

HW#2 Solution

Q1. Based on Williams & Brown model:

$$DL = 1 - Y^{(1-Q)}$$

$$\Rightarrow 0.001 = 1 - (0.7)^{(1-Q)}$$

$$\Rightarrow (0.7)^{(1-Q)} = 1 - 0.001 = 0.999$$

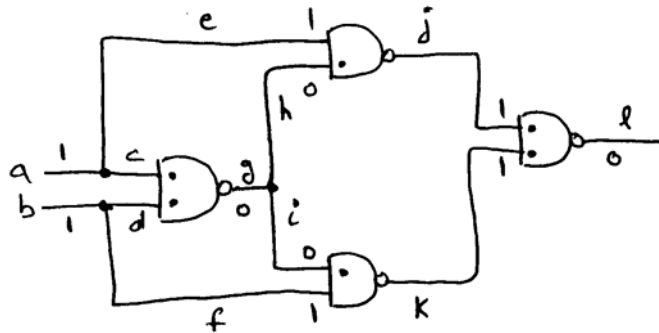
$$\Rightarrow 1 - Q = \log 0.999 / \log 0.7$$

$$\Rightarrow 1 - Q = 0.0028$$

$$\Rightarrow Q = 0.9972$$

Thus, the required fault coverage to achieve a defect level of 0.001 with yield = 70% is 99.72%.

Q2.



Fault list =  $\{a_0, a_1, b_0, b_1, c_1, d_1, g_0, g_1, e_1, h_1, i_1, f_1, j_1, k_1, l_1, l_0\}$

(i) Deductive fault simulation

$$L_a = \{a_0\}, \quad L_b = \{b_0\}$$

$$L_c = L_a = \{a_0\}, \quad L_d = L_b = \{b_0\}$$

$$L_e = L_a = \{a_0\}, \quad L_f = L_b = \{b_0\}$$

$$L_g = \{g_1\} \cup L_c \cup L_d = \{g_1, a_0, b_0\}$$

$$L_h = \{h_1\} \cup L_g = \{h_1, g_1, a_0, b_0\}$$

$$L_i = \{i_1\} \cup L_g = \{i_1, g_1, a_0, b_0\}$$

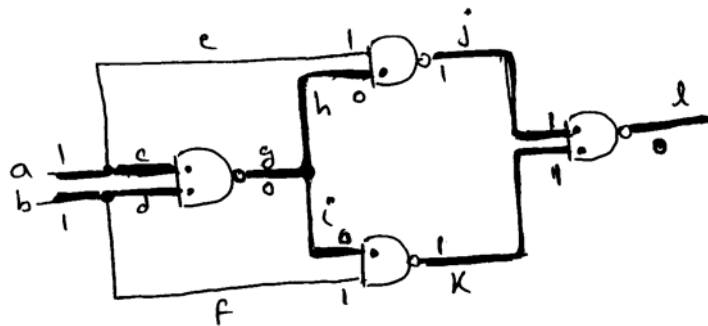
$$L_j = L_h - L_e = \{h_1, g_1, b_0\}$$

$$L_k = L_i - L_f = \{i_1, g_1, a_0\}$$

$$L_l = \{l_1\} \cup L_j \cup L_k = \{l_1, h_1, g_1, b_0, i_1, a_0\}$$

Thus, there are 6 detected faults by the test vector 11.

(ii) Critical Path Tracing



The critical lines are shown highlighted.

FFR	Critical Lines	Stems to check	Stem checked	Capture Lines
l	l, j, k, h, i	g	g	l
g	g, c, d	a, b	a	g or k or l
a	a	b	b	g or j or l
b	b	<del>g</del>		

Details of checking criticality of stems:

1. Stem g:

$$\text{Frontier} = \{j, k\}$$

Since both  $j$  &  $k$  are of the same level, any one of them can be picked.

If  $j$  is picked first, it is found that the fault propagates across  $j$  and  $\text{Frontier} = \{k, l\}$ .

Next,  $k$  is picked since it is of a lower level. Since the fault propagates across  $k$ ,

$\text{Frontier} = \{l\}$ . Since the fault propagates across  $l$  and  $l$  is critical, then  $g$  is

marked as critical. Thus,  $l$  is a capture line for  $g$ .

## 2. Stem a:

$$\text{Frontier} = \{g, j\}$$

Since both gates are of the same level, any one of them can be picked.

If  $j$  is picked, then it is found that  $j$  does not propagate the fault and  $\text{Frontier} = \{g\}$ . Since  $g$  propagates the fault and  $g$  is critical,  $a$  is marked as critical and  $g$  is a capture line.

However, if  $g$  is picked first, then  $\text{Frontier} = \{j, k\}$  since  $g$  propagates the fault. Next, either  $j$  or  $k$  could be picked since they are at the same level.

If  $j$  is picked, then  $\text{Frontier} = \{k\}$  since  $j$  does not propagate the fault. Since  $k$  propagates the fault, then  $a$  is marked as critical since  $k$  is critical. Thus,  $k$  is a capture line for  $a$ .

However, if  $k$  is picked first, then  $\text{Frontier} = \{j, l\}$ . Since  $j$  does not propagate the fault, then  $\text{Frontier} = \{l\}$ . Since  $l$  propagates the fault and is critical, then  $a$  is critical and  $l$  is a capture line.

## 3. Stem b:

The same analysis done for stem  $b$  will result in the conclusion that  $b$  is critical and that either  $g$  or  $j$  or  $l$  are capture lines.

(iii) Parallel Fault Simulation:

Fault Representation:

a0	a1	b0	b1	c1	d1	g0	g1	e1	h1	i1	f1	j1	k1	l0	l1	ff
----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

For Line a:

Ia:

1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Sa:

0	1															
---	---	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Line a before fault injection:

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line a after fault injection:

0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line b:

Ib:

0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Sb:

		0	1													
--	--	---	---	--	--	--	--	--	--	--	--	--	--	--	--	--

Line b before fault injection:

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line b after fault injection:

1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line c:

Ic:

0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Sc:

				1												
--	--	--	--	---	--	--	--	--	--	--	--	--	--	--	--	--

Line c before fault injection:

0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line c after fault injection:

0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line d:

Id:

0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Sd:

					1											
--	--	--	--	--	---	--	--	--	--	--	--	--	--	--	--	--

Line **d** before fault injection:

1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line **d** after fault injection:

1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line g:

Ig:

0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Sg:

						0	1									
--	--	--	--	--	--	---	---	--	--	--	--	--	--	--	--	--

Line **g** before fault injection:

1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line **g** after fault injection:

1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line e:

Ie:

0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Se:

								1								
--	--	--	--	--	--	--	--	---	--	--	--	--	--	--	--	--

Line **e** before fault injection:

0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line **e** after fault injection:

0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line h:

Ih:

0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Sh:

										1						
--	--	--	--	--	--	--	--	--	--	---	--	--	--	--	--	--

Line h before fault injection:

1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line h after fault injection:

1	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line i:

Ii:

0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Si:

										1						
--	--	--	--	--	--	--	--	--	--	---	--	--	--	--	--	--

Line i before fault injection:

1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line i after fault injection:

1	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line f:

If:

0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Sf:

											1					
--	--	--	--	--	--	--	--	--	--	--	---	--	--	--	--	--

Line f before fault injection:

1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line f after fault injection:

1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line j:

I<sub>j</sub>:

0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

S<sub>j</sub>:

													1				
--	--	--	--	--	--	--	--	--	--	--	--	--	---	--	--	--	--

Line **j** before fault injection:

1	1	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line **j** after fault injection:

1	1	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line k:

I<sub>k</sub>:

0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

S<sub>k</sub>:

														1			
--	--	--	--	--	--	--	--	--	--	--	--	--	--	---	--	--	--

Line **k** before fault injection:

0	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line **k** after fault injection:

0	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

For Line l:

I<sub>l</sub>:

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

S<sub>l</sub>:

															0	1	
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	---	---	--

Line **l** before fault injection:

1	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Line **l** after fault injection:

1	0	1	0	0	0	0	1	0	1	1	0	0	0	0	1	0	
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	--

a0	a1	b0	b1	c1	d1	g0	g1	e1	h1	i1	f1	j1	k1	l0	l1	ff	
----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--

Since l is a primary outputs, the detected faults are those that produce different values than the fault free value which include: {a0, b0, g1, h1, i1, l1}. This is consistent with the results obtained by deductive fault simulation and critical path tracing.



(iv) Verification using CPT:

Netlist:

INPUT(a)  
 INPUT(b)  
 OUTPUT(l)

g = NAND(a, b)  
 j = NAND(a, g)  
 k = NAND(g, b)  
 l = NAND(j, k)

CPT Fault Simulation Results:

Test # 1: 6 faults detected (vs 6 from CPT)

HOPE: newly detected faults are:

l /1  
 g->k /1  
 g->j /1  
 a /0  
 g /1  
 b /0

CPT: newly detected faults are:

l /1 through PO l\_PO  
 g->k /1 through PO l\_PO  
 g->j /1 through PO l\_PO  
 a /0 through PO l\_PO  
 g /1 through PO l\_PO  
 b /0 through PO l\_PO

(v) Verification using PROOFS:

<u>Circuit Netlist</u>	<u>Signal Names</u>
INPUT(a) INPUT(b) OUTPUT(l)  g = NAND(a, b) j = NAND(a, g) k = NAND(g, b) l = NAND(j, k)	1 a 2 b 3 g 4 j 5 k 6 l 7 l_\$OUTPUT
<u>Fault Simulation Statistics</u>	<u>Detected Faults</u>
user time 0.000000 sec sys time 0.000000 sec det faults 6 tot faults 16 coverage 0.3750000	7 0 1; 5 1 1; 3 0 1; 2 0 0; 1 0 0; 4 1 1;