Preliminary Design of Electronic System for the Optical Payload

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Abstract: In the development of a electronic system for a optical payload comprising mainly EOS(Electro-Optical Sub-system) and PDTS(Payload Data Transm ission Sub-system), many aspects should be investiga ted and discussed for the easy implementation, for th e higher reliability of operation and for the effective ness in cost, size and weight as well as for the sec ure interface with components of a satellite bus, etc. As important aspects the interfaces between a satellite bus and a payload, and some design features of the CEU(Camera Electronics Unit) inside the payload are described in this paper. Interfaces between a satellite bus and a payload depend considerably on whether t he payload carries the PMU(Payload Management Un it), which functions as main controller of the Payloa d, or not. With the PMU inside the payload, EOS a nd PDTS control is performed through the PMU keep ing the least interfaces of control signals and primar y power lines, while the EOS and PDTS control is performed directly by the satellite bus components using relatively many control signals when no PMU exists inside the payload. For the CEU design the ou tput channel configurations of panchromatic and mul ti-spectral bands including the video image data inter face between EOS and PDTS are described conceptua lly. The timing information control which is also important and necessary to interpret the received image data is described.

Keywords: payload, satellite bus, EOS, PDTS, CEU

1. Introduction

The payload is the component that fulfills the space mission. Even though all subsystems must work properly to ensure mission success, payload requirements largely define and size the spacecraft. In the past few years, as payloads have become more complex and sophisticated, their acquisition, integration and operational costs have greatly increased. So the optimal design of a payload to complete the assigned mission became an important issue. And the early negotiation over configuration of the payload system sets the technical tone for completing the payload's mission. As a preliminary design of a payload, the system can be configured in two ways in which the payload consists of EOS(Electro-Optical subsystem), PDTS(Payload Data Transmission subsystem) and PMU(Payload Management Unit), or of EOS and PDTS without PMU. This difference makes big changes in the design concept of a payload by affecting the interface between a satellite bus and a payload. With the PMU inside Payload, EOS and PDTS control is performed by the PMU keeping the least interfaces of control signals and primary power lines with a satellite bus, while the EOS and PDTS control is performed directly by a satellite bus through relatively many control signals when no PMU exists inside the payload. This point is one of what should be discussed and investigated thoroughly depending on the development plan, cost and manpower, etc. The video data interface between EOS and PDTS also should be carefully considered in terms of communication protocol and number of communication channel.

This paper describes the trade-off study in these two point and then preliminary design of CEU for a optical payload which employs CCD(Charge Coupled Device) as a image data generator. The CEU design describes conceptually the output channel configurations of panchromatic and multi-spectral bands respectively and the preliminary design for the handling of imaging time information.

2. Electronic System of a Payload

The payload consists of usually EOS, PMU, PDTS and interconnection harness. The EOS consisting of OM(Optical Module) and CEU(Camera Electronic Unit) is to obtain data for high resolution images by converting incoming light into digital stream of pixel data. The PDTS, which comprises DCSU(Data Compression & Storage Unit), CCU(Channel Coding Unit), QTX(QPSK Transmitter), APM(Antenna Pointing Mechanism) and Antenna, stores and transmits these digital image data which were generated in the EOS to the ground station through X band antenna. The PMU, consisting of several sub-assemblies with an architecture that supports a cold redundancy concept, provides electrical and software interfaces between a payload and a satellite bus, controls all the payload subsystem by the ground station commands and reports all the SOH(State Of Health) telemetry to the satellite bus. The PMU consists of the SBC(Single Board Computer), the THTM, the NUC(Non-Uniformity Correction board), the APDE(Antenna Pointing & Driving Electronics Board) and the PSM(Power Supply Module). Especially, as the main controller of the payload, the SBC provide serial communication channel to the payload's external subunits and other subunits inside PMU like THTM. It also executes arriving commands from the satellite bus, receives telemetry data from THTM and sends it to the satellite bus, and performs antenna control and self-test, etc. The THTM performs the thermal control of the EOS and signals for the power control according to the commands from SBC. The functions described above should be re-allocated to other sub-system like components inside the satellite bus if the payload decides not to keep the PMU inside the payload.

3. Comparison of the Payload System

This section describes the payload system with or without PMU inside it. The differences between them are major design factors for the interfaces between a payload and a satellite bus. Details are explained below.

3.1 Payload System with PMU

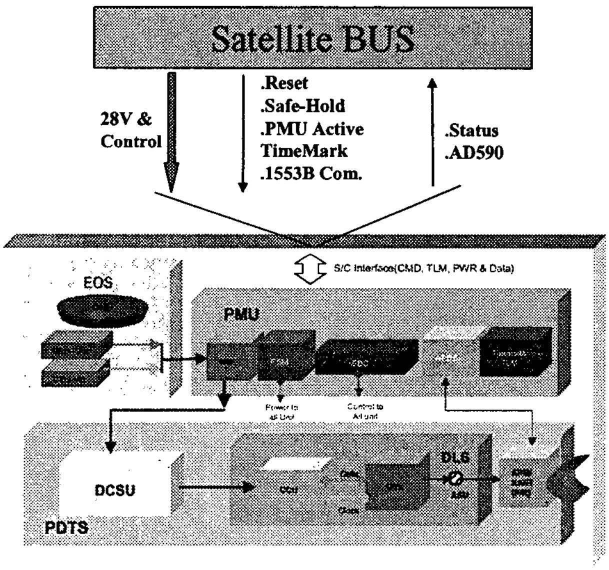

Figure. 1 Payload System with PMU

In the system with the PMU inside a payload, all interfaces between a satellite bus and a payload are through PMU as shown in Figure 1. The primary unregulated power of 28V or 50V, first of all, should be supplied to the PMU using the relay controls from a satellite bus. These powers are then converted into the secondary powers (voltages) which are needed in the all modules such as camera electronics boards for imaging and electronics boards in DCSU for image compression inside the payload. The most discrete signals like Reset, Safe-Hold, Time_Mark goes into PMU even if these signals are used for electronic boards in other units. The Reset signal is for re-booting the system. For that purpose PMU generates secondary reset signals and begins to reset some necessary modules inside the payload system immediately after it receives this signal. And Safe-Hold signal is used for notifying a payload that the power to the payload shall be off soon and so PMU should prepare for this situation not to be damaged by this abnormal condition. PMU is designed to turn off the payload system module by module to protect them from a sudden voltage down. The Time_Mark signal of dedicated RS-422 is used for providing time-reference of imaging. Timing information at imaging is attached to the image data based on Time_Mark signal and On-Board Time (OBT) which is sent to a payload via 1553B communication. And, as a discrete telemetry, PMU should send status information of PMU_Active which tells primary PMU is active or redundant PMU is active. It should send temperature data as well to give direct temperature information even when the payload is off. The biggest advantage of this configuration with the payload is that the interface to/from a satellite bus is simple and the integration and test on a payload level, without a satellite bus, is possible. Therefore we can isolate the development of a payload from a satellite bus. However as a disadvantage the PMU, even when a satellite bus has a capability to cover the management function of PMU, is unnecessarily required in this architecture causing another cost, and the delay of time-critical signal which is caused by signal path through PMU might increases and affect to the system badly.

3.2 Payload System without PMU

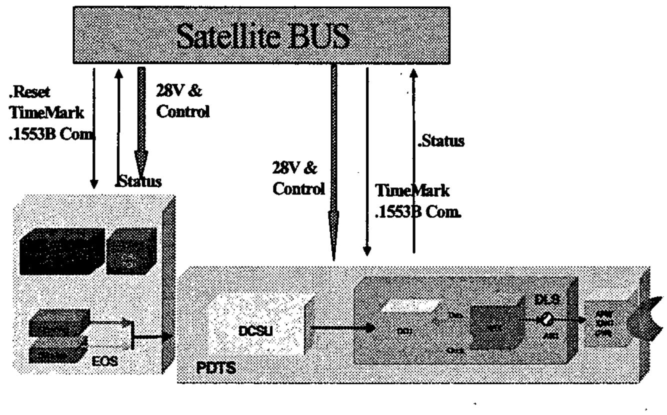

Figure. 2 Payload System without PMU

Without PMU, all signals from the satellite bus to the payload are distributed to the sub-systems directly, and a satellite bus, therefore, should control the payload consisting of EOS and PDTS directly as shown in Figure 2. The most functions of a payload management which would have been in PMU are moved into a satellite bus and some function such as thermal control is required to move into another sub-system which needs that function. As a result the EOS thermal control should be done inside EOS for example. And, the primary powers are supplied to EOS and PDTS in the unregulated voltage, and therefore are required to be converted into necessary secondary voltages for various modules inside them using DC/DC converters. The disadvantage of this configuration is that interface signals for sub-systems like EOS and PDTS should be connected respectively to and from the satellite bus while the PMU would handle them via just one channel of PMU interface as described in Figure 1. We need two 1553B communication channels for receiving commands and sending telemetry from / to the satellite bus one for EOS, another for PDTS. We however can decrease the expenditure and have better timing characteristics for the interface of timing-critical signal by not passing unnecessary equipment, PMU. In the some sense, we can also short the development period by connecting and testing each box of a payload to a satellite bus immediately after each box is ready for integration.

4. CEU Design

The EOS consists of two electro-optical channels: Panchromatic(PAN) and Multi-Spectral(MS) sharing the same mirror telescope. Both channels perform imaging at a synchronous rate. Each channel consists of the shared Mirror Telescope, CFA(Camera Focusing Assembly) and its own CEU(PAN-CEU and MS-CEU). Each CEU consists of DFPA(Detection Focal Plane Assembly) and FPE(Focal Plane Electronics). The incoming light is converted to electronic analog signals by the detector in the DFPA and amplified, biased and converted into digital signals (pixel data stream) in the FPEs and then sent to the PDTS for downlink. The CEU-MS manages 4 multi-spectral images using spectral band filters.

The CEU has the function, in addition to the imaging control, of EOS Heater Control, Focusing Mechanism Control, Shutter mechanism Control, secondary voltage generation and telemetry report on the internal status. The image data interface of CEU is described below. We used G-link interface as a protocol of image data communication, and 12 bits were assigned for a pixel resolution.

4.1 Panchromatic CEU Image data Interface

The CEU-PAN channel block diagram using one detector is described in Figure 3. As shown in this Figure detector has eight outputs and therefore eight ACs(Analog-output Circuits) and VPs(Video Processors). Each pixel output signal through AC is read with a Correlated Double Sampler (CDS) and amplified, digitized using 12-bit A/D converter inside VP. Every two consecutive detector outputs are then MUXed in FPGA to be sent to PDTS with attachment of some header information which is used for retrieving the received data at the ground station. G-link is used for the video data communication for high speed data communication. The SWATH can be increased by adding additional detector and FPE board. From the Figure it can be figured out that pixel rate of 20Mpixels/sec goes up to 40MPixels/sec after MUX, resulting in the 480Mbps/GLink channel resulting in 4 G-Link communication channels.

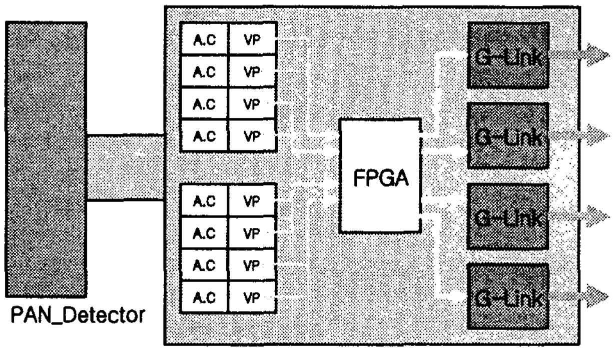

Figure. 3 PAN Channel FPE

4.2 Multi-Spectral CEU Image data Interface

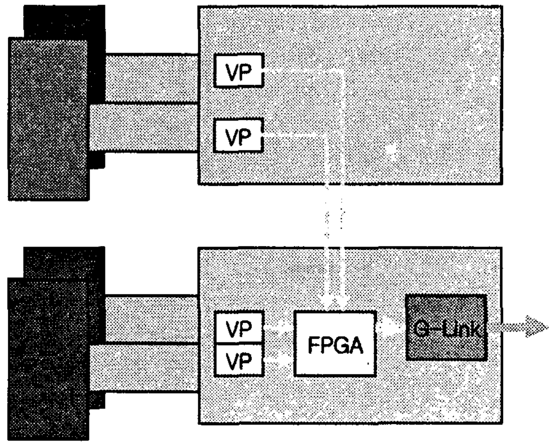

Figure. 4 MS Channel FPE

While a PAN-FPE board handles the one detector a MS-FPE board handles two detectors as shown in Figure 4. Each detector has just one output port and so one AC and VP for respective detector are required on the board. The output pixels are handled by the capability of detector called 4*4 binning resulting in the output rate of 10Mpixels/sec. The G-Link data rate becomes 40Mpixels/sec after two-stage MUX, which matches with PAN channel data rate of G-Link. A bridge connector is used for connecting two boards for multiplexing pixel data.

4.3 Imaging Time Information

The CEU should generate three kinds of imaging-time information called OBT, Line Counter and In-Line Timing Counter in order for ground station to retrieve and make a correct image based on these information. The CEU is required to generate and/or attach this information at the synchronization to the Time_Mark signal coming from a satellite bus every one second with high accuracy. The CEU, first of all, attaches a OBT, as received, which is basically GPS time, and a Line Counter which is 101 in the Figure 5 to represent the line number, that increases one every image line, synchronized to 1Hz Time_Mark and as a last InLine Timing Counter of 2.5usec resolution by which the image data maintain resolution of 2.5usec. The resolution is generated using the 25MHz clock source and the 14 bit-register as shown in Figure 6. Although LSB represent 40nsec resolution, the LSB in the header information when it is transmitted to PDTS and to a ground station represents 2.5usec because only upper 8 bits are attached as information. We can improve the resolution simply by increasing frequency of the clock source or by increasing the number of bits attached using the same method as one in Figure 6.

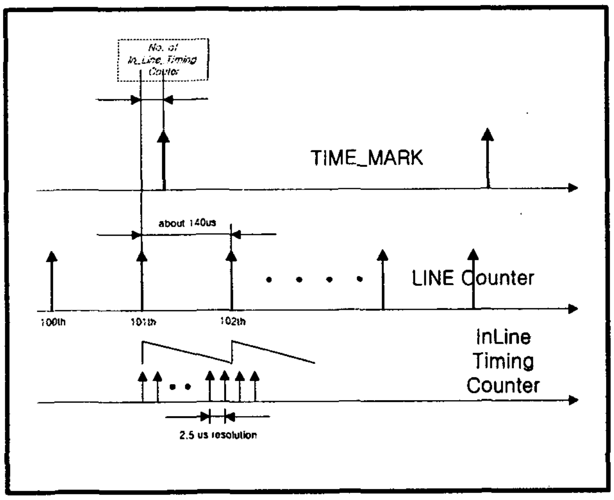

Figure. 5 Imaging-Time Information

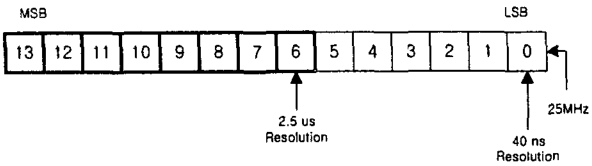

Figure. 6 InLine Timing Counter Generation

4. Conclusions

As a very preliminary design we configured a optical payload with a focus on the electronic system. We did a trade-off study on whether to employ PMU or not by describing the both advantages and disadvantages. We did conceptual design of CEU which is fundamental to the whole system configuration of the payload especially in terms of image data interface, and also discussed the operational aspects of timing-related interface signal which is critical to the system performance due to the its characteristics. This preliminary design might be used as a basic concept of a optical payload system and detail design shall be performed based on this design concept or on some modifications.

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