

KHARKOV NATIONAL UNIVERSITY OF RADIOELECTRONICS

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10th IEEE EAST-WEST DESIGN & TEST SYMPOSIUM (EWDTS 2012)

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The main target of the **IEEE East-West Design & Test Symposium (EWDTS)** is to exchange experiences between scientists and technologies of Eastern and Western Europe, as well as North America and other parts of the world, in the field of design, design automation and test of electronic circuits and systems. The symposium is typically held in countries around the Black Sea, the Baltic Sea and Central Asia region. We cordially invite you to participate and submit your contributions to EWDTS'12 which covers (but is not limited to) the following topics:

- Analog, Mixed-Signal and RF Test
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- FPGA Test
- HDL in test and test languages
- High-level Synthesis
- High-Performance Networks and Systems on a Chip
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- Modeling & Fault Simulation
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The Symposium will take place in Kharkov, Ukraine, one of the biggest scientific and industrial center. Venue of EWDTS 2012 is Kharkov National University of Radioelectronics was founded 81 years ago. It was one of the best University of Soviet Union during 60th - 90th in the field of Radioelectronics. Today University is the leader among technical universities in Ukraine.

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CONTENTS

An Efficient Fault Diagnosis and Localization Algorithm for Successive-Approximation Analog to Digital Converters Melkumyan T., Harutyunyan G., Shoukourian S., Vardanian V., Zorian Y.	15
Application of Defect Injection Flow for Fault Validation in Memories Amirkhanyan K., Davtyan A., Harutyunyan G., Melkumyan T., Shoukourian S., Vardanian V., Zorian Y.	19
SSBDDs and Double Topology for Multiple Fault Reasoning Raimund Ubar, Sergei Kostin, Jaan Raik	23
Self Compensating Low Noise Low Power PLL design Vazgen Melikyan, Armen Durgaryan, Ararat Khachatryan, Manukyan Hayk, Eduard Musaelyan	29
Optimization Considerations in QCA Designs Zahra NajafiHaghi, Marzieh Mohammadi, Behjat Forouzandeh, Zainalabedin Navabi	33
Implementation of Address-Based Data Sorting on Different FPGA Platforms Dmitri Mihhailov, Alexander Sudnitson, Valery Sklyarov, Ioulia Skliarova	38
Comparison of Model-Based Error Localization Algorithms for C Designs Urmaz Repinski, Jaan Raik	42
Synthesis of Clock Trees for Sampled-Data Analog IC Blocks Bilgiday Yuce, Seyrani Korkmaz, Vahap Baris Esen, Fatih Temizkan, Cihan Tunc, Gokhan Guner, I. Faik Baskaya, Iskender Agi, Gunhan Dundar, H. Fatih Ugurdag	46
Experiences on the road from EDA Developer to Designer to Educator H. Fatih Ugurdag	50
Multi-Beam Constant Modulus Adaptive Arrays in Real-Valued Arithmetic Victor I. Djigan	54
Simulation of Total Dose Influence on Analog-Digital SOI/SOS CMOS Circuits with EKV-RAD macromodel Petrosyants K. O., Kharitonov I. A., Sambursky L. M., Bogatyrev V. N., Povarnitcyna Z. M., Drozdenko E. S.	60
Models for Embedded Repairing Logic Blocks Hahanov V.I., Litvinova E.I., Frolov A., Tiecoura Yves	66
Real-time Interconnection Network for Single-Chip Many-Core Computers Harald Richter	72
Invariant-Oriented Verification of HDL-Based Safety Critical Systems Kharchenko V., Konorev B., Sklyar V., Reva L.	76
An Improved Scheme for Pre-computed Patterns in Core-based SoC Architecture Elahe Sadredini, Qolamreza Rahimi, Paniz Foroutan, Mahmood Fathy, Zainalabedin Navabi	80

Synthesis of Moore FSM with transformation of system in CPLD Aleksander Barkalov, Larysa Titarenko, and Sławomir Chmielewski	85
A WSN Approach to Unmanned Aerial Surveillance of Traffic Anomalies: Some Challenges and Potential Solutions David Afolabi, Ka Lok Man, Hai-Ning Liang, Eng Gee Lim, Zhun Shen, Chi-Un Lei, Tomas Krilavičius, Yue Yang, Lixin Cheng, Vladimir Hahanov, and Igor Yemelyanov	91
Synthesis of Qubit Models for Logic Circuits Wajeb Gharibi, Zaychenko S.A., Dahiri Farid, Hahanova Yu.V., Guz O.A., Ngene Christopher Umerah, Adiele Stanley	95
Theory of Optimal Nonlinear Filtering in Infocommunication's Problems Victor V. Panteleev	102
Verification of Specifications in the Language L with respect to Temporal Properties Expressible by GR(1) Formulas Anatoly Chebotarev	110
Properties of code with summation for logical circuit test organization Anton Blyudov, Dmitry Efanov, Valery Sapozhnikov, Vladimir Sapozhnikov	114
Loop Nests Parallelization for Digital System Synthesis Alexander Chemeris, Julia Gorunova, Dmiry Lazorenko	118
Decreasing the Power Consumption of Content-Addressable Memory in the Dataflow Parallel Computing System Levchenko N.N., Okunev A.S., Yakhontov D.E., Zmejev D.N.	122
WebALLTED: Interdisciplinary Simulator Based on Grid Services Zgurovsky M., Petrenko A., Ladogubets V., Finogenov O., Bulakh B.	126
Malfunctions Modeling of Converters and Homogeneous-chain Distributed Structure Devices Artur Gulin, Zhanna Sukhinets	130
On structure of quasi optimal algorithm of analogue circuit designing Zemliak A., Michua A., Markina T.	134
A Neuro-Fuzzy Edge Based Spectrum Sensing Processor for Cognitive Radios Mohammadreza Baharani, Mohammad Aliasgari, Mohammadreza {Najafi, Jamali}, Hamid Noori	138
Qubit Model for Solving the Coverage Problem Hahanov V.I., Litvinova E.I., Chumachenko S.V., Baghdadi Ammar Awni Abbas, Eshetie Abebech Mandefro	142
PDF testability of the circuits derived by special covering ROBDDs with gates Matrosova A., Nikolaeva E., Kudin D., Singh V.	146
Compositional Microprogram Control Unit with Operational Automaton of Transitions Alexander Barkalov, Roman Babakov, Larisa Titarenko	151
Observability Calculation of State Variable Oriented to Robust PDFs and LOC or LOS Techniques Matrosova A., Ostanin S., Melnikov A., Singh V.	155

Low-Voltage Low-Power 2.5 GHz Linear Voltage Controlled Ring Oscillator Hayk H Dingchyan	161
High Speed IC Output Buffer with Reduced Power Consumption Karine Movsisyan	165
Engineering-Maintenance Methods of the Calculation Service Area Fixed BWA-paths Sergey I. Myshlyakov, Victor V. Panteleev	170
Analyses of two run march tests with address decimation for BIST procedure Ireneusz Mrozek, Svetlana V. Yarmolik	176
Design of Area Efficient Second Order Low Pass Analog Filter Andranik Hovhannisyan	180
Power Consumption Analysis of Content-Addressable Memories Levchenko N.N., Okunev A.S., Yakhontov D.E.	183
IC Physical Design Optimization Due to Effects of Device Physical Geometries Avag Sargsyan	187
System-on-Chip FPGA-Based GNSS Receiver Alexander Fridman, Serguey Semenov	190
Testware and Automatic Test Pattern Generation for Logic Circuits Victor Zviagin	196
Artificial Neural Network for Software Quality Evaluation Based on the Metric Analysis Oksana Pomorova, Tetyana Hovorushchenko	200
Self-Compensation of Influence of Parasitic Gate-Drain Capacitances of CMOS Transistors in Analog Microcircuitry Sergey G. Krutchinsky, Grigory A. Svizev, Alexey E. Titov	204
Hash-based Detection of OFDM Watermarking Symbol for Radiotelephone Identification Aleksandr V. Shishkin, Aleksandr A. Lyashko	208
A Novel Wideband Circular Ring DGS Antenna Design for Wireless Communications Rakesh Sharma, Abhishek Kandwal, Sunil Kumar Khah	211
Universal technique of the analysis of round-off noise in digital filters with arbitrary structure described by topological matrixes Vladislav A. Lesnikov, Alexander V. Chastikov, Tatiana V. Naumovich, Sergey V. Armishev	215
Hardware Reduction for Compositional Microprogram Control Unit Dedicated for CPLD Systems Barkalov A., Titarenko L., Smolinski L.	219
Conservative Finite-difference Scheme for the Problem of Laser Pulse Propagation in a Medium with Third-order Dispersion Vyacheslav A. Trofimov, Anton D. Denisov	225
A Four Bit Low Power 165MSPS Flash-SAR ADC for Sigma-Delta ADC Applications Hasan Molaei, Khosrow Hajsadeghi	229
Matrix Implementation of Moore FSM with Nonstandard Presentation of State Codes Titarenko L., Hebda O.	233

Alowpower1.2GS/s4-bitflashADCin0.18mCMOS Mohammad Chahardori, Mohammad Sharifkhani, Sirous Sadughi	237
Symmetrical Differential Stages on CMOS Transistors with Circuits of Self-Compensation and Cancellation Sergey G. Krutchinsky, Grigory A. Svizev, Alexey E. Titov	241
Lower Bound of Error in AOA Based Passive Source Localization Using Single Moving Platform Hejazi F., Norouzi Y., Nayebi M.M.	245
A Design for Testability Technique for Quantum Reversible Circuits Joyati Mondal, Debesh K. Das, Dipak K. Kole, Hafizur Rahaman	249
A Flexible Design for Optimization of Hardware Architecture in Distributed Arithmetic based FIR Filters Fazel Sharifi, Saba Amanollahi, Mohammad Amin Taherkhani, Omid Hashemipour	253
Models for Quality Analysis of Computer Structures Murad Ali Abbas, Chumachenko S.V., Hahanova A.V., Gorobets A.A., Priymak A.	258
Expanding Wireless Bandwidth in a Power-Efficient Way: Developing a Viable mm-Wave Radio Technology Daniel Foty, Bruce Smith, Saurabh Sinha, Michael Schröter	264
Sampling Theorem for Finite Duration Signal in Limited Frequency Band Gamlet S. Khanyan	270
SiGe HBT Performance Modeling after Proton Radiation Exposure Konstantin Petrosyants, Maxim Kozhukhov	274
Classical Models of Test used in Advanced Electronics Quality Assurance Surendra Batukdeo	278
The Use of Natural Resources for Increasing a Checkability of the Digital Components in Safety-Critical Systems Drozd A., Kharchenko V., Antoshchuk S., Drozd J., Lobachev M., Sulima J.	283
New version of Automated Electro-Thermal Analysis in Mentor Graphics PCB Design System Petrosyants K.O., Kozyenko P.A., Kharitonov I.A., Sidorov A.V., Chichkanov Y. N.	289
An Approach to Testing of Planar Integrated Antennas in Frequency Range of 5–7 GHz Aleksandr Timoshenko, Ksenia Lomovskaya, Victor Barinov, Andrey Tikhomirov	293
Optimal project solution decision making in telecommunication systems using multicriteria optimization methods Valery Bezruk, Alexander Bukhanko	298
Software implementation and debugging of forward error correction codes Alexey Smirnov, Danila Migalin, Ilya Muravyev, Leonid Pertsev	303
Architecture of Built-In Self-Test and Recovery Memory Chips Andrienko V.A., Moamar Daa, Ryabtsev V.G., Utkina T.Yu.	307
The methods of exclusion of variables in symbolic time models of linear periodically time-variable circuit Yuriy Shapovalov, Dariya Smal	311

Two-Component Encoding of Approximating Picture Pixels in Telecommunication Facilities Barannik V., Dodukh A., Safronov R.	315
Development of parameterized cell using Cadence Virtuoso Vadim Borisov	319
Simulation Methods of Diffusion Alloying Process by Means of Taurus TSUPREM-4 Programme Lagunovich N.L., Borzdov V.M.	321
Control and Diagnosis by Complexity Indicators of System Functioning Process Tverdokhlebov V.A.	323
Features of the Transfer of Information with Different Reliability in a Single Channel Alexander Bakhtin, Leonid Pertsev, Olga Timofeeva	327
Construction of Signals with Controlled Peak-Factor Koshevyy V. M., Dolzhenko D.O.	330
The Effective Method of Space Filtering of Noise in Rayleigh Communication Channel with the Adaptive Antenna Maistrenko G. V., Rybalko A. M., Shokalo V. M., Strelnitskiy A. A.	333
A New Structure for Interconnect Offline Testing Somayeh Sadeghi-Kohan, Shahrzad Keshavarz, Farzaneh Zokaee, Farimah Farahmandi, Zainalabedin Navabi	336
Researching of Mathematical Models Based on Optimal Control Approaches for Congestion Control in Telecommunication Network Lemeshko A.V., Semenyaka M.V.	341
Higher Order Propagation Modes Error and Its Compensation Zaichenko O. B., Klyuchnyk I. I., Martynenko L. G.	345
Strategy of analyzing most common algorithms for path finding in discrete labyrinth using software statistic data collector Krasnov Evgeniy, Dmitry Bagaev	349
Method of Implementation of Technology of Orders Based Transparent Parallelizing for Solving Computationally Complex Problems on Cluster Vitaliy D. Pavlenko, Viktor V. Burdejnyj, Sergey V. Pavlenko	353
Scheduling Tests for 3D SoCs with Temperature Constraints Indira Rawat, Gupta M.K., Virendra Singh	356
Automated application mapping into Network-on-Chip topologies Bykov S. O.	360
MIMO Radar with Phase-coded waveforms Amirsadegh Roshanzamir, Bastani M. H.	363
BBN-based Approach For Assessment of Smart Grid And Nuclear Power Plant Interaction Eugene Brezhnev, Vyacheslav Kharchenko	367
Design, Test and Fault Detection in QCA 4-to-1 Multiplexer Zahra NajafiHaghi, Behjat Forouzandeh	374

The Evaluation of Statistical Characteristics of the Retransmission Meter Signal Frequency and Initial Phase on the Basis of VHDL-model Dmitry A. Velychko, Iegor I. Vdovychenko	378
A Research of Heuristic Optimization Approaches to the Test Set Compaction Procedure Based On a Decomposition Tree for Combinational Circuits Valentina Andreeva, Kirill A. Sorudeykin	382
Power Reduction of 7T Dual-Vt SRAM Cell Using Forward Body Biasing Sahba Sabetghadam Jahromi, Raziye Bounik	388
VLSI: An Investigation into Electromagnetic Signatures (EMS) for Non-Invasive Testing and Signal-integrity Verification Kadim HJ, Coulibaly L. M.	392
Secure Data over GSM based on Algebraic Codebooks Kazemi R., Nashtaali D., Boloursaz M., Behnia F.	397
Simulation of Telecommunication Channel Using Volterra Model Vitaliy D. Pavlenko, Viktor O. Speransky	401
Extracting Complete Set of Equations to Analyze VHDL-AMS Descriptions Arezoo Kamran, Vahid Janfaza, and Zainalabedin Navabi	405
A Data Modem for GSM Adaptive Multi Rate Voice Channel Boloursaz M., Hadavi A. H., Kazemi R., Behnia F.	409
Trends and prospects of development of techniques for extracting acoustic sounding information of the atmospheric boundary layer Klyuchnik I., Panchenko A., Umyarov R.	413
Decision-Making in Robotics and Adaptive Tasks Tsybmal A.M., Bronnikov A.I.	417
Design of Nonvolatile Memory Based on Magnetic Tunnel Junction for Special Electronic Systems Aleksandr Kostrov, Vladislav Nelayev, Viktor Stempitsky, Anatoly Belous, Arkady Turtsevich	421
Improving the Dependability of a Water Supply System via a Multi-Agent based CPS Teodora Sanislav, Liviu Miclea, Paolo Prinetto	425
Cyber Security Lifecycle and Assessment Technique for FPGA-based I&C Systems Illiashenko Oleg, Kharchenko Vyacheslav, Kovalenko Andriy	432
FPGA Technologies in Medical Equipment: Electrical Impedance Tomography Perepelitsyn Artem, Shulga Dmitry	437
A Trend-based Design Space Exploration of Multi-core Systems Using Regression Modeling Fazeleh Hajari Taheri, Omid Fatemi	441
Synchronous Rectifiers Enable High Efficiency for Buck-Boost Converter Yurii Shynkarenko and Igor Klyuchnyk	445

Test Data Compression Strategy While Using Hybrid-BIST methodology Elmira Karimi, Mohammad Hashem Haghbayan and Mahmood Tabandeh	449
Self-Adaptive Mobile Wireless Hotspot Zones Yanovsky M., Kharchenko V., Gorbenko A.	454
The Systolic Compositions of Two-dimensional and Multidimensional Lattice Filters for Space-Time Signal Processing David I. Lekhovyt'skiy, Andrii V. Semeniaka, and Dmytro S. Rachkov	458
Power Efficient Implementation of Homogenous Multi-Core Processors Aram Poghosyan	462
Assertion Based Method of Functional Defects for Diagnosing and Testing Multimedia Devices Vladimir Hahanov, Karyna Mostova, Oleksandr Paschenko	465
Improved Scaling-Free CORDIC algorithm Leonid Moroz, Taras Mykytiv, Martyn Herasym	470
Coding Tangible Component of Transforms to Provide Accessibility and Integrity of Video Data Barannik V.V., Hahanova A.V., Krivonos V.N.	475
Review of the botnet detection techniques Oleg Savenko, Sergiy Lysenko, Kryshchuk Andrii	479
MEMS Intellect Multiprobes Contacting Devices for Electrical Checking-up of Multilayers Commutative Boards and BGA/CSP Electronic Components Nevliudov I.Sh., Palagin V.A., Razumov-Frizjuk E.A., Zharikova I.V.	483
Internet of Things: A Practical Implementation based on a Wireless Sensor Network Approach Michele Mercaldi, Andrea D'Oria, Davide Murru, Hai-Ning Liang, Ka Lok Man, Eng Gee Lim, Vladimir Hahanov, Mischenko Alexander	486
Investigation of EM Wave Propagation of the Wireless Capsule in Human Body Eng Gee Lim, Zhao Wang, Jin Hui Chen, Tammam Tillo, Ka Lok Man	490
Using pyroelectric detectors in the design of temperature measuring devices Bondarenko A.Yu., Klyuchnik I.I.	494
Transaction Level Model of Embedded Processor for Vector-Logical Analysis Irina V. Hahanova, Volodymyr Obrizan, Alexander Adamov, Dmitry Shcherbin	497
Embedded Intelligent Control Systems on the Basis of Elementary Fuzzy-Logic Cells Dontsova A., Vassiliev A.E.	502
Interconnection Analysis of the Integral Reliability Characteristics of the Monoergative Computer System and User's Competency Krivoulya G., Shkil A., Kucherenko D.	505
System approach to determination of ADC parameters Knyshev Ivan	511
Methodological Aspects of Complex Ecological Estimation of Man-Caused Territory State and Mathematical Modelling of Processes in a Environment System Kozulia T. V., Sharonova N. V. , Emelianova D. I., Kozulia M.M.	514

Method for “Failure on Demand” Latent Faults Diagnosis of NPP Safety Control Systems Gerasymenko K.E.	519
Informational Saturation of Noise Signals Kolodiy Z. A., Kolodiy A.Z.	523
The Positional Structural-Weight Coding of the Binary View of Transformants Barannik V., Krasnoruckiy A., Hahanova A.	525
Synchronization of a Fuzzy Automata Speranskiy Dmitriy	529
Models for SoC Infrastructure of Radio Frequency Identification with Code-Division Multiple Filippenko I.V., Hahanova I.V., Filippenko I.O, Maksimov M., Chugurov I.	535
Factorization of Rhythmograms Parametric Spectra on the Base of Multiplicative Linear Prediction Models Nataliia V. Kudriavtseva, Iryna O. Fil	538
Logi-Thermal Analysis of Digital Circuits Using Mixed-Signal Simulator Questa ADMS Petrosyants K.O., Rjabov N.I.	541
Method of Hybrid Regression Analysis in the Calibration Experiments Ordinartseva N. P.	545
Keynotes speeches and Invited Reports	548
AUTHORS INDEX	554

Transaction Level Model of Embedded Processor for Vector-Logical Analysis

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Abstract

Transaction level model of embedded processor for improving the performance of logical relation analysis are proposed. It is based on the hardware implementation of vector operations. There are examples of the model using for the semantics analysis of Russian adjectives. The embedded processor was designed to be part of SoC that will be implemented on FPGA.

Introduction

With the increase in complexity and velocity of the modern digital devices its energy consumption and cost gross also. The division of tasks across multiple cores of the processor that leads to create some parallel systems using a coherent set of specialized calculators would be a trade-off in this situation. These structures could improve the performance of solving the computational problems, and could reduce the power consumption and the hardware implementation cost of the digital systems.

The special interest of electronic technology market is the scientific and technical direction of formalizing human mental activity to create the artificial intelligence components. These intelligent tools such as expert systems, image recognition and decision-making need creating effective and high-speed engines (multi-processor or specialized embedded processors). A typical example of this domain that requires a specialized processor is the analysis and synthesis of the natural language constructs. At the same time one of the main points of designing the word processor is the hardware implementation of the device that handle synthesis and analysis of the language constructs.

Purpose: Development of the transaction level model of the special embedded processor for hardware realization of the vector operations.

Objectives:

1. Analysis of publications about the specialized logic processor design [1-4].

2. Analysis of the syntactic and semantic models of word processing that implement for natural languages [5-6].

3. Creation of the architecture of the specialized embedded processor that analyze the logical net of the language constructs [6].

4. The hardware implementation of the transaction level model device that implements the grammatical analysis of the Russian adjectives.

The prototype design is used the specialized device that performed grammatical analysis of adjectives end was implemented in the FPGA [6]. The proposed model has more flexibility and can handle any logical net of syntactic and semantic relations. The use of the transaction level modes and design techniques allowed to focus on the order of the data processing and transmission, and reduce unimportant details.

1. Transaction level modeling

With the increasing complexity of software-hardware device such as SoC, designers need to use new digital system description models more abstract than register-transfer level (RTL) models. To address this problem, transaction level models (TLMs) were developed. TLM defines a transaction as the data transfer between sub-systems of a system. Throughout the SoC design cycle, TLM serves for three strategic activities: early software development; architecture analysis; functional verification. Modeling effort are vastly rationalized

A some variation of a model developed by Dan Gajski and Lucai Cai at CODES (HW/SW Co-design Conference) 2003 [1]. The first concept is that sub-system communication and functionality can be developed and refined independently. The communication and functionality components can be un-timed (UT), approximately-timed (AT), or cycle-timed (CT) (Fig. 1).

RTL model is cycle-timed accurate for communication and for functionality. System architectural model (SAM) is with un-timed communication and functionality. Approximately-timed models can rely on statistical timing, estimated

timing, or sub-system timing requirements derive from system requirements. A model with cycle-timed communication and approximately-timed functionality is Bus Functional Model (BFM). The three remaining TLM's don't have commonly accepted names. Gajski and Cai use following names:

1. Component Assembly Model - un-timed communication and approximately-timed functionality;
2. Bus Arbitration Model - approximately-timed communication and approximately-timed functionality;
3. Cycle-Accurate Computation - approximately-timed communication and cycle-timed functionality.

Using TLM for estimations of SoC performance enable the architect to perform initial estimates right in the beginning of the project without RTL or cycle-accurate models. Early estimations enabled by real software running on TLM of SoC before RTL is available to further assist the designer.

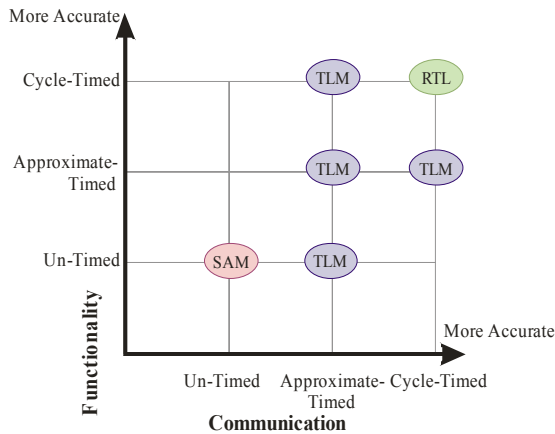


Figure 1. Models of digital systems

Very large Verilog or VHDL simulations along with emulation strategies have traditionally been used for system-level functional verification. With increasing system complexity, Verilog and VHDL simulations have become too slow for such verification. So it is better to use the transaction level simulation for this purpose.

In addition, classes that were included in hardware description language help to improve the productivity of designer and verifier teams by organizing the code in layers, separating model and testbench code.

2. Model of processor for logical relation analysis

This special processor was designed to handle the logical net, where each node is a set of attributes: A, B, C (fig. 3a), and each edge is a functional relation

between two attributes that are defined as a binary table. For example, these ones could be a relation between grammatical forms of Russian adjective "stress" – "word stem" that belongs to adjective logical network [6].

Figure 2 shows the framework special embedded processor that consists of three main units: Control block (Control), Logical block (LE), and Memory block (Mem). In turn the last one includes following components: a command memory, a function memory, and a set memory.

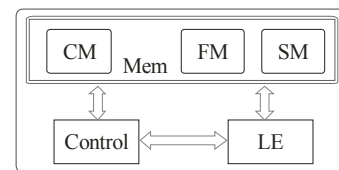


Figure 2. Processor framework

The advantage of the proposed embedded special processor model is that it was constructed to handle the logical nets of any dimensions and doesn't depend on the length of the set vectors and the sizes of the relation tables. It has only limitation that is defined by physical memory size.

The Logical block receives the data parts of a fixed size. If relation table or set vector has bigger size than memory buses dimension, they are broken apart. So there used window scrolling to traverse through whole table (fig 3). The size of scroll window is determined by the memory bus size that transferring data between memory and logic blocks. Process of table starts with the upper-left corner and finishes in the right-down corner. The number of steps for process a table with the $N \times M$ dimension are described by equations $N_R = N_n \cdot N_m$. Each relation table after dividing by 2D slice are stored in memory as 1D vectors. Similarly the set vectors are split on the memory words and stored in the memory by parts. Two separated memory blocks that storing relation tables and set vectors allow to read in one cycle two parts of data that are need to implement the elementary logical operation.

For example, if the size of the scrolling window equals 4×4 , the relation table with the dimension 26×13 would be split on 28 blocks. It means the processing of this table would need 28 elementary logical operations that make up the processing cycle of the table.

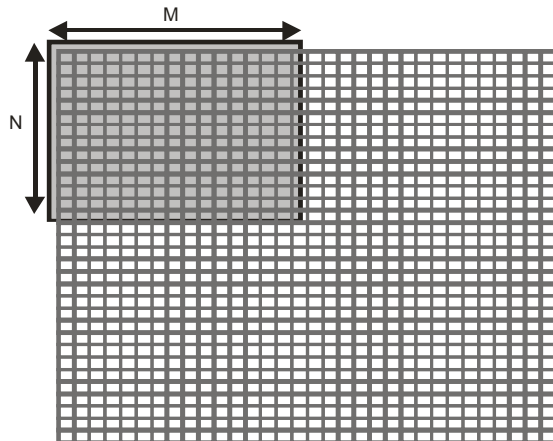


Figure 3. Relation table scrolling

Assume the relations table has a size of 2 to 7 and has following contents.

1	1	1	0	1	0	1	
0	0	0	1	0	1	0	
		1				2	

If size of the scrolling window is 4x4 so this table would take two 16 bit words (fig 4) of the Function memory.

The set vectors are binary where 1 means that the element is included in the set and 0 that it isn't. If relation table dimension is 2x7, the sizes of vectors are 2 and 7 bits, respectively. So R2 vector needs to store 1 memory word, and R1 vector needs 2 words (fig 5). For example,

R1	1	1	0	0	1	1	1
R2	1	0					

Command memory uses following format of the word.

size_W	size_H	addr_R0	addr_R1	addr_R2
--------	--------	---------	---------	---------

where size_W and size_H define the size of the relation table, addr_R0, addr_R1, and addr_R2 are start addresses of the data blocks. For the example above and according to Figure 6, the command memory word will have value

2	7	0	0	2
---	---	---	---	---

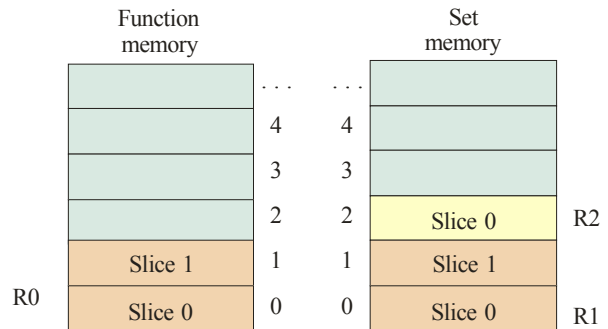


Figure 4. Memory that storing one relation table and its set vectors

3. The transaction level model of the processor

By the classification [1] the proposed model of the special embedded processor is with approximated time accurate for communication and for functionality, so it is the Bus Arbitration Model.

Object Oriented Programming (OOP) was used for developed the processor model. Each device unit was designed as class that communicates with the other ones through virtual interface. Then for refining design these classes could be replaced by a description of RTL-level, and the virtual interface could be changed to interface block.

For the developing of transaction level model are used object-oriented language features of the SystemVerilog hardware description and verification. Figure 6 shows the structure of the classes.

TLM_model includes objects of three classes: Control_block, LE_block, and Top_mem, which describe the three units of the embedded processor framework (fig. 2): Control block (Control), Logical block (LE), and Memory block (Mem).

Base class is DUT_object class (fig. 6). Other classes expanded upon its through inheritance. The Configuration class is designed to control the constraint random generation of the input stimuli that is used at the verification stage.

Micro_command encapsulate the data together with the routines that describe and manipulate processor commands. Mem_object class is blueprint The classes that describe memory have the methods: for variable value initial (read and write), for output data to the consol (print); for output data to text file (fprint); for work starting (run). In addition to these methods the Control block that is described as the class control_block, has routines: for reading a command (read_command), for generating the control signal

sequences for memory and logic unit (gen), for transmitting control signals through the interface (drive). Stable_check () method checks the time of the finishing of the logical net processing.

An object of the TLM_model class is implemented in the Top module that includes the bus interface also. The last one is a model of the special embedded processor bus. The SystemVerilog code of the interface is shown on listing 1. Also it has variable that describe transmitting data as well as events that synchronize the work of individual blocks of the system.

Listing 1. SystemVerilog model of the interface

```
interface interf;
  bit clk = 0;
  initial forever #5 clk = ~clk;

  //command
  event command_request;
  event command_resp;
  event PC_clear_e;
  event pass_end; // pass all commands
  event work_stop; //
  bit [7:0] size_r1, size_r2;

  bit [7:0] start_R0, start_R1, start_R2;
  clocking cb@(posedge clk);

  // output size_r1, size_r2;
  // output start_R0, start_R1, start_R2;

  endclocking: cb
  always @(pass_end)
    $display("1 pass command memory have finished");

  // memory
  event data_read, data_send, pass_start;
  bit [7:0] addr_R0, addr_R1, addr_R2;
  bit first_block, line_end, last_block, direction;
  logic [(`block_size*block_size)-1:0] R0;
  logic [`block_size-1:0] R1;
  logic [`block_size-1:0] R2;
  bit R3;
  event data_write;
  bit [7:0] addr_R2_w;
  logic [`block_size-1:0] R2_w;
  // stop

  event simul_finish;
endinterface
```

4. Conclusion

Scientific novelty. The transaction level model of the special embedded processor for logical analysis of the Russian adjectives was developed. The model allows creating the hardware implementation for any logical relations graph for natural language structure analysis. This device requires more time for processing of the system than one that was presented earlier [6], but exceeds it in versatility.

The object-oriented programming has been used to reduce the design time of creating the SystemVerilog transaction level model. This modern approach of the development of the digital systems significantly improves the design process performance.

Further studies are associated with the creating the generators of the complex architecture of the logical relations, with the possibility of combining several logic blocks to improve the functional performance.

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