MATEC Web of Conferences **79**, 01059 (2016) DOI: 10.1051/matecconf/20167901059
IME&T 2016

NI PXI-BASED AUTOMATED MEASUREMENT SYSTEM FOR DIGITAL ASICs VERIFICATION

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Abstract. The paper describes a structure of the automated measuring system used to control digital ASICs electrical and functional parameters. The automated measuring system is based on National Instruments PXI modules. The PXI-7954R module is the most significant module in the system. Hardware and software operations of the measuring system are discussed in the paper. The measuring system is based on test vectors for digital ASICs functional verification.

1 Introduction

Modern digital ASICs are an optimal solution for unique high-reliability systems with a broad class of applications: data collecting and processing, encoding / decoding and transmitting information over a long distance and others. The possibility of implementation of unique projects combining diverse digital blocks within single IC chip is an important reason behind a developers' choice of hardware digital ASICs. ASICs are widely used in design of electronic systems for operation in a spacecraft, for systems controlling technical processes in reactors of nuclear power plants and other high-reliability systems [1–4].

In modern digital ASICs, up to 200 user I/O lines and significant internal resources for the construction of various types of digital circuits are available for developers. A significant part of the equipment developers don't disclose information about electrical schematic or the firmware diagrams. Developers provide only an order card containing a composition of test vectors. The composition of test vectors describes all possible logic states of the digital ASICs firmware. Also composition of test vectors regulates points in which electrical parameters such as supply current, leakage current, high and low levels output voltage are controlled. In this case, the only possible way to conduct functional checks of a digital ASIC is to use a measuring system based on the operation by order cards. The important task is to control functional and electrical parameters of ASICs at different stages of equipment development. The capability of the measuring system to be used with different firmware is required for an easy modernization. The suggested technical solution allows us to minimize the measuring system setup time for controlling digital ASICs with different firmware.

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2 Equipment

Standard PXI modules (National Instruments) have been applied in order to solve this problem. PXI-7954R module is the main system component. NI PXI-7954R module is based on Virtex-5 LX110 FPGA chip. NI PXI-7954R module is a multifunctional reconfigurable I/O module and has the following features: 132 single-ended or 66 differential digital I/O lines, 128 MB onboard memory (DRAM) and direct memory access (DMA) to transfer data.

Standard composition of a measuring system is based on NI PXI modules: two DC power supplies modules PXI-4110; FPGA module PXI-7941R (when ASIC I/O lines are more than 132, another FPGA module PXI-7954R can be added). All measuring system modules are combined in PXI-1033 chassis.

The following tasks were solved using NI PXI-7954R module:

- storing test vectors sequence in DRAM and directing all I/O lines in the same vectors to enable signal discharge;
- storing test results for each unload vector in the current test frame;
- transferring test results information to PC.

3 Software

In order to load test vectors in PXI-7954R DRAM and to implement operation control algorithms and I/O, LabVIEW environment has been used. LabVIEW graphical programming allows user to build a virtual instrument (VI) logic algorithm, quickly developing data transmission algorithms from NI modules devices to a HOST PC, generating visual reports about testing in graphs, to analyze text documents that contain basic information for the measuring system, and generate text and graphical log reports.

The digital ASIC's order card is a text document containing a composition of test vectors that determines the condition of all I/O of the IC. The completeness of an order card may be different. Usually the composition of test vectors included in the order card allows us to check all possible modes and logic states of the test ASIC firmware. Figure1 shows an order card example. Adopted unique designation – string of characters «*» informs about the need to control the electrical parameters of test's sample ASIC in a given vector of order card. In some cases, the point of control of electrical parameters is given in the text description to an order card which is issued by the ASIC's manufacture.

Symbols «H», «L», «X», «Z» were used as a universal notation which indicates the status of ASIC's output lines – a logic high level, logic low level, the state of line is not important, high-impedance state. Characters «0», «1» indicate low and high input logic levels of the digital ASIC. The beginning and the end of the vector may be indicated by different symbols. In the example, this symbols are «R1 std» (beginning) and «;» (end). In the software, settings of the measuring system have the ability to define characters for the beginning and the end used in a given order card for the vectors.

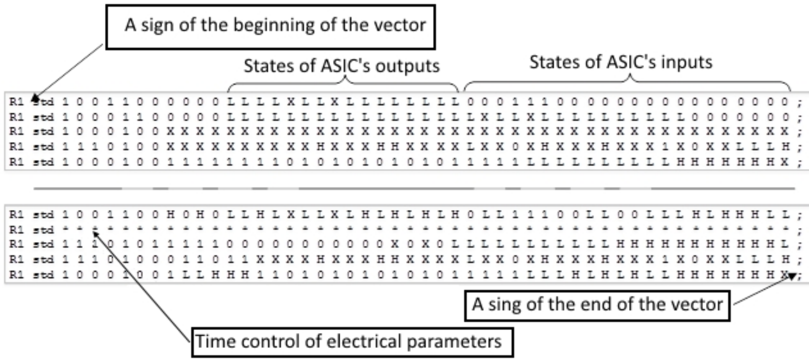

Figure 1. Example of typical order card.

Measurement system's software consists of two parts. The first part is the user part (HOST). The second part is the hardware based on FPGA module and DC power modules. The HOST is running on PC. The HOST provides a user interface and manages the hardware part of the measuring system. The HOST is also responsible for the accumulation of statistics about failures in a sample chip functional test. Types of faults are described in [5–11]. It's recording the results of parametric and functional control.

The main functions performed by the different parts of the software are following:

<u>HOST part</u>

1. Configuration of the measuring system. The user selects the number of involved FPGA PXI-7954R modules (1 or 2). The number of modules is based on the number of user I/O lines in ASIC.
2. Loading file with the order card. In the automatic transmission mode determined the direction of each I/O line in each vector.
3. Formed array of states I/O lines, transmission direction and control mask for each vector.
4. Formed array is loaded into the FPGA PXI-7941R module DRAM.

<u>FPGA part</u>

5. At the limit operating frequency, data is unloaded from DRAM. The data stream discharged from the module memory contains three vectors: data, direction and mask.
6. Data in direction array customize each I/O line of PXI-7954R module. Data array is used to set the values of the input ASIC's lines. Data array also has reference information on the output ASIC's lines. Figure 2 shows fragment of the code generating the output data which is based on data and direction arrays.
7. Next, the state of ASIC's I/O lines is read. Formed response array is based on the mask array. Then the formed data array is compared with the reference data array. The number of differences is determined. The response data array is then stored in FPGA module's memory and can be read by HOST for the detailed analysis of any failures.

Figure 3 shows the front panel of the developed HOST VI. Boot time and reading of the order card's vectors controlling the ASIC's currents are shown.

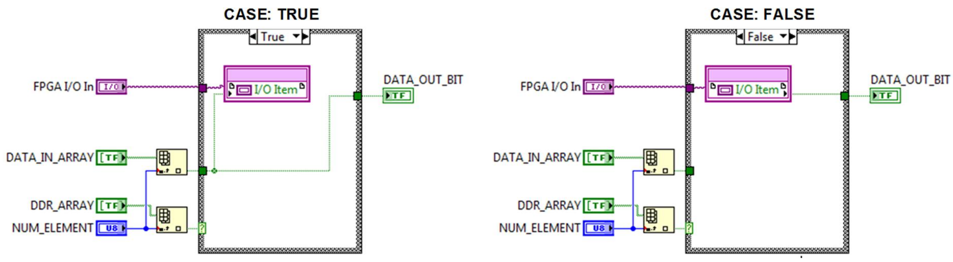

Figure 2. Fragment of the program code. Setting up, set and reading the state ASIC's line.

The number of vectors downloaded in the FPGA module's memory is limited by the memory volume available in the FPGA module (for the PXI-7954R module – 128 MB DRAM). If the volume of the order card exceeds available memory, the data from the order card divided into blocks of suitable size. Cyclic repetition of the operations described above allows us to perform complete verification of the test according to the ASIC's order card to limit frequency of enumeration test vectors with pauses to load the next part of the vectors into the FPGA module internal memory.

The software provides the logging results of the functional test (number of failures) and extended diagnostic information in text files. The diagnostic information contains the number of failure vectors, the read sate output lines of ASIC, and the reference value of ASIC's output lines. The measuring system controls electrical parameters of the ASIC in order card breakpoints. Currents of the test sample ASIC are monitored using built-in PXI-4110 module ammeters.

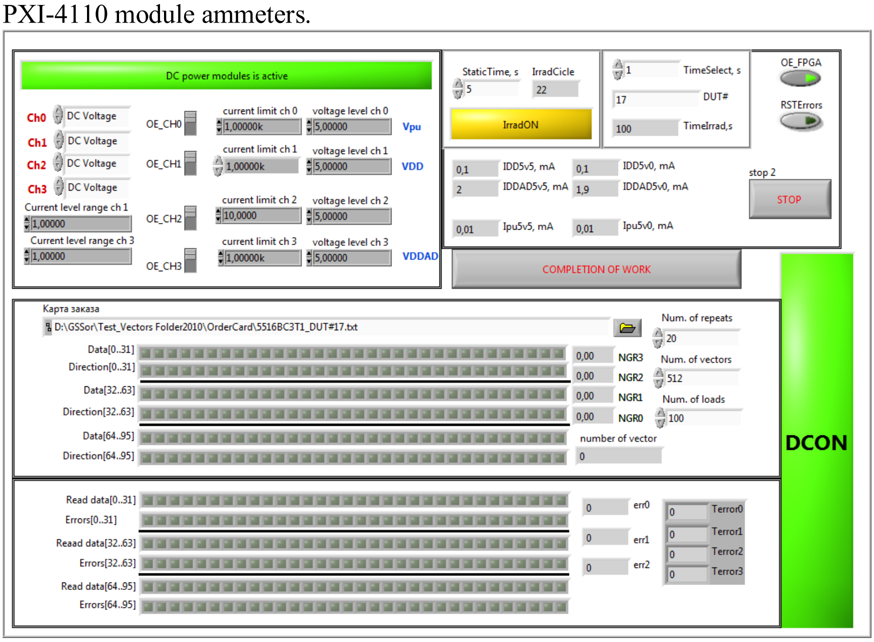

Figure 3. The designed HOST VI front panel.

4 Implementation and future prospects

The developed measuring system has been successfully tested in JSC «Specialized Electronic Systems» (ENPO SPELS) and Institute of Extreme Applied Electronics of National Research Nuclear University MEPhI. The principle of modularity of equipment, as well as the ability to easily zoom code, allows us to increase the number of used input-output lines proportionally to the number of lines used in FPGA modules of the measuring system. The choice of the base FPGA module is a positive decision for the entire system. FPGA module allows testing of integrated circuits not only using the order card, but, as described in [12–20], using the approach of building an FPGA module full test environment study of ASIC’s firmware.

Acknowledgements

The work was performed as a part of the grant RFBR № 14-29-09131.

References

[1] A. I. Chumakov, A. V. Afonin, V. A. Polunin, Russian Microelectronics **42**, 424 (2013) doi: 10.1134/S1063739713070032
[2] O.A. Kalashnikov, A.Y. Nikiforov, Proceedings of the International Conference on Microelectronics (ICM), 6842189 (2014) doi: 10.1109/MIEL.2014.6842189
[3] A.S. Artamonov, A.A. Sangalov, A.Y. Nikiforov, V. A. Telets, D.V. Boychenko, IEEE Radiation Effects Data Workshop **2015-January**, 7004600 (2014) doi: 10.1109/REDW.2014.7004600
[4] L.N. Kessarinskiy, D.V. Boychenko, A.G Petrov, P.V. Nekrasov, A.V. Sogoyan, V.S. Anashin, P.A. Chubunov, IEEE Radiation Effects Data Workshop **2015-January**, 7004562 (2014) doi: 10.1109/REDW.2014.7004562
[5] A.O. Akhmetov, D.V. Boychenko, D. V. Bobrovskiy, A. I. Chumakov, O. A. Kalashnikov, A.Y. Nikiforov, P. V. Nekrasov, Proceedings of the International Conference on Microelectronics (ICM), 6842156 (2014) doi: 10.1109/MIEL.2014.6842156
[6] A.I. Chumakov, A. A. Pechenkin, D.V. Savchenkov, A.S. Tararaksin, A. L. Vasil'ev, A. V. Yanenko, Proceedings of the European Conference on Radiation and its Effects on Components and Systems (RADECS), 6131420 (2011) doi: 10.1109/RADECS.2011.6131420
[7] G.N. Nazarova, V.V. Elesin, A.Y. Nikiforov, A. G. Kuznetsov, N. A. Usachev, G. V. Chukov, CriMiCo 2014 - 2014 24th International Crimean Conference Microwave and Telecommunication Technology Conference Proceedings, 6959663 (2014) doi: 10.1109/CRMICO.2014.6959663
[8] D.V. Boychenko, O. A. Kalashnikov, A.B. Karakozov, A. Y. Nikiforov, Russian Microelectronics **44**, 1 (2015) doi: 10.1134/S1063739715010035
[9] I. I. Shvetsov-Shilovskiy, P.V. Nekrasov, A. V. Ulanova, A. A. Smolin, A. V. Sogoyan, Proceedings of the International Siberian Conference on Control and Communications (SIBCON), 7147282 (2015) doi: 10.1109/SIBCON.2015.7147282
[10] A.G. Petrov, A.L. Vasil'ev, A.V. Ulanova, A I. Chumakov, A.Y. Nikiforov, Central European Journal of Physics **12**, 725 (2014) doi: 10.2478/s11534-014-0503-6
[11] D. V. Bobrovskii, O. A. Kalashnikov, P. V. Nekrasov, Russian Microelectronics **41**, 226 (2012) doi: 10.1134/S1063739712040038

[12] P. V. Nekrasov, A. A. Demidov, O. A. Kalashnikov, Instruments and Experimental Techniques **52**, 196 (2009), doi: 10.1134/S0020441209020092
[13] A. O. Akhmetov, A. V. Yanenko, A. I. Bazhan, Proceedings of the European Conference on Radiation and its Effects on Components and Systems (RADECS), 6937364 (2013) doi: 10.1109/RADECS.2013.6937364
[14] A.B. Boruzdina, A. V. Ulanova, A.G. Petrov, V. A. Telets, P.Reviriego and J.A. Maestro, Proceedings of the European Conference on Radiation and its Effects on Components and Systems (RADECS), 6937393 (2013) doi: 10.1109/RADECS.2013.69373693
[15] A.B. Karakozov, O.V. Korneev, P.V. Nekrasov, M. N. Sokolov and D. A. Zagryadsky, Proceedings of the European Conference on Radiation and its Effects on Components and Systems (RADECS), 6937407 (2013) doi: 10.1109/RADECS.2013.6937407
[16] A.V. Demidova, A.Y. Borisov, L. N. Kessarinskiy, D.V. Boychenko, Proceedings of the International Siberian Conference on Control and Communications (SIBCON), 7147036 (2015) doi: 10.1109/SIBCON.2015.7147036
[17] I.O. Loskutov, A.B. Karakozov, P.V. Nekrasov, A.Y. Nikiforov, Proceedings of the International Siberian Conference on Control and Communications (SIBCON), 7147128 (2015) doi: 10.1109/SIBCON.2015.7147128
[18] V.A .Marfin, P.V. Nekrasov, O. A. Kalashnikov, K. A. Kagirina, Proceedings of the International Siberian Conference on Control and Communications (SIBCON), 7147142 (2015) doi: 10.1109/SIBCON.2015.7147142
[19] A. B. Boruzdina, A. A. Orlov, A. V. Ulanova, N. G. Grigor'ev, A.Y. Nikiforov, Proceedings of the International Siberian Conference on Control and Communications (SIBCON), 7147007 (2015) doi: 10.1109/SIBCON.2015.7147007
[20] M.E. Cherniak , A.V. Ulanova, A.Y. Nikiforov, Proceedings of the International Conference on Microelectronics (ICM), 6842119 (2014) doi: 10.1109/MIEL.2014.6842119