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A Smart Self Repairing Digital System with Fault Detection Using a Unit Inspired By Endocrine Communication

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ABSTRACT: In this paper implementation of a checker unit for fault detection in self repairing digital system is proposed. Self-repairing digital systems plays a significant role in fault detection and correction. The proposed system is developed for automatic detection of fault and correcting it in digital system with high efficiency. The proposed system consists of functional layer and gene control layer. The functional layer consists of working cells, stem cells and their interconnections. A working cell is surrounded by four stem cells. So in the case of fault occurrence, a working cell can be replaced by any of the four stem cells. Gene control layer consist of index changing unit and differentiation unit. It determines the proper stem cell in the functional layer to replace the faulty working cell without collision. So a faulty working cell can be replaced by the stem cell and connections can be maintained by assigning the same encoded data to a stem cell. Self repairing system is inspired by the endocrine cellular communication system. In endocrine cellular communication when a cell dies or damaged, it is replaced by another cell having the same property for example in the case of skin. By adopting a similar mechanism in an electronic circuit, we are replacing a faulty working cell by adjacent stem cells. So the life time of digital circuits can be increased. The proposed system can be verified by simulating the system in Xilinx software.

KEYWORDS*:* Functional layer, Gene control layer, Working cells, Stem cells**.**

I. Introduction

Reliability plays a significant role in electronic devices. An electronic device should be reliable in its entire operation & it should be error free. Electronic circuit always faces an issue of fault infuriation and errors. Even a small error may cause the entire system useless. In the early stages, many conventional methods like dual modular redundancy and triple modular redundancy were used [1], but they provide a less fault coverage and it is a less efficient method. So, a new approach arises from biological concept inspired by endocrine cellular communication [1]-[14]. One of the conventional approaches includes MUX TREE method [13], it offers better self repairing but has only less fault coverage.

The proposed system is inspired by the endocrine cellular communication, in endocrine communication a special endocrine cell secretes a specific hormone only after it receives another specific hormone. The hormone flows through the blood vessel, adjacent to all endocrine cells. Thus, the blood vessel is able to maintain the connection among endocrine cells, even when the endocrine cell is replaced by a stem cell which differentiates into a cell having the same gene as the dead cell. As a result, the new endocrine cell is able to receive and send the same hormones as the previous cells through the blood vessel.

By adopting a similar mechanism in an electronic circuit, we can replace the faulty module with a stem module without any additional rerouting process. This paper presents a new methodology for fault detection. The proposed system simplifies the self repairing mechanism and helps the circuit to maximize the efficiency, so that life time of circuits can be increased.

II. Related work

The cell replacement and rerouting process of the proposed system, the primary process of self repairing, are completely different from other self-repairing methods. In particular, the primary difference between existing approaches and our approach is the reduction of steps for self repairing. In triple modular redundancy, three systems

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perform a process and that result is processed by a majority-voting system to produce a single output. If any one of the three systems fails, the other two systems can correct and mask the fault. In TMR, three identical logic circuits are used to compute the same set of specified Boolean function. If there are no circuit failures, the outputs of the three circuits are identical. But due to circuit failures, the outputs of the three circuits may be different. A voter circuit is used to decide the correct output. The disadvantage of this system is that if all the three modules are faulty, then this system does not produce the correct output .In the case of MUX TREE method it requires additional MUX and DEMUX for the routing purpose.

Self-healing system is one of the oldest fault tolerance techniques. This method is impractical in many cases due to the complex rerouting process. It has to implement extra router cells .The self-healing approach (Fig. 1) has a router cell that helps the system bypass a faulty cell after replacement of a cell. If a functional cell F2 in Fig.1 (a) is substituted by a stem cell S1 in Fig. 1(a), the router cell connects the output of the functional cell F1 in Fig. 1(b) to the new functional cell F2 in Fig.1 (b). The disadvantage of this system is if the router cell fails, it stops its operation and the efficiency cannot be achieved. It requires additional hardware for the rerouting after the replacement of a cell. It offers less efficiency due to the extra hardware. The proposed approach does not require additional hardware for the rerouting process.

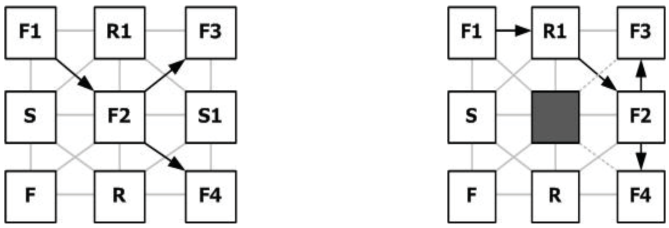

Fig. 1: Rerouting in the self-healing approach (a) State before fault occurrence (b) State after fault occurrence

Another method of fault detection is by the fault detection unit. In the fault detection unit the fault is determined on the basis of comparison. Fault detection unit is mainly for detecting the fault and correcting it. Flow chart of fault detection and correction operation is shown in Fig.2

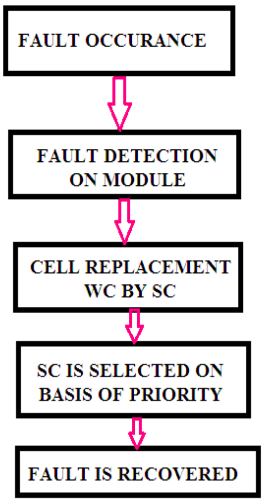

Fig 2: Fault Detection Unit

If any fault occurs to the working cell, the faulty detection unit identifies the faulty working cell by the comparison of output from the modules. If any fault occurs to the working cell, faulty signal is produced. On seeing the faulty signal produced on working cell, the gene control layer determines that which stem cell has to be replaced with the faulty working cell. In this method the working cell has four modules inside it. A working cell is capable of performing basic

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digital operations such as addition, subtraction, multiplication and shifting. If the working cell is an adder working cell, all the four modules performs addition operation. If the working cell is a subtraction working cell, all the four modules perform subtraction. If the working cell is a multiplication working cell all the four modules perform multiplication. If the working cell is shifting working cell, all the four modules perform shifting operation. Fig 3 shows the fault detection by fault detection method.

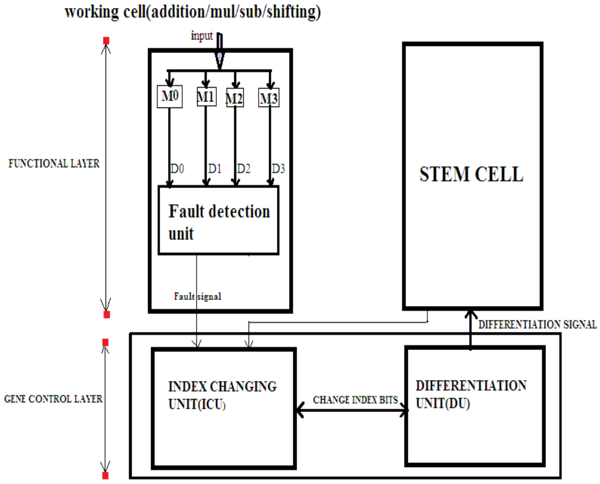

Fig 3: Fault detection by fault detection method

The output of four modules from the corresponding working cell is given to the fault detection unit. The corresponding output can be named as D0, D1, D2, D3 respectively. The Output is stored to corresponding memory location, i.e. stored to memory 0, memory 1, memory 2, memory 3. Fault detection unit compares the all these i.e. data stored in memory 0 is compared with memory 1, memory 2, memory 3. The memory location has count c0, c1, c2, c3 respectively. If any dissimilarity occurs with D0, D1, D2, D3 corresponding count will be incremented. Similarly data stored in memory 1 is compared with memory 0, memory 2 and memory 3. If any dissimilarity occurs with D0, D1, D2, D3 corresponding count will be incremented. Data stored in memory 2 is compared with memory 0, memory 1, and memory 3. If any dissimilarity occurs with D0, D1, D2, D3 corresponding count will be incremented. Finally Data stored in memory 3 is compared with memory 0, memory 1 and memory 2. If any dissimilarity occurs with D0, D1, D2, D3 corresponding count will be incremented. The higher value of count c0, c1, c2, c3 will be counted and this module will be faulty. If D0, D1, D2, D3 have same values there will not be any error and this module will be error free. The index changing unit determines which stem cell has to be replaced with faulty working cell. Thus a faulty working cell can be replaced by any of the four stem cells.

This method of fault detection using a fault detection unit is a time consuming approach and there are nearly 16 comparison steps. This method is a less efficient method. The proposed method can detect fault with the help of a checking unit, which is more efficient than a fault detection unit.

This paper is organized as follows. Section II presents the literature survey and the existing methods. Furthermore, a fault detection method is also introduced. Section III presents the proposed system which includes the architecture and fault detection by checker unit. Section IV presents the experimental results, followed by conclusion in section V.

III. PROPOSED METHOD

A. *Design architecture of self repairing digital system*

The proposed system architecture consists of a functional layer and a gene-control layer. In the functional layer it consists of working cells and stem cells. The functional layer consists of four modules and their interconnections. In each module consists of encoded data, contains information about the function. Therefore, a faulty cell can be replaced and the whole system's functions and connections are maintained by assigning the same encoded data to a stem cell. The working cell performs basic digital operation such as addition, subtraction, multiplication, shifting. A working cell is surrounded by four stem cells. If the working cell is damaged it can be replaced by any of

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the four surrounding stem cells. The gene-control layer determines the neighboring stem cell in the functional layer to replace the faulty module without collision.

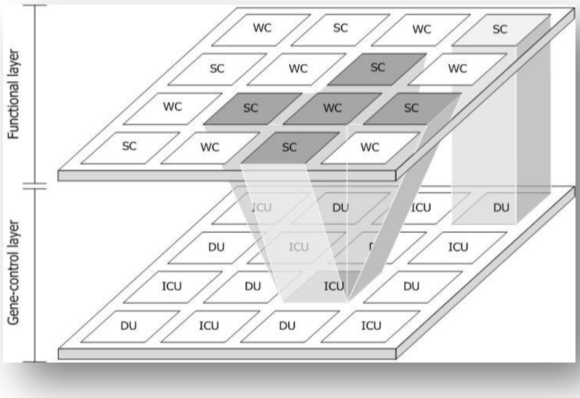

Fig 4: Architecture of self repairing digital system

B. *Block Diagram of Proposed Self Repairing Digital System*

The proposed self repairing digital system consist of working cells, stem cells, checker unit, index changing unit, differentiation unit etc.

Working cells:

Working cells perform basic digital operations. Digital operations which are performed can be of addition, multiplication, subtraction, shifting. So in order to perform these operations 4 working cells are designed.

(A) Addition working cell

(B) Subtraction working cell

(C) Multiplication working cell

(D) Shifting working cell

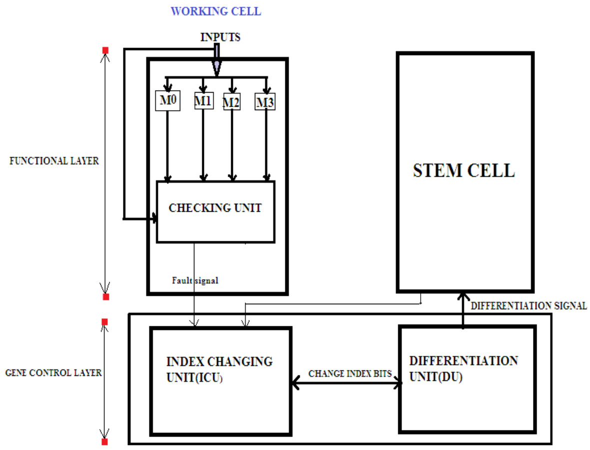

Fig:5 Block diagram of proposed self repairing digital system

Addition working cell:

An addition working cell performs basic addition operation. An addition working cell has 4 modules inside it. The input is given to the four modules and the checker unit. All 4 modules perform addition operation. The output of

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these modules is given to the checker unit. The output is datain0, datain1, datain2, datain3 respectively. In the checking unit bitwise operation corresponding for adder working cell is stored. The checker unit processes the input and corresponding output is produced. This output will be compared with the output from the four modules if all of them have the same value, there is no error. If any dissimilarity occurs there will be error and the faulty working cell can be replaced with any of four stem cells.

Subtraction working cell:

Subtraction working cell performs basic subtraction operation. A subtraction working cell has 4 modules inside it. All 4 modules perform subtraction operation. The input is given to the four modules and the checker unit. All 4 modules perform subtraction operation. The output of these modules is given to the checker unit. The output is datain0, datain1, datain2, datain3 respectively. In the checking unit bitwise operation corresponding for subtraction working cell is stored. The checker units process the input and corresponding output is produced. This output will be compared with the output from the four modules if all of them have the same value, there is no error. If any dissimilarity occurs there will be error and the faulty working cell can be replaced with any of four stem cells.

Multiplication working cell:

Multiplication working cell performs basic multiplication operation. A multiplication working cell has 4 modules inside it. All 4 modules perform multiplication operation. The input is given to the four modules and the checker unit. All 4 modules perform multiplication operation. The output of these modules is given to the checker unit. The output is datain0, datain1, datain2, datain3 respectively. In the checking unit bitwise operation corresponding for multiplication working cell is stored. The checker unit process the input and corresponding output is produced. This output will be compared with the output from the four modules if all of them have the same value, there is no error. If any dissimilarity occurs there will be error and the faulty working cell can be replaced with any of four stem cells.

Shifting working cell:

Shifting working cell performs basic shifting operation. A shifting working cell has 4 modules inside it. All 4 modules perform shifting operation. The input is given to the four modules and the checker unit. All 4 modules perform shifting operation. The output of these modules is given to the checker unit. The output is datain0, datain1, datain2, datain3 respectively. In the checking unit bitwise operation corresponding for shifting working cell is stored. The checker unit processes the input and corresponding output is produced. This output will be compared with the output from the four modules if all of them have the same value, there is no error. If any dissimilarity occurs there will be error and the faulty working cell can be replaced with any of four stem cells.

Stem cells:

Each and every working cell has four neighboring stem cells. Similarly every stem cells connected with four sides of working cells. In the event of fault occurrence working cell can be replaced by any of the available SC from four neighboring SC's. Consider SC1, SC2, SC3 and SC4 are placed left, down, right and top side of working cell respectively. When working cell gets faulty it can be replaced by SC1 (left SC). If SC1 is busy with some other working cell's, then the faulty working cell is replaced by SC2 (down SC). If SC2 is busy with some other working cells, then the faulty working cell is replaced by SC3 (right SC). If SC3 is busy with some other working cell's, then the faulty working cell is replaced by SC4 (top SC).A stem cell is capable of doing all the basic digital operation. So a working cell can be easily be replaced by stem cells.

Checking unit:

In the checking unit bitwise operation corresponding for each working cell is stored. The checker unit processes the input and corresponding output is produced. This output will be compared with the output from the four modules if all of them have the same value, there is no error. If any dissimilarity occurs there will be error and the faulty working cell can be replaced with any of four stem cells.

Gene-control layer:

The gene control layer is positioned in parallel with functional layer. It composed of ICU and DU. Gene control layer controls the operation of cells in the functional layer. Every ICU is the responsible for every working cell and its four neighboring SC's. DU is assigned proper SC for fault recovery by replacing SC from working cell. When the fault occurred, it propagates to the ICU. ICU changes the SC's index bits and isolates the working cell. Then DU in the SC differentiates the SC from the faulty working cell.

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Every SC has index bit, which is in the gene control layer. Index bit shows the state of each cell in structural layer. There are three types of index bits changing during runtime. The index bits for each SC in gene control layer are shown in Table 1.State bit: It shows the stem cell is available are not. Direction bit: It shows the direction of stem cell Differentiation bit: It differentiate stem cell from working cell.

State Bit	Stem cell Free	0	
	Stem cell not free/Engaged	1	
Direction Bit	The direction of WC for which SC is differentiated	Left	00
		Down	01
		Right	10
		Up	11
Differentiation Bit	No change	0	
	Differentiate stem cell	1	

Table 1: Index bits

Index changing unit:

W denotes the working cell and LS, DS, RS and TS are left stem cell, down stem cell, right stem cell and top stem cell of the working cell respectively. After receiving fault signal from the functional layer all the possible changes of index bits is shown in Table 2. In Table 2 the first line shows the condition for the change (W=1) fault will be present. When a fault occurs to the working cell, working cell can be replaced by left stem cell and direction bit for the left stem cell will be 00 and the left stem cell will be differentiated. If the left stem cell is not free it checks whether the down stem cell is free. If it is free the working cell will be replaced by the down stem cell. So the direction bit changes to 01 and the down stem cell will be differentiated. If the down stem cell is not free it checks whether the right stem cell is free or not. If the right stem cell is free the working cell will be replaced by right stem cells. So the direction bit changes to 10 and right stem cell will be differentiated. If the right stem cell is not free, the working cell will be replaced by top stem cell. So the direction bit changes to 11 and the top stem cell will be differentiated. So the priority order of stem cell will be left, down, right and up. That is priority order is assigned in the anti-clockwise direction. So a faulty working cell can be replaced by any of the four stem cell.

The condition for the change					The state before the fault occurrence					The state after the fault occurrence									
Fault signal					State bit					Differentiation bit					Direction bits				
W 1	LS	DS	RS	TS	W	LS 0	DS	RS	TS	W	LS 1	DS	RS	TS	W	LS 00	DS	RS	TS
1						1	0					1					01		
1						1	1	0					1					10	
1						1	1	1	0					1					11
Any kinds of faults						1	1	1	1	System fault									

Table 2: Index Changing Unit

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IV. EXPERIMENTAL RESULTS

The proposed system is verified in a digital platform with Xilinx software. In comparing with existing methods, the proposed method and mechanism are efficient enough for fault detection and fault recovery. By the help of checking unit fault detection is very easy compared to a faulty detection unit.

V. CONCLUSION

The proposed system simplifies the self repairing mechanism and helps the circuit to maximize its efficiency. A smart self-repairing digital system with good scalability and fault coverage is proposed. The functional layer and gene control layer plays a significant role in the self repairing digital system. The functional layer performs the functions and the gene-control layer controls the functional layer so that proper assignment of stem cell for the faulty working cell can be carried out. New architecture provides an efficient method of fault detection and correction. The cells can be arranged in a flexible manner so that the faulty working cell can be replaced by any of four neighboring stem cells. The proposed architecture and mechanism are efficient for fault detection and fault recovery. A new smart self repairing digital system with good scalability and fault detection is proposed.

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