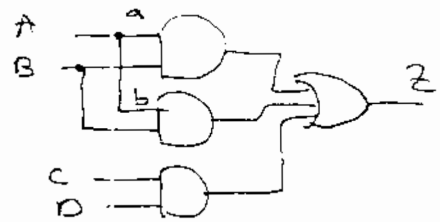
COE 464 Dr. Aiman El-Maleh

HW #1

Q1 a. Set of all tests that detect the fault a s-a-0.



$$Z_{a0} = AB + CD$$

$$Z = AB + AB + CD = AB + CD$$

$Z \oplus Z_{a0} = 0 \Rightarrow$ Fault is undetectable

b. Set of all tests that detect the fault b s-a-0

$$Z_{b0} = AB + CD$$

$Z \oplus Z_{b0} = 0 \Rightarrow$ Fault is untestable

c. Set of all tests that detect the multiple fault {a s-a-0, b s-a-0}

$$Z_{\{a0, b0\}} = CD$$

$$Z \oplus Z_{\{a0, b0\}} = (AB + CD) \oplus CD$$

$$= (AB + CD)(\overline{CD}) + (\overline{AB + CD})CD$$

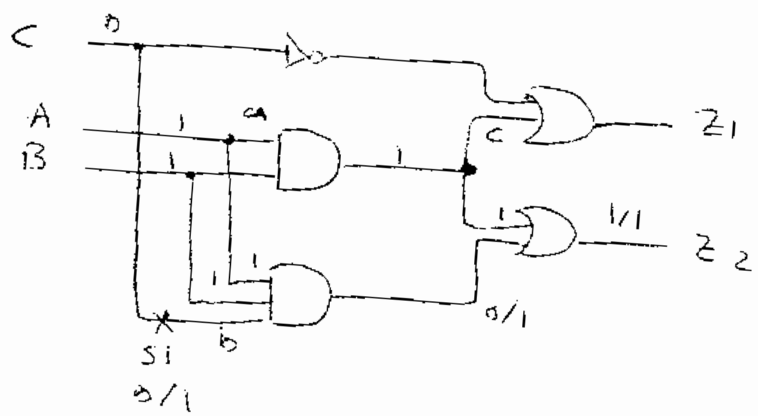
$$= (AB \cdot \overline{CD}) + \underbrace{\overline{AB} \cdot \overline{CD} \cdot CD}_{=0}$$

$$= AB\overline{C} + AB\overline{D}$$

$\Rightarrow$ set of tests $= \{110-, 11-0\}$

Q2

a.



So, the fault b s-a-1 is redundant

b. The set of tests that detect the fault a s-a-0 = {110, 111} (assuming ABC order)

The set of tests that detect the fault c s-a-0 = {111}

The set of tests that distinguish a s-a-0 and c s-a-0 = {110, 111}

$a0$: $Z_1 = \bar{C}$ $\quad Z_2 = ABC$

$c0$: $Z_1 = \bar{C}$ $\quad Z_2 = AB$

$$Z_2^{a0} \oplus Z_2^{c0} = ABC \oplus AB = 1 \Rightarrow AB\bar{C} = 1$$

Thus, there is one vector that distinguishes between the two faults namely {110}. However, this vector does not detect the fault c s-a-0. Since a distinguishing test set should be also a detecting test set, we need to add the vector {111}.

	fault free		a s-a-0		c s-a-0	
A B C	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2
1 1 0	1	1	1	0	1	1
1 1 1	1	1	0	1	0	1

c.

For the fault {a s-a-0, b s-a-1}

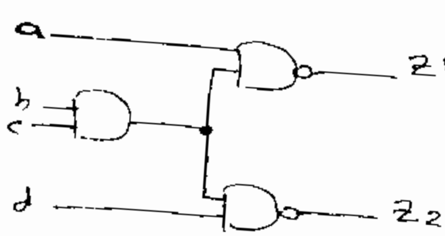
$Z_1 = \overline{C}$ $\qquad Z_2 = AB$

For the fault {c s-a-0, b s-a-1}

$Z_1 = \overline{C}$ $\qquad Z_2 = AB$

Since the two faulty functions are equivalent, then obviously the two multiple faults are undistinguishable.

Q3 f is b s-a-0
g is a s-a-1



a. Does f mask g under test 0110?

$Z1_f = 1$, $Z2_f = 1$

$Z1_g = \overline{bc}$, $Z2_g = \overline{bcd}$

$Z1_{\{f,g\}} = 1$, $Z2_{\{f,g\}} = 1$

For the test 0110 ; $Z1 = 1$, $Z2 = 1$
So, it does not detect the multiple fault {f,g}
Thus, f masks g under test 0110.

For the test 0111 : $Z1 = 1$, $Z2 = 0$
The test 0111 detects the multiple fault {f,g}.
So, f does not mask g. under the test 0111.

b. Are the faults f, {f,g} distinguishable ?

No, they are not because $Z1_f \oplus Z1_{\{f,g\}} = 0$
and $Z2_f \oplus Z2_{\{f,g\}} = 0$

Q4. Given an n-input XOR gate

(i) No fault is equivalent to any other fault. Thus, the number of SSFs after equivalence fault collapsing is $2(n+1)$

(ii) No fault dominates any other fault. Thus, the number of SSFs after equivalence and dominance fault collapsing is $2(n+1)$

(iii) The number of test vectors required to detect all the faults in an n-input XOR gate is:

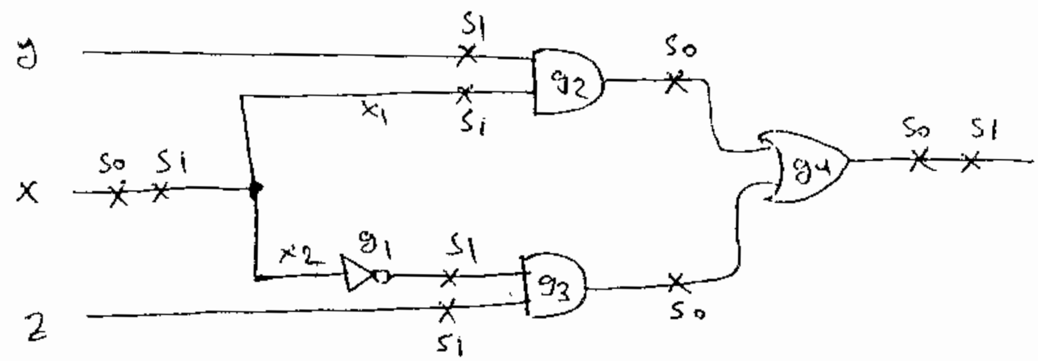
= 2 if n is odd

- The all 0 vector detects all the s-a-1 faults on the inputs & the output
- The all 1 vector detects all the s-a-0 faults on the inputs & the output

= 3 if n is even

- The all 0 vector detects all the s-a-1 faults on the inputs & the output
- The all 1 vector detects all the s-a-0 faults on the inputs
- An additional vector that produces a 1

Q5. First, let us collapse the faults based on fault equivalence.



The faults on the output can also be removed based on fault dominance. Thus, we have 8 faults to consider.

x y z	FF	x/s0	x/s1	y/s1	x1/s1	g1/s1	z/s1	g2/s0	g3/s0
0 0 0	0	0	0	0	0	0	1	0	0
0 0 1	1	1	0	1	1	1	1	1	0
0 1 0	0	0	1	0	1	0	1	0	0
0 1 1	1	1	1	1	1	1	1	1	0
1 0 0	0	0	0	1	0	0	0	0	0
1 0 1	0	1	0	1	0	1	0	0	0
1 1 0	1	0	1	1	1	1	1	0	1
1 1 1	1	1	1	1	1	1	1	0	1

Based on the above table, we build a covering table to select the minimum number of tests to detect all the faults

		✓	✓	✓	✓	✓	✓		
	x y z	x/s0	x/s1	y/s1	x_1/s1	g_1/s1	z/s1	g_2/s0	g_3/s0
	0 0 0						×		
	0 0 1		×						×
✓	0 1 0		×		×		×		
	0 1 1								×
	1 0 0			×					
✓	1 0 1	×		×		×			
	1 1 0	×						×	
	1 1 1							×	

First, we note that both the tests 010 and 101 are essential since 010 is the only test that detects z/s1 and 101 is the only test that detects g_1/s1. So, both tests are selected and all the faults detected by them are removed. The remaining undetected faults are g_2/s0 and g_3/s0. g_2/s0 can be detected by either 110 or 111. g_3/s0 can be detected by either 001 or 011.

Thus, the following test sets are minimal & complete detection test sets:

{010, 101, 110, 001} or

{010, 101, 110, 011} or

{010, 101, 111, 001} or

{010, 101, 111, 011}

Let us choose the test set

{010, 101, 001, 110}

Based on the first table, we can see that this test set is not a complete location test set. It does not distinguish between the faults y/s1 & g_1/s1. Also, it does not distinguish between the faults x1/s1 & z/s1.

The faults y/s1 & g_1/s1 can be distinguished by the test 100.

The faults x1/s1 & z/s1 can be distinguished by the test 000.

Thus, a complete location test set is

{000, 001, 010, 100, 101, 110}.

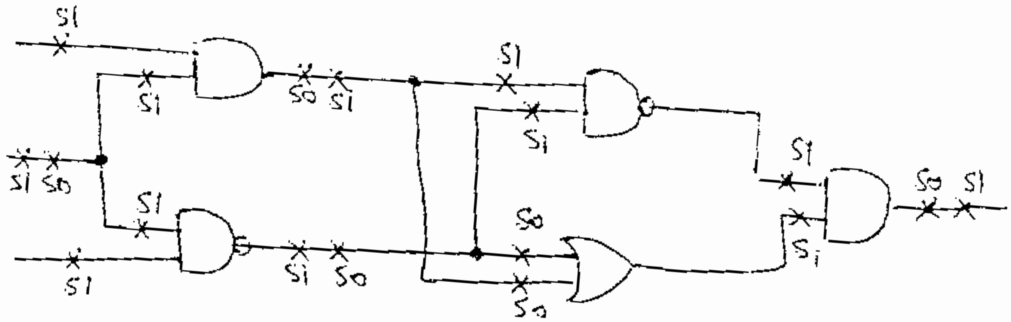
The fault dictionary is:

xyz	FF	x/s_0	x/s_1	y/s_1	x_1/s_1	y_1/s_1	z/s_1	y_2/s_0	y_3/s_0
000	0	0	0	0	0	0	1	0	0
001	1	1	0	1	1	1	1	1	0
010	0	0	1	0	1	0	1	0	0
100	0	0	0	1	0	0	0	0	0
101	0	1	0	1	0	1	0	0	0
110	1	0	1	1	1	1	1	0	1

As can be seen, base on the output response of the six vectors, it can be determined whether the machine is fault-free or faulty and if faulty the fault is uniquely determined.

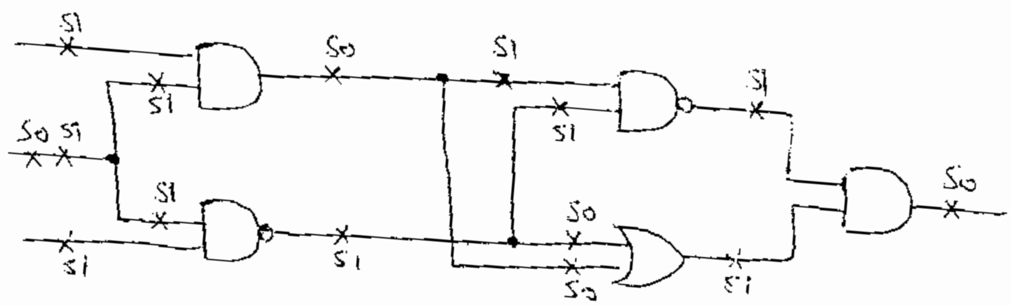
Q6

(i) Fault collapsing using fault equivalence



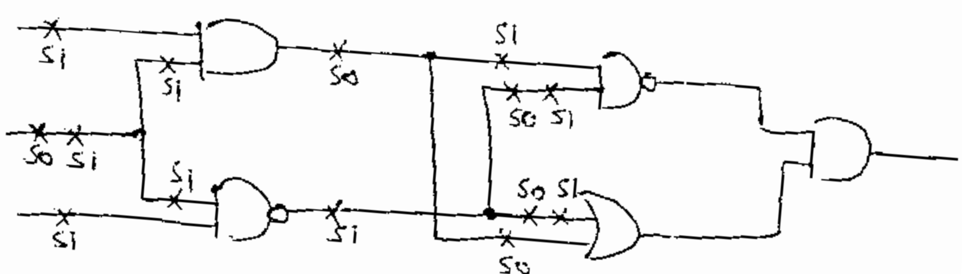
Number of collapsed faults = 13

(ii) Fault collapsing using fault equivalence and dominance



Number of collapsed faults = 15

(iii) Checkpoint theorem + fault equiv. & dominance

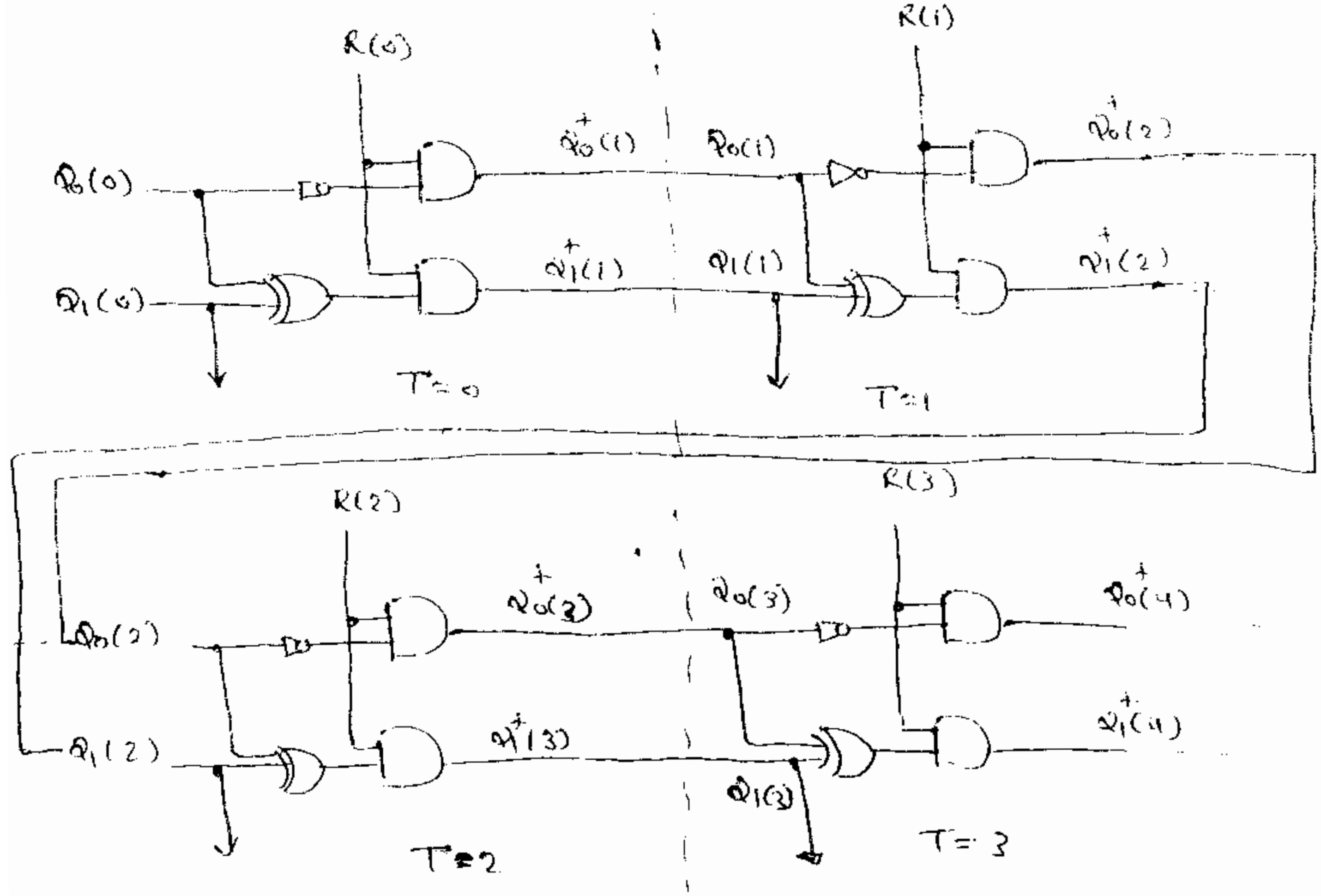


Number of collapsed faults = 14

(iv) Fault collapsing in HITEC is based on fault equivalence and hence the collapsed faults will be the same as in (i).

Q7.

(i) Iterative array model of four time frames



(ii) A test sequence for detecting the fault G2 s-a-0 is $R = \{0, 1, 1, x\}$

(iii) The fault R s-a-1

- <u>Fault-free state table</u>;

Present state		R = 0		R = 1	
Q_1	Q_0	Q_1^+	Q_0^+	Q_1^+	Q_0^+
0	0	0	0	0	1
0	1	0	0	1	0
1	0	0	0	1	1
1	1	0	0	0	0

- <u>Faulty state table</u>:

Present state		R = 0		R = 1	
Q_1	Q_0	Q_1^+	Q_0^+	Q_1^+	Q_0^+
0	0	0	1	0	1
0	1	1	0	1	0
1	0	1	1	1	1
1	1	0	0	0	0

First, the fault is testable since we can distinguish between every state in the fault free machine and every state in the faulty machine. Next, we need to determine whether the fault is detectable or strongly detectable. Obviously, it is not detectable because the fault prevents initialization. However, it is strongly detectable.

For example, the test sequence $K = \{0, 0, 0, 0\}$ is a strong detection sequence for the fault. Obviously, the fault is also partially testable since it is testable.

The fault is not detectable by HITEC because the fault prevents initialization of the faulty machine. Since the machine is initializable in the fault-free case, it means we will get a $0/u$ or $1/u$ when we apply a test sequence. If the value of the faulty machine produces an opposite value from the fault-free machine, then the fault will be detected. Otherwise, it will not. This is why the ATPG will mark the fault as potentially detectable.