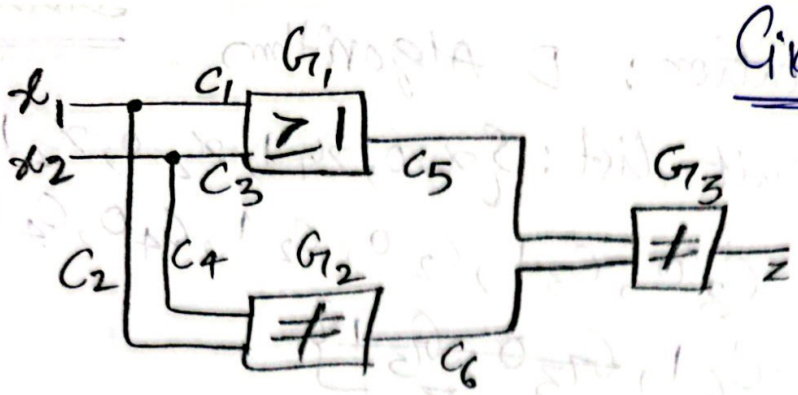
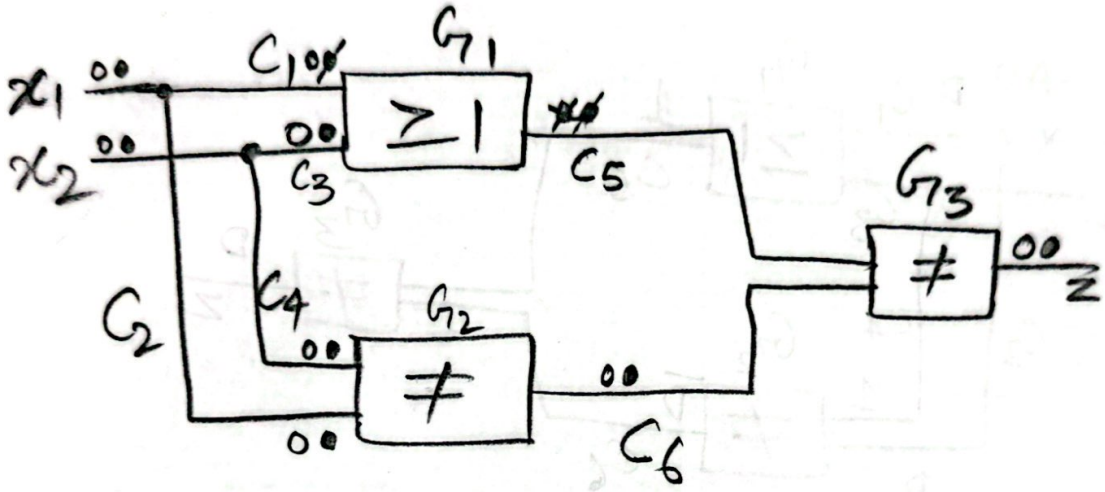
1) Circuit 3.23



Fault Collapsing using level by level dropping



Total Number of faults = 18

Number of faults remaining = 15

Collapse ratio = $\frac{\text{Number of faults remaining}}{\text{Total No. of faults}}$

$= 15/18 = 83.3\%$

Collapsed Faults = ~~$\{x_0, x_1, x$~~

$= \{x_1\,0, x_1\,1, x_2\,0, x_2\,1, C_1\,0, C_3\,0, C_3\,1, C_2\,0, C_2\,1, C_4\,0, C_4\,1, C_6\,0, C_6\,1,$ ~~$G_3\,0, G_3\,1$~~ $\}$

$Z\,0, Z\,1$

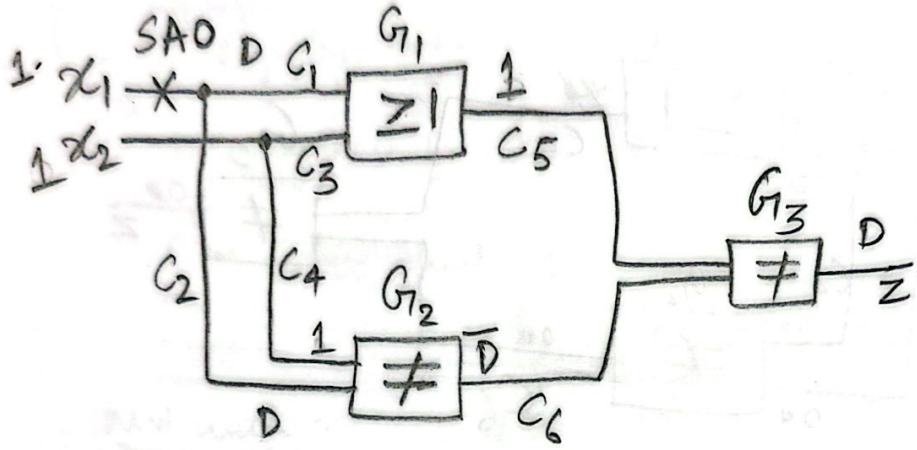
Test Generation: D Algorithm

Iteration 1

Current Fault list: $\{x_1/0, x_1/1, x_2/0, x_2/1, C_1/0, C_3/0, C_3/1, C_2/0, C_2/1, C_4/0, C_4/1, C_6/0, C_6/1, G_3/0, G_3/1\}$

Z_0, Z_1

(i) Consider SA0 fault at x_1

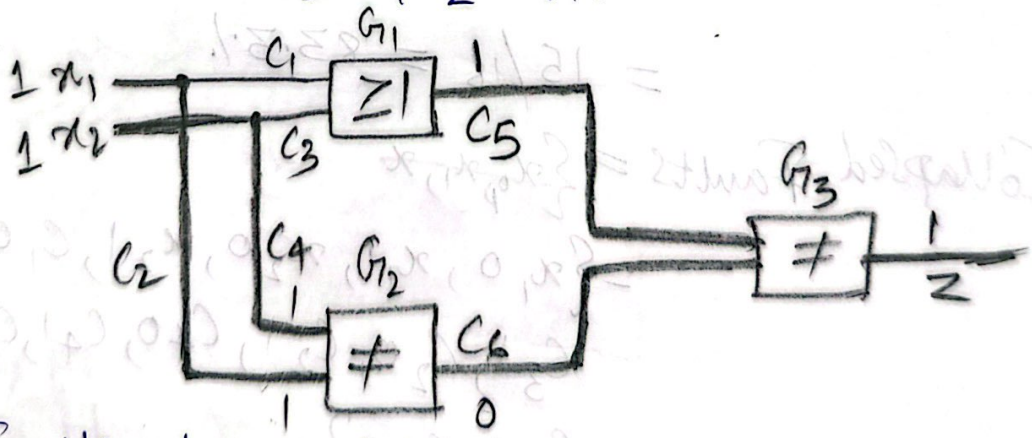


Test Pattern: $x_1 x_2 = 11$

$T = \{11\}$

Fault-free output $= \{1\}$

Fault Simulation, $x_1 x_2 = 11$:



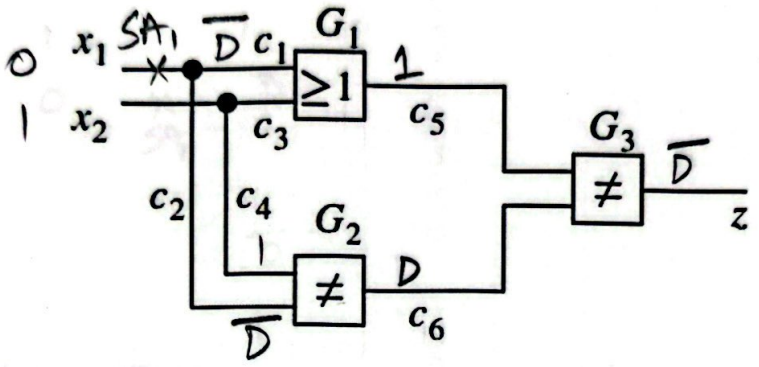
Faults detected by $11 = \{Z_0, C_6/1, C_5/0, C_1/0, C_3/0, C_4/0, C_2/0, x_1/0, x_2/0\}$

updated fault list $= \{x_1/1, x_2/1, C_3/1, C_2/1, C_4/1, C_6/0, Z_1\}$

Iteration 2:

Current Fault list = {x_1 1, x_2 1, c_3 1, c_2 1, c_4 1, c_6 0, z_1}

Consider SA1 fault at 'x_1'

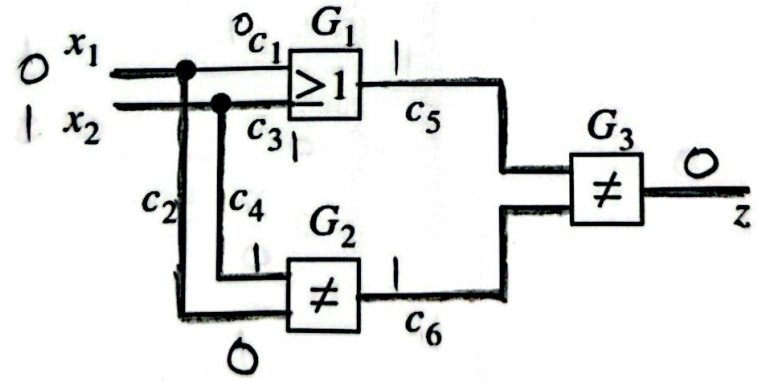


Test Pattern : $x_1 x_2$ = 01

T = {01}

Fault Free o/p = {0}

Fault Simulation, $x_1 x_2$ = 01

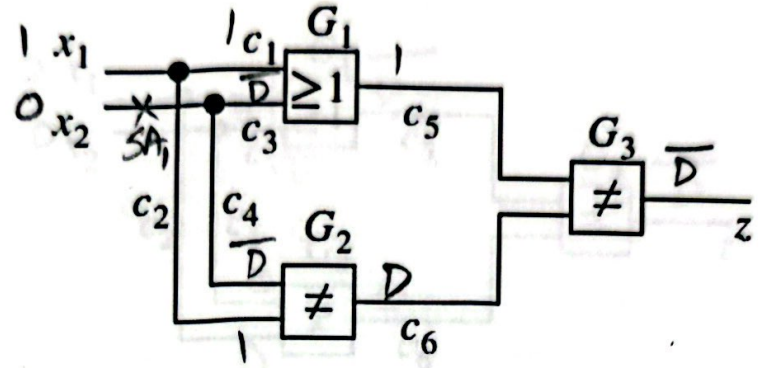


Faults detected by 01 = {z_1, c_5 0, c_6 0, c_4 0, c_2 1, c_3 0, x_2 0, x_1 1}

updated Fault list = {x_2 1, c_3 1}

Iteration 3: Current fault list = $\{x_2 1, C_3 1\}$

Consider SA_1 fault at 'x_2'

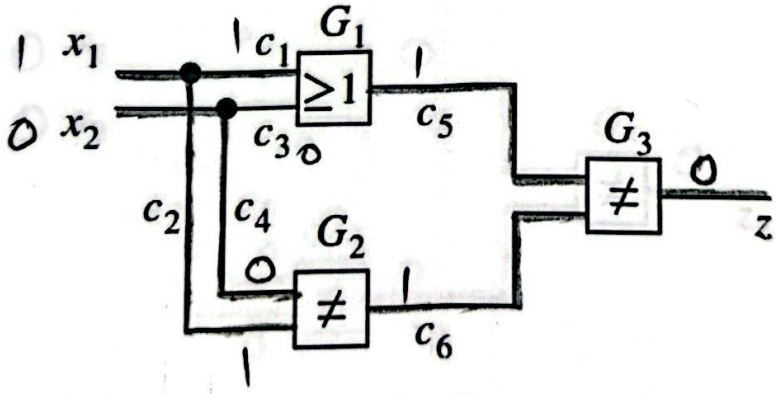


Test Pattern : $x_1 x_2 = 10$

$T = \{10\}$

Fault Free o/p = $\{0\}$

Fault simulation, $x_1 x_2 = 10$

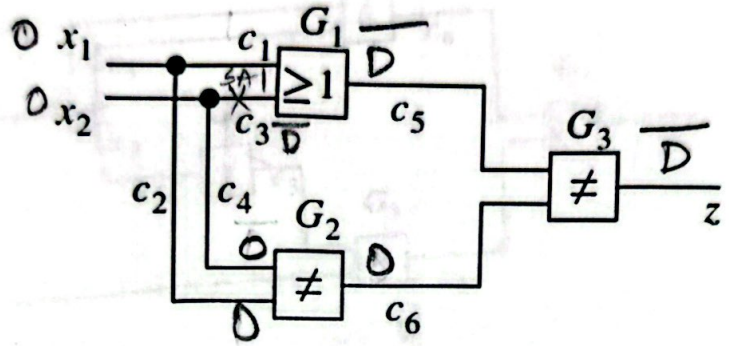


Faults detected by 10 = $\{z_1, C_6 0, C_5 0, C_4 1, C_2 0, C_1 0, x_1 0, x_2 1\}$

updated Fault list = $\{C_3 1\}$

Iteration 4: Current Fault list = $\{c_3 1\}$

Consider SA1 fault at 'c_3'

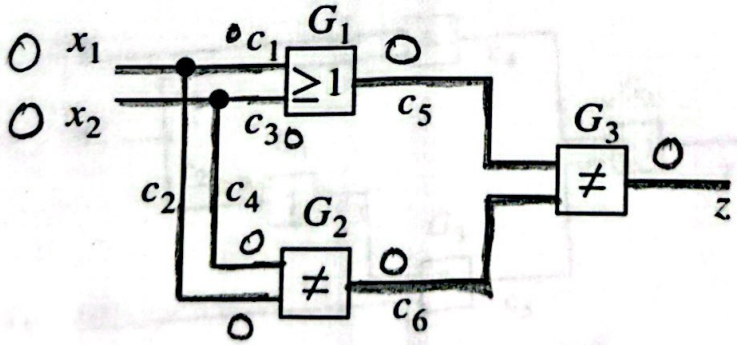


Test Pattern : $x_1 x_2 = 00$

$T = \{0\ 0\}$

Fault Free O/P = $\{0\}$

Fault Simulation, $x_1 x_2 = 00$

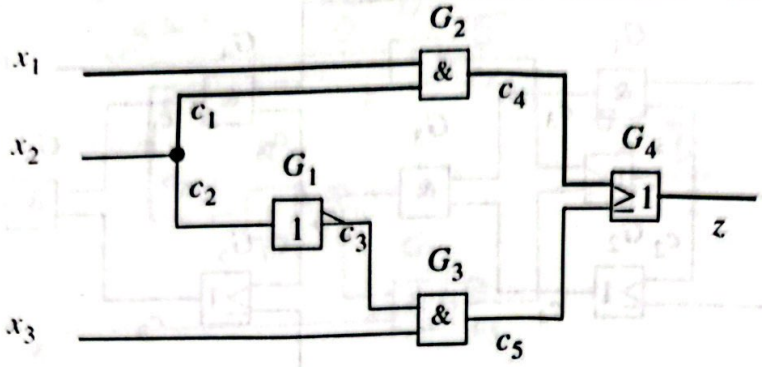


Faults detected by 00 = $\{z_1, c_5 1, c_6 1, c_4 1, c_2 1, c_1 1, c_3 1, x_1 1, x_2 1\}$

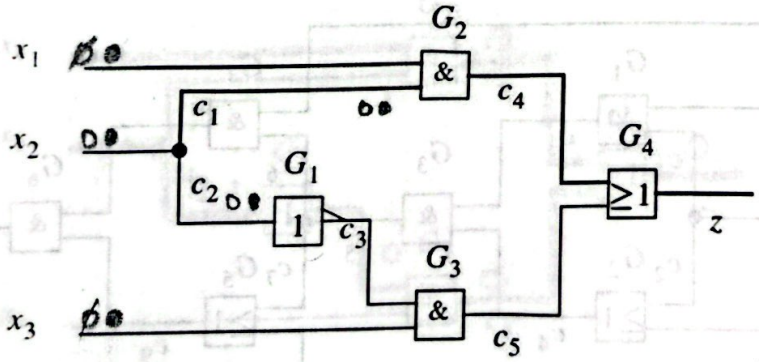
updated Fault list = $\{\}$ ∴ Test Pattern set: T

Fault Coverage = $\frac{15}{15}$ = 100% $\{11, 01, 10, 00\}$

Circuit 3.34



Fault Collapsing using check Point Theorem



Total No. of faults = 18

No. of faults remaining = 8

Collapse ratio = $8/18 = 0.44 = 44.4\%$

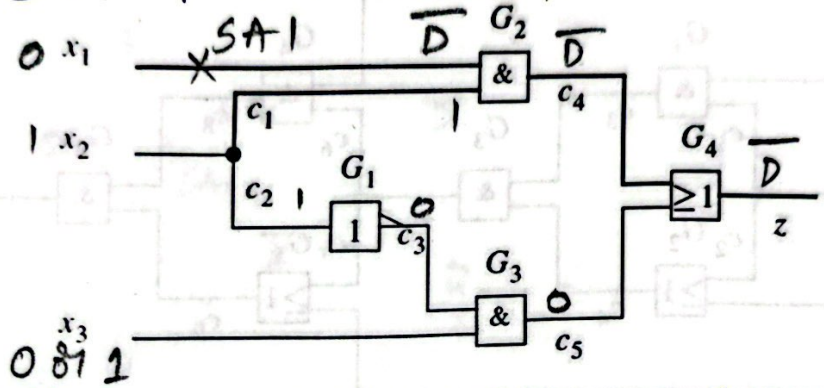
Collapsed faults = $\{x_1 1, x_2 0, x_3 1, x_2 1, c_1 0, c_1 1, c_2 0, c_2\}$

Iteration 1:

Test generation: D Algorithm

Current Fault list: $\{x_1 1, x_2 0, x_3 1, z 1, c_1 0, c_1 1, c_2 0, c_2 1\}$

Consider SA1 fault at x_1

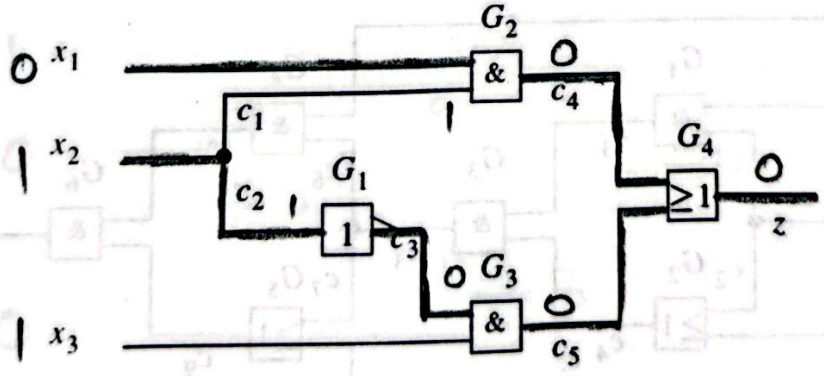


Test Pattern: $x_1 x_2 x_3 = 01X = 011$ or 010

Test Pattern set $T = \{011\}, 010\}$

Fault-Free o/p $= \{0\}$

Fault Simulation, $x_1 x_2 x_3 = 011$



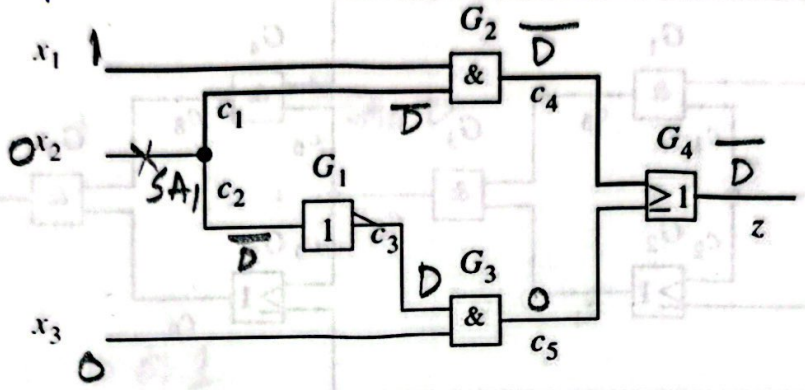
Fault detected by $011 = \{z 1, c_4 1, c_5 1, c_3 1, c_2 0, x_2 0, x_1 1\}$

updated Fault list $= \{x_2 1, x_3 1, c_1 0, c_1 1, c_2 1\}$

Iteration 2:

Current : $\{x_2 1, x_3 1, G_4 0, C_1 1, C_2 1\}$

SA1 fault at x_2 :

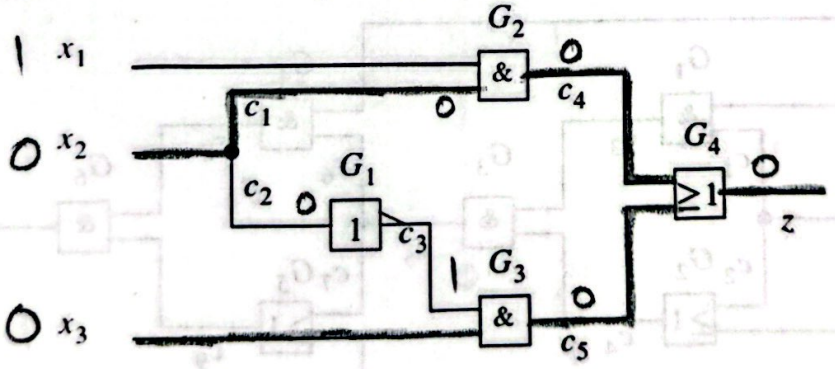


Test Pattern : $x_1 x_2 x_3 = 100$

$T = \{100\}$

Fault-free O/P = $\{0\}$

Fault Simulation, $x_1 x_2 x_3 = 100$



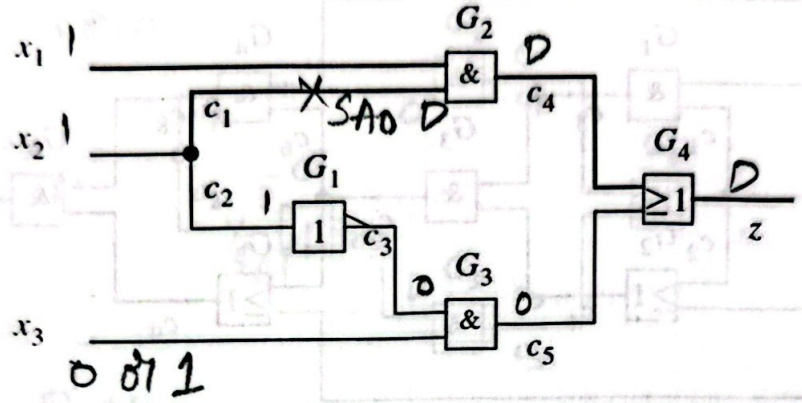
Faults detected by 100 = $\{Z_1, C_4 1, C_5 1, C_1 1, x_2 1, x_3 1\}$

updated fault list = $\{\cancel{x}\ C_1 0, C_2 1\}$

Iteration 3:

Current : $\{c_1 0, c_2 1\}$

SA0 fault at c_1 :

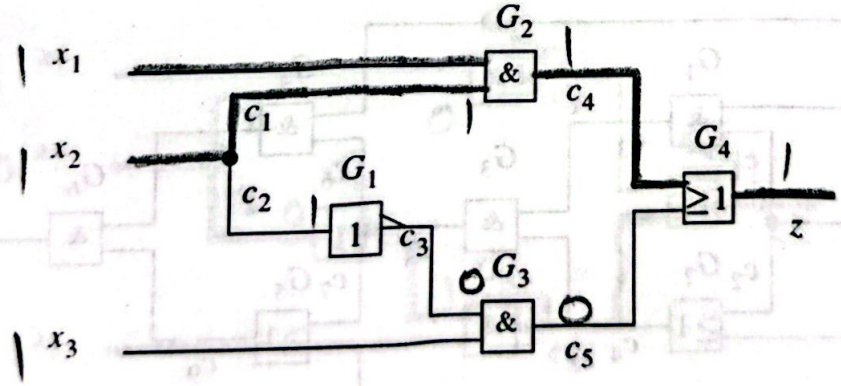


Test Pattern : $x_1x_2x_3 = 11x = 110$ or 111

$T = \{110, 111\}$

Fault-Free o/p = {1}

Fault Simulation $x_1x_2x_3 = 111$

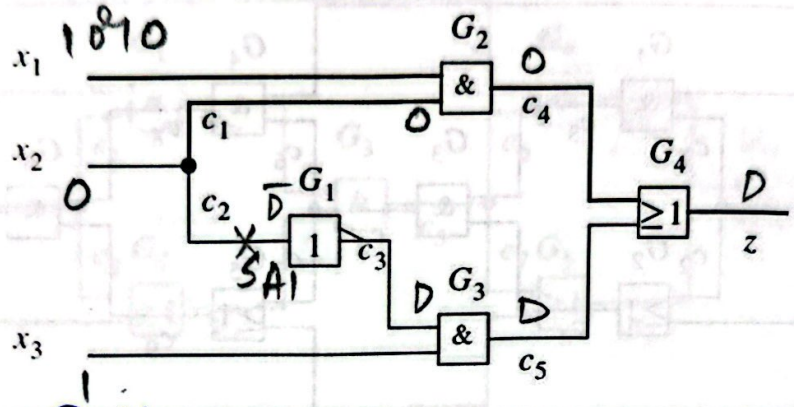


Faults detected by 111 = $\{z_0, c_4 0, c_1 0, x_2 0, x_1 0\}$

Updated = $\{c_2 1\}$

Iteration 4: Current: $\{c_2 1\}$

SA1 fault at c_2:

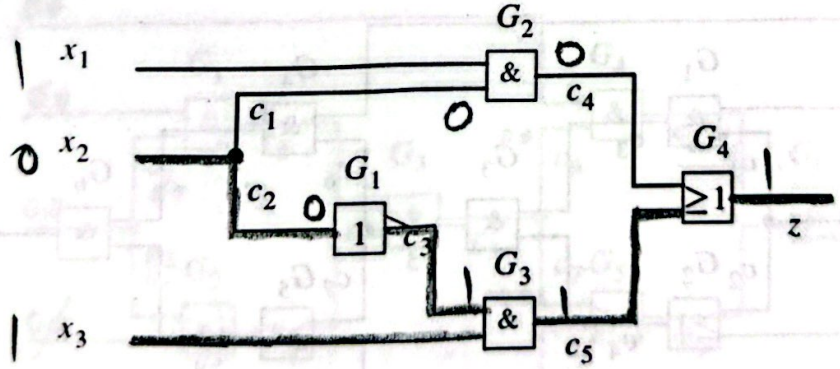


Test Pattern: $x_1x_2x_3 = x01 = 001$ or 101

$T = \{001, 101\}$

Fault-Free o/p = {1}

Fault Simulation, $x_1x_2x_3 = 101$



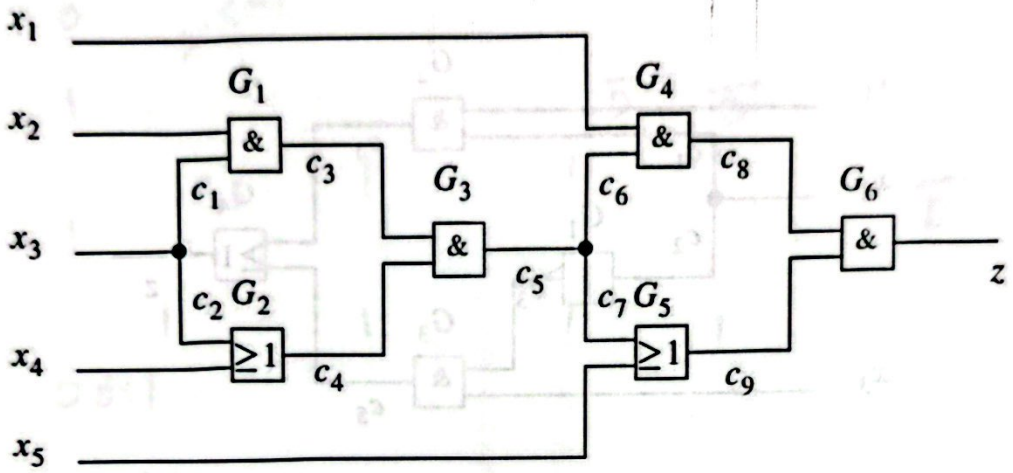
Faults detected by 101 = $\{z_0, c_5 0, c_3 0, x_3 0, c_2 1, x_2 1\}$

updated fault list = {}

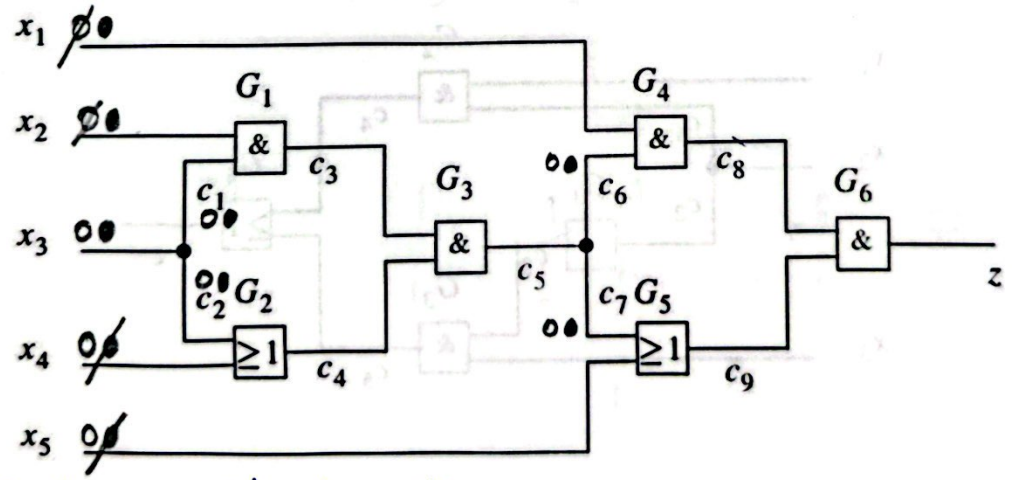
Fault Coverage = $\frac{8}{8} = 100\%$.

∴ Test Pattern set $T = \{011, 100, 111, 101\}$

Circuit 3.37:-



Fault Collapsing using Check Point theorem



Total No. of faults = 30

No. of faults Remaining = 14

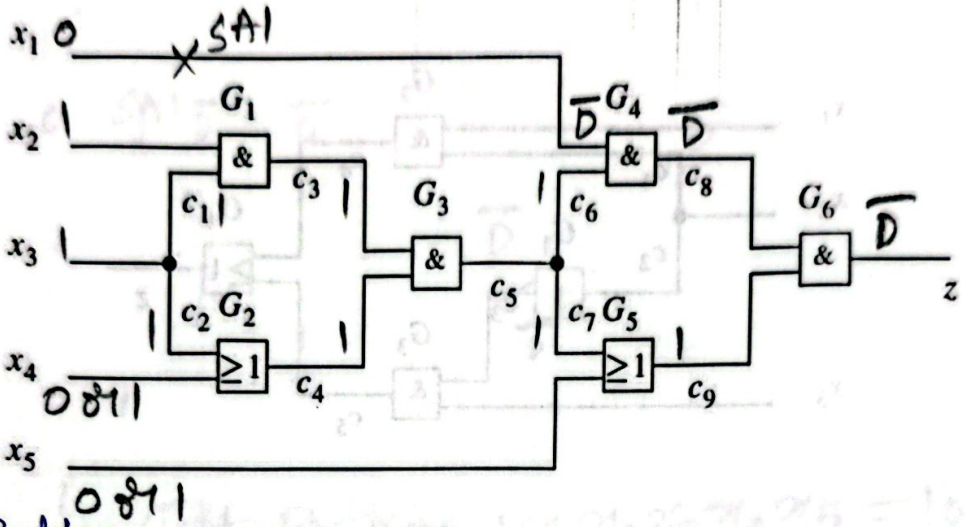
Collapse ratio = 14/30 = 46.6%

Collapsed Faults = $\{x_1 1, x_2 1, x_3 0, x_3 1, x_4 0, x_5 0, c_1 0, c_1 1, c_2 0, c_2 1, c_6 0, c_6 1, c_7 0, c_7 1\}$

Iteration 1: Test Generation : D-Algorithm

Current fault list : $\{x_1 1, x_2 1, x_3 0, x_3 1, x_4 0, x_5 0, c_1 0, c_1 1, c_2 0, c_2 1, c_6 0, c_6 1, c_7 0, c_7 1\}$

SA1 fault at 'x_1':

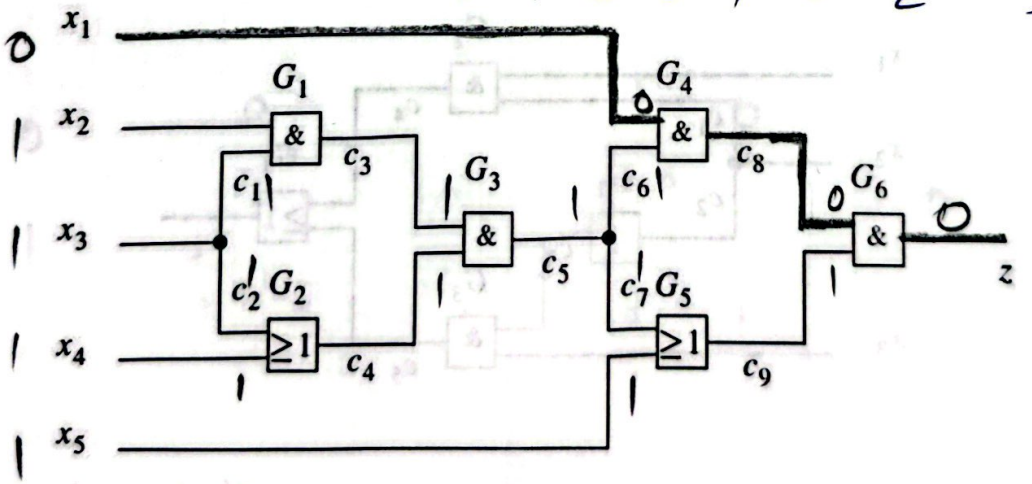


Test Pattern : $x_1x_2x_3x_4x_5 = 0\,1\,1\,X\,X = 01100, 01101, 01110, 01111$

$T = \{01100, 01101, 01110, 01111\}$

Fault-free o/p = $\{0\}$

Fault Simulation, $x_1x_2x_3x_4x_5 = \{01111\}$

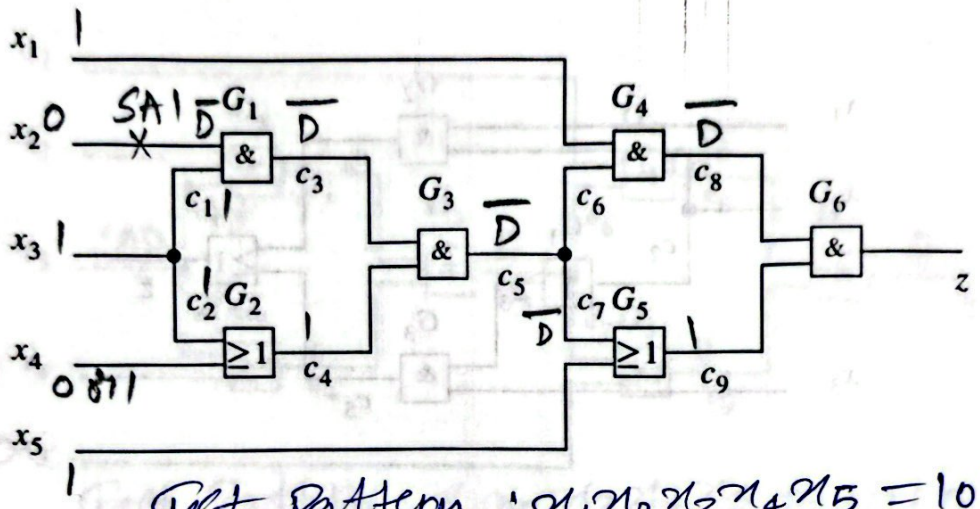


Faults detected by 01111 = $\{z_1, c_8 1, x_1 1\}$

updated Fault list = $\{x_2 1, x_3 0, x_3 1, x_4 0, x_5 0, c_1 0, c_1 1, c_2 0, c_2 1, c_6 0, c_6 1, c_7 0, c_7 1\}$

Iteration 2 :- Current Fault list = {x_2 1, x_3 0, x_3 1, x_4 0, x_5 0, c_1 0, c_1 1, c_2 0, c_2 1, c_6 0, c_6 1, c_7 0, c_7 1}

SA1 fault at 'x_2'



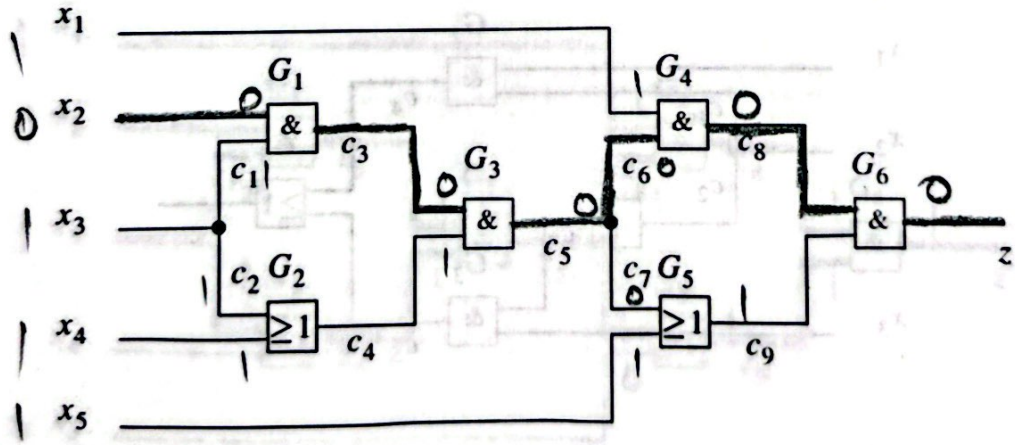
Test pattern : $x_1x_2x_3x_4x_5 = 101x1$

$= 10101$ or 10111

$T = \{10101, 10111\}$

Fault-free o/p = {0}

Fault-free simula^n, $x_1x_2x_3x_4x_5 = \{10111\}$

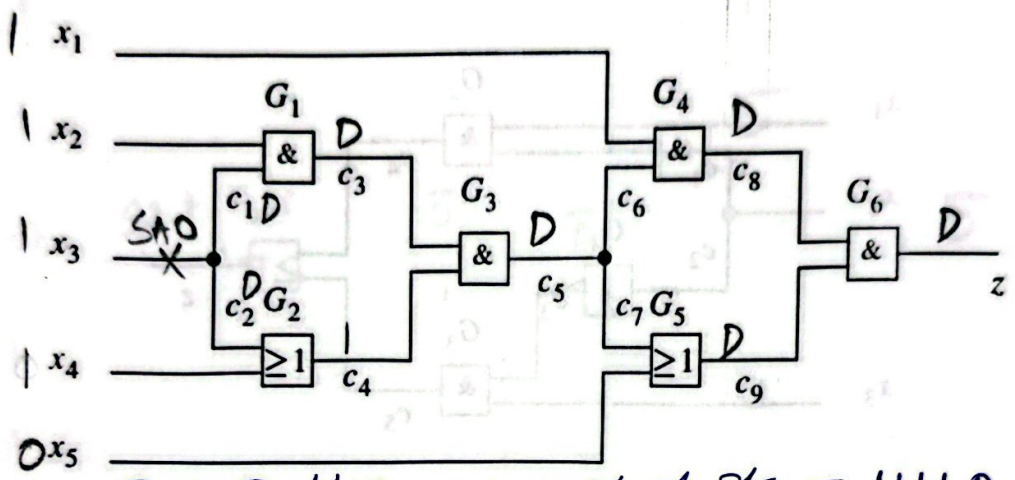


Faults detect by 10111 = {z_1, $c_8$1, $c_6$1, $c_5$1, $c_3$1, $x_2$1}

updated Fault list = {$x_2$0, $x_3$1, $x_4$0, $x_5$0, $c_1$0, $c_1$1, $c_2$0, $c_2$1, $c_6$0, $c_7$0, $c_7$1}

Iteration 3:- Current fault list = {x_3 0, x_3 1, x_4 0, x_5 0, c_1 0, c_1 1, c_2 0, c_2 1, c_6 0, c_7 0, c_7 1}

SA0 fault at 'x_3':

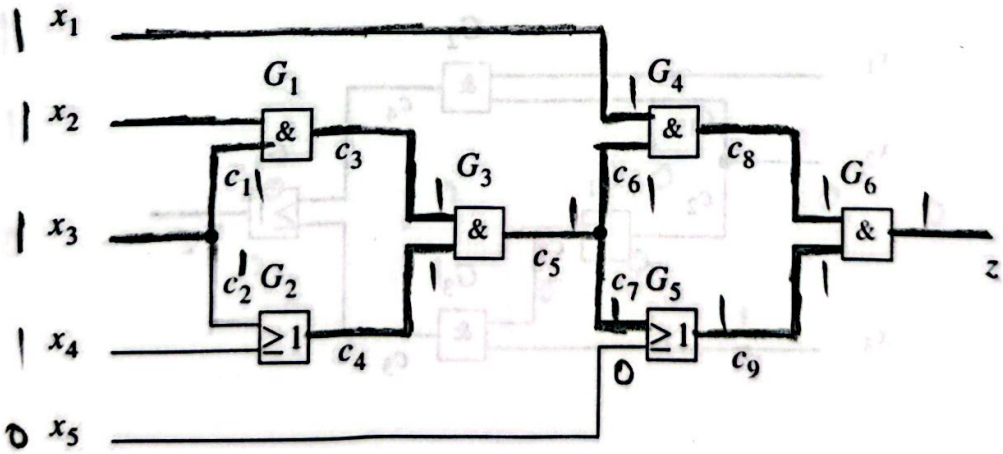


Test Pattern : $x_1x_2x_3x_4x_5$ = 11110

T = {11110}

Fault-free O/P = {1}

Fault Simulation, $x_1x_2x_3x_4x_5$ = {11110}

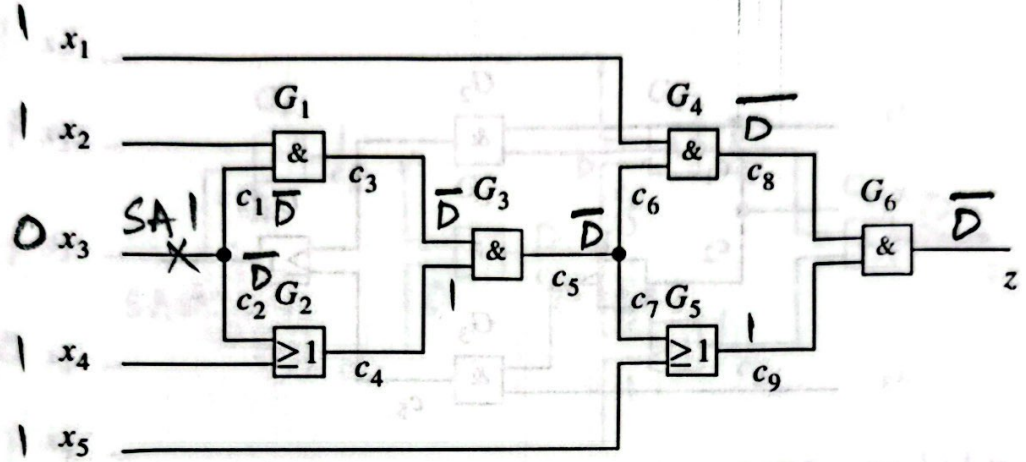


Faults detected by 11110 = {z_0, c_8 0, c_9 0, x_1 0, c_6 0, c_7 0, c_5 0, c_3 0, c_4 0, c_1 0, x_2 0, x_3 0}

updated fault list = {x_3 1, x_4 0, x_5 0, c_1 1, c_2 0, c_2 1, c_7 1}

Iteration 4: Current Fault list = {x_3 1, x_4 0, x_5 0, c_1 1, G_2 0, c_2 1, c_7 1}

SA1 fault at 'x_3'

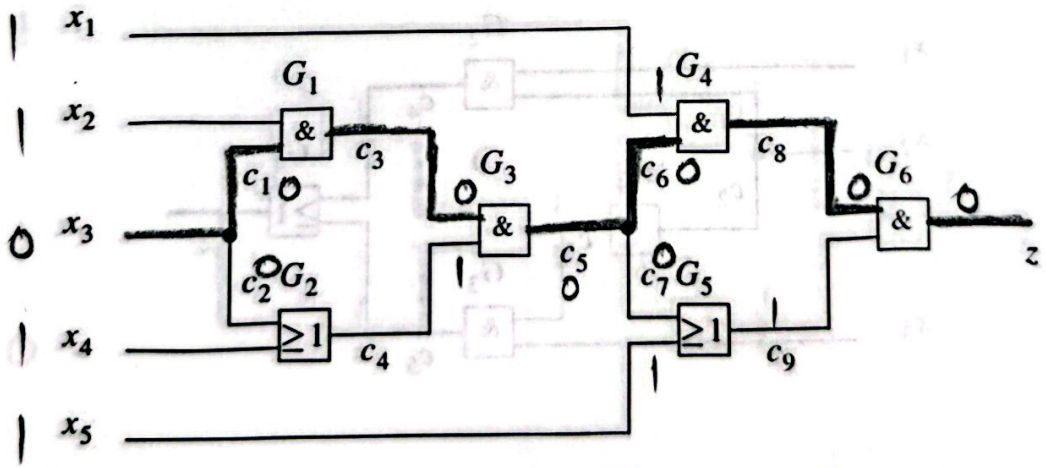


Test Pattern : $x_1 x_2 x_3 x_4 x_5$ = 11011

T = {11011}

Fault free o/p = {0}

Fault Simulation, $x_1 x_2 x_3 x_4 x_5$ = {11011}

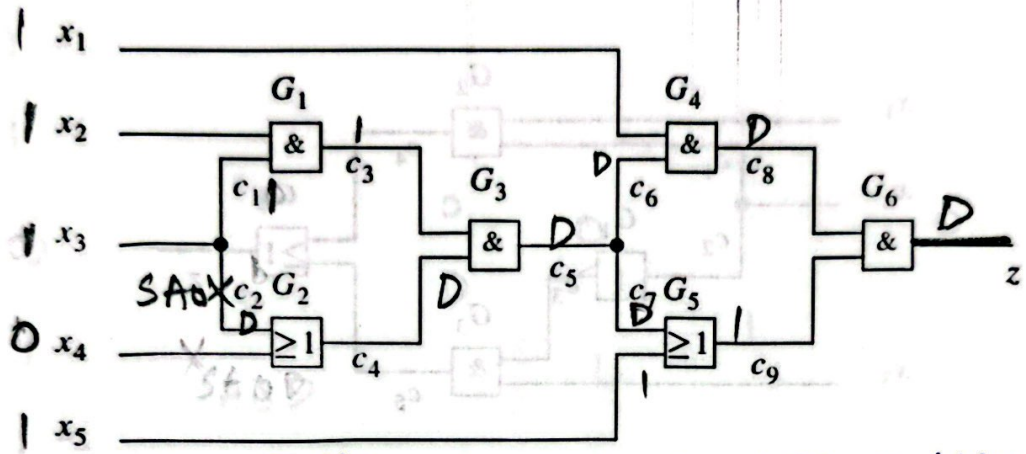


Faults detected by 11011 = {z_1, c_8 1, G_6 1, c_5 1, c_3 1, c_1 1, x_3 1}

updated Fault list = {x_4 0, x_5 0, c_2 0, c_2 1, c_7 1}

Iteration 5: Current Fault list = $\{x_4 0, x_5 0, c_2 0, c_2 1, c_7 1\}$

SA0 fault at '$c_2 0$'

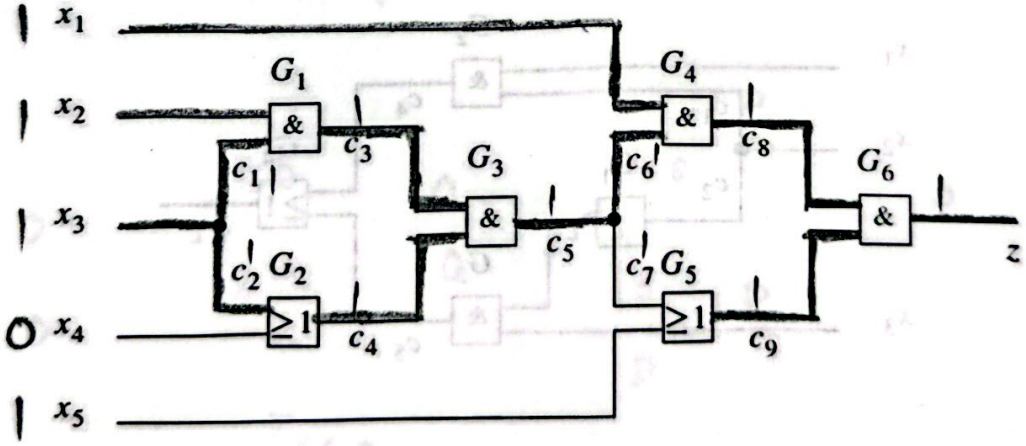


Test Pattern : $x_1 x_2 x_3 x_4 x_5 = 11101$

$P = \{11101\}$

Fault Free o/p = $\{1\}$

Fault Simulation, $x_1 x_2 x_3 x_4 x_5 = \{11101\}$



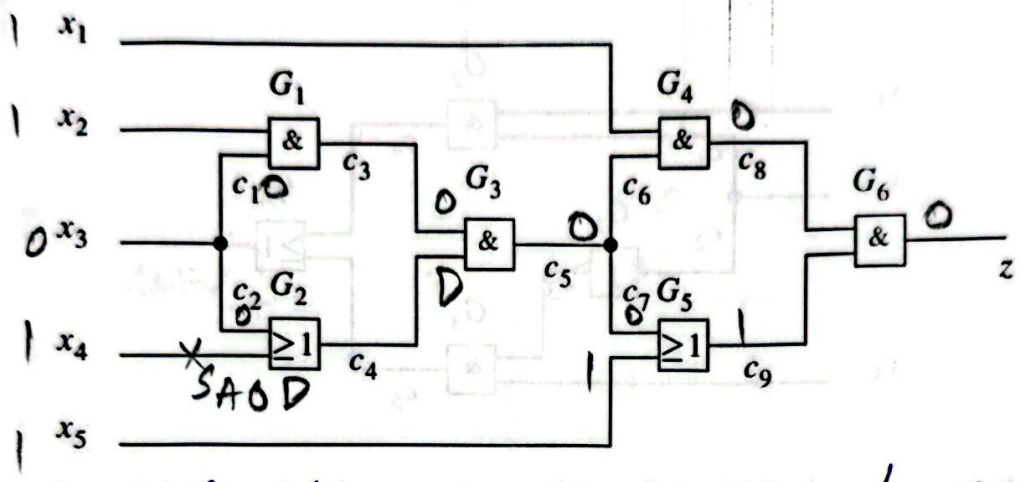
Faults detected by 11101 = $\{z_0, c_8 0, c_9 0, c_6 0, c_5 0, c_3 0, c_4 0, c_1 0, c_2 0, x_1 0, x_2 0, x_3 0\}$

updated Fault list = $\{x_4 0, x_5 0, c_2 1, c_7 1\}$

Iteration 6:

Current fault list = { $x_4 0, x_5 0, c_2 1, c_7 1$ }

SA0 fault at 'x_4'

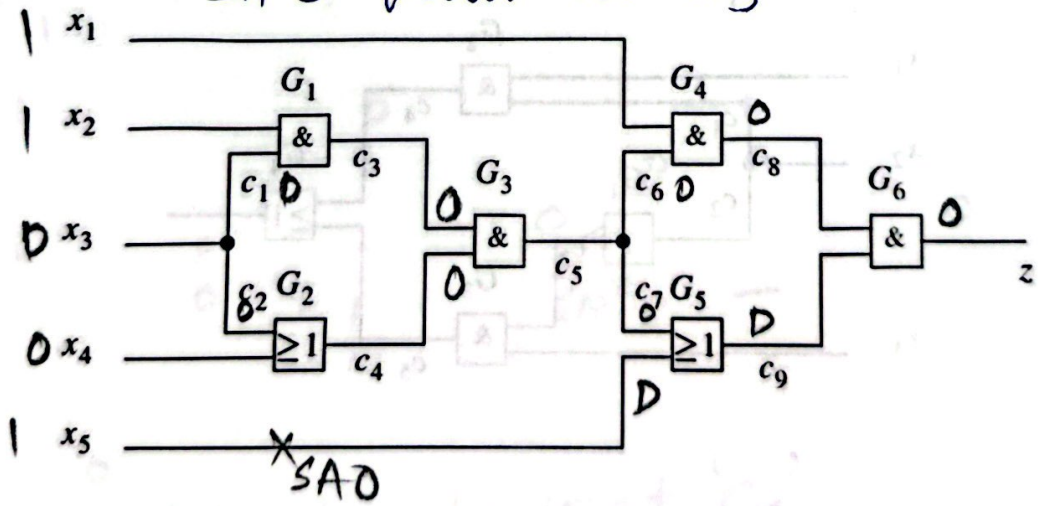


∴ Can't apply D algorithm for SA0 fault at 'x_4'

It is undetectable fault at 'x_4'.

Iteration 7:

SA0 fault at 'x_5'

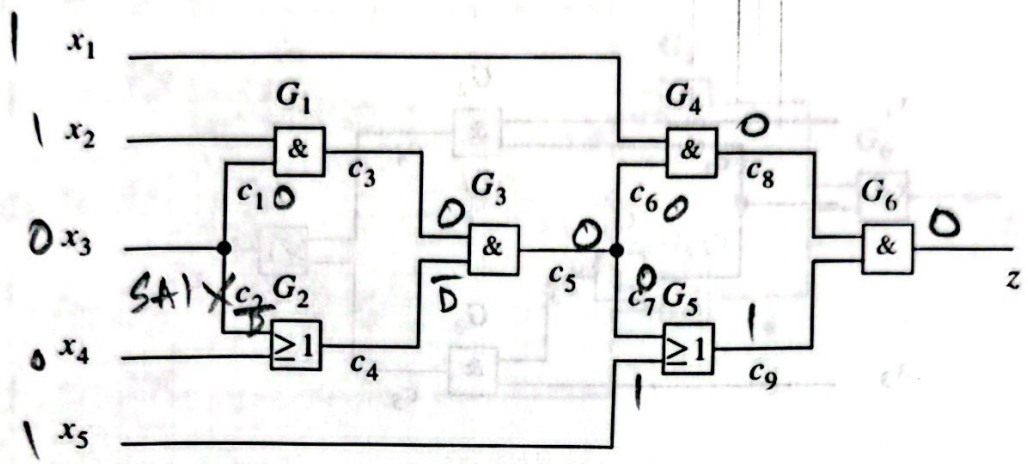


Can't apply D algorithm at 'x_5'

It is undetectable fault at 'x_5'.

Iteration 8:

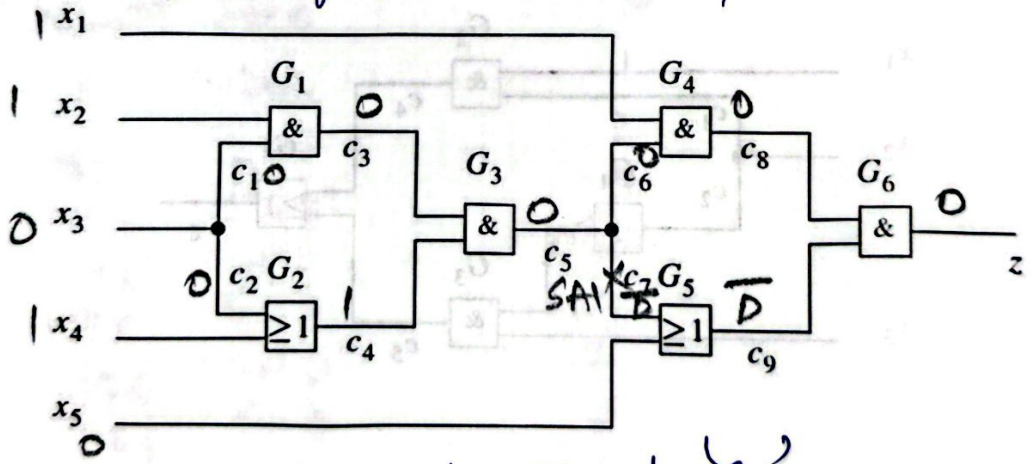
SA1 fault at 'c_2'



Can't apply D algorithm for SA1 fault at 'c_2'

It is undetectable fault at 'c_2'.

Iteration 9: SA1 fault at 'c_7'



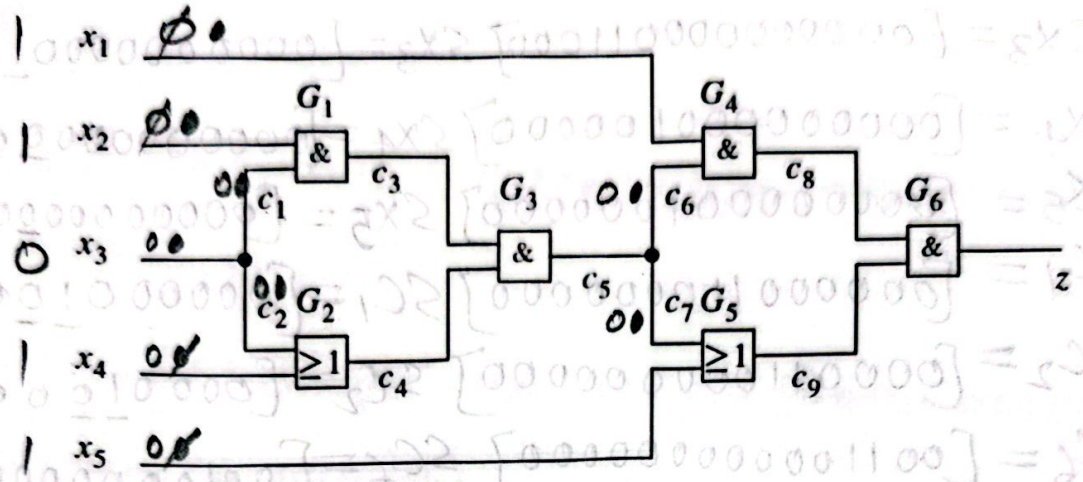
It is undetectable fault at 'c_7'

The final fault list = {$x_4$0, $x_5$0, $c_2$1, $c_7$1}

Test Patterns are = {01111, 10111, 11110, 11011, 11101}

Fault Coverage = $\frac{10}{14}$ = 71.42 %.

3) (i) Parallel fault Simulation:



Fault list: $\{x_1 1, x_2 1, x_3 0, x_3 1, x_4 0, x_5 0, c_1 1, c_1 0, c_2 0, c_2 1, c_6 0, c_6 1, c_7 0, c_7 1\}$

Faults		Bit Position
Fault Free		0
x_1	sa1	1
x_2	sa1	2
x_3	sa0	3
x_3	sa1	4
x_4	sa0	5
x_5	sa0	6
c_1	sa0	7
c_1	sa1	8
c_2	sa0	9
c_2	sa1	10
c_6	sa0	11
c_6	sa1	12
c_7	sa0	13
c_7	sa1	14

lines	I Mask	S Stuck-At-Faults
x_1	$IX1 = [0000000000000010]$	$SX1 = [0000000000000010]$
x_2	$IX_2 = [0000000000000100]$	$SX_2 = [0000000000000100]$
x_3	$IX_3 = [0000000000011000]$	$SX_3 = [0000000000010000]$
x_4	$IX_4 = [0000000000100000]$	$SX_4 = [0000000000000000]$
x_5	$IX_5 = [0000000001000000]$	$SX_5 = [0000000000000000]$
C_1	$IC_1 = [0000001100000000]$	$SC_1 = [0000001000000000]$
C_2	$IC_2 = [0000110000000000]$	$SC_2 = [0000100000000000]$
C_6	$IC_6 = [0011000000000000]$	$SC_6 = [0010000000000000]$
C_7	$IC_7 = [1100000000000000]$	$SC_7 = [1000000000000000]$

$$V_j' = V_j \cdot \overline{I_j} + I_j \cdot S_i$$

For $x_1x_2x_3x_4x_5 = \{11011\}$

$x_1 = [1111111111111111]$

$x_2 = [1111111111111111]$

$x_3 = [0000000000000000]$

$x_4 = [1111111111111111]$

$x_5 = [1111111111111111]$

$x_1' = ([1111111111111111] \cdot [1111111111111101] + [0000000000000010] \cdot [0000000000000010]$

$x_1' = [1111111111111111]$

$x_2' = ([1111111111111111] \cdot [1111111111111011] + [0000000000000100] \cdot [0000000000000100]$

$x_2' = [1111111111111111]$

$x_3' = ([0000000000000000] \cdot [1111111111100111] + [0000000000011000] \cdot [0000000000010000]$

$x_3' = [0000000000010000]$ $\boxed{x_3' = C_1 = C_2}$

$x_4^1 = [(1111111111111111) \cdot (1111111110111111) + (0000000001000000) \cdot (0000000000000000)]$

$x_4^1 = [1111111110111111]$

$x_5^1 = [(1111111111111111) \cdot (1111111101111111) + (0000000010000000) \cdot (0000000000000000)]$

$x_5^1 = [1111111101111111]$

$c_1^1 = [(0000000000010000) \cdot (1111110011111111) + (0000001100000000) \cdot (0000001000000000)]$

$c_1^1 = [0000001000010000]$

$c_2^1 = [(0000000000010000) \cdot (1111001111111111) + (0000110000000000) \cdot (0000100000000000)]$

$c_2^1 = (0000100000010000)$

$c_3 = x_2^1 \cdot c_1^1 = (0000001000010000)$

$c_4 = x_4^1 + c_2^1 = (1111111101111111)$

$c_5 = c_3 \cdot c_4 = (0000001000010000) = c_6 = c_7$

$c_6^1 = [(0000001000010000) \cdot (1100111111111111) + (0011000000000000) \cdot (0010000000000000)]$

$c_6^1 = (0010000100010000)$

$c_7^1 = [(0000010001000) \cdot (0011111111111111) + (1100000000000000) \cdot (1000000000000000)]$

$c_7^1 = (1000001000010000)$

$c_8 = c_6^1 \cdot x_4^1 = (0010000100010000)$

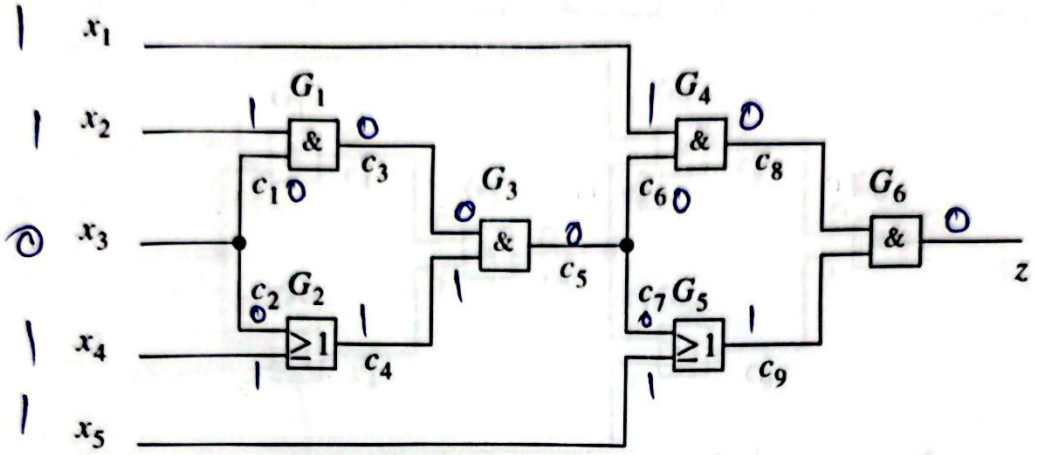
$c_9 = c_7^1 + x_5^1 = (1111111101111111)$

$Z = c_8 \cdot c_9 = (0010000100010000)$

$\therefore$ 'Z' shows faults at Position 4, 8, 12

$\therefore$ The faults are: $\{x_3 1, c_1 1, c_6 1\}$

(ii) Deductive Fault Simulation:



After Collapsing, the Faultlist: $\{x_1 1, x_2 1, x_3 0, x_3 1, x_4 0, x_5 0, c_4 0, c_1 1, c_2 0, c_2 1, c_6 0, c_6 1, c_7 0, c_7 1\}$

$L_{x_1} = \phi$, $L_{x_2} = \phi$, $L_{x_3} = \{x_3 1\}$, $L_{x_4} = \{x_4 0\}$, $L_{x_5} = \{x_5 0\}$

$L_{c_1} = L_{x_3} \cup \{c_1 1\} = \{x_3 1, c_1 1\}$

$L_{c_2} = L_{x_3} \cup \{c_2 1\} = \{x_3 1, c_2 1\}$

$L_{c_3} = (L_{c_1} - L_{x_2}) \cup \{c_3 1\} = (x_3 1, c_1 1, c_3 1)$

$L_{c_4} = (L_{x_4} - L_{c_2}) \cup (c_4 0) = (x_4 0, c_4 0)$

$L_{c_5} = (L_{c_3} - L_{c_4}) \cup (c_5 1) = (x_3 1, c_1 1, c_3 1, c_5 1\}$

$L_{c_6} = L_{c_5} \cup \{c_6 1\} = \{x_3 1, c_1 1, c_3 1, c_5 1, c_6 1\}$

$L_{c_7} = L_{c_5} \cup \{c_7 1\} = \{x_3 1, c_1 1, c_3 1, c_5 1, c_7 1\}$

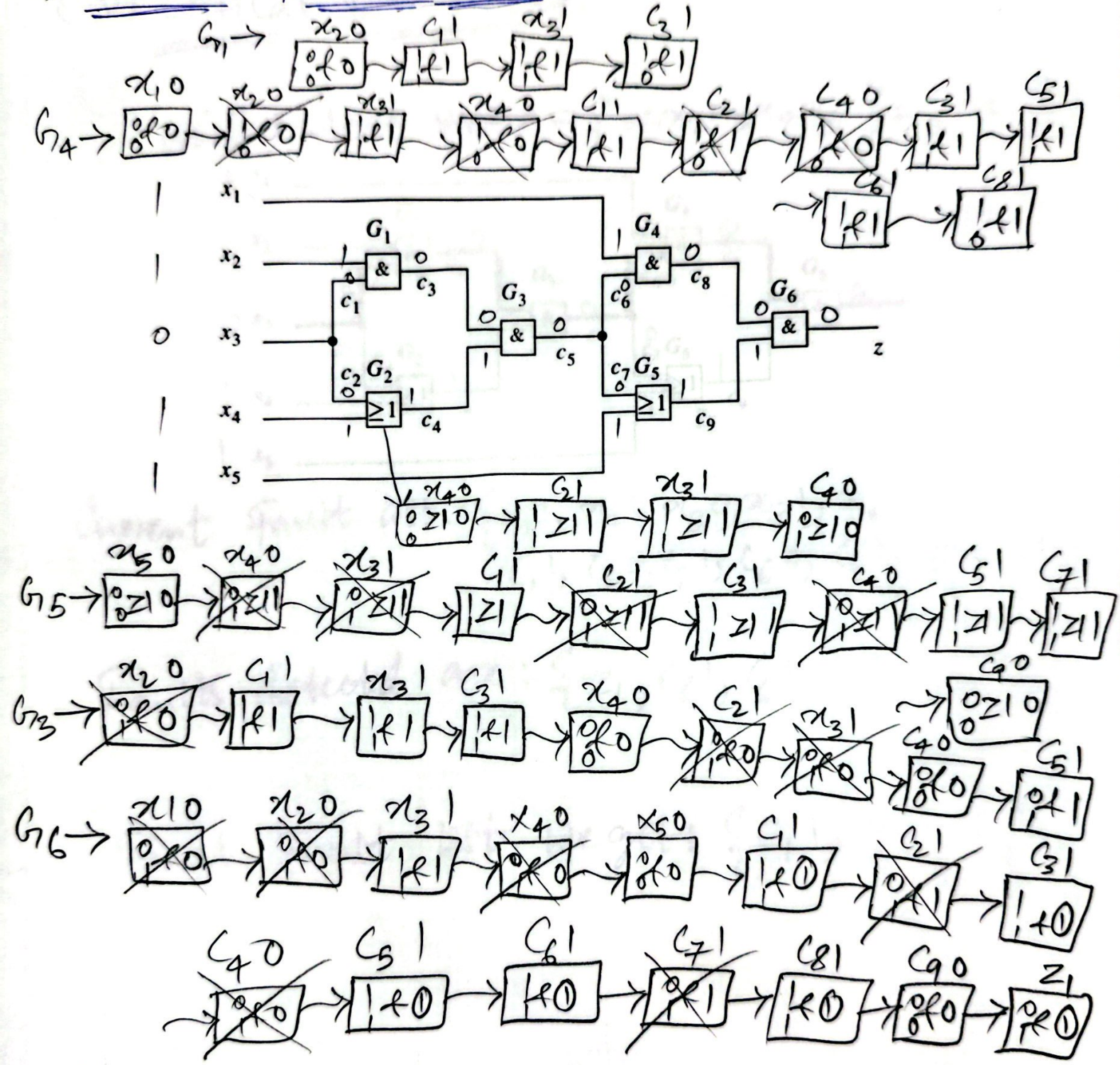
$L_{c_8} = (L_{c_4} - L_{x_4}) \cup \{c_8 1\} = \{x_3 1, c_8 1, c_6 1, c_5 1, c_3 1, c_1 1\}$

$L_{c_9} = (L_{x_5} - L_{c_7}) \cup \{c_9 0\} = \{x_5 0, c_9 0\}$

$z = (L_{c_8} - L_{c_9}) \cup \{z_1\} = \{c_1 1, c_3 1, x_3 1, c_8 1, c_5 1, c_8 1, z_1\}$

∴ Faults Detected are $\{c_1 1, x_3 1, c_6 1\}$

(iii) Concurrent Fault Simulation:

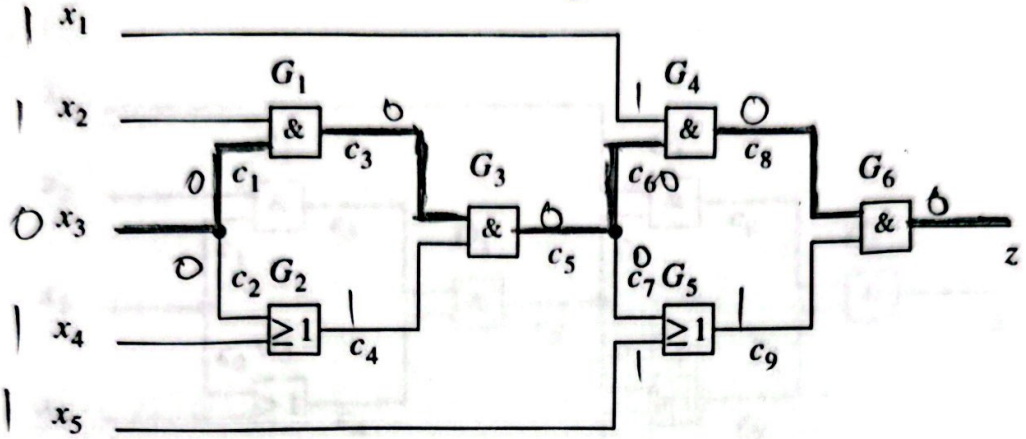


After collapsing fault list: $\{x_1 1, x_2 1, x_3 0, x_3 1, x_4 0, x_5 0, c_1 0, c_1 1, c_2 0, c_2 1, c_6 0, c_6 1, c_7 0, c_7 1\}$

Faults detected are: $\{c_1 1, x_3 1, c_6 1\}$

(iv) Critical Path Tracing:

using test vector = $\{x_1 x_2 x_3 x_4 x_5\} = \{11011\}$



Current fault list: $\{x_1 1, x_2 1, x_3 0, x_3 1, x_4 0, x_5 0, c_4 0, c_1 1, c_2 0, c_2 1, c_6 0, c_6 1, c_7 0, c_7 1\}$

Faults detected are: $\{z_1, c_8 1, c_6 1, c_5 1, c_3 1, c_4 1, x_3 1\}$

Final fault list we get: $\{c_1 1, x_3 1, c_6 1\}$