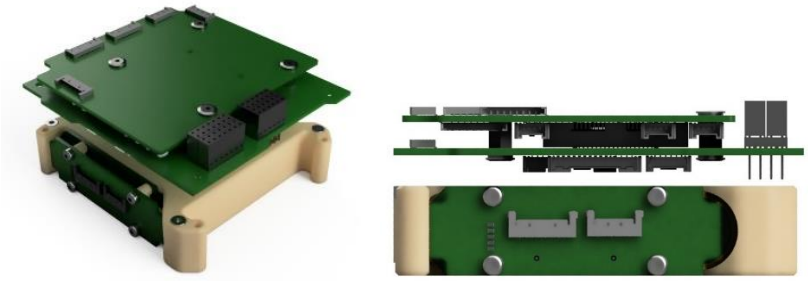
## ICEPS Types

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:<br>1. PIU mainboard<br>2. PBP-2S1P |  |
| **Type B** | |
| Elements:<br>1. PIU mainboard<br>2. PBP-4S1P |  |
| **Type C** | |
| Elements:<br>1. PIU mainboard<br>2. PBP-4S1P<br>3. PIU Daughter Board |  |

## Specification

Table 2 ICEPS Specification

| Parameter | | | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Environmental Characteristics | | | | | | | |
| Without battery[2] | Operational temperature | | | -40 | | +85 | °C |
| | Storage temperature | | | -50 | | +65 | °C |
| | Storage lifetime (at relative humidity < 60 %) | | | | 12 | | months |
| With battery | Operational temperature[3] (heaters disabled) | charge | | +10 | | +45 | °C |
| | | charge up to 800 mA | | 0 | | +45 | °C |
| | | discharge | | -20 | | +60 | °C |
| | Storage condition[4] (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[5] | | -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[6] | | 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[7] | | 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[7] | | 4 | | | A |
| | VD3 (Type C | Number of output channels | | 2 | | | - |
| | | Output voltage default | | 4.91 | 4.99 | 5.07 | V |

[2] Estimate from design evaluation.

[3] 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. See software ICD [**Error! Reference source not found.**] for information on enabling the heaters.

[4] 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.

[5] Estimated by analysis, intermediate check would be recommended when exceeding 8 months.

[6] Battery voltage range.

[7] 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 |
|---|---|---|---|---|---|---|---|---|
| | only) | Custom output voltage range[8] | | | 2.8 | | 12.0[9] | V |
| | | Output max. current per channel | | | 3.0 | 3.3 | 3.6 | A |
| | | Output max. current total for voltage domain[7] | | | 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[8] | | | 2.8 | | 12.0[9] | V |
| | | Output max. current per channel | | | 3.0 | 3.3 | 3.6 | A |
| | | Output max. current total for voltage domain[7] | | | 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[8, 10] | | | $V_{bat}$[11] | 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[12, 13] | | | Type A | 3.5 | | 7.5 | V |
| | | | | Type B and C | 3.5 | | 13.0 | |
| | Input current per channel[14,15] | | | | | | 2 | A |
| Battery Unit | Cell[16] | Voltage | | | 2.5 | 3.6 | 4.0 | V |
| | | Nominal Capacity | | | | 3.2 | | Ah |
| | Pack[16] | 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[17] | 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 | | |

[8] Custom output voltage possible, additional costs apply.

[9] Requires a higher battery voltage

[10] If a voltage > Vbat and < 2 x Vbat is required outside 28V – 32.1V range, contact ISIS.

[11] Maximum battery voltage

[12] If one channel input voltage is above 3.5V on other channels 2.0V is sufficient.

[13] 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.

[14] If a higher current limit is required, please contact ISIS.

[15] Not enforced in hardware. Hardware limit set to 2.5A.

[16] Specification of default 18650 cells. Alternative 18650 cells can be provided upon request. Contact ISIS.

[17] Trickle bypass path included for reviving cells that are below charge under voltage limit. Current: ~8mA.

| Parameter | | | | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| | | under voltage limits[17] | Vth rising | | | 8.42 | | V |
| | | | Vth falling | | | 7.82 | | |
| | Battery discharge | under voltage limits | Vth rising | | | 11.88 | | V |
| | | | Vth falling | | | 11.04 | | |
| | Operating Voltage (software limits)[18] | | | 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 | | | - |

[18] 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.

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