The Development of 260W Power Processing Units for Hall Effect Propulsion System

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Abstract: The purpose of this paper is to describe the requirements, functions and development of 260W power processing unit used in the hall effect propulsion system((HEPS) for 300 kg LEO satellite. The PPU regulates and converts +28V from Li-ion battery into different voltage levels. The purpose of the PPU is to supply the required power and electrical interface for Hall Effect propulsion system. In this system, an electric field subjected to a magnetic field perpendicularly generates force. The principle of Hall Effect propulsion system is the plasma discharge reaction between anode and cathode. The PPU is designed to supply the power to different thruster unit such as anode, cathode, magnetic coil and fuel tank valve. The anode requires 250V to generate electric potential in this system. The Cathode requires minus 100V bias voltage for electron ignition and voltage control for ion-electron neutralization during firing. In addition, magnetic coil requires constant current to generate the required magnetic flux where electrons are trapped. Also, The PPU is connected to the fuel tank (xenon compressed gas) valve, which requires power to control the flow of the fuel into the reaction zone. The most important idea in the PPU design is the bias power supply which provides power for the cathode unit for the electron emission and neutralization. The bias power supply maintains -50V to -30V between cathode and satellite ground for the neutralization.

Nomenclature

A	=	amplitude of oscillation
e	=	electron
Xe^+	=	Xenon ion
E	=	Electrical field
B	=	Magnetic field
c	=	chord
dt	=	time step
Fx	=	X component of the resultant pressure force acting on the vehicle
Fy	=	Y component of the resultant pressure force acting on the vehicle
R	=	Resistor

H	=	height
W	=	width
D	=	Depth
K	=	trailing-edge (TE) non-dimensional angular deflection rate

1.0 Introduction

DubaiSat-2(DS-2) is a high resolution optical earth observation satellite. It is scheduled to be launched by the end of 2012 and will be placed in a 600km sun-synchronous orbit. The spacecraft includes two payloads, which are the High Resolution Advanced Imaging System (HiRAIS) and the Hall Effect Propulsion System (HEPS). HiRAIS is the main optical payload capable of generating 1 meter resolution images. The secondary payload, which is also an experimental payload, is HEPS.

The Hall Effect Propulsion System (HEPS) was designed in DS-2 to maintain the satellite's orbit, to insure better image quality and longer satellite lifetime. The overall DubaiSat-2 HEPS configuration is shown in Figure 1.

HEPS consists of the following modules and parts: Power Processing Unit (PPU), Thruster Head Unit (THU), Xenon Fuel Unit (XFU), HEPS Control Interface Board (HCIB), Microwave Oscillator, and Cathode naturalize. The satellite batteries provides unregulated +28V DC main power supply to HEPS, which is converted to different voltage levels depending on the load requirement, using converters included in PPU. The grounding for the Battery is different than the grounding used for HEPS. All power and telemetries and telecommands between HEPS and the onboard computer are handled by HCIB. The role of the PPU is to provide the power that enables the electrons to confine. In addition, the PPU controls the Xenon gas tank valves and supplies them with power when required. It also protects the satellite body from over charging during beam time because it provides the same current for anode and cathode. PPU design, configuration, function and development phases are described below.

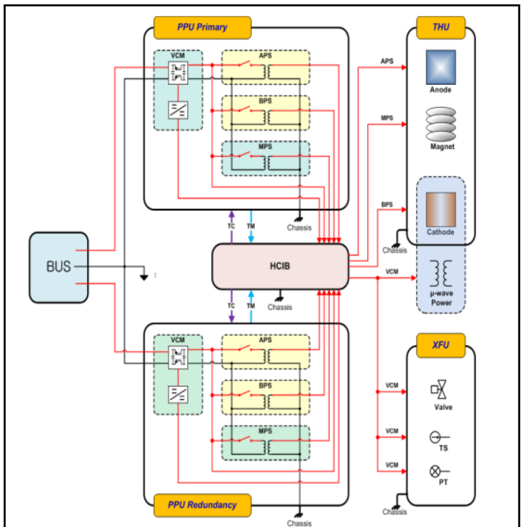


Figure 1 HEPS configuration

1.1.1 HEPS overview

1.1.2 THU

THU consists of Anode, Magnet and Cathode. The Anode and Magnet coil were designed in one structure to provide ExB condition to the system where the electrons are confined and then generates plasma from electrons collision. The cathode generates plasma as a result of electrons resonance. The cathode is exposed by microwave that is resonant the electron to create the plasma base on Electron cyclotron resonance theory, and then the electrons moved to anode side where the collision is acted. Figure 2 shows the real design of THU.

1.1.3 XFU

Xenon fuel Unit figure 3 provides xenon gas for Anode and Cathode. Xenon gas is ignited to Anode and Cathode and produced positive and negative partial as equation 1 shows below:

$X_e \rightarrow X_e^{+} + e^{-}$, Eq1

XFU is consisting of high (middle) and low (side) pressure tanks. The gas follow is controlled by solenoid valves.

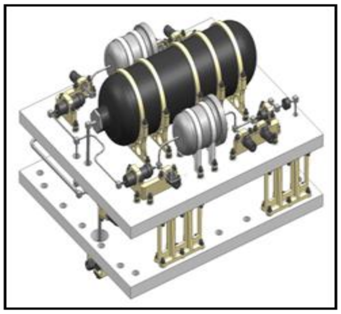


Figure 3: XFU

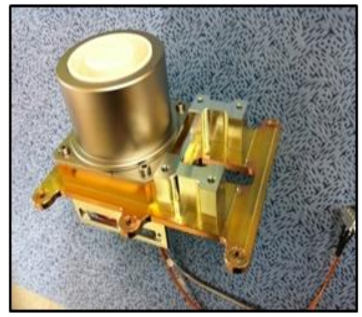


Figure 2: THU

1.1.4 PPU overview

The PPU is divided into two parts; primary and redundant. It uses the cold redundancy configuration. Each part consists of Valve Control Module (VCM), Magnet Power Supply (MPS), Anode Power Supply (APS) and Bias Power Supply (BPS).

2.0 PPU

2.1 Valve Control Module

VCM was designed to control the operation of solenoid valves used in XFU. It converts the unregulated +28V from the battery to regulated +28V, which is then converted to regulated +10V and +4V to reduce the power consumption of the valves. The pressure sensors in the two tanks send telemetries to the Onboard Computer (OBC) to control the tank's pressure. The commands are forwarded to the valve driver circuit to open and close the valves. Figure 4 the design and interface of XFU and VCM. Moreover, the VCM contains input power path for APS, MPS, BPS and other Cathode unit parts. Refer to figure1.

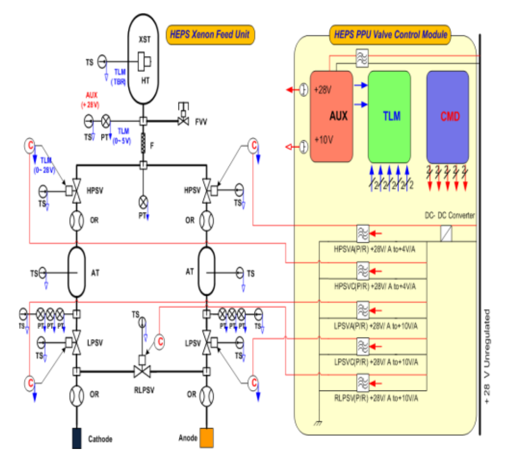


Figure 4: VCM and XFU configuration

2.2 Anode power supply

The Anode Power Supply (APS) converts unregulated +28V to +250V using forward topology. APS is responsible for providing constant voltage for the Anode to create the ignition. The system was provided with voltage and current feedback to maintain 600mA current. The module uses CV and CC mode to control the PWM controls the transformer switch. Protection circuits were designed in APS to prevent output over voltage, input under voltage, and to limit inrush current. Signals from protection circuitry are combined using oring-diode, which is connected to inhabit pin in PWM control IC.

2.3 Bias power Supply

The BPS provides -100V to Cathode during nominal time and it changes to -40V or -30 during ignition and beam time. BPS current should follow the APS current for better beam performance. Figure 5a shows the APS and BPS configuration. Figure 5b shows the wave form of both current and voltage of APS and BPS starting from initial time, then Cathode ignition time and finally firing time. Thus, BPS receives APS current telemetry and compares it with BPS current telemetry. The telemetry values drive the BPS to operate either in CC or CV mode. Similar to APS, BPS contains output over voltage and input under voltage protection circuits.

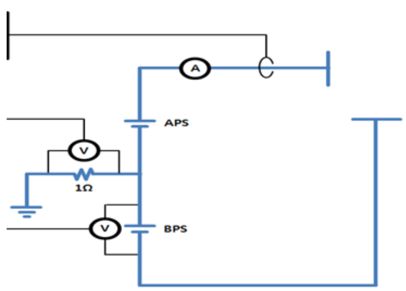


Figure 5a: APS&BPS configuration

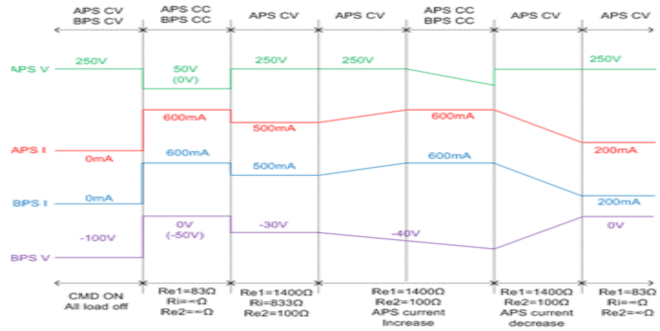


Figure 5b: APS & BPS wave form.ionR (R_I), neturlizerR(R_{e2}), RecycleR(R_{e2})

2.4 Magnet power supply

The Magnet Power Supply (MPS) provides power to the magnet coil. It converts the unregulated+ 28V to +5V maximum using forward topology. It contains feedback loop to maintain constant current supply to the coil. Similar to APS and BPS, MPS includes protection circuitry to turn on the inhabit switch in PWM control IC when the under input voltage or over output voltage is accrued .It also includes inrush current limiter to limit the input current during turn on.

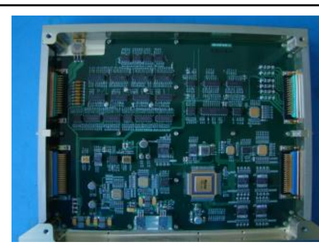
2.0 PPU Mechanical Structure

The table below contains the mechanical specifications of each module box:

Module	Dimension(HxWxD)Cm	Mass
VCM and MPS	25.7x34.9x4.4	2.4kg
APS/BPS	25.7x34.9x5.3	2.7Kg
HCIB	25.8x34.9x3.6	1.5kg

APS&BPS

VCM



HCIB

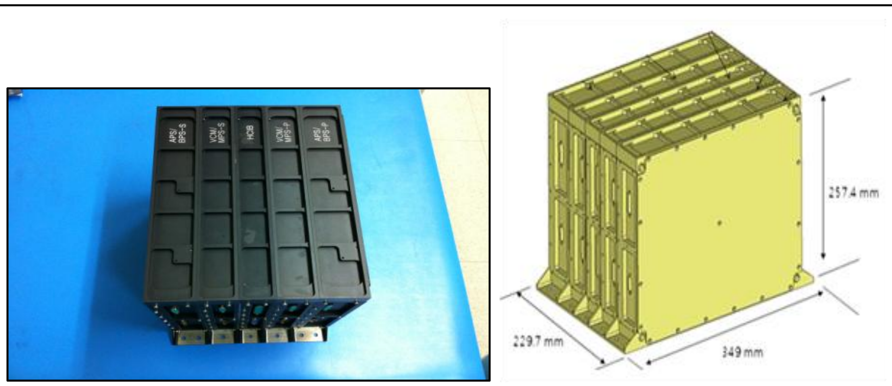


Figure 6: PPU mechanical structure

4.0 Result

The QM PPU was tested in July 2011 and the results are shown below:

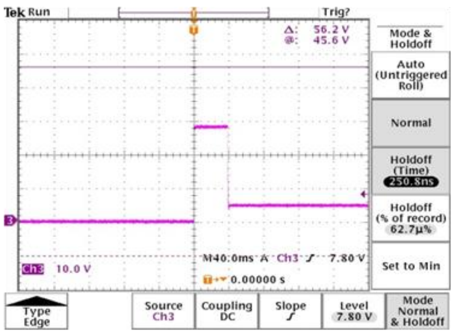


Figure 7: **High** pressure valve control switch output

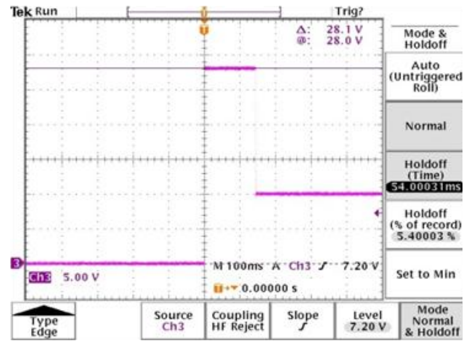


Figure 8: **Low** pressure valve control switch output

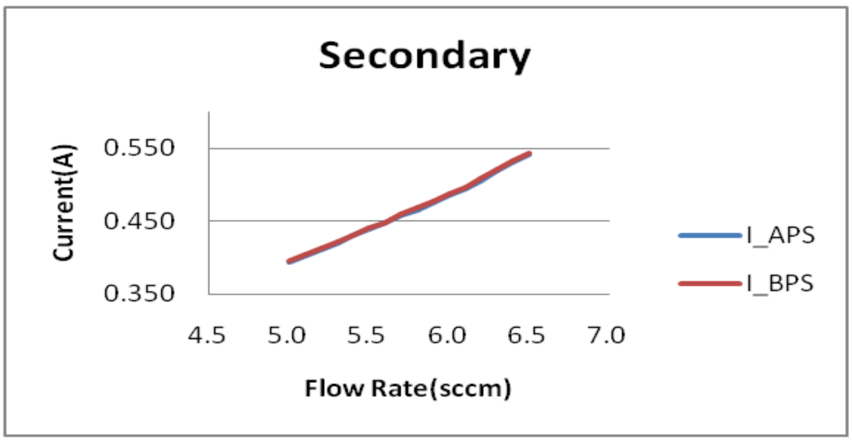


Figure 9: APS &BPS current status during fire

The presented results are only for PPU testing, which did not include other HEPS parts and modules. The VCM functional test was performed using a power supply and an electrical load. The APS and BPS was tested using hallow cathode.Figure10, shows test results of APS and BPS current during the ignition time. As per the requirement, the test showed that I_BPS followed the I_APS.

5.0 Conclusion

In Conclusion, DS-2 HEPS PPU consists of VCM, MPS, BPS and APS. The PPU provides power to modules and parts of HEPS. Engineering model HEPS integration test was performed in January 2011.The qualification model integration testing for HEPS was not done yet. However, qualification model PPU was tested using Hallow Cathode and the results were satisfied. The QM integration test will be held early October 2011. As soon as the qualification model integration testing is complete, the flight model manufacturing will start.

Acknowledgments

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