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MODERN APPROACH OF DETECTING PERMANENT FAULTS FOR MULTIPURPOSE PROCESSOR DESIGN OF NOC RELEVANCES

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ABSTRACT:

This brief proposes an on-line straightforward test system for discovery of inert hard blames which create in first info first yield supports of switches amid field operation of NoC. The method includes rehashing tests intermittently to forestall collection of deficiencies. A model usage of the proposed test calculation has been incorporated into the switch channel interface and on-line test has been performed with manufactured self-comparable information activity. The execution of the NoC after expansion of the test circuit has been explored as far as throughput while the region overhead has been considered by integrating the test equipment. Likewise, an on-line test strategy for the directing rationale has been proposed which considers using the header bounces of the information activity development in transporting the test designs.

Key Words:- Straightforward test, NoC, Switch Channel, On-line test

INTRODUCTION:

Over the last decade, network-on-chip (NOC) has emerged as a better communication infrastructure compared with bus-based communication network for complex chip designs overcoming the difficulties related to bandwidth, signal integrity, and power dissipation However, like all other systems-on-a-chip (SOCs), NOC-based SOCs must also be tested for defects. Testing the elements of the NOC infrastructure involves testing routers and interrouter links. Significant amount of area of the NOC data transport medium is occupied by routers, which is predominantly occupied by FIFO buffers and routing logic. Accordingly, the probabilities of run-time faults or defects occurring in buffers and logic are significantly higher compared with the other components of the NOC. Thus, test process for the NOC infrastructure must begin with test of buffers and routing logic of the routers. In addition, the test must be performed periodically to ensure that no fault gets accumulated.

The occasional run-time functional faults have been one of the major concerns during testing of deeply scaled CMOS-based memories. These faults are a result of physical effects, such as environmental susceptibility, aging, and low supply voltage and hence are *intermittent* (nonpermanent indicating device damage or malfunction)in nature. However, these *intermittent* faults usually exhibit a relatively high occurrence rate and eventually tend to become permanent. Moreover, wear-out of memories also cause intermit-tent faults to become frequent enough to be classified as permanent. Thus, there is a need for online test techniques that can detect the run-time faults, which are intermittent in nature but gradually become permanent over time.

CONTRIBUTION:

In this brief, we have proposed an online transparent test technique for first-input first-output (FIFO) buffers and routing logic present within the routers of the NOC infrastructure. Our contributions are as follows. A transparent SOA-MATS++ test generation algorithm has proposed targeting in-field permanent faults developed in SRAM-based FIFO memories and it has been utilized to perform online and periodic test of FIFO memory present within the routers of the NOC. In addition, we have also proposed an online test technique for the routing logic that is performed simultaneously with the test of buffers. The proposal involves two ways of utilizing the unused portion of the header flits of the incoming data packets in transporting the test patterns. First, deterministic test patterns for the routing logic generated by *Tetramax* are placed in the unused fields of the header flit and are transported during the normal cycle. Second, the pseudorandom patterns in the synthetic data traffic used during normal operation and arriving at the routing logic are considered as test patterns. Fault coverage is estimated for either of the two proposals.

LITERATURE REVIEW:

As fault tolerance in NoC design has gained importance among research community, a number of papers have been published covering different aspects of fault tolerance, such as failure mechanisms, fault modeling, diagnosis, and so on. A detailed survey summarizing the research work in these papers has been provided in. Over the years, researchers have proposed a number of Design-For-Testability (DFT) techniques for NOC infrastructure testing (test-ing routers as well as NOC interconnect) and for NOC based core testing. Built-in self test (BIST)-based techniques have also been used for testing routers as well as NOC interconnect, such as . A recent paper on NOC and router testing in provides a summary of the DFT techniques employed for testing NOC interconnects and routers in particular. In addition to novel test architectures, fault tolerant routing algorithms have also been proposed.

FIFO buffers in NOC infrastructure are large in number and spread all over the chip. Accordingly, probability of faults is significantly higher for the buffers compared with other components of the router. Both online and offline test techniques have been proposed for test of FIFO buffers in NOC. The proposal in is an offline test technique (suitable for the detection of manufacturing fault in FIFO buffers) that proposes a shared BIST controller for FIFO buffers. Online test techniques for the detection of faults in FIFO buffers of NOC routers have been proposed in. However, the technique considers standard cell-based FIFO buffers, while we consider SRAM-based FIFO designs. Thus, faults considered in this brief are different from those targeted in.

To the best of our knowledge, no work has been reported in the literature that proposes online test of SRAM-based FIFO buffers present within routers of NOC infrastructure. Thus, we surveyed online test techniques for SRAM-based FIFOs in general. The survey revealed that SRAM based FIFOs are tested using either of the following two approaches, dedicated BIST approach as proposed by Barbagallet *al.*in and or distributed BIST proposed by Grecu*etal.* in. However, both dedicated and distributed BIST approaches being offline test techniques fail to detect permanent faults, which develop over time.

PROPOSED METHOD:

faults considered in this project, if applied for SRAMs or DRAMs, can be detected using standard March tests . However, if the same set of faults are considered for SRAM-type FIFOs, March test cannot be used directly due to the address restriction in SRAM-type FIFOs mentioned in and thus we were motivated to choose single-order address MATS++ test (SOA-MATS++) for the detection of faults considered in this brief. The word-oriented SOA-MATS++ test is represented as {*(wa)*; ↑*(r a, wb)r b, wa)*}; *(r a)*}where*a*is the data background and*b*isthecomplement of the data background. ↑and↓ are increasing and decreasing addressing order of memory, respectively. means memory addressing can be increasing or decreasing. Application of SOA-MATS++ test to the FIFO involves writing patterns into the FIFO memory and reading them back. As a result, the memory contents are destroyed. However, online memory test techniques require the restoration of the memory contents after test. Thus, researchers have modified the March tests to transparent March test so that tests can be performed without the requirement of external data background and the memory contents can be restored after test. We have thus transformed the SOA-MATS++ test to trans-parent SOA-MATS++ (TSOA-MATS++) test that can be applied for online test of FIFO buffers. The transparent SOA-MATS++ test generated is represented as {↑*(r x, wx*¯*,r x*¯*, wx,r x)*}

The operations performed during the test represent three phases of the test, namely, *invert*phase, *restore* phase, and *read* phase. The first two operations form a read write pair (*rx, wx*) representing the invert phase where the initial content (content before start of test) of the FIFO buffer location under test (*lut*) is read and its complement is written back to the same location. The invert phase is followed by restore phase involving the operations (*rx*¯ ,*wx*), where the content of *lut* are read and reinverted. At this point of the test, the contents of *lut* have been flipped twice to get back the original content. The last phase, (*rx*) involves reading the content of *lut* without any write operation to follow

TEST ALGORITHM

The algorithmic interpretation of the transparent SOA-MATS++ test is presented in Algorithm 1. It describes the step-by-step procedure to perform the three phases of the transparent SOA-MATS++ test for each location of the FIFO memory. The target location for test is given by the loop index *i* that varies from 0 to *N*− 1, where *N* is thenumber of locations in the FIFO memory. In other words, *i*represents the address of the FIFO memory location presently under test. For each location, the three test runs are performed during three iterations of the loop index *j*.

For a particular FIFO memory location (present value of *i*), the first iteration of *j* (address run1) performs the invert phase, where the content of the FIFOlocation is inverted. The invert test phase involves reading the content of *lut* into a temporary variable *temp* and then backing it up in *original*. Then, the inverted content of *temp* is written back to *lut*. At this point, the content of *lut* is inversion of content of *original*.

Algorithm 1 Transparent SOA-MATS++ Test Algorithm

```
Require: N = number of rows of the FIFO memory
1: i ← 0;                          /* memory address pointer */
2: while (i ≤ N − 1) do
3:    j ← 0;                       /* test cycle counter */
4:    while (j ≤ 2) do
5:       temp ← read(i);
6:       if (j = 0) then
7:          original ← temp;
8:          write(i, !temp);
9:       else
10:         if (j = 1) then
11:            result ← compare(temp, original);
12:            write(i, !temp);
13:         end if
14:      else
15:         result ← compare(temp, original);
16:      end if
17:      j ← j + 1;
18:   end while
19:   i ← i + 1;
20: end while
```

In the next iteration of *j* (address run2), the restore phase is performed. The content of *lut* is reread into *temp* and compared with the content of *original*. The comparison should result in all 1's pattern. However, deviation from the all 1's pattern at any bit position indicates fault at that particular bit position. Next, the inverted content of *temp* is written back to *lut*. Thus, the content of *lut*, which were inverted after the first iteration get restored after the second.

The third iteration of *j* performs only a read operation of*lut*, where the content of *lut* is read into *temp* and compared with the contents of *original*. At this stage of the test, all 0's pattern in the result signifies fault free location, while deviation at any bit position from all 0's pattern means fault at that particular bit position. The last read operation ensures the detection of faults, which remained undetected during the earlier two test runs. At the end of the three test runs (iterations of *j*), the loop index *i* is incremented by one to mark the start of test for the next location.

FAULT COVERAGE OF THE PROPOSED ALGORITHM

The transparent SOA-MATS++ algorithm is intended for test of stuck-at fault, transition fault, and read disturb fault fault tests developed during field operation of FIFO memories. The fault coverage of the algorithm is shown in Fig. 1. In both the figures, the word size of FIFO memory is assumed to be of 4 bits. The text in italics against the arrows indicates the operation performed, while the text in bold font corresponds to the variables used in Algorithm 1.As shown in Fig. 1, assume the data word present in *lut* be 1010. The test cycles begin with the invert phase (memory address pointer *j* with 0 value) during which the content of location addressed is read into *temp* and then backed up in the *original*. The data written back to*lut*is the complement of content of *temp*. Thus, at the end of the cycle,the data present in *temp* and *original* is 1010, while *lut* contains 0101. Assume a stuck-at-1 fault at the most significant bit (MSB) position of the word stored in *lut*. Thus, instead of storing 0101, it actually stores 1101 and as a result, the stuck-at-fault at the MSB gets excited.

During the second iteration of *j*, when *lut* is readdressed, the data read into *temp* is 1101. At this point, the data present in *temp* and *original* are compared (bitwiseXORed). An all 1's pattern is expectedas result. Any 0 within the pattern would mean a stuck-at fault at that bit position. This situation is shown in Fig. 1, where the XOR of 1010 and 1101 yields a 0 at the MSB position of the *result* indicating a stuck-at-fault at the MSB position. However, for cases where the initial data for a bit position is different from the faulty bit value, the stuck-at-fault cannot be detected for the bit position after the restore phase of the test. It thus requires one more test cycle to excite such faults.

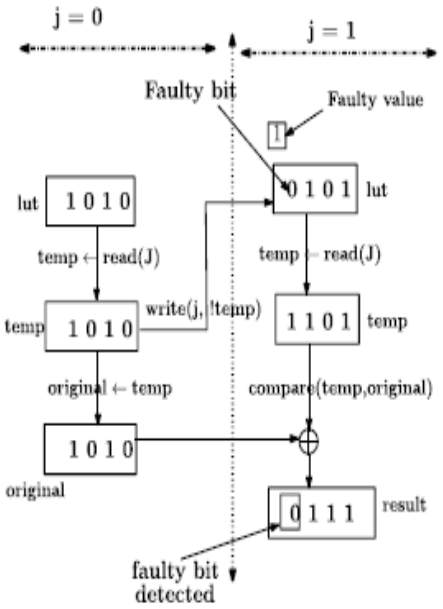


Fig. 1. Fault detection during invert phase and restore phase of the transparent SOA-MATS++ test.

BLOCK DIAGRAM

In this section, we present the technique used for implementing the proposed transparent SOA-MATS++ test on a mesh-type NoC. Data packets are divided into flow control units (*flits*) and are transmitted in pipeline fashion . The flit movement in a mesh-type NoC infrastructure considered for this work is assumed to require buffering only at the input channels of routers. Thus, for a data traffic movement from one core to another, the online test is performed only on the input channel FIFO buffers, which lie along the path. The buffers operate in two modes, the *normal* mode and the *test* mode. The normal mode and test mode of operation of a FIFO buffer are synchronized with two different clocks. The clock used for test purpose (referred as *test_clk* in this brief) is a faster clock compared with the clock required for normal mode (*router clock*).
A test burst involves series of test read and write cycles. It requires three read and two write cycles, or in other words three cycles of the faster test clock to perform a transparent SOA-MATS++ test on a single location of a FIFO buffer. It may be argued that during a test burst, not all FIFO buffer locations are tested or a test of a location can get interrupted. These two problems can be avoided by periodically testing the FIFO buffers. Periodic testing of a FIFO buffer allows test of a different set of locations of the FIFO buffer in each test burst. Every time

the buffer is switched to test mode, the normal process gets interrupted. The FIFO memory location currently addressed in normal mode, at the instant of switching, becomes the target location for test. Since normal operation is interrupted at different instants in different test bursts, the locations tested in each burst would be different. Thus, repeating the test bursts for a number times on a FIFO buffer would cover the test of each location as the number of locations in a FIFO buffer is few. Moreover, periodic testing prevents accumulation of fault in the buffer.

TEST ARCHITECTURE

The FIFO buffer present in each input channel of an NoC router consists of a SRAM-based FIFO memory of certain depth. During normal operation, data flits arrive through a *data_in* line of the buffer and are subsequently stored in different locations of the FIFO memory. On request by the neighboring router, the data flits stored are passed on to the output port through the *data_out* line. Fig. 3.3.1 shows the FIFO memory with *data_in*and*data_out* line. To perform the transparent SOA-MATS++ test on the FIFO buffer, we added a test circuit, few multiplexers and logic gates to the existing hardware, as shown in Fig. 3.3.1. The read and write operations on the FIFO buffer are controlled by the read enable and write enable lines, respectively. The multiplexers*mu*7 and *mu*7 select the read and write enable during the normal and test process. During normal operation when the *test_ctrl* is asserted low, the internal write and read enable lines, *wen_int*and*ren_int*, synchronized with the router clock, provide thewrite and the read enable, respectively. However, during test process, the write enable and read enable are synchronized with the test clock. As mentioned earlier, the read and write operations during test are performed at alternate edges of a test clock. The read operations are synchronized with the positive edges, while the *write_clk* is obtained by inverting the test clock. In test mode (*test_ctrl* high), the test read and write addresses are generated by test address generators implemented using gray code counters similar to the normal address generation. Muxes*m*4 and *m*5 are used to select between normal addresses and test addresses.

Consider the situation when the FIFO buffer is in normal mode with flits being transferred from the memory to the *data_out* line. After a few normal cycles, the *test_ctrl* is asserted high, switching the buffer to test mode. As long as the buffer is in test mode, no external data is allowed to be written to the buffer, or in other words, the buffer is locked for the test period. As a result, the input data line for the FIFO memory is switched from the external *data_in* line to *test_data* line available from the test circuit. At the switching instant, the flit which was in the process of being transferred to the *data_out* line is simultaneously read into the *Test Circuit*. However, a one clock cycle delay is created for the flit to move to the *data_out* line. This delay ensures that the flit is not lost during the switching instant and is properly received by the router, which requests for it. The single cycle delay in the path of the traveling flit is created by the D-type flip-flop and the multiplexer *m*3, as shown in Fig. 3.3.1. The flit, which is read in the testcircuit, is stored in a temporary register *temp* and the test process begins with this flit.

To avoid packet loss during testing, the *FULL* signal of the FIFO is asserted *high* so that neighboring routers can be prevented from transferring packets to the corresponding router. However, applying such technique increases the network latency as reflected in the results shown in Section V.

PROPOSAL FOR TEST OF ROUTING LOGIC

The other part of the router, besides the buffers, vulnerable to run-time permanent faults is the routing logic. In this section, we propose an online test proposal for the routing logic that utilizes the data packets for testing and thus overcomes the need for test access mechanism. Since the router design considered for this brief is taken from , both flit size and link width equal to 32-bit as used in . For the header flit, after allocation of address bits (source and destination) and bits for virtual channel selection, some fields in the header flit remain unused. Our proposal is to utilize these unused fields for test pattern encoding. An automatic test pattern generation tool generates deterministic offline test patterns for the routing logic. Once the set of test patterns are available, each pattern can be placed in the unused fields of the header flit. If the size of the test pattern does not fit the size of the available field size in a single header, the test pattern is adjusted in two header flits. In such a situation, it requires two test cycles before the test pattern reaches the routing logic. The test patterns are carried to the routing logic by the NoC infrastructure during normal operation and are applied for testing during the test mode. The test of the routing logic is simultaneously performed with test of the FIFO buffers during the test mode when the normal operation of the router remains suspended.

To validate our proposal, the router has been synthesized using *Design Vision* supporting 90-nm technology and then*Tetramax*hasbeen used to generate deterministic test patterns for the synthesized netlist. A total of 39 test patterns have been generated covering 242 faults for 100% fault coverage. Each pattern is of size 41 bits, which required two test cycles for transporting the test patterns. Thus, in total, 78 test cycles have been required for test of routing logic. We have also experimented with an alternate proposal of using pseudorandom patterns for test. Instead of using deterministic test patterns, we utilize the pseudorandom synthetic data traffic used during normal operation. Similar to the earlier proposal, the pseudorandom bits in each header flit have been treated as test patterns and have been applied to the routing logic. Fault simulation performed on the routing logic using the pseudorandom patterns utilizing a standard fault simulator provides 70% fault coverage.

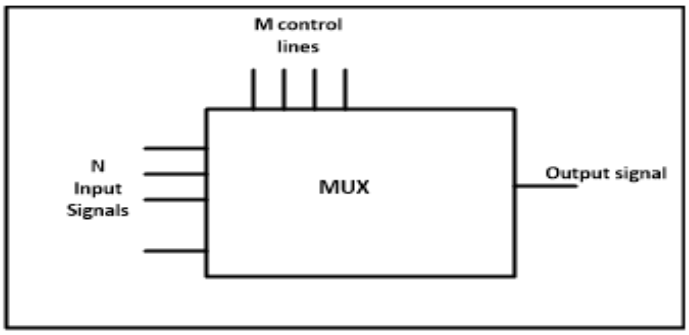
MULTIPLEXER:

Multiposition switches are widely used in many electronics circuits. However circuits that operate at high speed require the multiplexer to be automatically selected. A mechanical switch cannot perform this task satisfactorily. Therefore, multiplexer used to perform high speed switching are constructed of electronic components.

Multiplexer handle two type of data that is analog and digital. For analog application, multiplexer are built of relays and transistor switches. For digital application, they are built from standard logic gates.

The multiplexer used for digital applications, also called digital multiplexer, is a circuit with many input but only one output. By applying control signals, we can steer any input to the output. Few types of multiplexer are 2-to-1, 4-to-1, 8-to-1, 17-to-1 multiplexer.

Following figure shows the general idea of a multiplexer with n input signal, m control signals and one output signal.



Multiplexer Pin Diagram

D-FLIPFLOP:

The flip flop is a basic building block of sequential logic circuits. It is a circuit that has two stable states and can store one bit of state information. The output changes state by signals applied to one or more control inputs.

The basic D Flip Flop has a D (data) input and a clock input and outputs Q and Q (the inverse of Q). Optionally it may also include the PR (Preset) and CLR (Clear) control inputs.

TRUTH TABLE

INPUTS				OUTPUTS	
$\overline{PR}$	$\overline{CLR}$	CLK	D	Q	$\overline{Q}$
0	1	X	X	1	0
1	0	X	X	0	1
0	0	X	X	X	X
1	1	↑	1	1	0
1	1	↑	0	0	1
1	1	0	X	Q_o	$\overline{Q}_o$

D-Flip Flop Truth table

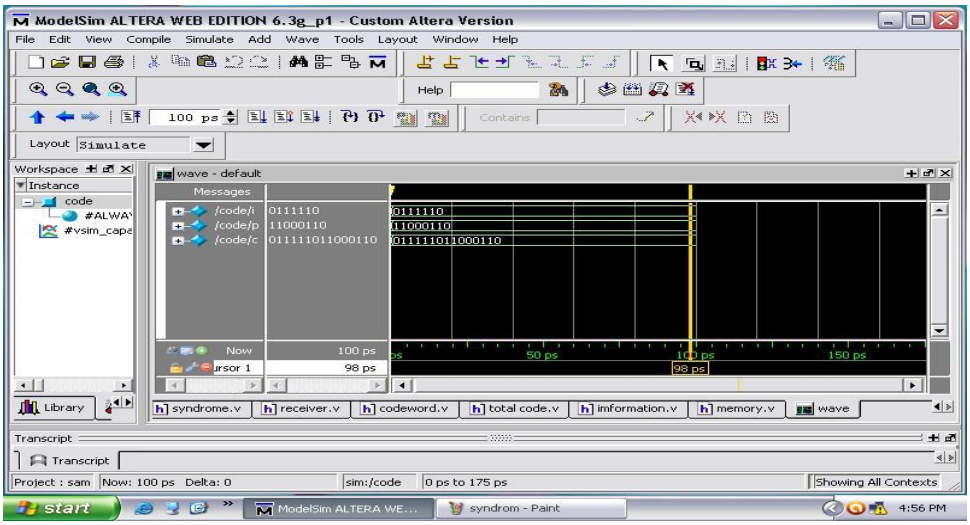
SIMULATION RESULTS:

Information vector snapshot:

Here in this information vector input is: 001111100000000, inorder to get the output corrector is given as ‘0’, and we get the output as ‘0111110’ because theoutput is of 7 bitthats why first 7 bits are accepted.

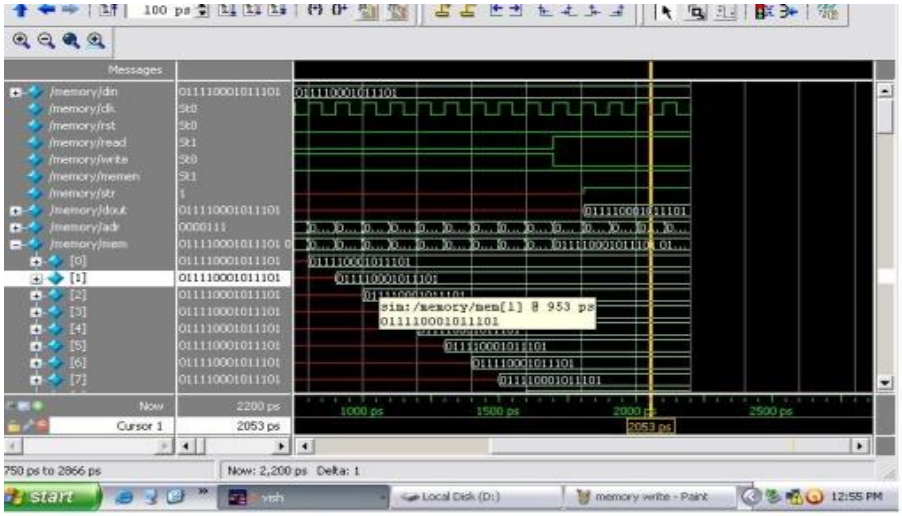
Snapshot of the code word:

The input of codeword is the output of information vector the input is given as '0111110' and the generator matrix is '11000110' the output is the combination of generator matrix and message therefore the output is '0111110111000110' the output is of the form (n,k) where n is the message bits.



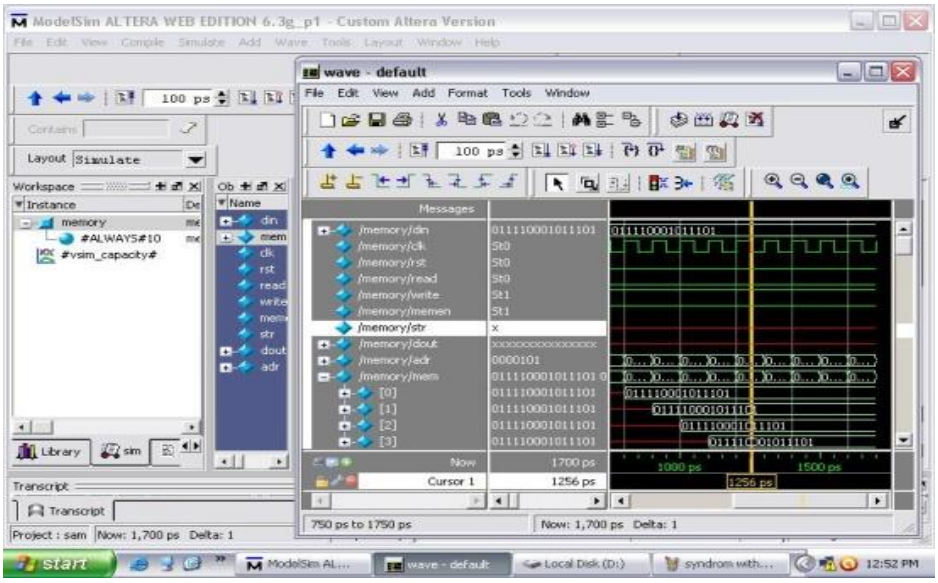
Memory with the read:

In the memory block both read and write operation are performed in 'read' operation here the input data stored in the memory is collected and it is displayed in the output section, here the input '0111100010111101' is collected from 7thaddress location.



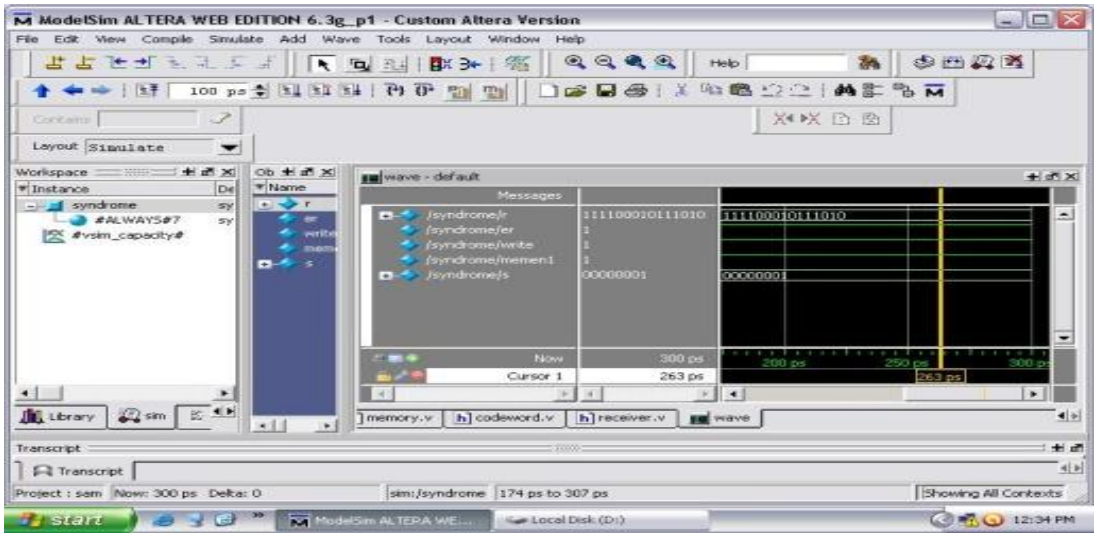
with the write

In the memory write the input data given is stored in the memory location, here the input data ' 011110001011101' is stored in the 1st memory location (i.e, 0000101).



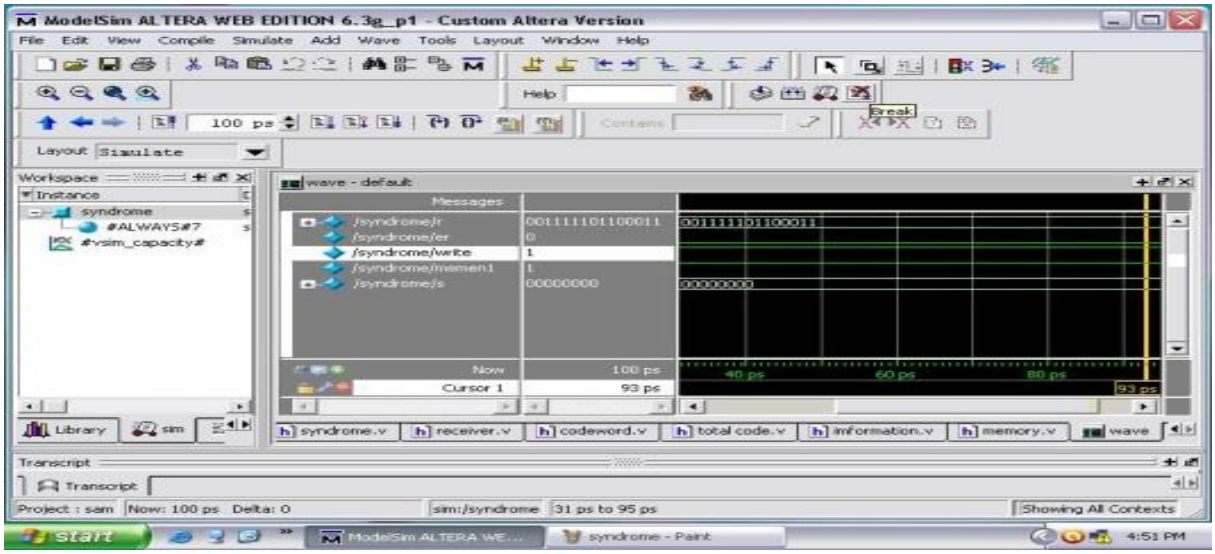
Syndrome with the errors

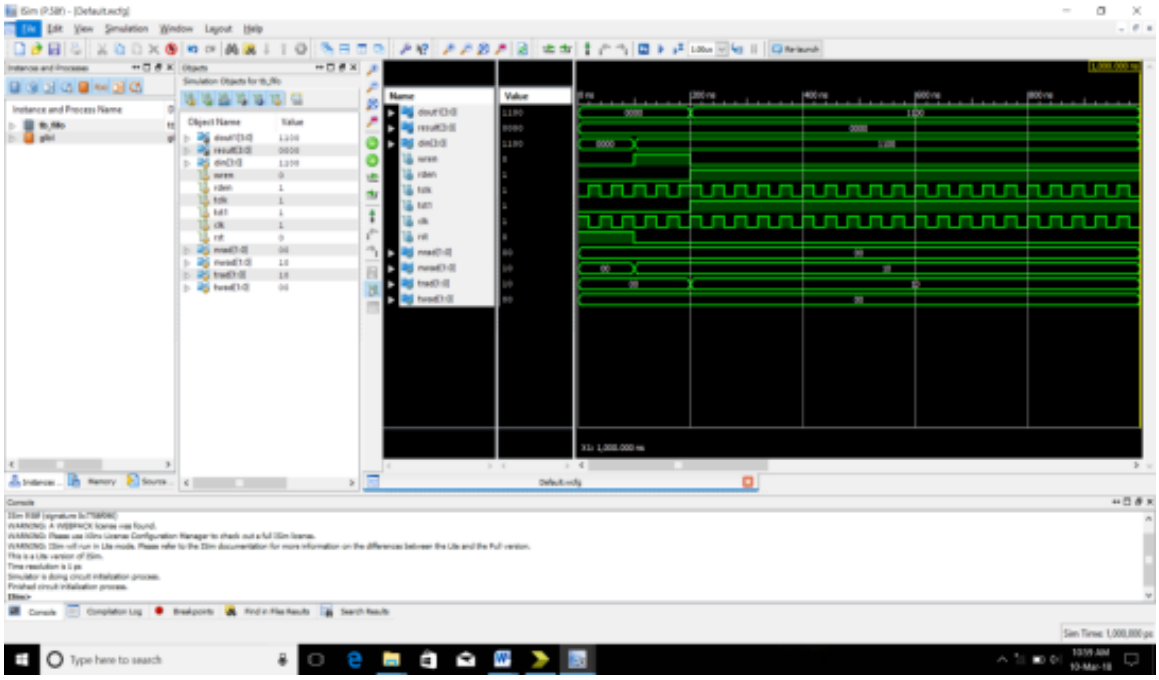
Here in the syndrome if the original code word matches with the suspected code word the syndrome output is '0', if it does't match the its value is '1', here the original code word is '111100010111011' but the suspected is '111100010111010' that's why the syndrome output is '1'.



syndrome with out errors:

Here the suspected code word is matched with the original code word thats why the output is '0'.





CONCLUSION:

In this project, we have proposed transparent SOA-MATS++test generation algorithm that can detect run-time permanent faults developed in SRAM-based FIFO memories. The proposed transparent test is utilized to perform online and periodic test of FIFO memory present within the routers of the NoC. Periodic testing of buffers prevents accumulation of faults and also allows test of each location of the buffer. Simulation results show that periodic testing of FIFObuffers do not have much effect on the overall throughput of the NoCexcept when buffers are tested too frequently. We have also proposedan online test technique for the routing logic that is performed Simultaneously with the test of buffers and involves utilization of the unused fields of the header flits of the incoming data packets. Test algorithm and RAM was designed by the Verilog HDL synthesized in Xilinx

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