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Development of a modular central electronic unit (CEU) for data handling and management in Martian atmosphere investigations

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Abstract. This article describes the development of a highly modular Central Electronic Unit (CEU) for data handling and management in Martian atmosphere investigations as part of the DREAMS experiment in ExoMARS 2016 Mission. The CEU was developed by TEMIS and Centro Interdipartimentale di Studi e Attività Spaziali G. Colombo (CISAS) to handle, acquire and transmit medium and low-rate data from sensors dedicated to investigating the Martian atmosphere. The CEU subsystem was designed to communicate with an external host to receive commands and transfer telemetry, transform power from different sources, perform sensors' switch on and off, acquire scientific sensors and their housekeeping monitors, and provide CEU health status. The high modularity of the CEU architecture makes it easy to customize and interface with different types of equipment and instrumentation for various missions. The CEU subsystem is housed on Entry and Descent Module (EDM) and serves as the data handling platform of the DREAMS payload for the EXOMARS 2016 Mission. The CEU has proven to be an effective and flexible solution for data handling and management in Martian atmosphere investigations.

Introduction

The Dust characterization, Risk assessment, and Environment Analyser on the Martian Surface (DREAMS) [1] mission was part of the ExoMARS 2016 mission, which aimed to explore the Martian environment and gather data on meteorological conditions, hazards, and atmospheric electric phenomena. The Central Electronic Unit (CEU) subsystem was developed by TEMIS and CISAS to serve as the data handling platform [2] for the DREAMS payload and was installed inside the warm compartment of Entry and Descent Module (EDM) [3].

The CEU subsystem consisted of primary boards and expansion boards, which distributed functionalities among various modules. The primary boards included the CEU Backplane and the On-Board Data Handling (OBDH) Board, while the expansion boards included the Analog-to-Digital Converter (ADC) Board and the Central Processing Unit (CPU) Board.

Fig. 1 - CEU subsystem

The DREAMS payload included additional subsystems such as MarsTem (thermometer), DREAMS-P (pressure sensor), DREAMS-H (humidity sensor), MetWind (wind sensor), MicroARES (electric probe), SIS (Solar Irradiance Sensor), and a primary battery. These subsystems worked in conjunction with the CEU to fulfil the mission objectives.

CEU Architecture

The CEU subsystem [4] was designed to fulfil its objectives through the implementation of two sets of boards: primary boards and expansion boards. The primary boards are responsible for supplying power, managing the entire subsystem (including sensor configuration), and processing and transmitting data from the sensors to the external host. On the other hand, the expansion boards are specifically designed to interface with various types of sensors (analog and/or digital) by adapting the electronics accordingly. To ensure modularity and efficient distribution of functionalities, the CEU was developed with a plug-in design and a common backplane, allowing for the integration of different boards and modules.

Primary boards

1) CEU Backplane:

The CEU was a modular equipment designed to grant power connections to supply all the boards and enable communication interfaces between the peripheral boards and the CEU Core (OBDH Board). The backplane of CEU (Fig. 2) was a fully passive PCB populated with one connector for each board. The passive backplane strategy was useful during integration as it allowed inspection of the assembled PCB to ensure compliance with requirements without specific electrical tests. This streamlined the AIT phase and enabled adding one board at a time using the backplane as a consolidated part.

Fig. 2 - CEU Backplane

2) OBDH Board

The OBDH Board (Fig. 3) comprised several main blocks, namely a host interface for communication with an external unit, a microprocessor based on LEON2 (Atmel AT697F) along with its associated support memories, an FPGA (RT PROASIC3L) for expanding the microprocessor interfaces and handling low-level control of peripherals, and a non-volatile mass memory (1 Gbyte NAND FLASH). The interfaces used for communication with the expansion boards were implemented on the FPGA, offering customization options based on user requirements within the limitations of the RT PROASIC3L technology. The microprocessor had the capability to operate with a core clock of up to 100 MHz, providing a performance of 86 MIPS (Dhrystone 2.1). The communication interface between the microprocessor and the FPGA could be selected from the following choices: a PCI interface up to 33 MHz, an asynchronous 32-bit memory-mapped interface up to 20 Mbyte/s, or up to 2 UART interfaces up to 250 Kbit.

Fig. 3 - OBDH Board

3) DCDC Board

The DC/DC Board (Fig. 4) was responsible for managing the primary power supply source and distributing power to all the CEU boards. It generated the necessary secondary power rails, including +/-12V, 5V, 3.3V, and 1.8V.

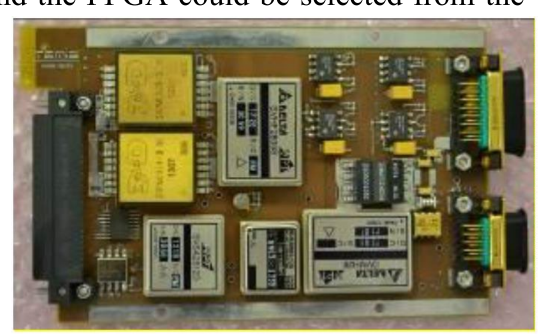

Fig. 4 - DCDC Board

Extension boards

1) ADC board:

The ADC board (Fig. 5) was specifically designed to facilitate the interface between the CEU and sensors that required analog-to-digital conversion and dedicated conditioning electronics. Its main components consisted of an ADC section utilizing the Aeroflex 14-bit Analog-to-Digital Converter (RHD5950) with 16 input channels, and an Acquisition Handler FPGA (RT PROASIC3L device) responsible for managing acquisitions and establishing communication with the OBDH board.

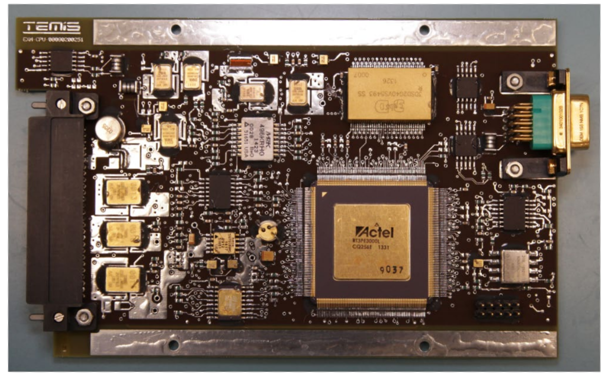

Fig. 5 - ADC Board

2) CPU board:

The CPU board (Fig. 6) was developed to establish connections with digital sensors. It included an Interfaces section that could be customized to meet the specific requirements of the sensors, an Acquisition Handler FPGA (RT PROASIC3L device) for managing acquisitions and interfacing with the OBDH board, and a 256 Mbyte SDRAM memory connected to the FPGA to support onboard data manipulation.

Fig. 6 - CPU Board

Both boards were equipped with onboard FPGAs, allowing for the manipulation of scientific data acquired from the sensors before transmitting them to the CEU's mass memory. Additionally, the FPGAs handled low-level control of peripherals and established communication with the OBDH board.

Power Consumption

The overall efficiency of the CEU was around 70%. To save power, the CEU was designed to have a "low power" mode where only the FPGA on the OBDH board was powered on while all other parts of the OBDH and other CEU boards were powered off. This configuration allowed the CEU system to consume less than 1 W of power.

The interfaces used to communicate with the expansion boards were implemented on FPGA and could be customized based on user requirements. The microprocessor worked with a core clock up to 100 MHz, resulting in a performance of 86 MIPS (Dhrystone 2.1). The communication interface between the microprocessor and the FPGA could be chosen from options such as PCI interface up to 33 MHz, Asynchronous 32-bit memory-mapped interface up to 20 Mbyte/s, or Up to 2 UART interfaces up to 250 Kbit.

Failures management

To automatically detect and correct failures, a detailed monitoring system was implemented to track critical parameters of the CEU boards and DREAMS sensors. This information was used by the CEU's Application Software (ASW) to make decisions to ensure safety and guarantee mission continuity even with reduced functionalities or performance degradations.

Conclusions

The CEU subsystem played a vital role in handling data, managing power, and controlling interfaces for the DREAMS payload during the EXOMARS 2016 mission. The modular design and flexibility of the CEU allowed customization and integration of different boards and sensors, making it suitable for various scientific missions. The successful deployment and operation of the CEU subsystem contributed to the scientific success of the EXOMARS 2016 mission by providing valuable data about the Martian environment during the dust storm season.

During the descent of EDM of the Exomars 2016 mission and its subsequent impact on the Martian surface, both the CEU subsystem and the DREAMS payload performed their designated tasks flawlessly. The CEU subsystem remained fully functional throughout the descent process, demonstrating its reliability in the challenging Martian environment. Likewise, the DREAMS payload successfully carried out its scientific measurements and data acquisition during the descent and impact phase. This successful performance of the CEU and DREAMS subsystems further solidified their capabilities and effectiveness in capturing vital scientific data in extreme conditions on Mars.

In addition to their successful performance during the descent and impact of the ExoMARS 2016 EDM, the CEU subsystem and the DREAMS payload also demonstrated their reliability and optimal health during the intermediate checkout phase while the spacecraft was en route to Mars. During this period, the CEU and DREAMS experiment effectively conducted the necessary checkouts and provided crucial health information about the experiments. Their flawless operation and optimal health state reassured the mission team about the robustness and functionality of the CEU and DREAMS systems, further enhancing confidence in their capabilities to carry out scientific investigations on Mars.

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