Anton V. Khnykin

RECONFIGURABLE ONBOARD COMPUTER FOR SMALL SPACECRAFT

Mater's Programme Spacecraft system design

The abstract of the Master's Thesis

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The thesis work is done at the "Applied physics and space technology" department of Federal State Autonomous Educational Institution of Higher Professional Education «Siberian Federal University».

Supervisor:
Sergey G. Kochura, PhD in Engineering Science, Assistant professor

Peer Reviewer:
Philippe Brochain, director of Aerospace International Services

The thesis defence will take place on July 8, 2014 at Siberian Federal University, venue: 12A, Kirova Street, Zheleznogorsk, 662971, Russia

Master's Program Leader Victor E. Chebotarev, Professor
Doctor in Engineering Science

GENERAL DESCRIPTION OF WORK

Topicality. Currently, the traditional approaches to the architecture of onboard control system (OCS) for Small Spacecraft, based on a centralized control hierarchy relations, can not fundamentally affect the decision of the main tasks of Space Instrument for OCS. Achievement of high reliability, failure and fault tolerance at an acceptable cost of hardware redundancy to withstand stringent requirements for weight and dimensions and power consumption are included, achievement unification of interfaces and data channels and, consequently, to achieve the necessary technical and economic indicators to compete in the the global market with the best world analogues are included. The main reasons for the lack of competitive domestic platforms for Small Spacecraft can be attributed significant differences from the network architecture currently used by Small Spacecraft centralized hardware-redundant structures with a complex system of mutual relations.

The number of required changes is so great that high technical risks are associated with implementing modular network technology have been as a major constraint. Thus, the transition to modular network architectures of onboard control significantly changes the conceptual approaches to design of not only the OCS, but also the Small Spacecraft platform. Technological risks introducing qualitatively new OCS network architecture can be significantly reduced through the using of the latest achievements in the field of domestic microelectronics, recessed ground experimental testing a prototype of the OCS and space flight tests in technological Small Spacecraft. Currently, the Russian space industry has created the necessary technological advance that allows to develop a consistent**,** unified hardware and software platform for different classes of OCS of Small Spacecraft based on highly efficiency information-management onboard networks and modular design that combines all the functional units into a unified small- size OCS hardware and software complex with extensive functional and hardware upgrades.

The aim of the dissertation is to develop a concept of modular network architecture, network controller and controller of control engineering for the onboard computer complex of small spacecrafts.

The following challenges are to be solved:

1. Analize of methods and ways of organizing the onboard computer.
2. Design a concept of modular network architecture of the onboard computer.
3. Develop of the controller of SpaceWire and engine controller antenna aperture on position.
4. Experimentally test of functional modules.

Study of subject the dissertation is methods and ways of organizing an onboard computer complex of small spacecraft.

Scope of research are increasing of performance characteristics of onboard computer of Small Spacecraft by the modern methods and ways of its organizing.

Research methods. To solve the problems were used the foundations of the design theory, computer and systems theory mathematical modeling of computing

devices and systems, methods and means of experimental simulation of VLSI structures and systems.

Scientific novelty of the dissertation is to develop a method of devices communicate by a modular network architecture of onboard computer system for increasing of reliability, performance characteristics and active shelf life of Small Spacecrafts.

Evaluation of results of the research. Basic theoretical and practical results of the dissertation were discussed and reported at the following conferences:

1. International scientific conference «Informatization– 2012», Minsk, 24th-27thOctober, 2012.
2. XIII International youth scientific conference «Intelligence and Science», Zheleznogorsk, 16th-18th April, 2013.
3. IX Russian scientific and technical conference of students, postgraduates and young scientists with international participation «Youth and Science», Krasnoyarsk, 15th-25th April, 2013.
4. Regional scientific and technical conference of master students «Special engineering education–preparation of modern of engineering personnel», Krasnoyarsk, 19th November, 2013.
5. XIV Russian youth scientific conference with international participation «Intelligence and Science», Zheleznogorsk, 16th-18th April, 2014.
6. X Anniversary Russian scientific and technical conference of students, postgraduates and young scientists with international participation «Youth and Science», Krasnoyarsk, 15th-25th April, 2014.

Results of the dissertation has also influence of international internships in France in Thales Alenia Space.

CONTENT

The first chapter describes the module-network architecture of OCS of Small Spacecraft. The implementation standards of OCS are considered.

Modular network architecture has a data infrastructure feature that can duplicate of basic infrastructure components of OCS, has a several alternative ways for transferring data, can scaling or modifing existing equipment for OCS of Small Spacecraft. OCS structure is fixed and previously known of any units which data can be transmitted.

SpaceWire can be recognized as one of the most perspective standards, satisfying the requirements to the onboard network of modern aerospace discussed above. This is the most perspective technology for high-speed system-communication and aggregation of aerospace systems. Technology was developed by the European Space Agency ESA (with the participation Russian universities and software companies) and was designed to replace the currently used standards that do not meet the increasing demands of modern space and aircraft.

The most difficult problem for the onboard equipment of Small Spacecraft is to provide radiation resistance during long-term active operation. Triple Modular Redundancy, TMR is one of the widely used method to solve this problem, which is

based on the creation of duplicate critical circuit elements.

To achieve the goal of the dissertation was decided to use SpaceWire standard and TMR technology to provide the required reliability characteristics (radiation resistance) imposed on the area of demanding application at the software (realization of the circuit) level. OCS module development is the platform FPGA development which is the perspective technology in aerospace and military fields.

The second chapter is devoted to the development of modular network architecture of OCS. As the SpaceWire controller was chosen MC-24R, because it operates at high frequencies and takes less logic cells that enables the implementation of an additional module.

Thus, on the basis of the information about the underlying architecture of the selected microprocessor core, we can work out an overall functional block diagram of the system being developed, with a system bus which will act as AMBA, because through it the microprocessor is able to connect to the rest of the peripheral devices, one of which is the controller channel interface SpaceWire.

SpaceWire channel interface controller, in accordance with standard ECSS-E-50 - 12 should include a receiver, a transmitter and an interface to a host device.

The unit receives the data from the host device, encodes, and sends the data to its transmitter connected directly to the line (Fig. 1). At the other end of the line the data receiver receives the data that decodes and transmits the data to the destination (another host device). The transmitter and receiver with the necessary controls and interfaces to a host device forms the SpaceWire controller channel. The channel controller operates the connection and data flow, detects disconnects, reconnects after failures, etc.

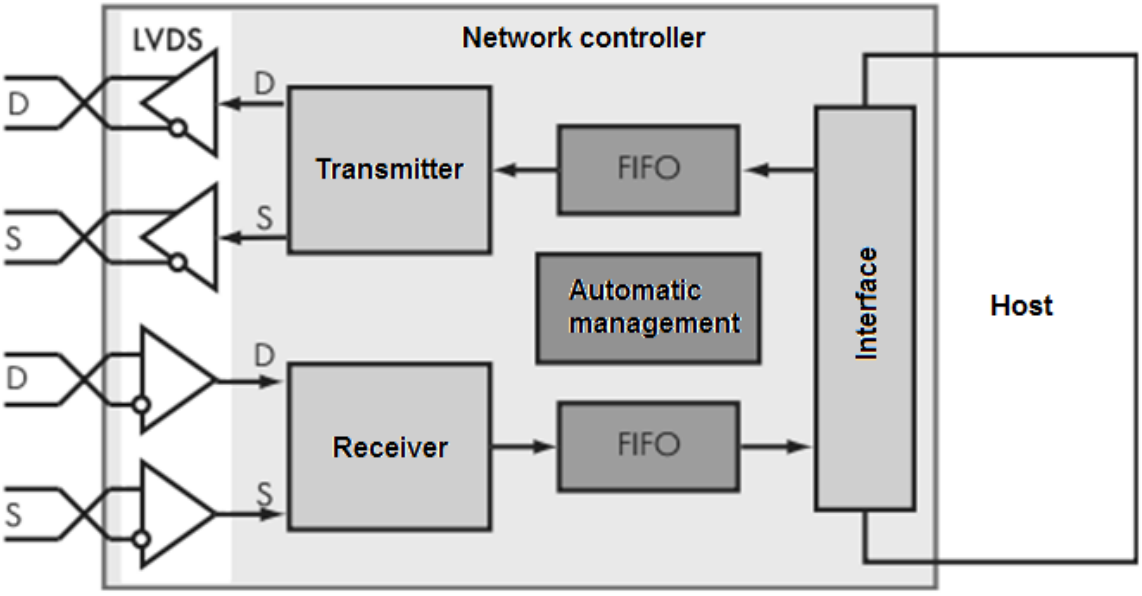

Fig. 1 – SpaceWire network interface controller

In **the third chapter** consideres the design of the controller module SpaceWire in the VHDL language. All the design is VHDL - based and medium-aided (CAD) Xilinx ISE.

Xilinx ISE CAD allows the synthesis of the project according to the description in the language of HDL to build RTL (Register transfer level, register transfer level) scheme. RTL diagram shows the implementation of description in HDL language at the level of primitive circuitry elements.

Block top level module is the designed spwstream block. The spwstream unit is a complete network SpaceWire unit with FIFO (FIFO processing) interface that implements the protocol stack, except for routing network layer. Fig. 2 shows a block diagram of the spwstream.

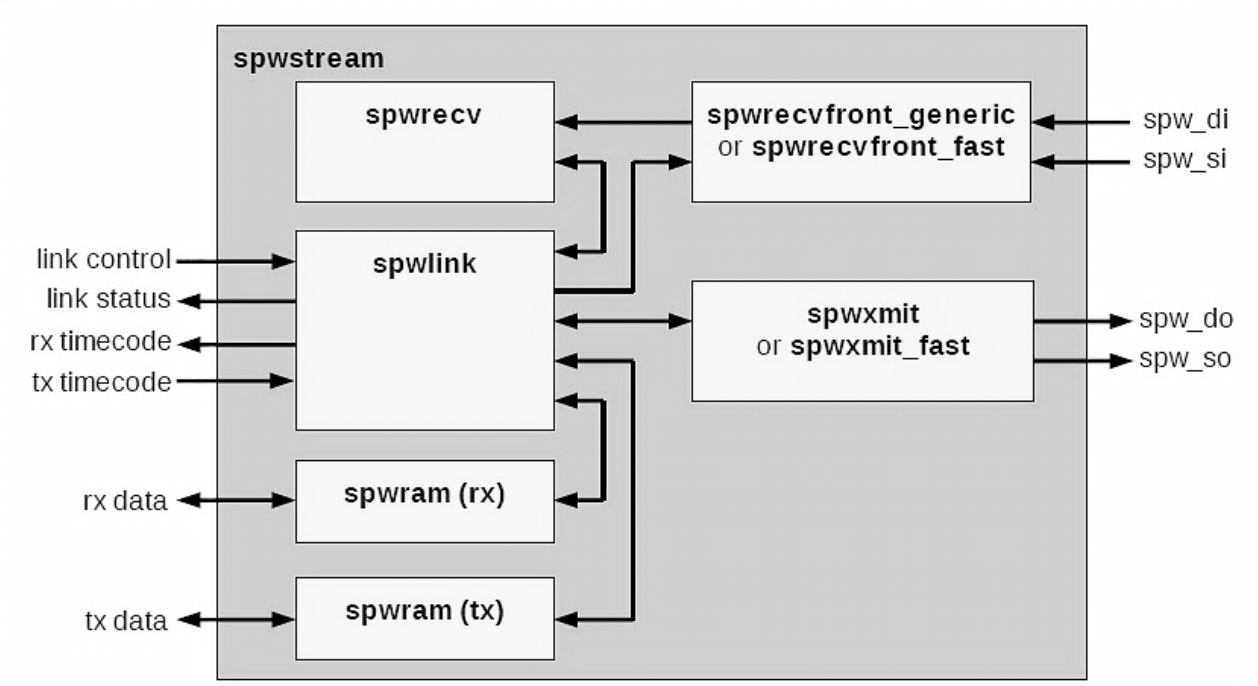

Fig. 2 – The unit upper level spwstream

The block preprocessing receiver allows for two possible implementations: the standard and speed. The particular implementation is carried out in a top-level block with parameter spwstream rximpl.

Functional diagram of a repeater motor are shown on Fig. 3.

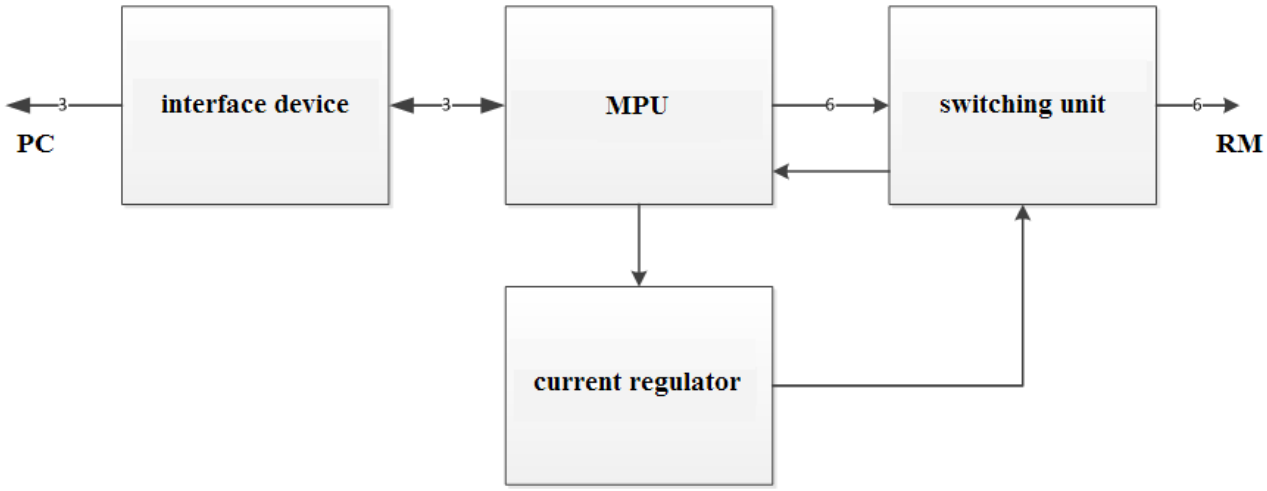

Fig. 3 – Functional diagram of a repeater motor

The fourth chapter presents the controller SpaceWire test results.

In accordance with the internal structure of the device being developed the tests were developed describing by means of VHDL input data and the principles of their processing.

At the start-up of the process of receiving - transmitting data the channel initializizes then on the output line signals are generated, forming a NULL-code, which according to strandarts is always transmitted if the channel transmits no data symbols or control (this enables to maintain channel's activity and detect an error of disconnection). Thereafter, at a time that corresponds 200 ms, the receiver by setting up a tx_full_n signal at a zero state enables the data transmission that appear first on the line rx_fifo_d (i.e, the output of the transmitter buffer) and then on line rx_dout, which corresponds the data in the transmission process. After transmitting one packet on the line FCT signal is generated, which operates the data flow in the network in order to avoid buffer overflow of the receivers. Each FCT symbol transmitted indicates that the receive buffer has space for reception. After completion of the data the receiver sets up tx_full_nat a logical unit state thus prohibiting further data transmission. After some time the self-test disconnection error is detected.

CONCLUSION

Components' weight reduction preserving high levels of reliability is a challenge today, which can be solved by using standard SpaceWire and reconfigurable OCS.

The theoretical study and practical implementation of such OCS confirmed high performance characteristics.

Further development of the dissertation topic should be carried out in the direction of unification of the components being used that will help create a universal space platform for a series of scientific, communication and other types of Small Spacecraft.

CONTRIBUTION OF INTERNSHIP

During the internship at Thales Alenia Space the best practice of leading European companies has studied in the field of development of spacecraft for a wide range of applications. Visits to manufacturing and design departments gave a good opportunity to discuss with our French colleagues the issued on the topic of the dissertation. As a results of the internship was designed onboard computer system for spacecraft Telcom-3S.

The main content of the dissertation was published in the papers:

1. Khnykin A.V., Krasko K.F. Integrated information system // Materials of Interrnational scientific conference, Minsk, 24th-27th October 2012 / V. V. Kazachenok. – Minsk : BSU, 2012. – P. 421–423.

2. Nepomnyashy O.V., Khnykin A.V. Analysis of computer system design on the chip // The research of the science city. – 2012. – Vol. 1(1). – P. 42–46.

3. Nepomnyashy O.V., Andreev A.S., Komarov A.A., Ryzhenko I.N., Khnykin A.V. Problems and solutions of designing specialized onboard computing systems /

Intelligence and Science : Proceedings of XIII International youth scientific conference / A. V. Khnykin ; The branch of Siberian Federal University in Zheleznogorsk. – Zheleznogorsk, 2013. – P. 36–37.

4. Nepomnyashy O.V., Khnykin A.V., Matyukov V.A. Network technologies in space exploration - SpaceWire standard / Intelligence and Science : Proceedings of XIII International youth scientific conference / A. V. Khnykin ; The branch of Siberian Federal University in Zheleznogorsk. – Zheleznogorsk, 2013. – P. 38–39.

5. Khnykin, A.V. New ways for high-level design SoC for prospective spacecrafts // Special engineering education − preparation of modern of engineering personnel : thesis [first] regional scientific and technical conference of master students 19th November 2013 / Siberian Federal University; E. A. Schipilova. – 2013. – P. 13-14.

6. Nepomnyashy O.V., Khnykin A.V., Mambetaliev N.A. Single chip computer systems of responsible applying // The research of the science city. – 2013. – Vol. 2. – P. 54–57.