Data Processing Hardware for the NEAR Instruments

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By using a modular approach and common board designs, the Near Earth Asteroid Rendezvous (NEAR) program saved valuable resources in the development of data processing units for the instruments. The system is based on the Harris RTX 2010RH processor and includes a MIL-STD-1553B bus interface. The design uses a processor expansion bus to provide flexibility for the installation of custom boards supporting unique instrument interfaces.

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INTRODUCTION

On the Near Earth Asteroid Rendezvous (NEAR) spacecraft, many of the instruments are controlled by data processing units (DPUs), which respond to commands and process instrument data. The DPUs perform several tasks such as scheduling observations and performing data compression.

By developing a modular DPU, common hardware designs were used in multiple systems to meet the requirements of four of the NEAR instruments: the Multispectral Imager (MSI), the X-Ray/Gamma-Ray Spectrometer (XGRS), the Near-Infrared Spectrometer (NIS), and the Magnetometer (MAG). In addition to sharing common hardware designs, the requirements of the NIS and the MAG allowed these two instruments to share the same DPU.

DATA PROCESSING UNIT DESIGN

During the DPU design phase, the requirements of the four instruments were organized into common and unique functions. Common functions included onboard processing, interfacing with the spacecraft MIL-STD-1553B bus, and monitoring various analog sensor signals. The MSI and XGRS both required stepper motor control circuitry, and the MSI needed internal storage of 1.6 megabytes (MB) for image data. The specific data and control interfaces to each instrument were unique.

After identifying the common and unique functions, the system was designed so that the common functions were located on common boards that could be easily interfaced through a generic expansion bus to other boards implementing unique functions. This approach provided a modular design that could be expanded to meet the requirements of each instrument.

Figure 1 shows the division of functions between the boards in the MSI DPU. All three DPUs of the NEAR instruments shared the same designs for the power motor board, the RTX processor board, the 1553 board, and the analog input board. Although the instrument input/output (I/O) board and instrument power board were unique designs, all three DPUs contained boards...
to perform these functions. Because the MSI needed a large amount of internal data storage, it contained two additional memory boards. Detailed descriptions of each board follow.

**RTX Processor Board**

The RTX processor board uses a Harris RTX 2010RH processor running at 6 MHz for the computing core. The board is equipped with 4K words of programmable read-only memory (PROM), 96K words of random access memory (RAM), and 32K words of electrically erasable PROM (EEPROM). The processor board also has access to additional resources through the expansion bus. A block diagram of the RTX processor board is shown in Fig. 2. Other important features include a watchdog reset, four edge or level sensitive interrupts, a low-voltage reset circuit, and an EEPROM write-protect circuit. The board is also equipped with 48 internal general-purpose I/O bits and an external processor test port for loading and troubleshooting software.

**1553 Board**

The 1553 board is designed to operate as a remote terminal on a MIL-STD-1553B bus. The core component for the bus communication processing is the United Technologies Microelectronics Center SuMMIT chip, which communicates over the redundant bus under software control. Data are transferred to and from the RTX processor board through 32K words of shared memory, as well as internal registers in the SuMMIT chip, which are memory mapped on the expansion bus. The RTX board...
Instrument Power Board

The instrument power board performs the arbitration for accessing the shared memory and shared registers. The board address, remote terminal address, and SuMMIT mode are configurable through the expansion bus connector.

In addition to the 1553 bus capabilities, this board has optically isolated inputs for spacecraft timing pulses from the NEAR command and telemetry processors. This signal is used to synchronize many of the DPU functions to a universal time.

Analog Input Board

The analog input board contains analog and digital electronics for gathering the instrument housekeeping and science telemetry data. This board is designed for four different input signal types: 5-V single-ended voltages, 5-V differential voltages, 50-mV differential voltages, and Analog Devices AD590 temperature sensors. The 50-mV differential voltage channels are for monitoring currents with an additional sense resistor. The board also has a flexible configuration to allow some of the signals to be input from either the internal expansion bus connector or external connectors.

The 12-bit analog-to-digital converter and the input multiplexer are memory mapped and controlled by the processor through the expansion bus. The board address is configurable through the expansion bus connector.

Instrument Memory Board

The instrument memory board provides for temporary internal storage of instrument data. Since the MSI is the only instrument requiring large amounts of internal storage, this board is unique to its DPU. Two copies of this board are installed to achieve a total of 2 MB of storage, mapped on the expansion bus in two 1 M words.

Power Motor Board

The power motor board performs three functions for the DPU. First, it conditions the power from the spacecraft to provide internal voltages at 5, 15, and -15 V using the common building blocks defined previously. Second, it provides the drive to instrument two-phase stepper motors. To minimize power dissipation on the power motor board, the current to each motor phase is regulated using pulse-width modulation. As part of the stepper motor control circuitry, interfaces for fiducial sensors monitor the motor position. Finally, this board can switch spacecraft power to another device, such as an operational heater, with its solid-state relay.

Instrument I/O Boards

In each instrument, the I/O board accommodates all unique instrument interfaces. The MSI I/O board is equipped with a 12-bit parallel input interface from the MSI for image data. This board also contains a 2-megabit serial link for high-speed image transfers to the solid-state recorder. The data to and from these interfaces are buffered using first-in-first-out memories. For real-time display of MSI images on ground support test equipment, the MSI I/O board has an image output test port.

The XGRS I/O board has an 8-bit parallel output and a 16-bit parallel input data bus to communicate with the XGRS. Eight discrete flags and six 24-bit counters are used to monitor sensor events. This board also provides a 12-bit parallel interface to control the high-voltage power supplies within the instrument. The NIS/MAG I/O board controls and gathers data from both of these instruments. Discrete signals are used to control the NIS optics and analog-to-digital converters. Data from both NIS detectors are gathered via two parallel 12-bit interfaces and stored in 8K words of RAM on this board. This RAM is also used to store MAG data, which are gathered from the serial MAG data interface. The RAM is mapped onto the expansion bus and read out by the processor following an interrupt at the completion of the data gathering cycle. The configuration of the MAG is carried out through a serial command interface.

Instrument Memory Board

The instrument memory board provides for temporary internal storage of instrument data. Since the MSI is the only instrument requiring large amounts of internal storage, this board is unique to its DPU. Two copies of this board are installed to achieve a total of 2 MB of storage, mapped on the expansion bus in two 1 M words.
128K word pages. To access the entire 2 MB memory, pages are swapped by the RTX processor board through the general-purpose I/O bits. The board address is configured through the expansion bus connector.

PHYSICAL CHARACTERISTICS

Because of the common card size, all DPU’s have the same footprint of $20.6 \times 19.1$ cm. However, the MSI DPU is taller than the rest to accommodate the extra memory boards. The dimensions of the MSI DPU are $20.6 \times 19.1 \times 19.8$ cm, and the dimensions of the NIS/MAG and XGRS DPU’s are $20.6 \times 19.1 \times 16.8$ cm. The mass of the MSI DPU is 4.0 kg, the NIS/MAG DPU is 3.1 kg, and the XGRS DPU is 3.2 kg. Figure 3 is a photograph of the XGRS DPU.

CONCLUSIONS

By reusing common designs in multiple systems, the NEAR program saved significant resources in the development of the DPU hardware. In addition, the savings from the DPU hardware affected other areas of system development. For example, the common board size led to a common chassis design, reducing the mechanical engineering costs. The common processor allowed reuse of software routines, saving software development resources. Finally, the ground support test equipment shared many common components as a result of common interfaces in the DPUs. Thus, a modular design and reuse of components led to lower costs in many areas of development.

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