



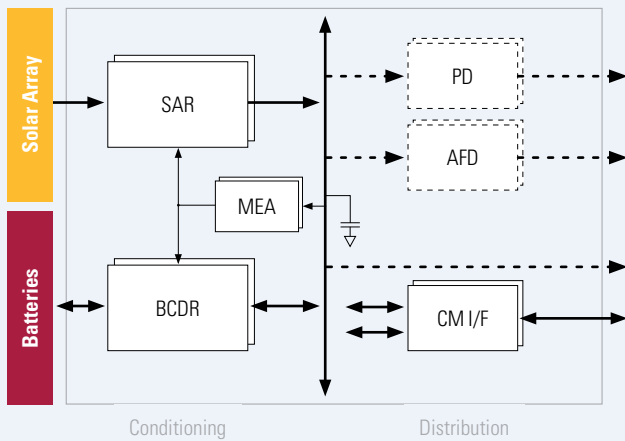
POWER CONDITIONING AND DISTRIBUTION UNITS

FOR ALL TYPES OF SATELLITES

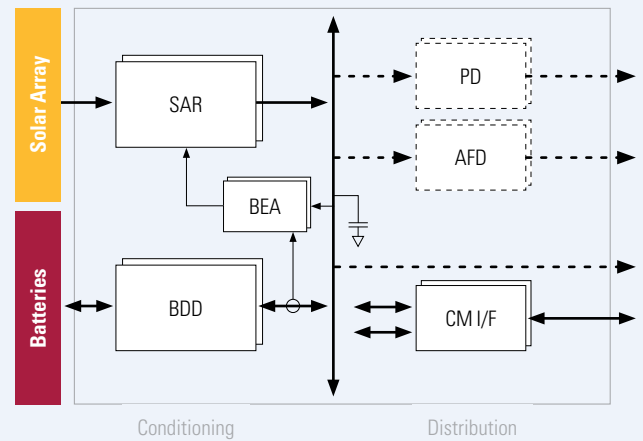


TERMA[®]
ALLIES IN INNOVATION

Regulated Bus System



Unregulated Bus System



Power Conditioning and Distribution Units

For all types of satellites

Power Conditioning & Distribution Function

The Terma power system electronics functions are developed and build in a modular concept to adapt to most classical applied power system technologies like:

- Regulated and unregulated bus concept
- Bus voltages from 28 - to 100 volt

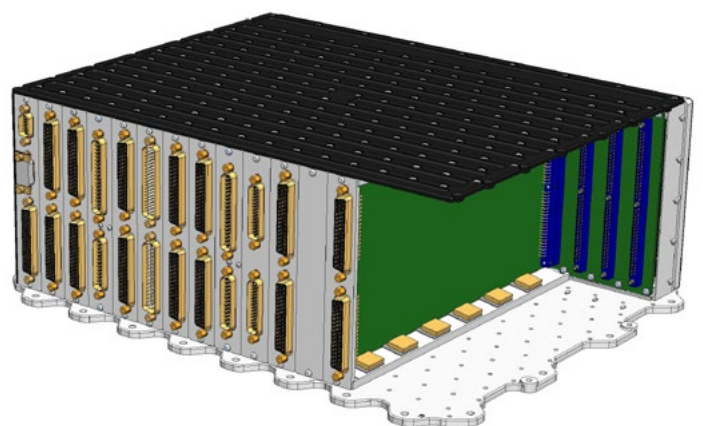
To meet mission demand of high reliability, the PCDU design typically comprises full redundancy and internal cross-strapping, all operating in hot redundancy to obtain full autonomy and no sensitivity to any single failure that might occur during the mission.

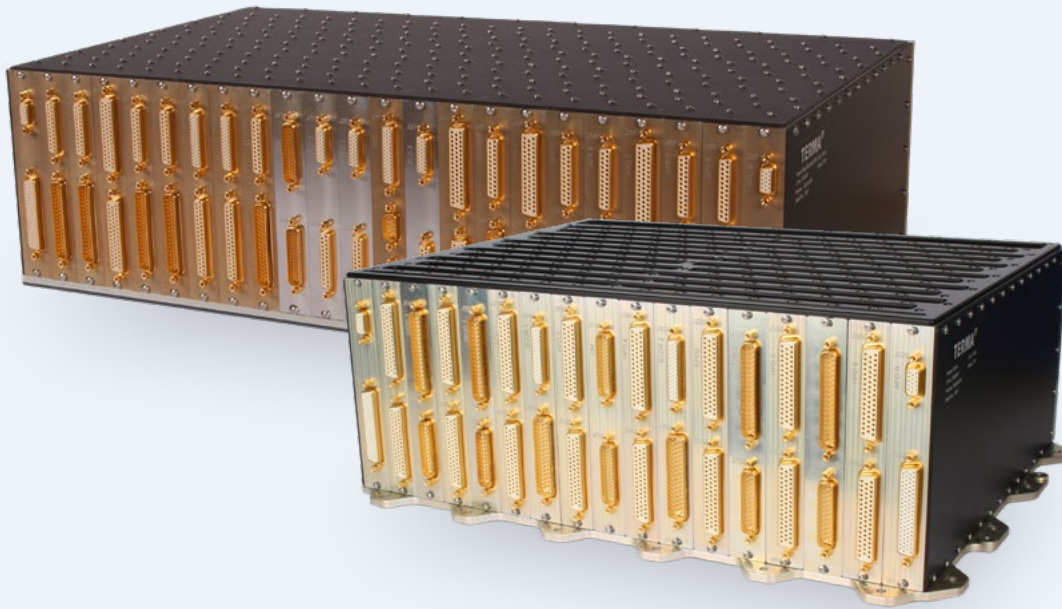
To guarantee failure robustness and functional segregation, each module provides to the extent possible an autonomous function itself that shares only a few transparent interfaces distributed along all modules via a backplane module.

ECSS required low bus impedance is always fulfilled, even for an unregulated bus without the battery connected.

Technology

Terma has developed a unique implementation technology that provides superior mass/performance ratio for power system units compared to competitors. Each module has its own mechanical structure that ensures sufficient unit mechanical strength when accommodated, to sustain the mission mechanical load profile. A direct module thermal contact area to the unit baseplate ensures thermal segregation between functions and proper temperature balance in the unit during all electrical load and failure combinations.





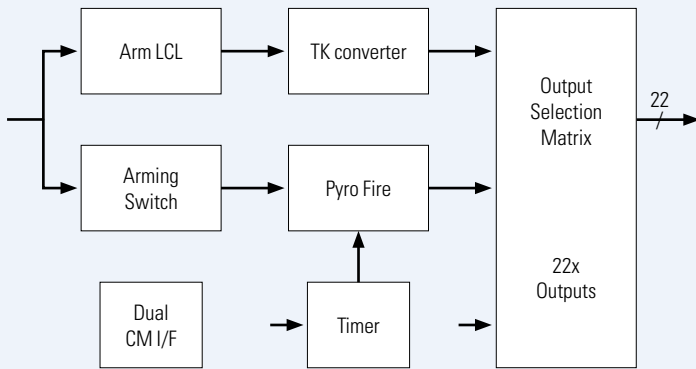
Background

Terma has participated in European space missions for more than four decades and has pioneered several power system electronics technology development initiatives during more than tree decades for advanced ESA missions.

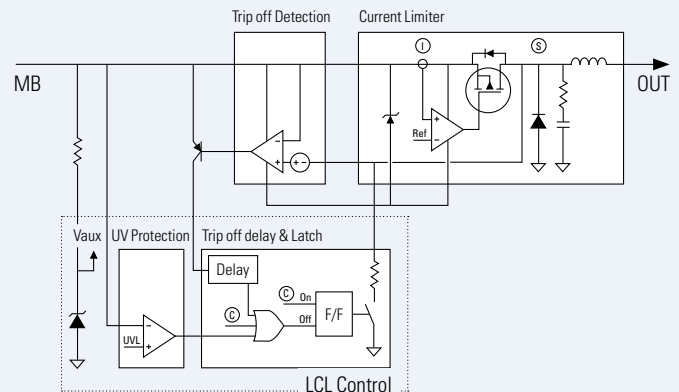
These developed technologies have formed the basis for number of Power Conditioning & Distribution units for ESA missions as well as various military satellites:

| Mission | Launch | Equipment | Features | Status |
|---------------|--------|-----------|--|---------------------------|
| XMM-Newton | 1999 | PDU | 28V, 1500W, 96 LCLs / switches | Operating in-orbit |
| INTEGRAL | 2002 | PDU | 28V, 1500W, 96 LCLs / switches | Operating in-orbit |
| Mars Express | 2003 | PCU | 28V, 1500W, voted MPPT | Operating in-orbit |
| Rosetta | 2004 | PCU | 28V, 1500W, voted MPPT | Mission completed |
| Venus Express | 2005 | PCU | 28V, 1500W, voted MPPT | Mission completed |
| Galileo IOV | 2011 | 4 x PCDU | 50V, 2000W, Shunt, 160 LCLs / switches | Operating in-orbit |
| ExoMars | 2016 | RTPU | 28V, 73 switches, 130 A/D I/F | Mission completed |
| Small Geo | 2017 | PDU | 50V, 1000W, 160 LCLs / switches | Operating in-orbit |
| BepiColombo | 2018 | PCDU | 100V, 14 kW, MPPT, 28V, 60V, 104 LCLs / switches | Operating in cruise phase |
| Eu:CROPIS | 2018 | PCDU | 28V, 500W, MPPT, 56 LCLs | Mission completed |
| Classified | 2023 | 2 x PCDU | 100V, ☐ kW, shunt, 28V, 146 LCLs / switches | Operating in-orbit |
| Euclid | 2023 | PCDU | 28V, 2300W, shunt, 202 LCLs / switches | Operating in-orbit |
| Classified | 2025 | 3 x PCDU | 100V, ☐ kW, shunt, 28V, 252 LCLs / switches | In satellite integration |
| PLATO | 2026 | PCDU | 28V, 2200W, voted MPPT, 338 LCL / switches | In satellite integration |
| ExoMars | 2028 | PCDU | 28V, 400W, BCR, 184 LCL / switches | In production |
| Harmony | 2028 | PCDU | 28V, 2200W, voted MPPT, 338 LCL / switches | In production |
| EMA | 202? | PCU | 100V, 7.25kW, 30 x MPPT | In production |

Pyro and Thermal Knife



Latching Current Limiter



Module functions

To cover the actual power range for satellites, varying from few hundred watts up to 15 kW, with the best unit power/mass ratio, several module functions are available in low- and high-power formats.



Solar Array Regulation (SAR)

For solar array power regulation Terma applies two different methods:

1. Sequential Switching Shunt Regulation (S3R)
2. Maximum Power Point Tracking (MPPT), implemented on Array Power Regulator (APR) module

The shunt regulation function is available in a simple shunt cell version and an advanced version that cannot lose the section power due to a single failure. Maximum power point tracking functions are available as simple, sectional segregated MPPT functions, and as a voted function that cannot lose power tracking - or transfer capability due to a single failure.

Battery Interface

The type of battery interface module to be applied depends on if the power bus is of unregulated or regulated type. The unregulated bus typically needs a Battery Disconnection Device (BDD) function to allow the disconnection of the battery during satellite integration activities while the regulated bus requires a Battery Charge & Discharge Regulator (BCDR) function to ensure power transfer from the bus to and from the battery.

Command & Monitoring (CM)

The CM function serves as communication link to the spacecraft on-board computer, for PCDU commanding as well as telemetry reading. The communication bus is either MIL-STD-1553 or RS422.

Equipment Power Distribution (EPD)

In the Terma power system units the bus power is distributed to external equipment via Latching Current Limiters (LCL). The LCL function is to limit the load current to a specific class current until the selected trip class time is reached, with stable current regulation into any practical input filter sizing. At switch on the LCL will limit the equipment inrush current as well due to its functionality. One module can accommodate up to 24 LCLs.

The LCL protects the main bus against any type of external load failure, including a sudden short occurring just at the external module connector. In such case the current is limited immediately without any critical main bus load current transition.

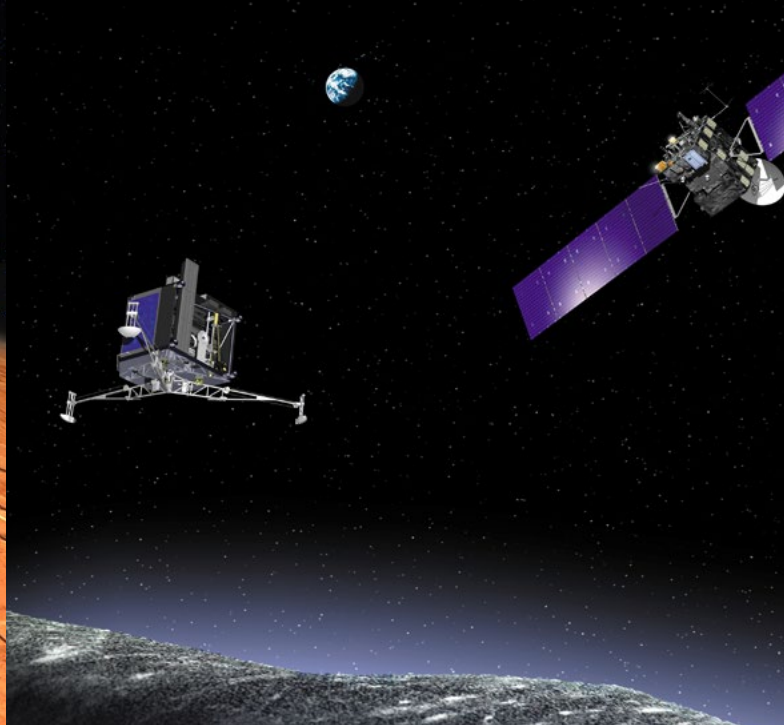
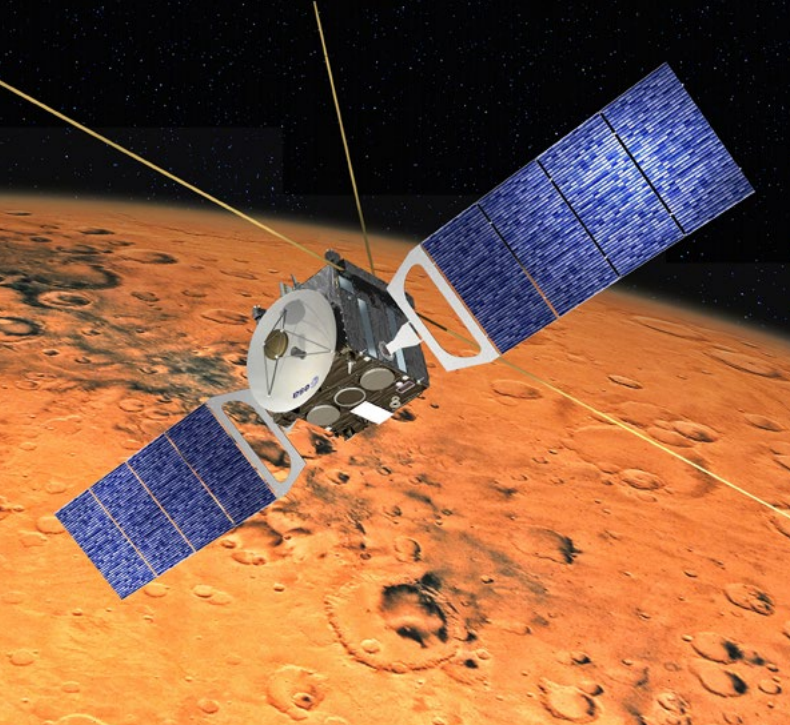
Heater Power Distribution (HPD)

Main bus power for the spacecraft heaters is distributed by heater switches in groups protected by an upstream LCL. One module can accommodate 48 switches and 12 group LCLs. The groups size can be four or eight switches. Remaining LCLs can be allocated for EPD functions or as Protected LCLs that has a series switch.

Actuator Firing Drive (AFD)

To prevent unintended firing in case of hardware failure as well as operator mistake, the function is built as a three-barrier concept: Arm, Selection, and Fire. The Arm function is to be activated by a specific hardware command, while the Selection and Fire are commanded via the CM interface.

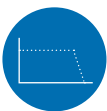
The function is designed to activate current driven pyros and/or voltage driven thermal knives and other actuators with similar drive interfaces.



Secondary Bus Distribution (SBD)

High power level spacecraft using bus voltage of 50 or 100V often applies equipment developed for lower bus voltages and therefore need a secondary regulated bus voltage of 28 or 50 volt.

The SBD function is designed as a mini PCDU function with redundant power conditioning function supplied from primary bus and protected secondary bus distribution via LCLs.



Power Link Distribution (PLD)

The PLD function is designed to simulate a solar array characteristic such that it can support a passenger satellite with power during interplanetary cruise phase. It provides an output characteristic that can substitute the passenger satellite solar array, even allowing the passenger satellite MPPT function to perform normally. PLD modules can be operated in parallel to provide sufficient power.

Qualification and Flight Heritage

The following figures shows the module types available for PCDU integration and demonstrates their actual qualification status (Q) and obtained flight heritage in Module-Years (MY).

Low power modules:

| Module | Capability | Bus voltage | Heritage |
|------------|--------------------|-------------|------------|
| APR (MPPT) | 1 x 250W | 28V | Q / 260 MY |
| S3R | 8 x 150W | 28V - 50V | Q / 100 MY |
| S4R | 4 x 150W | 28V - 50V | Q / 50 MY |
| BCDR | 1 x 300W | 28V | Q / 129 MY |
| BDR | 1 x 600W | 50V | Q / 200 MY |
| BM | 1 x 20A | 28V | Q / 1 MY |
| EPD | 16 x LCL 1-5A | 28V - 50V | Q / 154 MY |
| HPD | 16 x Sw., up to 3A | 28V - 50V | Q / 300 MY |
| PPD | 28V/75W, 5 LCL | 50V | Q / 50 MY |
| PFD | 12 x Pyro, 5A | 50V | Q / 14 MY |
| TKA | 12 x TK, 20V | 50V | Q / 100 MY |
| CM (RS422) | 2 x RS422 I/F | 28V | Q / 1 MY |
| CM (TM/TC) | ESA TM/TC | 28V | Q / 86 MY |
| CM (1553) | 1553 | 50V | Q / 100 MY |

High power modules:

| Function | Capability | Bus voltage | Heritage |
|---------------|--------------------|-------------|-----------|
| APR (I-MPPT) | 3 x 500W | 100V | Q / 60 MY |
| APR (V-MPPT) | 3 x 250W | 28V | Q / - |
| S3R | 12 x 250W | 100V | Q / 4 MY |
| SS3R | 4 x 200W | 28V | Q / 8 MY |
| BCDR | 420W | 28V | Q / 4 MY |
| BDD | ☒A | 100V | Q / 10 MY |
| SBD (28V/50V) | 350W + 16 LCL | 50V - 100V | Q / 22 MY |
| PLD | 2 x 60V/340W | 100V | Q / 18 MY |
| EPD | 24 x LCL 1-5A | 28V - 100V | Q / 16 MY |
| HPD | 48 x Sw., up to 3A | 28V - 100V | Q / 36 MY |
| AFD | 24 x Pyro / TK | 28V - 100V | Q / 20 MY |
| CM | 2 x 1553 | 28V - 100V | Q / 10 MY |



Operating in the aerospace, defense, and security sector, Terma supports customers and partners all over the world. With more than 1,900 committed employees globally, we develop and manufacture mission-critical products and solutions that meet rigorous customer requirements.

At Terma, we believe in the premise that creating customer value is not just about strong engineering and manufacturing skills. It is also about being able to apply these skills in the context of our customers' specific needs. Only through close collaboration and dialog can we deliver a level of partnership and integration unmatched in the industry.

Our business activities, products, and systems include: command and control systems; radar systems; self-protection systems for ships and aircraft; space technology; and advanced aerostructures for the aircraft industry.

Terma has decades of hands-on know-how in supporting and maintaining mission-critical systems in some of the world's most hostile areas. Terma Support & Services offers through-life support of all our products to maximize operational availability, enhance platform lifetime, and ensure the best possible cost of ownership.

Headquartered in Aarhus, Denmark, Terma has subsidiaries and operations across Europe, in the Middle East, in Asia Pacific as well as a wholly-owned U.S. subsidiary, Terma Inc., with offices in Washington D.C., Georgia and Texas.

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