Development of the data acquisition system for the X-ray CCD camera (SXI) onboard ASTRO-H

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Introduction: ASTRO-H

• The 6th X-ray astronomy satellite of Japan to be launched in 2014, which is developed with NASA and other international collaborators.
• Four types of mission instruments are loaded.
  - Soft X-ray Imager (SXI)
  - Soft X-ray Spectrometer (SXS)
  - Hard X-ray Imager (HXI)
  - Soft Gamma-ray Detector (SGD)
• Wide energy range from soft X-ray to soft gamma-ray (0.3-600 keV) is covered.

http://www.astro-h.isas.jaxa.jp

Takahashi et al. (2010)
This presentation is focused on
- the electronics of the SXI
- the development of the breadboard model

Introduction: SXI

- An X-ray CCD camera for ASTRO-H.
- SXI sensor is placed at the focal plane of the Soft X-ray Telescope (SXT-I).
- A wide field of view (38x38 arcmin) is covered by 2x2 CCD array.
- P-channel back-illuminated CCDs are adopted (by Hamamatsu Photonics K.K.).
- The CCDs are cooled to -120 degree C using Stirling coolers.
Overview of the SXI Electronics

Four CCDs are grouped into two, and each group has its own video/driver/MIO boards.
Overview of the SXI Electronics

SXI-S contains 4 CCDs and two sets of ΔΣ-ADC unit.  
- ΔΣ-ADC is realized with an ASIC and an FPGA in a video board.
The ASIC contains the preamplifier and the ΔΣ modulator, and the FPGA the decimation filter.

Odd and even pixels are processed separately and simultaneously using the individual chain.

Separate processing of the odd/even pixels results in systematic difference of the zero level: raw image always shows vertical stripe pattern.
SXI-FE contains four sets of CCD drivers.

- Each driver generates and distributes the analog signals to drive CCDs.
- Driver board also collects the housekeeping (HK) information (e.g. temperature, voltage)
Overview of the SXI Electronics

SXI-PE contains two sets of SpW I/Os called “MIO Board”.

- generates all of the timings
- collects the HK information from CCD driver
- buffers the frame images
- provides SpW I/F to SXI-DE

A MIO board has two FPGAs and 64MB SDRAM.
Overview of the SXI Electronics

SXI-DE contains one SpW CPU called “MDE”.
• controls the SXI system
• buffers the CCD data and the HK information from MIO board
• communicates with the spacecraft management unit (SMU)
Development of data acquisition system

• Purposes of the breadboard models (BBMs) are:
  - to verify the function of each circuit boards
  - to establish the DAQ system from CCD to SpW I/F
• Development of the BBM is separated into two steps:
  - BBM0: development was done (2007-2010)
  - BBM1: development is in progress (since 2011)
• A smaller format of CCD than the flight model is used for the BBM development.
Verification items

BBM0

- SpW communication
- acquisition of the frame images
- concept of the CCD driver
  (generation of the driving signals)
- the $\Delta \Sigma$-ADC with the ASIC and the FPGA
- energy resolution at 5.9 keV
Differences from the flight model

- $\Delta \Sigma$-ADC was realized with the prototype ASIC board and an FPGA in DE I/F
- SXI-PE was divided into two boards
- SpaceCube and POSIX OS were used instead of SpW CPU.
Setup of CCD and analog boards

- CCD I/F board
- CCD
- cold head
- thermometer
- cold plate
- prototype ASIC board (hidden)
- prototype Driver (hidden)
- refrigerant
• The images are successfully obtained.
• Pixel rate: 100 kHz, CCD temperature: -35 degC, 55Fe source is used.
• The vertical stripe pattern is due to the separate processing of odd/even pixels in the ΔΣ-ADC.
• We extracted X-ray events from obtained images.
• Two peaks are seen.
• The energy resolution at 5.9 keV was 164 eV (FWHM).
Verification results

BBM0

- SpW communication ➔ stable over 24 hours
- acquisition of the frame images ➔ OK
- concept of the CCD driver ➔ OK
- (generation of the driving signals)
- the ΔΣ-ADC with the ASIC and the FPGA ➔ OK
- energy resolution at 5.9 keV ➔ 164 eV (FWHM)
**Verification items**

### BBM0
- SpW communication ➔ stable over 24 hours
- acquisition of the frame images ➔ OK
- concept of the CCD driver ➔ OK
  (generation of the driving signals)
- the $\Delta\Sigma$-ADC with the ASIC and the FPGA ➔ OK
- energy resolution at 5.9 keV ➔ 164 eV (FWHM)

### BBM1
- function of the MIO boards (except for the event extraction)
- collecting the HK information
- acquisition of the frame images
- energy resolution at 5.9 keV
Configuration of the electronics

Differences from BBM0
- CCD driver, SpW I/O and ΔΣ-ADC unit have almost the same function as the flight model.
- Protocol converter is updated to SpaceWire-to-Gigabit Ether (SpW2GbE).
• CCD temperature: 28 deg C, Pixel rate : 69 kHz
• A frame transfer CCD was operated in a full-frame transfer mode. This causes the difference between the imaging area and the frame store area.
Verification status

**BBM0**

- SpW communication
- acquisition of the frame images
- concept of the CCD driver
  (generation of the driving signals)
- the $\Delta \Sigma$-ADC with the ASIC and the FPGA
- energy resolution at 5.9 keV

- stable over 24 hours
- OK
- OK
- OK
- 164 eV (FWHM)

**BBM1**

- function of the MIO boards
  (except for the event extraction)
- collecting the HK information
- acquisition of the frame images
- energy resolution at 5.9 keV

- OK
- OK
- OK
- in progress
Summary

• SXI is the X-ray CCD camera onboard ASTRO-H.
• Using the BBM0, we verified
  - acquisition of the frame image via SpaceWire
  - the ΔΣ-ADC with the ASIC and the FPGA
  - concept of the CCD driver
• Using the BBM1, we verified
  - functions of the MIO board
  - acquisition of the HK information and the frame images
• Based on these results, the engineering model was designed and produced, and is now being tested.