VERIFICATION OF HIGH RESOLUTION TIMING SYSTEM WITH SPACEWIRE NETWORK ONBOARD ASTRO-H

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Short Paper

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and ASTRO-H collaborations

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ABSTRACT

ASTRO-H is an X-ray observatory satellite exploring in the universe to be launched in 2014. The data acquisition system of this mission will be constructed based on the SpaceWire network. One of the most important issues is to evaluate the time assignment system on the SpaceWire network. In this paper, detail descriptions of timing system of ASTRO-H are shown, as well as verification experiments performed with SpaceWire modules. Based on the obtained results, the timing accuracy of the ASTRO-H system is estimated to be a few microseconds, which is well below the requirement.

1 INTRODUCTION

1.1 THE ASTRO-H MISSION

ASTRO-H [1] is the 6th satellite in Japanese X-ray observatory series to be launched in 2014. It is a Japan-US mission leaded by JAXA and NASA, and collaborated with

ESA. The data acquisition system of ASTRO-H is required to have high timing capability with timing resolution of about 10 μs and accuracy of about 30 μs in order to archive the scientific goals of the mission, for example, high energy physics from observations of astrophysical objects showing rapid variability like pulsars, black holes etc.

1.2 Data Acquisition System of the SpaceWire Network in ASTRO-H

The command and telemetry communication onboard ASTRO-H will be constructed on the SpaceWire network. Figure 1 shows the current design of the network onboard ASTRO-H. The boxes in the figure except for that denote as GPSR (GPS Reciever) represent the network nodes having SpaceWire interfaces. The messages transmitted between nodes, "Space Packets", are sent via the RMAP protocol. To guarantee the quality of service (QoS) of the data transfer, communication time is divided into 64 time slots by highly prioritized 64 Hz time-codes.

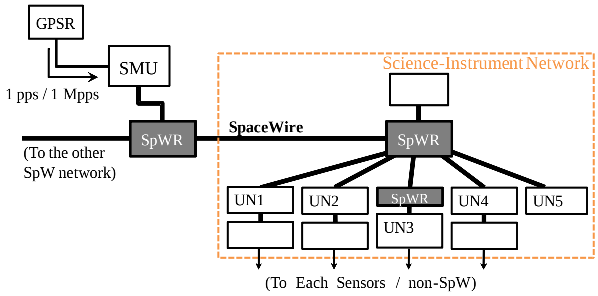

Figure- 1 : SpaceWire-based data acquisition system onboard ASTRO-H. GPSR, SpWR and UNs mean a GPS Reciever, SpaceWire routers and User Nodes (see text), respectively.

2 Design of the Timing System in the ASTRO-H Network

2.1 Distribution of the Spacecraft Time

Time when the space packet is generated on the spacecraft is to be assigned as a UTC (Universal Time, Calculated) value on ground. Onboard the spacecraft, the data-acquisition system delivers a monotonously increasing time counter called "TI". A node performed as a “Time Master” [2] distributes TIs to all the nodes, and all the components onboard share the single time source, TI. On the ground station, UTC from caesium clocks and the satellite TI monitored via real time telemetry are compared to produce a conversion table. This method is previously used in scientific satellites of JAXA, like the *Suzaku* satellite [3].

In the ASTRO-H network, the top node called Satellite Management Unit (SMU) has the function of “Time Master”, where TIs are generated from 1 pps and 1 Mpps clocks of GPSR. Then, the Time Master distributes the TI values to the other nodes. We call these slave nodes as “User Nodes”. In order to distribute TIs properly, the TI is divided into two parts: one is 32-bit “TIME DATA” above a second, which is distrubuted via “RMAP write”, and the other is 6-bit Time-Code for sub-second distributed by the time-code manner [2]. With this method, the accurate timing of the leading edge of the time clock of TI is notified by the Time-Code, and thus, the jitters in distributing the Time-Code [4] will limit the timing accuracy of this system.

2.2 TIME ASSIGNMENT OF X-RAY EVENTS

ASTRO-H carries X-ray sensors as the User Nodes. They detect X-ray photons coming from celestial objects randomly. The arrival time is required to be assigned event by event with the timing accuracy of 10 µs. Therefore we need finer time counters at the User Nodes for the time assignments of X-ray events. We call them "LocalTime". Although LocalTime can be simply realized by a phase locked loop to the TI counter, we implement LocalTime with free-run clocks to reduce required resource in each User Node. The information of each X-ray event carries LocalTime value, and such event data are gathered into a space packet with a corresponding TI value. To assign time of each event, we should know a mapping table between TI and LocalTime. This mapping table is acquired periodically by a constant time interval (hereafter, Sample Period), which is summarized into the House-Keeping space packet. In order to realize this system with a sufficient accuracy, we should determine the Sample Period referring the stability of the quartz oscillators onboard the spacecraft under the expected temperature circumstances.

3 VERIFICATION OF THE TIMING SYSTEM

3.1 AIMS OF THE VERIFICATION EXPERIMENTS

The aim of the experiment is to examine the concept of the time assignment system described in section 2. As already mentioned in section 2.2 and 2.3, we should check the following two items with the actual hardware: (i) jitters of Time-Codes and (ii) stability of LocalTimes.

3.2 SET UP AND ANALYSIS

The configuration of the experiment is shown in figures 2 and 3. The link rate between Time Master and User Node was set to be 100 MHz without any other data transfer; i.e, it was in communication of NULL (8 bits). In experiment (i), time lags between Time-Code “ticks” of Time Master and User Node were taken by a Time-to-Analogue Converter with and without the router hop. In experiment (ii), the mapping table of TI and LocalTime was recorded on the User Node into its own SDRAM every second, and was read out via a CPU node named SpaceCube [5]. The User Node was set into a thermostat bath under the temperature of 10 ±5, ±10, or ±20 ºC with no router between the two nodes. Then, we calculated the interpolation function from data sampled every Sample Period, and we got the residuals (hereafter “Timing errors”) by comparison with the function and the original fine data.

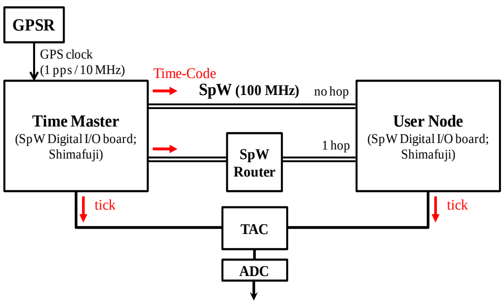

Figure- 2 : Set up of the experiment (i).

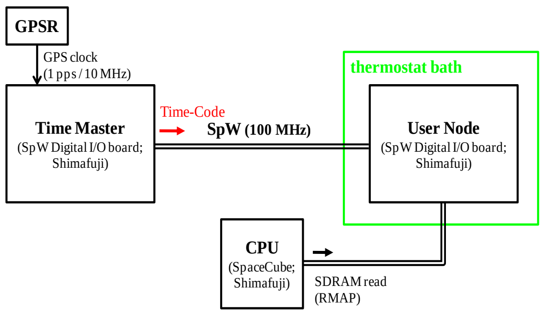

Figure- 3: Set up of the experiment (ii).

3.3 Results and Discussions

Figure 4 shows the results of the experiment (i); histograms of time delays of Time-Codes between Time Master and User Node. Full widths of the distributions are 90 and 160 ns without and with the router between the two nodes, respectively. These values can be interpreted as time jitters of 70 or 140 ns by one or two routers, respectively. The rest 20 ns is due to other unknown origin. In other words, N hops causes $70 \times N$ ns jitter. In the ASTRO-H configuration, the minimum link rate is to be 20 MHz so that jitters of Time-Codes should be 70 ns × (100 MHz / 20 MHz) = 350 ns at 1 hop. In the ASTRO-H network, 4 or 5 hops are expected (figure 1), and thus the total jitters of Time-Codes are expected to be 1.4-1.8 μs. This value is well below the timing accuracy required.

Figure 5 shows the results of the experiment (ii); Timing errors as a function of Sample Periods. Even if the temperature varies ±20 ºC, timing distortion by sampling the mapping table is less than the requirement.

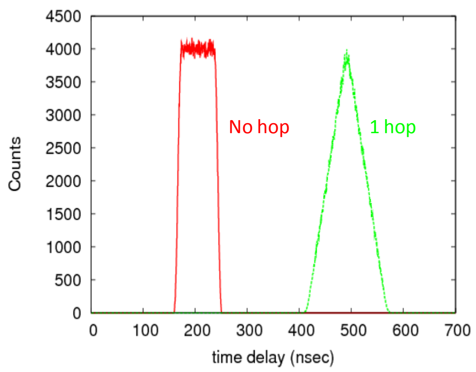

Figure- 4: Histograms of jitters of Time-Codes.

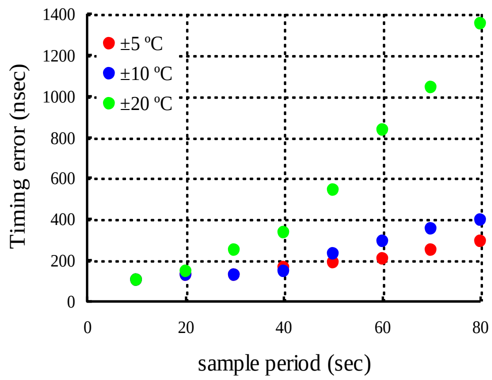

Figure- 5: Timing errors an a function of Sample period, under temperature variety of ±5, 10, 20 K (red, blue and green, respectively).

In summary, the method proposed by us fulfils required time performance to the ASTRO-H satellite.

4 References

[1] T. Takahashi et al., “The NeXT mission”, Proc. SPIE, 7011, 70110-O, 2008

[2] S. M. Parkes, “The Operation and Uses of the SpaceWire Time-Code”, International SpaceWire Seminar, 4-5 November 2003, ESTEC Noordwijk, The Netherlands

[3] Y. Terada et al., “In-Orbit Timing Calibration of the Hard X-Ray Detector on Board Suzaku”, Publications of the Astronomical Society of Japan, 60, 25

[4] C. Christophe & P. Frederic, “SpaceWire in the SIMBOL-X Hard X-ray Mission”, International SpaceWire Conference 2008, 4-6 November 2008, Nara, Japan

[5] T. Yuasa et al., “A Portable SpaceWire/RMAP Class Library for Scientific Detector Read Out Systems”, International SpaceWire Conference 2008, 4-6 November 2008, Nara, Japan