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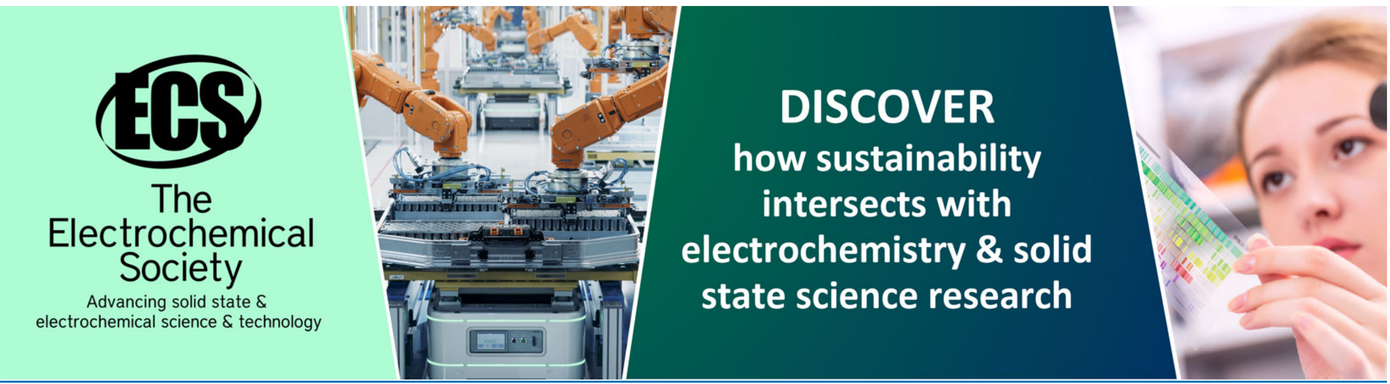

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Status of the scientific data acquisition system for the GAMMA-400 space telescope mission

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Abstract. The present status of scientific data acquisition system (SDAQ) developed by SRISA for the GAMMA-400 space gamma-ray telescope mission is presented. SDAQ provides the collection of the data from telescope detector subsystems (up to 100 GB per day), the preliminary processing of scientific information and its accumulation in mass memory, transferring the information from mass memory to the satellite radio line for its transmission to the ground station, the control and monitoring of the telescope subsystems. SDAQ includes special space qualified chipset designed by SRISA and has scalable modular net structure based on fast and high-reliable SerialRapidIO 1.25 Gbit/s interface.

1. Introduction
The future GAMMA-400 space mission [1] is aimed for the study of gamma rays in the energy range from ~20 MeV up to 1 TeV. The observations will carry out with GAMMA-400 gamma-ray telescope installed on-board the Russian Space Observatory.

The GAMMA-400 instrument is composed by the following main subsystems: anticoincidence subsystem (AC), converter-tracker subsystem (C), a Time of flight subsystem (TOF), an imaging calorimeter (CC1), deep electromagnetic calorimeter (CC2), trigger system (Tr), scientific data acquisition system (SDAQ), and telescope power supply subsystem (PSS). The detailed description of the GAMMA-400 telescope can be found in [2]. The volume of data acquired from the instrument subsystems for separate detected event is not exceeded 1 MByte. The estimated maximum volume of scientific information collected by the telescope per day is about 100 GByte.

The SDAQ is the heart of scientific complex and so it should be a high-reliable subsystem. It provides the instrument control, the acquisition, pre-processing and accumulation in mass memory of the scientific and housekeeping data from telescope detector subsystems, transferring the collected data to the satellite radio line. The SDAQ architecture proposed in this work allows us to realize the effective control and fast scientific data acquisition for the GAMMA-400 instrumentation complex. In order to increase the reliability of SDAQ, it is designed using a scheme with reserved subsystems. All control and data transfer interfaces are double redundant. Additional reliability level of SDAQ is achieved by minimization of the number of high integrity chips.

2. The main scientific data acquisition system functions

The main functions of the scientific data acquisition system are the following:

- The data acquisition from the subsystems of the scientific complex.
- Preliminary processing of scientific information and storage it in non-volatile mass memory (1 TByte total).
- Scientific data transfer into high-speed (320 Mbit/s) scientific radio line for its transmission to the data acquisition ground stations.
- Control information reception from the satellite on-board control system (OCS) via MIL-STD-1553B interface, its decoding and transfer to telescope subsystems. Acquisition of housekeeping data and their transmission to OCS.
- Receiving signals from on-board time and frequency standard system and on-board control system and generating high-stable reference synchronization signals and on-board time code for precise timing of telescope subsystems.

3. The description of the GAMMA-400 scientific data acquisition system

The functional diagram of SDAQ is shown in figure 1. The SDAQ consists of two identical subsystems: SDAQ main and SDAQ spare.

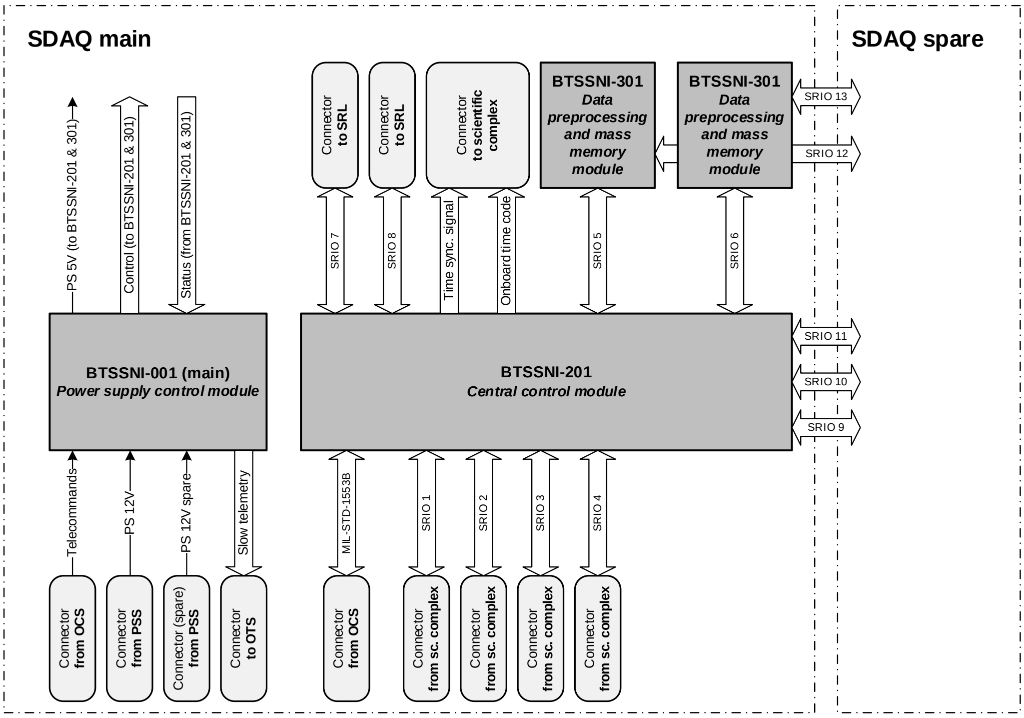

Figure 1. Functional diagram of GAMMA-400 scientific data acquisition system (OCS is on-board control system, PSS is telescope power supply system, OTS is on-board telemetry system, SRL is scientific radio line, SRIO is Serial Rapid Input-Output interface).

Each subsystem includes three types of modules: BTSSNI-001 (power supply control module), BTSSNI-201 (central control module), BTSSNI-301 (data pre-processing and mass memory module).

The main tasks of BTSSNI-001 are the conversion of the primary power (12 V) obtained from the telescope power supply system and switch-on/off the BTSSNI-201 and BTSSNI-301 units. Each of main and spare BTSSNI-001 can switch main and spare BTSSNI-201 and BTSSNI-301 modules. The control and monitoring of the BTSSNI-001 are carried out by on-board control and telemetry systems with pulse telecommands and “dry” contacts.

The central control module BTSSNI-201 is the intelligent core of SDAQ. It executes the receiving of macrocommands from OCS and distributing of the control information to telescope subsystems, the scientific and housekeeping data acquisition from the subsystems and their distribution between two data pre-processing and mass memory modules BTSSNI-301. BTSSNI-201 receives the signals from on-board time and frequency standard system and on-board control system and generates high-stable reference synchronisation signals (1 Hz, 1 kHz and 1 MHz) and 32-bit on-board time code for precise timing of scientific complex. BTSSNI-201 controls the whole SDAQ functioning.

The BTSSNI-301 unit is intended for acquired data preliminary processing and storage in non-volatile mass memory. BTSSNI-301 contains 256 GBytes NAND flash memory bank. Two BTSSNI-301 modules are utilised in SDAQ to increase the speed of scientific data acquisition, the volume of collected information and reliability of the system.

All main and spare SDAQ modules with backplane are installed in special aluminium alloy case.

SDAQ has the following redundant external interfaces: pulse telecommand interface (from on board control system (OCS), power channel +12 V (from telescope power supply system (PSS)), slow telemetry channel (to on board telemetry system (OTS)), intelligent control interface MIL-STD-1553B (to OCS), four fast 1.25 Gbit/s Serial RapidIO (SRIO) interfaces for the control and scientific data acquisition from telescope subsystems, two fast 1.25 Gbit/s Serial RapidIO channels for the data transmission from mass memory into satellite scientific radio line (SRL), time synchronisation interface (to the instrument subsystems).

The SDAQ technical characteristics are: the total maximum throughput of four SRIO channels for scientific data acquisition from telescope subsystems is 70 MBytes/s; the maximum data rate of two SRIO channels for the data transmission to SRL is 40 MBytes/s; mass memory volume is 1024 GByte; maximum power consumption is 80 W; outline dimensions are 400×250×240 mm; mass is 24 kg.

The detailed design of BTSSNI-001, BTSSNI-201, BTSSNI-301 units, as well as the architecture of internal SRIO network and description of the used software are presented below.

3.1. The power supply control module BTSSNI-001

The flowchart of power supply control module BTSSNI-001 is shown in figure 2. The core of BTSSNI-001 is 1907VM044 microcontroller. It provides separate switching-on/off of BTSSNI-201, BTSSNI-301 main and spare modules. After switching-on of BTSSNI-001 the microcontroller tests the functionality of BTSSNI-201, BTSSNI-301 main and spare modules and automatically chooses the operating configuration of SDAQ. This provides the full backup of SDAQ subsystems.

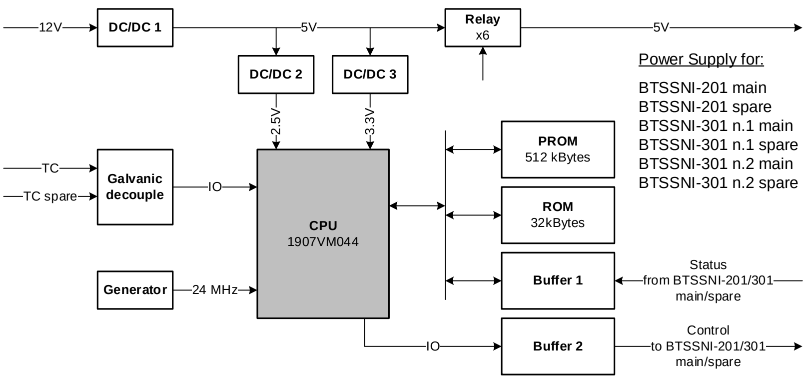

Figure 2. BTSSNI-001 scheme.

3.2. The central control module BTSSNI-201

The scheme of central control module BTSSNI-201 is shown in figure 3. BTSSNI-201 contains 1907VM038 microprocessor and two 1907KX018 Serial RapidIO switches. System-on-chip

1907VM038 [3] consists of 32-bit central processing unit (CPU), 128-bit arithmetic co-processor CP2, system controller with DDRII, SPI, two 1.25 Gbit/s SRIO ports, SpaceWire (4 ports), I2C, GPIO, UART. Clock frequency is 100 MHz, the throughput of RAM is 512 Mbytes/s. The SRIO switch 1907KX018 [3] consists of six SRIO ports; the transferring environment is configured independently: LP-Serial 4X or 1X. Maximum transferring speed is 1.25 Gbit/s (per channel).

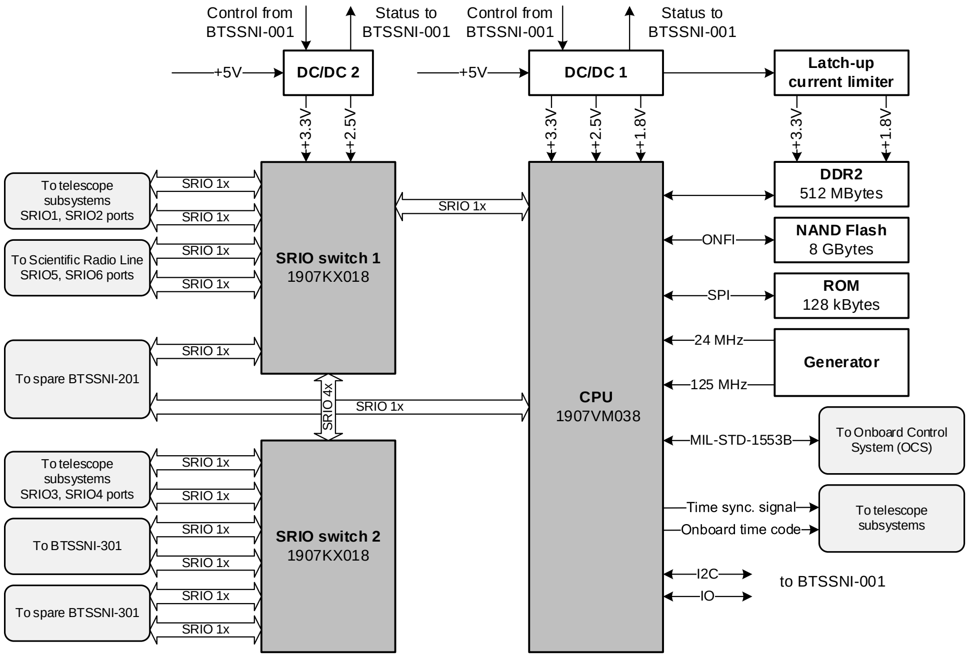

Figure 3. BTSSNI-201 scheme.

3.3. The data pre-processing and mass memory module BTSSNI-301

The BTSSNI-301 module contains 1907VM038 microprocessor and 256 GByte NAND flash memory bank. It detailed flowchart is presented in figure 4.

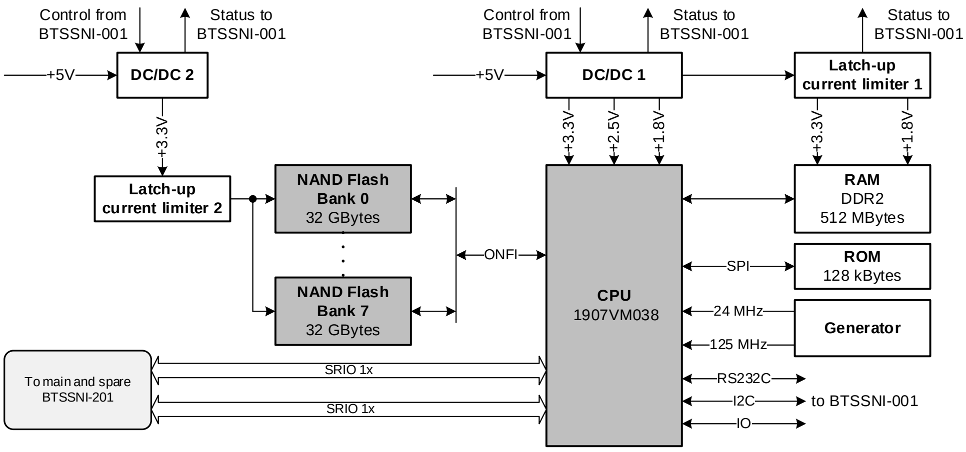

Figure 4. BTSSNI-301 scheme.

3.4. The architecture of internal Serial RapidIO network

The architecture of SDAQ internal Serial RapidIO network is shown in figure 5. The control of the telescope and the data acquisition from its subsystems are provided with four 1.25 Gbit/s Serial

RapidIO x1 channels (SRIO1-SRIO4). Another two 1.25 Gbit/s SRIO x1 interfaces (SRIO5, SRIO6) is used for the transferring of the data stored in NAND flesh banks to scientific radio line of the satellite. This architecture of SRIO network allows to achieve the full backup of SDAQ subsystems.

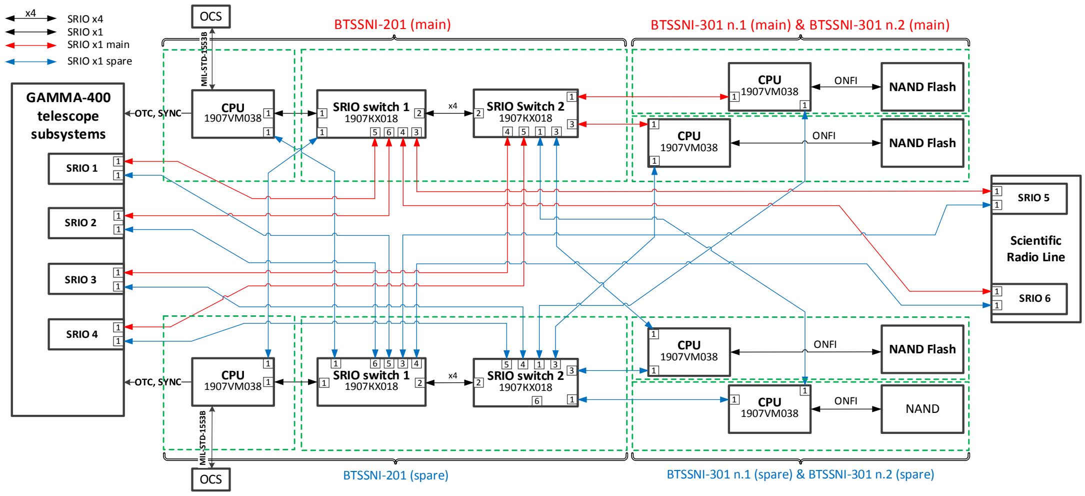

Figure 5. The architecture of SDAQ internal Serial RapidIO network.

3.5. The SDAQ real-time operational system

As operating system for SDAQ, the real-time OS (RTOS) Baget 3.0 [4] was chosen. This RTOS is developed on the base of the following general approaches: use of the standards (ARINC 653 and POSIX 1003.1 for programming interface; C standard for C language and libraries); portability; advanced facilities for tracing, logging, diagnostics and error handling (health monitor); flexible scheduling; object-oriented approach; scalability (configuration tools); instrumental software for developing and debugging user cross-applications; large number of the environmental packages for creating graphics applications, and databases.

4. Conclusion

For developing of the GAMMA-400 SDAQ the modern technical solutions were utilised. Thereby SDAQ has cross-redundant and high reliable structure. The applying of parallel architecture in combination with fast Serial RapidIO interfaces for scientific information acquisition will allow us to decrease the instrument dead time and obtain up to 100 GBytes of experimental data per day.

At present stage of the GAMMA-400 development the prototype of SDAQ was designed and the principle engineering solutions were justified.

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