Final HPcu Design and Build
Preliminary Design of HPcu
Industry Partner for Deep Space 1
Deep Space 1 Mission

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Conclusions
Flight Data & Analyses
Operations
Testing & Stability
Design & Fabrication of High Voltage Power Converter
High Voltage Bus Requirements

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OVERVIEW
paramount in accomplishing the mission goals.

As the available power from the solar array power decreases as the square of the distance from the sun, the need to operate near the peak power point is significant.

Significance of the Requirements

- Provide Current and Voltage Telemetry from Solar Array and Batteries
- Load Each of 8 Solar Cell Modules to Measure I-V Profiles of Array Segments
- Provide Battery Charge Control
- 33+1/11.1V @ 18.2 A Maximum for Spacecraft Power
- HV Switching for PPU & PPU Heaters (2500W, 100W & 70W, Respectively)

Other HPCU Design Requirements

- to support S/C loads occasionally during Isp thrusting.
- The power subsystem has to allow the battery for the spacecraft to reach the asteroid.
Keep the PPU from getting too cold during low power and "off"

PPU Heaters

Designed to provide over 3600 W of output power.

Converts high voltage to seven voltages to drive an ion thruster.

Power Processing Unit (PPU) - part of the Ion Propulsion Subsystem (IPS)

and trickle charging.

V-T (voltage-temperature) curves account for cell aging, cell short,

includes a charge control unit to charge the battery based on one of 16

includes a charge control unit to charge the battery.

A to the engineering loads and science instruments.

Converts high voltage to low voltage (~32 Vdc) while providing up to 18

Estimated output power is 2500 W at 1 a.u. from Sun.

Output voltage range is from 80 V to 120 Vdc.

Solar Array

THE HIGH VOLTAGE BUS INTERFACES
Ion Propulsion Subsystem (IPS)

33V (from switches in the PDU)

Commands

SA Module & Load Select
RIY Dry ON/Off for PPU
RIY Dry ON/Off PPU HITS
Array Voltage Set Point
V/T Select

33V BTR

Control

2 x 12 A-HR N/H²
33 +1/-1 Vdc (Low Voltage Bus)

HPCU

4 Taps

Solar Array

S/C

Distribution

Power

DS1 POWER SYSTEM ARCHITECTURE
Based on the projected estimate of the PPT Voltage, the array voltage regulation set-point is

- The voltage range is 78 to 132.4 Vdc in 64 x 0.85 volt steps.

- Voltage set-points in the HPCU.

- The flight operations team or an on-board sequence can command any one of 64 array
  voltage set-points by an up-link command.

- An additional control loop was added in the HPCU that allows regulation to an array voltage set-
  point shifted to modifying the HPCU design.

The focus shifted to modifying the HPCU design. Since the PPU design was frozen, the decision of a PPT approach was abandoned.

Since the PPU design was frozen, the decision of a PPT approach was abandoned.

- The PPU being a 2500 W load is a better choice for implementing a PPT.
- The goal was to maximize power to the PPU not the spacecraft loads.
- Incorporating a PPT in the HPCU has very limited advantage since it is a small load (~450 W)

Initially, the use of a peak power tracker (PPT) was considered. (Including PPU/Thrusteer) demanded more power than the solar array could supply.

With the original HPCU design, the array voltage would collapse if the spacecraft loads
side of the PPU (without collapsing the array voltage).

On-board flight tests indicated that the HPCU can operate at a set-point voltage on either ground is near the power source.

A single-point ground approach is used on the spacecraft's power return lines; the star grounding configuration.

As expected, the magnitude of the noise on the high voltage is dependent on the collapsing the array voltage did not affect the operation of either the HPCU or the PPU.

The test results showed that although the PPU with a thruster load generated some noise on the high voltage bus, the HPCU performed in a stable manner.

Using a solar array simulator as a power source, compatibility tests were performed with a HPCU breadboard and a PPU breadboard.
autonomous.

Software algorithm on-board sends a command to IPS to throttle back one step if the battery discharges too deep (projected to reach 65% SOC in about 30 minutes), then a

- from the array minus the expected spacecraft power consumption.
- IPS is commanded to a throttle level that corresponds to the maximum projected power.
- The set-point selection is updated every week during spacecraft tracking.
- Operating voltage set-point selected slightly to the right of the PPP.
- Based on a projected PPP voltage, an up-link command is sent to the HPCU to have the array operate near the PPP of the array.
- A predetermined minimum required loads are turned on during this phase.
- To provide maximum power to the IPS during the thrusting phase, the spacecraft has to

Spacecraft On-Orbit Operations
1. Upon sun acquisition, HPCU operates in battery current limit mode.

2. During nominal cruise, HPCU operates in V-T battery charge limit mode.

3. While thrusting, HPCU operates in solar array voltage control mode; the voltage set-point is near the PPP.
Battery Current vs SA Voltage

Results from a PFP search test performed in flight.
The SUMMARY of the High Voltage Power Converter Unit on DSI allows both the spacecraft avionics and ion propulsion to operate in a stable manner near the PFP of the solar array.

This approach relies on a fairly well-defined solar array model to determine the projected PFP. The solar array voltage set-points have to be updated every week to maintain operation near PFP.

Stable operation even at the left of the peak power point is achievable so long as you do not change the operating power level of the ion engine.

The next step for this technology is to investigate the use of onboard autonomy to determine the optimum SA voltage regulation set-point (i.e., near the PFP). This is for future missions that have one or more ion propulsion subsystems.