KHARKOV NATIONAL UNIVERSITY OF RADIOELECTRONICS

Proceedings of IEEE East-West Design & Test Symposium (EWDTS'08)

SPONSORED BY

IEEE Computer Society Test Technology Technical Council

Lviv, Ukraine, October 9 – 12, 2008

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Diagnosis of SoC Memory Faulty Cells for Embedded Repair

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Abstract

A method of optimal memory fault repair that differs from analogs by application of algebra-logical technology of fault covering by two-dimensional memory matrix topology is proposed. It enables to obtain minimal and full solutions for subsequent repair in real time, which is based on utilization of spares in the form of memory rows and columns.

1. Introduction

Modern digital systems-on-chip (SoC) include millions of equivalent gates and new high-level design technologies are necessary for their creation [1-3]. SoC memory in the future will occupy more than 90% of chip area that is oriented on use flexible software [3-7,11]. Development of models and methods of quick and exact diagnosis, as well as technologies for repair of faulty cells by on-chip facility in real time and on all life cycle stages of a product are urgent problems. It will enable to decrease quantity of chip pins, to raise yield, to decrease time-to-market, to reduce service costs, as well as to remove output diagnosis and repair facility [1,6,7,12].

The research aim is development of algebra-logical method of embedded matrix memory diagnosis and repair in real time.

The problems: 1) Analysis of SoC Infrastructure Intellectual Property Technologies; 2) Development of an Infrastructure Intellectual Property method on basis of the covering matrix; 3) Formalization of the algebra-logical AL-method for embedded memory repair; 4) Analysis of obtained results.

Modern design technologies of digital systems on chips propose along with creation of functional blocks F-IP development of service modules I-IP, which are oriented on complex solving of the project quality problem and yield increasing in manufacturing that is determined by implementation of the following services into a chip [11,14,16]:

1) Diagnosis of failures and faults by analysis of information, which is obtained on the stage of testing and use of special methods of embedded fault lookup on basis of the standard IEEE 1500 [8,13,15];

2) Repair of functional modules and memory after fixation of a negative testing result, fault location and identification of a fault type in carrying out of the diagnosis phase;

3) Measurement of the general characteristics and parameters of a device operation on basis of on-chip facilities, which enable to make time and volt-ampere measurements;

4) Reliability and fault tolerance of a device operation in working that is obtained by diversification of functional blocks, redundancy of them and repair of SoC in real time.

2. SoC Memory Diagnosis and Repair

It is represented the exact method of memory elements diagnosis and repair by spares that enables to cover a set of fault cells by minimally possible quantity of spares. The method is oriented on implementation to the Infrastructure Intellectual Property for SoC functionality. The structure solutions for realization of the method of diagnosis and repair of memory matrix fault cells are proposed. [5-7, 10].

The aim function Z of given research can be defined on the basis of modern progress in the field of on-line memory repair in the following way: minimization of the repair cost (hardware costs) of a memory module $M = |M_{ij}|$ in the process of SoC operation by means of use the algebra-logical method of minimization of the faulty cells set covering by a system of reserve elements under the constraints N on quantity of ones:

$$Z = \min_i [Q_i(F)]_{|Q_i(F) \le N_{max} = N_r + N_c},$$

where $Q_i(F)$ – the cost of i-th solution variant of the memory module $M = |M_{ij}|$ repair by means of the minimal subset of rows and columns $R = \{R_r, R_c\}$ of

chip reserve that covers the set F of faulty memory cells $R \cap F = F, Z^* = \max |F_i|, F_i \in F \leftarrow \forall R_i$.

Method of minimal covering obtainment on an example a memory matrix with five faulty cells [10], two reserve rows and a reserve column (Fig. 1) is considered below. Every reserve component (a row or a column) can repair from one up to n faulty cells, which belong to a row or a column.

The method idea is optimal replacement of faulty memory matrix elements by means of solution of the covering problem of faulty columns by row reserve. For the method illustration it is proposed originally to use the covering matrix of given faults F by some quantity of rows (it can be test patterns or reserve rows) X and

$$|F| \geq |X| = \{F_1, F_2, F_3, F_4, F_5, F_6, F_7, F_8\} \geq$$

$$\geq \{X_1, X_2, X_3, X_4, X_5, X_6\}.$$

Let the matrix Y is specified:

$(F_j \cap X_i \neq \varnothing \rightarrow Y_{ij} = 1) \& (F_j \cap X_i = \varnothing \rightarrow Y_{ij} = 0)$:

$Y =$

X_i / F_j	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8
X_1	1					1		
X_2		1	1				1	1
X_3					1			1
X_4	1			1				
X_5			1	1				
X_6					1	1		

The exact solution of the covering problem of faults by minimal quantity of reserve memory rows is based on synthesis of the Boolean function [9] that is written as product of sums, written by constituents of unities, which correspond to columns of the matrix:

$$Y = (X_1 \vee X_4) \& (X_2) \& (X_2 \vee X_5) \& (X_4 \vee X_5) \&$$

$$\& (X_3 \vee X_6) \& (X_1 \vee X_6) \& (X_2) \& (X_2 \vee X_3).$$

In given case an analytic notation in the Boolean function form, represented in conjunctive normal form (CNF), is the initial model that contains a full set of covering problem solutions that is solved by finding of disjunctive normal form (DNF). The transformation procedure of CNF to DNF by means of all terms multiplication is performed for it. In result of the equivalent transformations, performed in compliance with the algebra of logic rules, it is came out the Boolean function that contains all possible fault covers, defined by four variants of row combinations:

$$Y = (X_1X_2 \vee X_2X_4)(X_2X_4 \vee X_4X_5 \vee X_5X_5 \vee X_2X_5) \&$$

$$\& (X_1X_3 \vee X_1X_6 \vee X_6X_6 \vee X_3X_6)(X_2X_2 \vee X_2X_3) =$$

$$= (X_1X_2X_3X_4 \vee X_2X_4X_6 \vee X_1X_2X_3X_5 \vee X_1X_2X_5X_6).$$

The minimal solution of covering problem contains three reserve rows, which can cover 8 faults in a memory matrix: $Y = X_2X_4X_6$.

For use of the proposed memory repair method it is necessary to remember that every fault Fi in a memory matrix belongs to a row and a column simultaneously. So, transformation of the topological fault model to the covering matrix consists of assignment of row and column numbers, which are distorted by given fault, to every fault.

For instance (Fig.1), where there are 5 faulty cells, which are covered by three columns and 4 rows, the transformation turns a memory matrix into the covering table, where left column specifies one-to-one correspondence between fault coordinates (row and column numbers of a memory matrix) and rows of a fault covering:

$Y =$

X_i / F_j	F_1	F_2	F_3	F_4	F_5
$C_2 \rightarrow X_1$		1		1	
$C_4 \rightarrow X_2$			1		1
$C_8 \rightarrow X_3$	1				
$R_3 \rightarrow X_4$	1	1			
$R_5 \rightarrow X_5$			1		
$R_7 \rightarrow X_6$				1	
$R_{10} \rightarrow X_7$					1

In other words, the memory matrix topology is transformed from two-dimensional metrics to one-dimensional row structure, which have defined covering features concerning about fault columns.

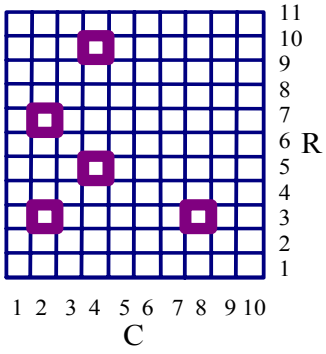

Fig. 1. Memory matrix with fault cells

The following Boolean function forms logical product of disjunctions, written by constituents of

unities, corresponding to columns of the matrix $(F_j \cap X_i \neq \varnothing \rightarrow Y_{ij} = 1)$:

$$Y = (X_3 \vee X_4)(X_1 \vee X_4)(X_2 \vee X_5)(X_1 \vee X_6)(X_2 \vee X_7) =$$
$$= (X_1X_3 \vee X_1X_4 \vee X_3X_4 \vee X_4)(X_1X_2 \vee X_1X_5 \vee X_2X_6 \vee$$
$$\vee X_5X_6)(X_2 \vee X_7) = (X_1X_3 \vee X_4)(X_2 \vee X_7)(X_1X_2 \vee$$
$$\vee X_1X_5 \vee X_2X_6 \vee X_5X_6) = (X_1X_2X_3 \vee X_2X_4 \vee X_1X_3X_7 \vee$$
$$\vee X_4X_7)(X_1X_2 \vee X_1X_5 \vee X_2X_6 \vee X_5X_6) = (X_1X_2X_3 \vee$$
$$\vee X_1X_2X_4 \vee X_1X_2X_3X_7 \vee X_1X_2X_4X_7 \vee X_1X_2X_3X_5 \vee$$
$$\vee X_1X_2X_4X_7 \vee X_2X_4X_6 \vee X_2X_4X_5X_6 \vee X_1X_2X_3X_7 \vee$$
$$\vee X_1X_3X_5X_7 \vee X_1X_2X_3X_6X_7 \vee X_1X_3X_5X_6X_7 \vee$$
$$\vee X_1X_2X_4X_7 \vee X_1X_4X_5X_7 \vee X_2X_4X_6X_7 \vee X_4X_5X_6X_7 =$$
$$= (X_1X_2X_3 \vee X_1X_2X_4 \vee X_2X_4X_6 \vee X_1X_3X_5X_7 \vee$$
$$\vee X_1X_4X_5X_7 \vee X_4X_5X_6X_7.$$

The equivalent transformations enable to simplify the complex construction – conjunctive normal form – and to obtain the minimal set of all solutions, a number of that is equal to six in this case. Subset of minimal solutions is defined by three conjunctive terms, every of which contains 3 reserve elements for memory matrix repair:

$$Y = X_1X_2X_3 \vee X_1X_2X_4 \vee X_2X_4X_6.$$

3. Algebra-Logical Memory Repair Method

The aim function is defined as minimization of reserve components of the memory matrix (S – spare), which are needed for its repair in the process of SoC operation by means of synthesis of disjunctive normal form of faulty elements covering and subsequent choice of the minimal conjunctive term $X^t(R^t, C^t) \in Y$ that satisfies to limitations on quantity of the reserve rows and columns S^r_{max}, S^c_{max}, which enter into the logical product:

$$Z = \min_{t=\overline{1,n}}\left(\left|X^t\right|\right)\Big|_{\left|S^r\right|+\left|S^c\right| \le S_{max};\ \left|S^r\right| \le S^r_{max};\ \left|S^c\right| \le S^c_{max}},$$

$$X^t \in Y = \{X^1, X^2, ..., X^t, ..., X^n\},$$

$$X^t = (X^t_1 \,\&\, X^t_2 \,\&, ..., \&X^t_i \,\&, ..., \&X^t_{m_t}),$$

where every resulting conjunctive term of the function Y is made from the row and column identifiers $X^t = (R^t, C^t)$, which cover all faults in a memory matrix. The best solution is a term of minimal length at Quinn mark [9], in which there are rows and columns, covering all faults. In particular case a solution can contain none rows (columns), when existing columns (rows) from memory matrix reserve are sufficient for memory repair. The model of definition process of minimal quantity of spares, which cover all detected faults in a memory matrix, comes to the following items:

1. Transformation of two-dimensional model of a memory matrix faults to the fault covering table by reserve rows and columns. To achieve of the aim the topological memory model in the form of matrix, identifying detected faults, is considered:

$$M = \left|M_{ij}\right|, M_{ij} = \begin{cases} 1 \leftarrow T \oplus f = 1; \\ 0 \leftarrow T \oplus f = 0. \end{cases}$$

Here a matrix coordinate is equal to 1, if the fault-free behaviour function of a cell gives unit value on a test, the coordinate is identified as faulty. After fixation of all faults construction of the fault covering table $Y = \left|Y_{ij}\right|, i = \overline{1,n};\ j = \overline{1,m}$ is carried out, where columns correspond to the set of detected faults m and rows are numbers of columns and rows of a memory matrix, which have faults:

$$Y = \left|Y_{ij}\right|, Y_{ij} = \begin{cases} 1 \leftarrow C_i(R_i) \cap F_j \neq \varnothing; \\ 0 \leftarrow C_i(R_i) \cap F_j = \varnothing. \end{cases}$$

Instead of the two-dimensional metrics components C and R the one-dimensional vector is used, it is concatenated from two sequences C and R, the power of which is equal to n = p + q:

$$X = C * R = (C_1, C_2, ..., C_i, ..., C_p) * (R_1, R_2, ..., R_j, ..., R_q) =$$
$$= X^c * X^r = (X_1, X_2, ..., X_i, ..., X_p, X_{p+1}, X_{p+2}, ...,$$
$$X_{p+j}, ..., X_{p+q}).$$

At that there exists one-to-one correspondence between the initial set elements (C, R) and the resulting vector X, which is defined in first column of the matrix Y. It is necessary to say that transformation $X = C * R$ is carried out for ease of consideration and subsequent forming of disjunctive normal form (uniformity of variables, forming the Boolean function). If the procedure is not carried out the function is defined by two kinds of variables, containing rows and columns of a memory matrix..

2. Construction of conjunctive normal form for analytic, complete and exact solution of the covering problem. After generation of the covering matrix that contains zero and unit coordinates the synthesis of analytic covering form is carried out by writing of CNF by columns. Here a number of conjunctive terms are equal to quantity of table columns and every disjunction is written by unit values of a current column:

$$Y = \bigwedge_{j=1}^{m} (Y_{pj} \vee Y_{qj})_{\{Y_{pj}, Y_{qj}\}=1} = \bigwedge_{j=1}^{m} (X_{pj} \vee X_{qj}).$$

From last expression it is obvious that every column has two coordinates only, which have unit value, and a number of logical products is equal to total quantity of faults m, detected in a memory matrix.

3. Transformation of CNF to DNF that enables to determine all solutions of the covering problem. For that it is necessary to apply an operation of logical multiplication and the minimization (absorption) rules to conjunctive normal form to obtain of disjunctive normal form:

$$Y = \bigvee_{j=1}^{w} (k_1^j X_1 \wedge k_2^j X_2 \wedge ... \wedge k_i^j X_i \wedge ... \wedge k_n^j X_n), k_i^j = \{0,1\}.$$

It is the generalized DNF notation, where in the limit a number of terms is equal to $w = 2^n$, where n is quantity of rows in the generalized set (C,R) or quantity of the variables X in the matrix Y, on the set of which all solutions are formed (fault covering by reserve components); if k_i^j at X_i is equal to zero the variable X_i is nonessential.

4. Choice of minimal and exact solutions of the covering problem. It is related to determination of minimal length conjunctions in the obtained DNF. The following transformation executing rows and columns of a memory matrix on basis of above-mentioned correspondence enables to write a minimal covering or set of ones in two-dimensional metrics of rows and columns, which satisfies the conditions (limitations) of the aim function on quantity of reserve components.

An illustration of the memory matrix repair process model is proposed below. Minimal quantity of reserve components, which cover all faults, is determined. A memory matrix with faults and reserve [10] is represented in Fig. 2.

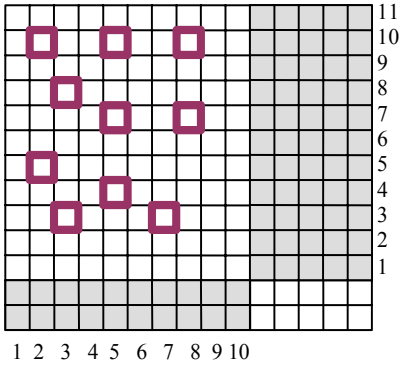

Fig. 2. Memory matrix with faults and reserve

The matrix has limitations on diagnosis and repair capabilities of ten faulty cells, which are defined by two rows and five columns. In compliance with item 1 of the model of definition process of minimal quantity of spares, which covers all detected faults in a memory matrix, the covering table of ten faults

$$F = (F_1, F_2, F_3, F_4, F_5, F_6, F_7, F_8, F_9, F_{10})$$

is formed. Faults are covered by 11 rows, which are represented in the form of concatenation of the subsets C and R, which are in one-to-one correspondence with the variable vector X:

$$C*R = (C_2, C_3, C_5, C_7, C_8)*(R_3, R_4, R_5, R_7, R_8, R_{10}) \approx$$

$$\approx X = (X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}).$$

$Y =$

X_i / F_j	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
$C_2 \to X_1$				1						1
$C_3 \to X_2$		1					1			
$C_5 \to X_3$			1			1			1	
$C_7 \to X_4$	1									
$C_8 \to X_5$					1			1		
$R_3 \to X_6$	1	1								
$R_4 \to X_7$			1							
$R_5 \to X_8$				1						
$R_7 \to X_9$					1	1				
$R_8 \to X_{10}$							1			
$R_{10} \to X_{11}$								1	1	1

In compliance with the covering table construction of DNF is performed, the terms are written by unit values of columns:

$$Y = (X_4 \vee X_6)(X_2 \vee X_6)(X_3 \vee X_7)(X_1 \vee X_8)(X_5 \vee X_9) \&$$

$$\&(X_3 \vee X_9)(X_2 \vee X_{10})(X_5 \vee X_{11})(X_3 \vee X_{11})(X_1 \vee X_{11}).$$

Subsequent transformations related to obtainment of disjunctive normal form are based on application of The Boolean algebra lows and identities, which enable to carry out logical multiplication of all ten multipliers, subsequent minimization of DNF terms by application of the minimization operator, the absorption axioms, removal of the same terms. Skipped intermediate calculus the final result is represented in the following form:

$$Y = X_1 X_2 X_3 X_4 X_5 \vee X_2 X_3 X_4 X_5 X_8 X_{11} \vee$$
$$\vee X_1 X_2 X_4 X_9 X_3 X_{11} \vee X_1 X_3 X_2 X_4 X_9 X_{10} X_{11} \vee$$
$$\vee X_1 X_7 X_{10} X_{11} X_6 X_9 \vee X_6 X_9 X_7 X_8 X_{10} X_{11} \vee$$
$$\vee X_2 X_4 X_9 X_3 X_8 X_{11} \vee X_1 X_2 X_4 X_9 X_7 X_{11} \vee$$
$$\vee X_2 X_4 X_9 X_7 X_8 X_{11} \vee X_3 X_2 X_4 X_9 X_8 X_{10} X_{11} \vee$$
$$\vee X_1 X_2 X_4 X_9 X_7 X_{10} X_{11} \vee X_1 X_2 X_3 X_5 X_6 \vee$$
$$\vee X_1 X_3 X_5 X_6 X_{10} \vee X_2 X_3 X_5 X_6 X_8 X_{11} \vee$$
$$\vee X_3 X_5 X_6 X_8 X_{10} X_{11} \vee X_1 X_2 X_3 X_{11} X_6 X_9 \vee$$
$$\vee X_1 X_3 X_{10} X_{11} X_6 X_9 \vee X_2 X_3 X_8 X_{11} X_6 X_9 \vee$$
$$\vee X_1 X_2 X_7 X_{11} X_6 X_9 \vee X_2 X_7 X_8 X_{11} X_6 X_9 \vee$$
$$\vee X_3 X_8 X_{10} X_{11} X_6 X_9.$$

The choice of minimal length terms, which contain 5 variables, forms a set of optimal (minimal) solutions:

$$Y = X_1X_2X_3X_4X_5 \vee X_1X_2X_3X_5X_6 \vee X_1X_3X_5X_6X_{10}.$$

Transformation of obtained function to a coverage that contains variable designations in the form of rows and columns of a memory matrix enables to represent solutions in the following form:

$$Y = C_2C_3C_5C_7C_8 \vee C_2C_3C_5C_8R_3 \vee C_2C_5C_8R_3R_8.$$

All obtained minimal solutions satisfy the requirements (limitations) on spare quantity that is determined by numbers:

$$(\left|C^r\right| \le 5) \,\&\, (\left|R^r\right| \le 2).$$

Other solutions, determined in DNF, are no interest, because they have not optimal covering of faulty cells that is determined by quantity of variables (rows + columns) in terms, greater then five. Subsequent technology of embedded repair of faulty cells consists of electrical reprogramming of an address decoder of a column or a row of a memory matrix. In respect to memory, represented in Fig. 2, a procedure of writing or reading of information at access to any cell of column 2 will be readdressed to reserve column 11. In compliance with last obtained solution (first term of DNF function Y) other faulty columns will be replaced on fault-free ones from memory reserve: 3 – on 12; 5 – on 13; 7 – on 14, 8 – on 15.

The computational complexity of algebra-logical memory repair method in the part of solving of the covering problem is determined by the following expression:

$$Q = 2^{|F|} + \left|C + R\right| \times 2^{|F|},$$

where $2^{|F|}$ is costs related to DNF synthesis by logical multiplication of two-component disjunctions (fault coordinate is defined by row and column numbers), quantity of them is equal to quantity of faulty cells; $\left|C + R\right| \times 2^{|F|}$ is upper limit of computational costs, which are needed for minimization of obtained DNF on maximum set of variables that is equal to total quantity of rows and columns $\left|C + R\right|$. In the worst case, when coordinates of all faulty cells are not correlated by rows and columns (they are unique), for instance, diagonal faults, the computational complexity of the matrix method is dependent from quantity of faulty cells only and its analytic notation is transformed to the following view:

$$Q = 2^{|F|} + \left|C + R\right| \times 2^{|F|}\Big|_{|C+R| \le 2\times|F|} =$$

$$= 2^{|F|} + 2 \times |F| \times 2^{|F|} = 2^{|F|} \times (1 + 2 \times |F|)$$

If instead of fault set power to use quantity m of them, the previous expression can be represented in more simple form:

$$Q = 2^m \times (1 + 2 \times m) = 2^m (2m + 1).$$

According to the SoC Functional Intellectual Property Infrastructure, the matrix repair method on basis of solving of the covering problem is implemented into a chip as one of I-IP components that is designed for the operability support of SoC matrix memory.

4. Conclusion

The algebra-logical memory repair method is based on solving of the faulty cells covering problem by spares by means of the Boolean algebra apparatus. The method has quadratic computational complexity and can have hardware or software realization that is service module of fault correction, which enables to carry out memory elements repair in the process of operation.

The classical covering problem use two one-dimensional vectors (X, F), where the covering operator P enables to find minimal subset of the components X, which cover all elements from F: $X_{min} = P(X, F) \leftarrow X \cap F = X_{min}$ by its aggregate functionality. The statement of covering problem of one-dimensional vector F features by two-dimensional matrix $M = (C \times R)$ is needed in reduction of both components to a single metrics (such coordinate system that is common denominator for both structures). Such metrics for the matrix $M = (C \times R)$ and the vector F is one-dimensional structure. So, in this case it is necessary to carry out transformation of two-dimensional structure (memory fault matrix) $M = (C \times R)$ to one-dimensional one by means of the concatenation operation $X = (C * R)$ for subsequent solving of the classical covering problem by application of formal actions, which are defined by the operator $X_{min} = P(X, F)$.

Proposed method of optimal memory fault repair differs from analogs by application of algebra-logical technology of fault covering by two-dimensional memory matrix topology that enables to obtain minimal and full solutions for subsequent repair in real time, which is based on utilization of spares in the form of memory rows and columns.

Practical importance of the research consists of implementation of the method to SoC Functional Intellectual Property Infrastructure. It enables to raise yield essentially (5-10%) on the electronic technology market by means of faulty chip repair in the process of production and operation, as well as to increase the life

cycle duration of memory matrixes by repair of them in real time.

On-chip repair is oriented on all objects, which have an address: memory, multiplexers, matrix processors. If it is necessary to repair other structures, they must be designed with an allowance for component addressability. The addressability and regularity of components turns a system into reliable, robust, repairable and durable one.

Further research is oriented on development of testability structure of the system and hardware BIRA module for embedded memory repair in appearance of faults on production and operating stages.

5. References

[1] P. Rashinkar, P. Paterson, L. Singh *System-on-chip Verification: Methodology and Techniques*, Kluwer Academic Publishers, 2002, 393 p.

[2] *IEEE-1800 IEEE Standard for System Verilog Language*, 2005, 586 p.

[3] S. Hamdioui, G. N. Gaydadjiev, A. J. Van de Goor. The State-of-the-art and Future Trends in Testing Embedded Memories, *Records IEEE International Workshop on Memory Technology, Design and Testing*, San Jose, CA, August 2004, pp. 54-59.

[4] Y. Zorian Today's SoC Test Challenges, *ITC International Test Conference*, 2005.

[5] S.Shoukourian, V. Vardanian, Y.Zorian SoC Yield Optimization via an Embedded-Memory Test and Repair Infrastructure, *IEEE Design and Test of Computers*, 2004, pp. 200-207.

[6] L. Youngs, S. Paramanandam Mapping and Repairing Embedded-Memory Defects, *IEEE Design and Test of Computers*, 1997, pp. 18-24.

[7] Y.Zorian, S. Shoukourian Embedded-Memory Test and Repair: Infrastructure IP for SoC Yield, *IEEE Design and Test of Computers*, 2003, pp.58-66.

[8] Y. Zorian, A. Yessayan IEEE 1500 Utilization in SoC Design and Test, *ITC International Test Conference*, 2005.

[9] K. Rossen *Discrete Mathematics and its Applications*, McGraw Hill, 2003, 824 p.

[10] A.N. Parfentiy, V.I. Hahanov, E.I. Litvinova SOC Infrastructure Intellectual Property Models, *ASU and automation devices*, No. 138, 2007, C.83-99.

[11] Z. Yervant What is Infrustructure IP?, *IEEE Design & Test of Computers*, May-June 2002, pp. 5-7.

[12] Z. Yervant, G. Dmytris Gest editors' introduction: Design for Yield and reliability, *IEEE Design & Test of Computers*, May-June 2004, pp. 177-182.

[13] IEEE 1500 Web Site. http://grouper.ieee.org/groups/1500/.

[14] D. Densmore, R. Passerone, A. Sangiovanni-Vincentelli A Platform-Based taxonomy for ESL design, *Design&Test of Computers*, September-October 2006, pp. 359-373.

[15] F. DaSilva, Y. Zorian, L. Whetsel, K. Arabi, R. Kapur Overview of the IEEE P1500 Standard, *ITC International Test Conference*, 2003, pp. 988–997.

[16] M.F. Bondarenko, G.F. Krivoula, V.G. Ryabtsev, S.A. Fradkov, V.I. Hahanov *Design and diagnosis of computer systems and networks*, Kiev: NMTS VO, 2000, 306 p.

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Approved for publication: 20.09.2008. Format 60×841/8.
Relative printer's sheets: . Circulation: 150 copies.
Published by SPD FL Stepanov V.V.
Ukraine, 61168, Kharkov, Ak. Pavlova st., 311

Матеріали симпозіуму «Схід-Захід Проектування та Діагностування – 2008»
Макет підготовлено у Харківському національному університеті радіоелектроніки
Редактори: Світлана Чумаченко та Володимир Обрізан
Пр. Леніна, 14, ХНУРЕ, Харків, 61166, Україна

Підписано до публікації: 20.09.2008. Формат 60×84$^{1}/_{8}$.
Умов. друк. арк. . Тираж: 150 прим.
Видано: СПД ФЛ Степанов В.В.
Вул. Ак. Павлова, 311, Харків, 61168, Україна