DEVELOPMENT OF SPACEWIRE BASED DATA ACQUISITION SYSTEM FOR THE X-RAY CCD CAMERA ON BOARD ASTRO-H

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Short Paper

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ABSTRACT

We present the development status of the ground-support digital data acquisition system for the X-ray CCD camera (SXI: Soft X-ray Imager) onboard the ASTRO-H satellite. ASTRO-H employs SpaceWire (SpW) as its information network overall, and the CCD data are also acquired through it. We have developed the data acquisition system for the SXI BBM (breadboard model). In the system, the digitized data are are first stored in the SDRAM of the DE I/F, digital circuit board with SpW interface. Then, they are transferred to a SpaceCube1 (SpC) and finally received by a POSIX-OS computer. The DE I/F board and the SpC are connected by a SpW, and the SpC and the POSIX machine is connected by an Ethernet. We used the SpC as a protocol converter between SpW and TCP/IP, and run the DAQ software on the POSIX system. The DAQ system was stable more than 24 hours. The mean transfer speed was, however, 4.4 Mbps, which is slower than the system requirement 8.8 Mbps. We succeeded in obtaining and storing the CCD images continuously by this system with the analogue part of the BBM.

1 INTRODUCTION

ASTRO-H is an X-ray observatory scheduled to be launched on 2014. It carries four kinds of science detectors covering the 0.1-600 keV energy band, and is expected to reveal various high energy phenomena. The information network of ASTRO-H is based on SpaceWire (SpW) (see [1]).

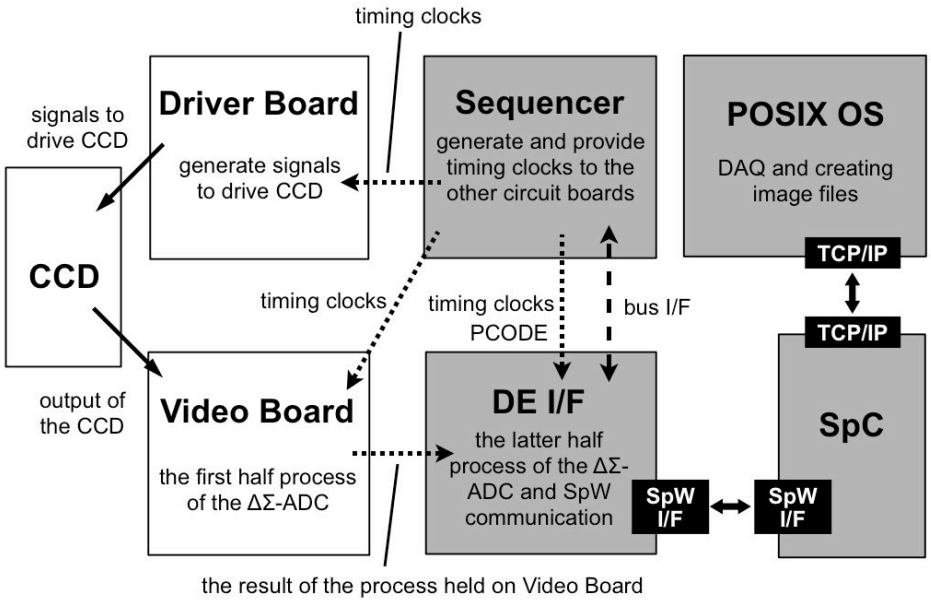

Figure 1: A block diagram of the SXI BBM, which consists of circuit boards of Driver Board, Video Board, Sequencer and DE I/F. The solid, the dotted, and the dashed arrows show analogue signals, LVDS, and LVTTL respectively. The greyed boxes are the digital components discussed in the section 3.

The X-ray CCD camera onboard ASTRO-H is called SXI[2], and covers the 0.5-12 keV energy band. The system has four (2x2 array) CCDs, each of which has 1280x1280 imaging pixels and is read out as the 640x640 format with the on-chip pixel binning technique. The data are digitized to 12 bits per pixel with a 4-bit attribute. As all of the digital data have to be acquired within an exposure cycle (4 sec), the data transfer speed of 8.8 Mbps (including margin) is required.

2 SXI BBM

The components of the breadboard model (BBM) [3] are shown in Figure 1. Sequencer supplies timing clocks to DE I/F, Driver Board and Video Board. Driver Board provides analogue signals for a CCD. Video Board performs the former-half of ΔΣ-digitization for the outputs of a CCD and send the bit stream out to DE I/F.

DE I/F was developed by Mitsubishi Heavy Industries Ltd. using the Universal SpW Board, which includes two FPGAs: User FPGA and SpW FPGA. User FPGA convolves the CCD bit stream to 12 bit values, attaches the 4 bit pixel codes (PCODEs) to them and stores them in SDRAM. PCODEs are supplied from Sequencer and have the pixel-type information such as active, inactive, frame start or line start. The 2 MB space is allocated for the frame data in the SDRAM. DE I/F is connected to a SpW network, and the SpW FPGA takes care of the communication. As the first step of the SpW-based communication, we used a SpaceCube1 (simply SpaceCube or SpC, hereafter) as the counterpart. The SpC is also connected to the POSIX OS computer by Ethernet.

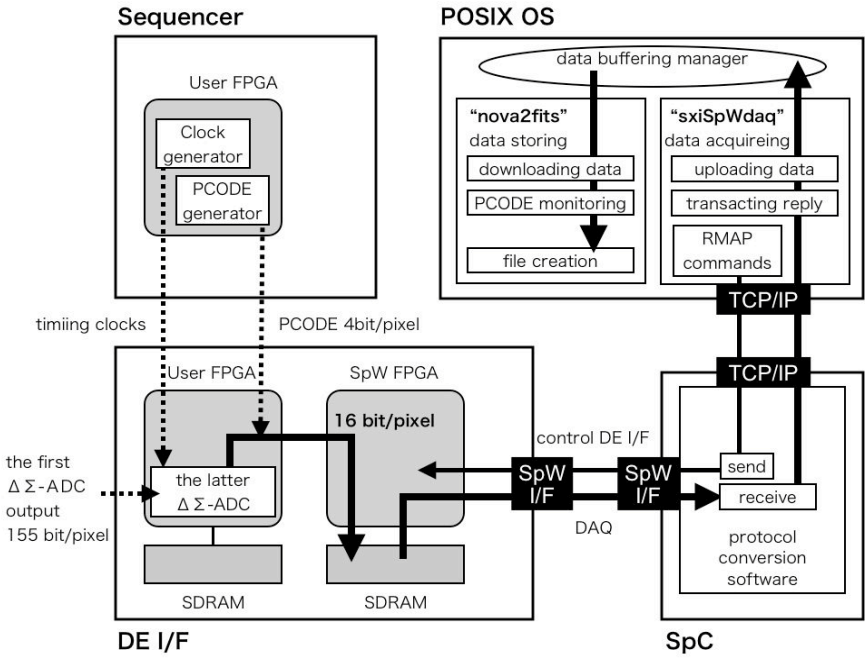

Figure 2: A schematic diagram of the developed DAQ system. We implemented the data acquiring software and the data storing software running on POSIX OS. The accesses to DE I/F are handled by RMAP communication library. Digitized data are acquired from the SDRAM attached to the SpW FPGA to the POSIX system.

3 DEVELOPMENT OF THE DATA ACQUISITION SYSTEM

In this section, we focus on the digital components of the BBM, which are drawn as the greyed boxes in Figure 1. Using the digital part of the BBM, we developed the X-ray CCD data acquisition system as shown in Figure 2.

3.1 DATA ACQUISITION STRATEGY

We set up the SpC as the protocol converter between SpW and TCP/IP; the conversion software is a part of "SpaceWire/RMAP Library" [4]. To retrieve the SDRAM data, we implemented the data acquisition software named "sxiSpWdaq", which uses the library and carries out the RMAP-related functions such as the packet formation and handling. This software repeats the following two steps: (1) sending the data-acquisition start command out to the User FPGA logic and (2) reading the stored data through SpW. The software receives 6 KB of data by each RMAP access, and sends them to internal data buffering manager in order to store them in a file system.

3.2 SPACEWIRE PERFORMANCE

After implementing the system, we carried out a test run over 24 hours, and the system continued working until stopped explicitly. This shows the stability of the SpW system. The transfer speed was, however, insufficient: the achieved mean speed was 4.4 Mbps, which is faster than the speed for 1 CCD but too slow for 4 CCDs. The bottle neck is the protocol conversion. To send SpW packets over TCP/IP, we have to send each packet with a header that acts as the packet delimiter and includes the packet length: thus the SpC has to receive an RMAP read command packet with two steps, reading the header and the body. It seems, unfortunately, that the TCP/IP driver on the SpC is not optimised for such bytes-to-bytes read

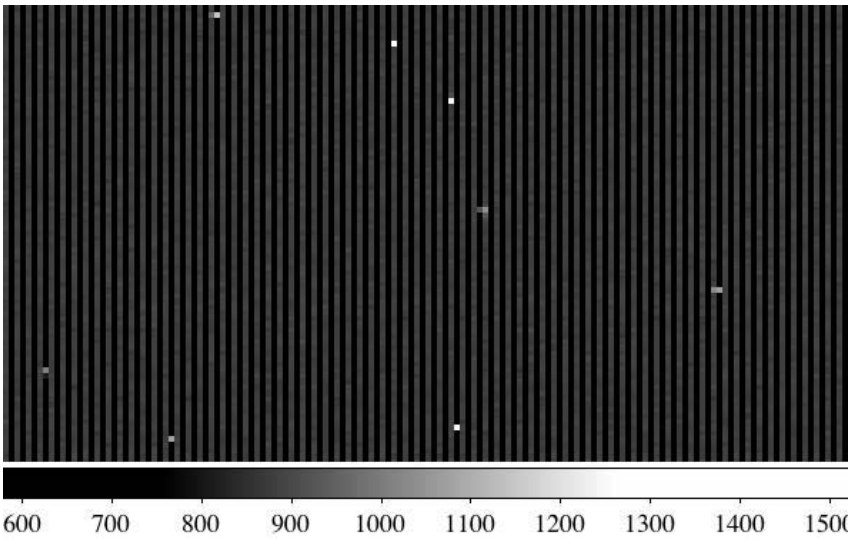

Figure 3: An example of a part of the frame image: we selected a part of the CCD chip. The X-ray events are seen as white dots.

call and the throughput decreases significantly.

3.3 DATA STORING

We also implemented the data storing software called "nova2fits", which obtains the acquired data from the data buffering manager. This software monitors the PCODE of each pixel, and creates an image file of the FITS format, which is the standard of astronomical electric data, with CCfits and CFITSIO libraries [5] when the last pixel of the image comes. This kind of the image reconstruction is required because the SDRAM data does not start from the beginning of a frame every time due to a skew between the starts of Sequencer clock and of User FPGA process of DE I/F. This software does not have a significant affect on the DAQ throughput because this runs on the POSIX machine with plenty of processing power.

4 DEMONSTRATION OF END-TO-END DATA ACQUISITION

With this system, we drove the whole BBM components including the analogue parts. We used a 512x608 CCD chip, cooled it to -15 °C in a vacuum chamber in order to reduce the thermal dark current, and irradiated X-rays of ^{55}Fe. The readout pixel rate is 100 kHz and no pixel binning was held. One of the obtained images is shown in Figure 4. We verified that the BBM adequately works as an X-ray CCD system.

5 REFERENCES

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