24.03.2024.

Homework-4-Solutions

Solution 1 : (4.5):

→ Assume a memory with B-bit words ($B \geqslant 2$).
MATS+ algorithm detects all AF's and SAF's.

→ MATS+ algorithm for a memory with B=4;

General MATS+ algorithm: $\{\Updownarrow(w0);\ \Uparrow(r0, w1);\ \Downarrow(r1, w0)\}$
M0 M1 M2

For a 4-bit word. Lets say a = 0000 & b = 1111

MATS+ algorithm for 4-bit word: $\{\Updownarrow(wa);\ \Uparrow(ra; wb);\ \Downarrow(rb, wa)\}$
M0 M1 M2.

Faults	Sensitizing	Detection	Comments
SAF <∀/0>	M1 Sensitized at w1 of M1	M2 Detected at r1 of M2.	(M1+M2) detects the fault <∀/0>. Similarly it detects <∀/a>.
SAF <∀/1>	M0 Sensitized at w0 of M0	M1 Detected at r0 of M1	(M1+M2) detects the fault <∀/1>. Similarly it detects <∀/b>.

Thus; all the SAF's are detected by the MATS+ algorithm.

Address Decoder Faults : The condition for AF :

① $\Uparrow(rx, \dots wx^*)$ ② $\Downarrow(rx^* \dots wx)$; are satisfied by

M1 $\Uparrow(r_a, w_b)$ and M2 $\Downarrow(r_b, w_a)$.

Thus; AF's are detected by the MATS+ algorithm.

→ For a = 0000 and b = 1111 ; the condition of

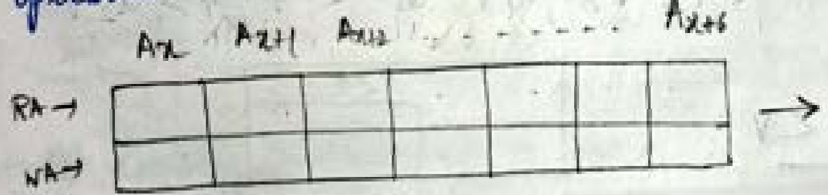
$\Uparrow(r_a, w_b)$ and $\Downarrow(r_b, w_a)$ will satisfy the AD faults.

Solution 14.6 :

→ Given : FIFO memory has separate read/write ports.

→ Every read and write operation increments the address register.

→ Reset operation resets both RA & WA to 0.



→ FIFO as the name states means First-In & First-Out.

which means; whatever was in went out first.

→ March test can be traversed in increasing + decreasing order but given the conditions of FIFO, after every read/write operations; the address will increment. Thus; it will contain only incremental order of sequences.

Ex: $\{\Uparrow(r_x, w_x^*), \Uparrow(r_x^*, w_x)\}$

→ Similarly, consider the decremental order of sequence.

$$\{ \Downarrow (rx^*, wx) \; , \; \Downarrow (rx, wx^*) \}$$

:→ Thus; the only possible march elements for the incremental address in FIFO are;

$\Uparrow(rx)$, $\Uparrow(wx)$; $\Uparrow(rx, wy)$, $\Uparrow(wy, rx)$: where $x, y \in \{0, 1\}$

→ Thus; the consequence of these restrictions is that, not all AF's and not all CF's will be detectable.

Solution 14.7 :

Given: for $I = 0$ to 1023

$A[I] := (I \bmod 256)$

$A[0] = 0$ $\quad$ $A[256] = 0$ $\quad$ $\Uparrow(w_a)$

$A[1] = 1$ $\quad$ $A[257] = 1$

$\vdots$ $\quad$ $\vdots$

$A[255] = 255$

For $I = 0$ to 1023

Read $A[I]$

$A[I] := 255 - (I \bmod 256)$ $\quad$ $\Uparrow(r_a, w_b)$

$A[0] = 255$ $\quad$ $A[256] = 255$

$A[1] = 254$ $\quad$ $\vdots$

$\vdots$

$A[255] = 0.$

For $I = 0$ to 1023 $\quad$ $\Uparrow(r_b)$

Read $A[I]$

$A[0] = 255$ $\quad$ $A[257] = 255$

$\vdots$ $\quad$ $\vdots$

$A[255] = 0.$

Thus; the sequence from above;

$$\Uparrow(W_a) \quad \Uparrow(r_a, W_b) \quad \Uparrow(r_b).$$

Consider 1-bit word: $\Uparrow(w_0) \quad \Uparrow(r_0, w_1) \quad \Uparrow(r_1)$.

$M_0 \quad M_1 \quad M_2$

(i). In order to detect unlinked AF's; they should satisfy the condition $\Uparrow(r_x, \ldots W_a^*)$ & $\Downarrow(r_x^*, \ldots W_{\bar{a}})$

But in the above case; we only have $\Uparrow(r_0, W_1)$ or $\Uparrow(r_1, w_0)$. Thus; only partial detection occurs.

→ Similarly; for the memory consisting of 1024 8-bit words; we cannot completely detect the AF's.

(ii). Unlinked SAF's:

→ Since there exists write and read operation one after another; both SA1 & SA0 faults are detectable

→ From the example of 1-bit word; $\Uparrow(w_0) \; \Uparrow(r_0, w_1)$ will be able to detect SA1 fault.

→ Thus, $\Uparrow(r_0, W_1), \Uparrow(r_1)$ will be able to detect SA0 fault.

(iii). Unlinked TF's :

→ There exists only one transition, either 0 to 1 or 1 to 0.

But in the sequence obtained; only lower to higher transition is obtained that's 0 to 1.

→ Thus; all TF's cannot be detected.

(iv). Unlinked CF's : Consider $c_i < c_j$

Step	March Element	State S_{ij} before operation	operation	State S_{ij} after operation
1	M0	—	w_0 into i	—
2		—	w_0 into j	S_{00}
3	M1	S_{00}	r_0 from i	S_{00}
4		S_{10}	w_1 into i	S_{10}
5		S_{10}	r_0 from j	S_{10}
6		S_{10}.	w_1 into j	S_{11}.
7	M2	S_{11}	r_1 from i	S_{11}
8		S_{11}	r_1 from j	S_{11}.

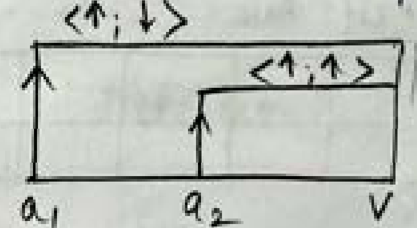
For the above 1-bit word example, CF's aren't detected.

Similarly; for the memory with 1024 8-bit words, not all states of CF's can be detected.

Solution 14.8 :

ⓐ. Linked CF id's : $<\uparrow ; \downarrow> a_1 v \;\#\; <\uparrow ; \uparrow> a_2 v$.

Case 1 : $a_1 < a_2 < v$:



	M0	r0 w1
v	0	→ 1
a_2	0	0 → 1
a_1	0	0 → 1

Step 1 : Write zeroes (Initializing all values to 0).

→ this is done by M0 : ⇕ w(0).

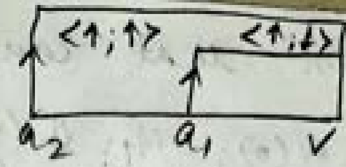
Step 2 : Reading zero & Writing one will sensitize a_2.

→ This is done for incrementing addresses.

$$M1 : \Uparrow (r(0) ; w(1))$$

→ This is for detecting a_2.

Case 2: $a_2 < a_1 < V$:



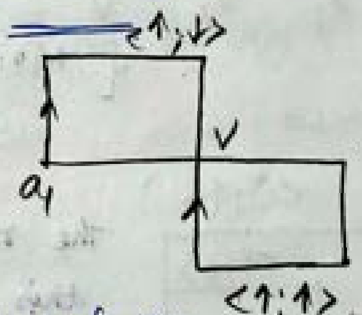
→ In the incremental order of the address, the action to be performed to detect a_1 is;

Read 1 → Write 0 → Write 1.

∴ M2: ⇑ (r(1), w(0), w(1)).

Thus; combining cases ① & ②, the foll. will be the march test to detect CFids;

{M0: ⇕ (w0); M1: ⇑ (r(0), w(1)); M2: ⇑ (r(1), w(0), w(1))}



Case 3. $a_1 < V < a_2$:

Step 1: Writing zeroes. Initializing to zero.

→ This is done by M0: ⇕ w(0).

Step 2: Reading zero & writing 1 will detect a_2 in decrementing address.

M1: ⇓ (r(0), w(1)).

→ This detects a_2.

Step 3: Reading '1' in incrementing address.

M2: ⇑ (r(1)) → This detects a_1.

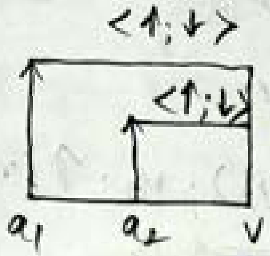
Thus, the march test that can detect the faults for cases is; $\{M0: \Updownarrow w(0);\ M_1: \Downarrow(r(0), w(1));\ M_2: \Uparrow(r(1))\}$.

(b). the possible scenarios if the a-cells can take any position relative to the v-cell are;

(i). $a_1 < a_2 < v$ (iii). $V < a_1 < a_2$ (v). $a_1 < V < a_2$

(ii). $a_2 < a_1 < V$ (iv). $V < a_2 < a_1$ (vi). $a_2 < V < a_1$

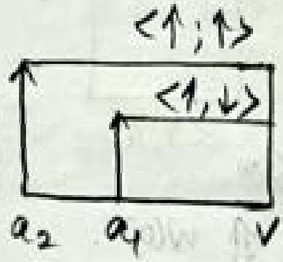
(i). $a_1 < a_2 < V$:



→ The March test that can detect this fault will be;

$\{M0: \Updownarrow w(0);\ M1: \Uparrow(r(0)(w(1))\}$.

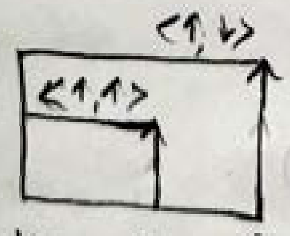
(ii). $a_2 < a_1 < V$:



The march test that can detect this fault will be,

$\{M0: \Updownarrow w(0);\ M1: \Uparrow(r(0), w(1));$
$M2: \Uparrow(r(1)\ w(0)(w(1))\}$

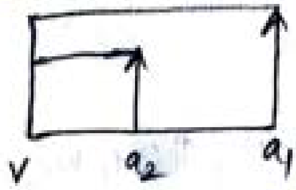
(iii). $V < a_1 < a_2$:



The march test that can detect this fault will be,

$\{M0: \Updownarrow w(0);\ M1: \Downarrow(r(0)\ w(1));$
$M2: \Downarrow(r(1)\ w(0), w(1))\}$

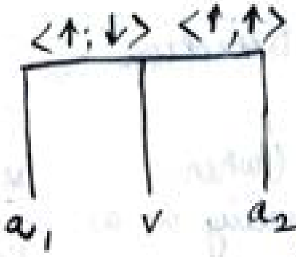
(iv). $v < a_2 < a_1$:



The March test that can detect this fault will be;

$\{ M0: \Updownarrow w(0)\ ;\ M1: \Downarrow (r(0)\, w(1)) \}$.

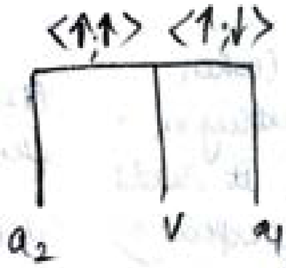
(v). $a_1 < v < a_2$:



The march test that can detect this fault will be;

$\{ M0: \Updownarrow w(0)\ ;\ M_1: \Downarrow (r(0)\, w(1))\ ;$
$M_2: \Uparrow (r(1)\, w(0)\, w(1)) \}$.

(vi). $a_2 < v < a_1$:



The march test that can detect this fault will be;

$\{ M0: \Updownarrow w(0);\ M1: \Uparrow (r(0)\, w(1));$
$M2: \Downarrow (r(1)\, w(0)\, w(1)) \}$.

Solution 2 :

Given. March sequence : $\{ \Updownarrow(w0)_{M0} ; \Uparrow(r0, w1)_{M1} ; \Uparrow(r1, w0)_{M2} ; \Downarrow(r0, w1)_{M3} ; \Downarrow(r1, w0)_{M4} ; \Updownarrow(r0)_{M5}$

(i), (ii), (iii).

Fault	Condition	Sensitizing	Detection	Comments
SAF <∀/0>		M1 (when operating on a cell, it tries to write 1).	M2 (when operating on a cell, it reads and expects 1).	M3 + M4 also sensitizes and detects the fault as
SAF <∀/1>		M0 (when operating on a cell, it tries to write 0).	M1 (when operating on a cell, it reads and expects 0)	M2 + M3 also sensitizes and detects the fault as
TF <↑/0>		M1 (tries to write a 1) 0 → 1	M2 (tries to read a 1 but detects a 0).	M3 + M4 together do the same action
TF <↓/1>		M2 (tries to write a 0) 1 → 0	M3 (tries to read a 0 but detects a 1).	M4 + M5 together do the same action.
AF_4'			M1 + M4 M2 + M3	M1+M4/ M2+M3 Can detect AF_4' since they satisfy the condition for it.

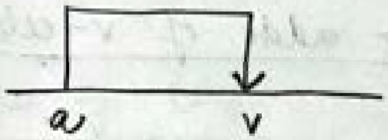
(iii). Unlinked CF's (CFin, CFid, CFst) :

The 2 subtypes of CFin : $< \uparrow ; \Updownarrow >$ $< \downarrow ; \updownarrow >$.

The different address combinations possible are;

1. addr of a-cell < addr of v-cell.
2. addr of a-cell > addr of v-cell.

Case 1 : addr of a-cell < addr of v-cell :



March sequence : $\{ \Updownarrow(w0) ; \Uparrow(r0, w1) ; \Uparrow(r1, w0) ; \Downarrow(r0, w1) ; \Downarrow(r1, w0) ; \Updownarrow(r0) \}$

M0 M1 M2 M3 M4 M5

1. Fault. $< \uparrow ; \updownarrow >$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0) (w1)	M4 (r1) (w0)	M5 (r0)
v	0	1 → 1	1 → 0	0 → 1 → 0	0 → 0	0
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0

→ Thus, we see that the aggressor cell (a) is sensitised in w_1 of M_1 and is detected in r_0 of M1.

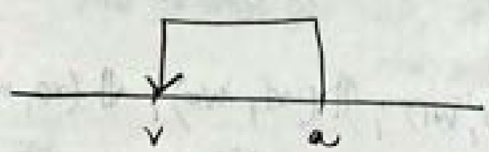
→ Also, we see that the aggressor cell (a) is sensitised in w_1 of M_3 and is detected in r_1 of M4.

② Fault : $\langle \downarrow ; \updownarrow \rangle$

	M0 (W0)	M1 (r0) (W1)	M2 (r1) (W0)	M3 (r0) (W1)	M4 (r1) (W0)	M5 (r0)
v	0	0 → 1	0 → 0	0 → 1	1 → 0 → 1	1
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a) is sensitised in W0 of M4 and is detected in r0 of M5.

Case 2 : addr of a-cell > addr of v-cell.



③ Fault : $\langle \uparrow ; \updownarrow \rangle$

	M0 (W0)	M1 (r0) (W1)	M2 (r1) (W0)	M3 (r0) (W1)	M4 (r1) (W0)	M5 (r0)
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0
v	0	0 → 1 → 0	0 → 0.	1 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a) is sensitised in W1 of M1 and is detected in r_1 of M2.

→ Also, the aggressor cell (a) is sensitised in W1 of M3 and is detected in r0 of M3.

(4). **Fault** : $\langle \downarrow ; \updownarrow \rangle$.

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0) (w1)	M4 (r1) (w0)	M5 (r0)
a	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1$	$1 \to 0 \to 1$	$1 \to 1$	$1 \to 0$	0

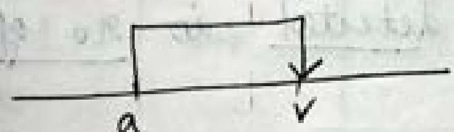
→ thus; the aggressor cell (a) is sensitized in W0 of M2 and is detected in r0 of M3.

The 4 subtypes of CFid : $\langle \uparrow ; 0 \rangle$, $\langle \uparrow ; 1 \rangle$, $\langle \downarrow ; 0 \rangle$, $\langle \downarrow ; 1 \rangle$

①. addr of a-cell < addr of v-cell.

②. addr of a-cell > addr of v-cell.

case1: addr of a-cell < addr of v-cell:



①. **Fault** : $\langle \uparrow ; 0 \rangle$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0) (w1)	M4 (r1) (w0)	M5 (r0)
v	0	$0 \to 1$	$1 \to 0$	$0 \to 1 \to 0$	$0 \to 0$	0
a	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ thus, the aggressor cell (a) is sensitized in W1 of M3 and is detected in r_1 of M4.

②. **Fault** : < ↓ ; 0 >

	M0 (W0)	M1 (r0) (W1)	M2 (r1) (W0)	M3 (r0) (W1)	M4 (r1) (W0)	M5 (r0)
v	0	0 → 1	0 → 0	0 → 1	1 → 0	0
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a) is sensiti[zed] in W0 of M2 and is detected in r_1 of M2.

③. **Fault** : < ↑ ; 1 >

	M0 (W0)	M1 (r0) (W1)	M2 (r1) (W0)	M3 (r0) (W1)	M4 (r1) (W0)	M5 (r0)
v	0	1 → 1	1 → 0	0 → 1	1 → 0	0
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0

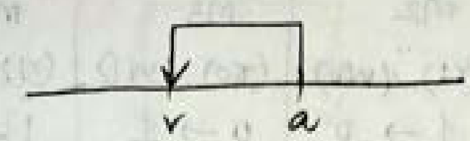
→ Thus; we see that the aggressor cell (a) is sensitized in W1 of M1 and is detected in r0 of M1.

⑦. **Fault** : < ↓ , 1 >

	M0 (W0)	M1 (r0) (W1)	M2 (r1) (W0)	M3 (r0) (W1)	M4 (r1) (W0)	M5 (r0)
v	0	0 → 1 →	1 → 0	0 → 1	1 → 0 → 1	1
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a) is sensitized in W0 of M4 and is detected in r_0 of M5.

Case 2 : addr of a-cell > addr of v-cell :



① . fault : < ↑ ; 0 >

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0) (w1)	M4 (r1) (w0)	M5 (r0)
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0
v	0	0 → 1 → 0	0 → 0	0 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a) is sensitized in w1 of M1 and is detected at r_1 of M2 .

② . fault : < ↓ ; 0 >

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0) (w1)	M4 (r1) (w0)	M5 (r0)
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0
v	0	0 → 1	1 → 0	0 → 1	0 → 0	0

→ Thus; we see that the aggressor cell (a) is sensitized in w0 of M4 and is detected at r_1 of M4 .

③. **Fault**: <↑; 1>

	M0 (W0)	M1 (r0) (W1)	M2 (r1) (W0)	M3 (r0) (W1)	M4 (r1) (W0)	M5 (r0)
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0
v	0	0 → 1	1 → 0	1 → 1	1 → 0	0

→ Thus, we see that the aggressor cell (a) is sensitized in W1 of M3 and detected in r0 of M3.

④. **Fault**: <↓; 1>

	M0 (W0)	M1 (r0) (W1)	M2 (r1) (W0)	M3 (r0) (W1)	M4 (r1) (W0)	M5 (r0)
a	0	0 → 1	1 → 0	0 → 1	1 → 0	0
v	0	0 → 1	1 → 0 → 1	1 → 1	1 → 0	0

→ Thus, we see that the aggressor cell (a) is sensitized in W0 of M2 and detected in r0 of M3.

The 4 subtypes of CF_{st}: <1;0>, <1;1>, <0;0>, <0;1>.

①. addr of a-cell < addr of v-cell.

② addr of a-cell > addr of v-cell.

Case 1 : addr. of v-cell < addr. of a-cell :

(ci) (cj).

Step	March Element	State S_{ij} before operation	operation	State S_{ij} after operation.
1	M0	–	w_0 into i	–
2		–	w_0 into j	S_{00}
3	M1	S_{00}	r_0 form i	S_{00}
4		S_{00}	w_1 into i	S_{10}
5		S_{10}	r_0 from j	S_{10}
6		S_{10}	w_1 into j	S_{11}.
7	M_2	S_{11}	r_1 from i	S_{11}
8		S_{11}	w_0 into i	S_{01}
9		S_{01}	r_1 from j	S_{01}
10		S_{01}	w_0 into j	S_{00}
11	M_3	S_{00}	r_0 from j	S_{00}
12		S_{00}	w_1 into j	S_{01}
13		S_{01}	r_0 from i	S_{01}
14		S_{01}	w_1 into i	S_{11}
15	M_4	S_{11}	r_1 from j	S_{11}
		S_{11}	w_0 into j	S_{10}
		S_{10}	r_1 from i	S_{10}
		S_{10}	w_0 into i	S_{00}

→ Thus; from the above; we observe that in each state the values of cell 'ci' & 'cj' are read. Thus; all the state faults are detected.

Case 2: addr. of v-cell > addr. of a-cell
(C_i) (C_j).

Step	March element	state S_{ij} before operation	operation	state S_{ij} after operation.
1	M0	–	w_0 into i	–
2		–	w_0 into j	S_{00}
3	M1	S_{00}	r_0 from j	S_{00}
4		S_{00}	w_1 into j	S_{01}
5		S_{01}	r_0 from i	S_{01}
6		S_{01}	w_1 into i	S_{11}
7	M2	S_{11}	r_1 from j	S_{11}
8		S_{11}	w_0 into j	S_{10}
9		S_{10}	r_1 from i	S_{10}
10		S_{10}	w_0 into i	S_{00}
11	M_3	S_{00}	r_0 from i	S_{00}
12		S_{00}	w_1 into i	S_{10}
13		S_{10}	r_0 from j	S_{10}
14		S_{10}	w_1 into j	S_{11}
15	M_4	S_{11}	r_1 from i	S_{11}
16		S_{11}	w_0 into i	S_{01}
17		S_{01}	r_1 from j	S_{01}
18		S_{01}	w_0 into j	S_{00}

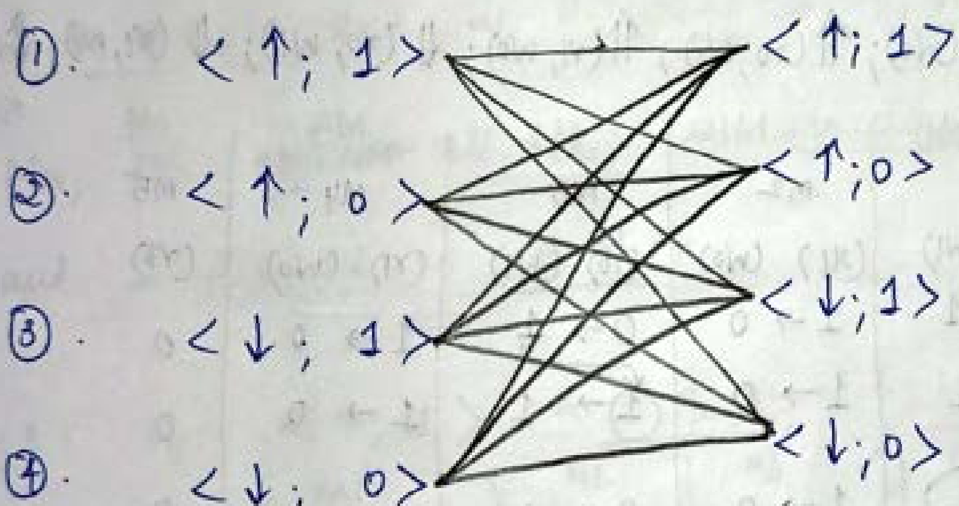
→ Thus, from the above, we observe that in each state, the values of cells 'C_i' and 'C_j' are read. Thus, all the state faults are detected.

Linked Coupling Fault: For linked faults; we would have 2 aggressors say a_1 & a_2 and one victim (v). The ways in which these a_1, a_2, v can be arranged is $3! = 6$ ways.

→ The total no. of fault combinations would be 16 (4×4).

→ as below; each matched with another:

For aggressor 1 (a1) For aggressor 2 (a2)



→ The 6 different combinations of a_1, a_2, v would be:

① $a_1 < v < a_2$

② $a_1 < a_2 < v$

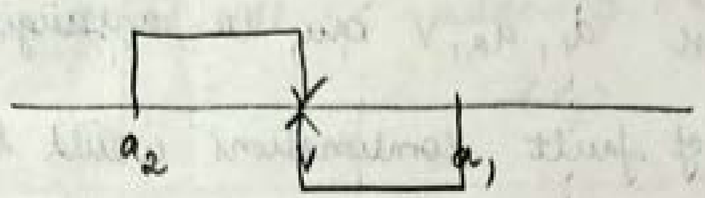
③ $v < a_1 < a_2$

④ $v < a_2 < a_1$

⑤ $a_2 < a_1 < v$

⑥ $a_2 < v < a_1$

→ Lets consider the 6th case as $\boxed{a_2 < v < a_1}$ and check for all 16 combinations,



Case 1 : $a_1 : < \uparrow ; 1 >$ & $a_2 : < \uparrow ; 1 >$

March sequence : $\{ \Updownarrow (w0) ; \Uparrow (r0, w1) ; \Uparrow (r1, w0) ; \Downarrow (r0, w1) ; \Downarrow (r1, w0) ; \Updownarrow$

		M0	M1	M2	M3	M4
	M0	M1	M2	M3	M4	M5
	(w0)	(r0) (w1)	(r1) (w0)	(r0) (w1)	(r1) (w0)	(r0)
a_1	0	0 → 1	1 → 0	0 → 1	1 → 0	0
v	0	1 → 1	1 → 0	1 → 1	1 → 0	0
a_2	0	0 → 1	1 → 0	0 → 1	1 → 0	0

→ thus; we see that the aggressor cell (a_2) is sensitized in w_1 of M_1 and detected in r_0 of M1.

→ Also; the aggressor cell (a_1) is sensitized in w_1 of M_3 and detected in r_0 of M_3.

Case 2 : $a_1 : \langle \uparrow ; 1 \rangle$ & $a_2 : \langle \uparrow ; 0 \rangle$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0) (w1)	M4 (r1) (w0)	M5 (r0)
a_1	0	$0 \rightarrow 1$	$1 \rightarrow 0$	$0 \rightarrow 1$	$1 \rightarrow 0$	0
v	0	$0 \rightarrow 1$	$1 \rightarrow 0$	$1 \rightarrow 1 \rightarrow 0$	$0 \rightarrow 0$	0
a_2	0	$0 \rightarrow 1$	$1 \rightarrow 0$	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus; we see that the aggressor cell (a_1) is sensitized in w_1 of M_3 and is detected in r_0 of M_3.

→ Also; the aggressor cell (a_2) is sensitized in w_1 of M_3 and is detected in r_1 of M_4.

Case 3 : $a_1 : \langle \uparrow ; 1 \rangle$ & $a_2 : \langle \downarrow ; 1 \rangle$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0) (w1)	M4 (r1) (w0)	M5 (r0)
a_1	0	$0 \rightarrow 1$	$1 \rightarrow 0$	$0 \rightarrow 1$	$1 \rightarrow 0$	0
v	0	$0 \rightarrow 1$	$1 \rightarrow 0$	$1 \rightarrow 1$	$1 \rightarrow 0 \rightarrow 1$	1
a_2	0	$0 \rightarrow 1$	$1 \rightarrow 0$	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus; we see that the aggressor cell (a_1) is sensitized in w_1 of M_3 and is detected in r_0 of M_3.

→ Also; the aggressor cell (a_2) is sensitized in w_0 of M_4 and is detected in r_0 of M_5.

Case 4 : $a_1 : \langle \uparrow ; 1 \rangle$ & $a_2 : \langle \downarrow ; 0 \rangle$

	M0 (w_0)	M1 (r_0) (w_1)	M2 (r_1) (w_0)	M3 (r_0) (w_1)	M4 (r_1) (w_0)	M5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1$	$0 \to 0$	$1 \to 1$	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor cell (a_2) is sensitized in w_0 of M_2 and is detected in r_1 of M_2

→ Also, the aggressor cell (a_1) is sensitized in w_1 of M_3 and is detected in r_0 of M_3.

Case 5 : $a_1 : \langle \uparrow ; 0 \rangle$ & $a_2 : \langle \uparrow ; 0 \rangle$

	M0 (w_0)	M1 (r_0) (w_1)	M2 (r_1) (w_0)	M3 (r_0) (w_1)	M4 (r_1) (w_0)	M5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1 \to 0$	$0 \to 0$	$0 \to 1 \to 0$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor cell (a_1) is sensitised in w_1 of M_1 and is detected in r_1 of M_2

→ Also, the aggressor cell (a_2) is sensitized in w_1 of M_3 and is detected in r_1 of M_4.

Case 6 : $a_1 : \langle \uparrow ; 0 \rangle$ & $a_2 : \langle \uparrow ; 1 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$1 \to 1 \to 0$	$0 \to 0$	$0 \to 1$	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor cell (a_2) is sensitized in w_1 of M_1 and is detected in r_0 of M_1.

→ Also; the aggressor cell (a_1) is sensitized in w_1 of M_1 and is detected in r_1 of M_2.

Case 7 : $a_1 : \langle \uparrow ; 0 \rangle$ & $a_2 : \langle \downarrow ; 1 \rangle$

	$\Updownarrow M_0$ (w_0)	$\uparrow M_1$ (r_0) (w_1)	$\uparrow M_2$ (r_1) (w_0)	$\downarrow M_3$ (r_0) (w_1)	$\downarrow M_4$ (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1 \to 0$	$1 \to 0$	$0 \to 1$	$1 \to 0 \to 1$	1
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus, we see that the aggressor cell (a_2) is sensitized by w_0 of M_4 and is detected in r_0 of M_5.

Case 8 : a_1: $<\uparrow; 0>$ & a_2: $<\downarrow; 0>$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1 \to 0$	$0 \to 0$	$0 \to 1$	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor cell (a_1) is sensitized in w_1 of M_1 and is detected in r_1 of M_2.

Case 9 : a_1: $<\downarrow; 1>$ & a_2: $<\uparrow; 1>$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$1 \to 1$	$1 \to 0 \to 1$	$1 \to 1$	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor cell (a_2) is sensitized in w_1 of M_1 and is detected in r_0 of M_1.

→ Also; we see that the aggressor cell (a_1) is sensitized in w_0 of M_2 and detected in r_0 of M_3.

Case 10 : a_1 : < ↓ ; 1 > & a_2 : < ↑ ; 0 >

	⇕M_0 (w_0)	↑M_1 (r_0) (w_1)	↑M_2 (r_1) (w_0)	↓M_3 (r_0) (w_1)	↓M_4 (r_1) (w_0)	⇕M_5 (r_0)
a_1	0	0 → 1	1 → 0	0 → 1	1 → 0	0
V	0	0 → 1	1 → 0 → 1	1 → 1 → 0	→ 1 → 0	0
a_2	0	0 → 1	1 → 0	0 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a_1) is <u>sensitized</u> in <u>w_0 of M_2</u> and is <u>detected</u> in <u>r_0 of M_3</u>.

Case 11 : a_1 : < ↓ ; 1 > & a_2 : < ↓ ; 1 >

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	0 → 1	1 → 0	0 → 1	1 → 0	0
V	0	0 → 1	1 → 0 → 1	1 → 1	1 → 0 → 1	1
a_2	0	0 → 1	1 → 0	0 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a_1) is <u>sensitized</u> is <u>w_0 of M_2</u> and is <u>detected</u> in <u>r_0 of M_3</u>.

→ Also; the aggressor cell (a_2) is <u>sensitized</u> in <u>w_0 of M_4</u> and is <u>detected</u> in <u>r_0 of M_5</u>.

Case 12 : $a_1 : < \downarrow ; 1 >$ & $a_2 : < \downarrow ; 0 >$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1 \to$	$0 \to 0 \to 1$	$1 \to 1$	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor cell (a_1) is <u>sensitized</u> in <u>w_0 of M_2</u> and is <u>detected</u> in <u>r_0 of M_3</u>.

Case 13 : $a_1 : < \downarrow ; 0 >$ & $a_2 : < \uparrow ; 1 >$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	$0 \to$	$1 \to 1$	$1 \to 0$	$0 \to 1 \to$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor (a_2) is <u>sensitized</u> in <u>w_1 of M_1</u> and is <u>detected</u> in <u>r_0 of M_1</u>.

→ Also; the aggressor cell (a_1) is sensitized in <u>w_0 of M_4</u> & is <u>detected</u> in <u>r_1 of M_4</u>.

Case 14: $a_1 : \langle \downarrow ; 0 \rangle$ & $a_2 : \langle \uparrow ; 0 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1$	$1 \to 0$	$0 \to 1 \to 0$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus, we see that the aggressor cell (a_2) is sensitized in w_1 of M_3 and is detected in r_1 of M_4.

Case 15: $a_1 : \langle \downarrow ; 0 \rangle$ & $a_2 : \langle \downarrow ; 1 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$0 \to 0 \to 1$	1
a_2	0	$0 \to 1$	$1 \to 0$	$0 \to 1$	$1 \to 0$	0

→ Thus, we see that the aggressor cell (a_1) is sensitized in w_0 of M_4 and is detected in r_1 of M_4.

→ Also, the aggressor cell (a_2) is sensitized in w_0 of M_4 and is detected in r_0 of M_5.

Case 1b: $a_1 : \langle \downarrow ; 0 \rangle$ & $a_2 : \langle \downarrow ; 0 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0) (w_1)	M_4 (r_1) (w_0)	M_5 (r_0)
a_1	0	$0 \rightarrow 1$	$1 \rightarrow 0$	$0 \rightarrow 1$	$1 \rightarrow 0$	0
v	0	$0 \rightarrow 1$	$0 \rightarrow 0$	$0 \rightarrow 1$	$0 \rightarrow 0$	0
a_2	0	$0 \rightarrow 1$	$1 \rightarrow 0$	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus; the aggressor cell (a_2) is sensitized in w_0 of M

and is detected in r_1 of M_2.

→ Also; the aggressor cell (a_1) is sensitized in w_0 of

and is detected in r_1 of M_4.

Solution 2:

For 2 more address combinations:

Summarizing the remaining few combinations of Linked Idempotent Faults for MARCH C- :

As mentioned earlier, we would obtain a total of 16 * 6 = 96 combinations for linked faults which constitutes 6 different aggressor-victim combinations (a1, a2, v) namely;

1) A1 < a2 < v
2) A1 < v < a2
3) A2 < a1 < v
4) **A2 < v < a1**
5) V < a1 < a2
6) V < a2 < a1

Apart from case 4 which is a2 < v < a1 as solved above, the below for 2 more address combinations has also been checked and is tabulated as shown below: (A total of 16 * 2 = 32 combinations for 2 different address combinations is shown below):

a1 < v < a2

Fault (a1 , a2)	Condition	Sensitizing	Detection	Comment
<↑;1> <↑;1>	a 1<v< a 2	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M3 and detected in M3
<↑;1> <↑;0>	a 1<v< a 2	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M1 and detected in M2
<↑;1> <↓;1>	a 1<v< a 2	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M2 and detected in M3
<↑;1> <↓;0>	a 1<v< a 2	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M4 and detected in M4
<↑;0> <↑;1>	a 1<v< a 2	aggressor a1 is sensitized in M3	M4	aggressor a2 can also be sensitized in M3 and detected in M3
<↑;0> <↑;0>	a 1<v< a 2	aggressor a1 is sensitized in M3	M4	aggressor a2 can also be sensitized in M1 and detected in M2
<↑;0> <↓;1>	a 1<v< a 2	aggressor a1 is sensitized in M3	M4	aggressor a2 can also be sensitized in M2 and detected in M3
<↑;0> <↓;0>	a 1<v< a 2	aggressor a1 is sensitized in M3	M4	
<↓;1> <↑;1>	a 1<v< a 2	aggressor a1 is sensitized in M4	M5	aggressor a2 can also be sensitized in M3 and detected in M3

<↓;1> <↑;0>	a 1<v< a 2	aggressor a1 is sensitized in M4	M5	
<↓;1> <↓;1>	a 1<v< a 2	aggressor a2 is sensitized in M2	M2	aggressor a1 can also be sensitized in M4 and detected in M4
<↓;1> <↓;0>	a 1<v< a 2	aggressor a1 is sensitized in M4	M5	aggressor a2 can also be sensitized in M4 and detected in M4
<↓;0> <↑;1>	a 1<v< a 2	aggressor a1 is sensitized in M2	M2	aggressor a2 can also be sensitized in M3 and detected in M3
<↓;0> <↑;0>	a 1<v< a 2	aggressor a1 is sensitized in M2	M2	
<↓;0> <↓;1>	a 1<v< a 2	aggressor a1 is sensitized in M2	M2	aggressor a2 can also be sensitized in M2 and detected in M3
<↓;0> <↓;0>	a 1<v< a 2	aggressor a1 is sensitized in M2	M2	aggressor a2 can also be sensitized in M4 and detected in M4

a1 < a2 < v

Fault (a1 , a2)	Condition	Sensitizing	Detection	Comment
<↑;1> <↑;1>	a 1<a2< v	aggressor a2 is sensitized in M1	M1	
<↑;1> <↑;0>	a 1<a2< v	aggressor a2 is sensitized in M3	M4	
<↑;1> <↓;1>	a 1<a2< v	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M4 and detected in M5
<↑;1> <↓;0>	a 1<a2< v	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M4 and detected in M4
<↑;0> <↑;1>	a 1<a2< v	aggressor a2 is sensitized in M1	M1	
<↑;0> <↑;0>	a 1<a2< v	aggressor a2 is sensitized in M3	M4	
<↑;0> <↓;1>	a 1<a2< v	aggressor a2 is sensitized in M4	M5	
<↑;0> <↓;0>	a 1<a2< v	aggressor a1 is sensitized in M4	M5	aggressor a2 can also be sensitized in M2 and detected in M2
<↓;1> <↑;1>	a 1<a2< v	aggressor a2 is sensitized in M1	M1	aggressor a1 can also be sensitized in M4 and detected in M5
<↓;1> <↑;0>	a 1<a2< v	aggressor a2 is sensitized in M1	M1	aggressor a1 can also be sensitized in M4 and detected in M5

<↓;1> <↓;1>	a 1<a2< v	aggressor a2 is sensitized in M2	M2	aggressor a1 can also be sensitized in M4 and detected in M5
<↓;1> <↓;0>	a 1<a2< v	aggressor a2 is sensitized in M2	M2	aggressor a1 can also be sensitized in M4 and detected in M5
<↓;0> <↑;1>	a 1<a2< v	aggressor a2 is sensitized in M1	M1	aggressor a1 can also be sensitized in M2 and detected in M2
<↓;0> <↑;0>	a 1<a2< v	aggressor a1 is sensitized in M2	M2	aggressor a2 can also be sensitized in M3 and detected in M4
<↓;0> <↓;1>	a 1<a2< v	aggressor a2 is sensitized in M4	M4	
<↓;0> <↓;0>	a 1<a2< v	aggressor a2 is sensitized in M2	M2	

Solution 3 :

Given : March sequence : $\{M0: \Updownarrow(w0)\ ;\ M1: \Uparrow(r0, w1);\ M2: \Downarrow(r1, w0);\ M3: \Updownarrow(r0)\}$

(i). Address Decoder Fault: (AF's):

The condition for AF is ; ① $\Uparrow(rx, \ldots, wx^*)$ and ②. $\Downarrow(rx^*, - wx)$. From the above given sequence; we see that the march sequence satisfies both ① & ② Conditions with incremental (rx, wx^*) and Complementing i.e; decremental (rx^*, wx). Thus; all the AFs can be detected.

(ii). Stuck At faults (SAF's) :

Fault	Condition	Sensitizing	Detection	Comments
SAF $\langle \forall/0 \rangle$		M1 (when operating on a cell, it tries to write 1).	M2 (when operating on a cell, it reads and expects 1).	
SAF $\langle \forall/1 \rangle$		M0 (when operating on a cell, it tries to write 0).	M1 (when operating on a cell, it reads and expects 0).	M2 + M3 also sensitizes and detects the fault SA1.

(iii). Transition Faults (TFs):

Fault	Condition	Sensitizing	Detection	Comments
TF $\langle \uparrow/0 \rangle$		M1 (tries to write a 1) $0 \rightarrow 1$	M2 (tries to read a 1 but detects a 0).	
TF $\langle \downarrow/1 \rangle$		M2 (tries to write a 0). $1 \rightarrow 0$	M3 (tries to read a 0 but detects a 1).	

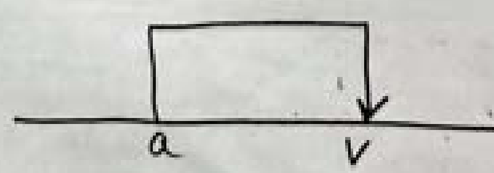
(iv). Unlinked CFs (CFin, CFid, CFst):

The 2 subtypes of CFin: $\langle \uparrow ; \updownarrow \rangle$ $\langle \downarrow ; \updownarrow \rangle$

The different address combinations possible are;

1. addr. of a-cell < addr. of v-cell.
2. addr. of a-cell > addr. of v-cell.

Case 1: Addr. of a-cell < Addr. of v-cell:



March Sequence : { $\Updownarrow(w0)$; $\Uparrow(r0, w1)$; $\Downarrow(r1, w0)$; $\Updownarrow(r0)$ }

M0 M1 M2 M3

1. Fault : $< \uparrow ; \updownarrow >$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
v	0	1 → 1	1 → 0	0
a	0	0 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a) is sensitized in w_1 of M_1 and is detected in r_0 of M_1.

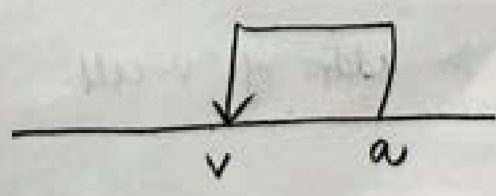
2. Fault : $< \downarrow ; \updownarrow >$.

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
v	0	0 → 1	1 → 0 → 1	1
a	0	0 → 1	1 → 0	0

→ Thus; we see that the aggressor cell (a) is sensitized in w_0 of M_2 and is detected in r_0 in M_3.

2. Case 2 : addr. of a-cell > addr of v-cell .

1. Fault : $< \uparrow ; \updownarrow >$



Fault: < ↑; ↕ >

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
a	0	1 → 1	1 → 0	0
v	0	0 → 1	1 → 0	0

→ Thus, we see that the aggressor cell (a) is sensitized in w_1 of M_1 and is detected in r_0 of M_1.

④. Fault: < ↓; ↕ >

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
a	0	0 → 1	1 → 0	0
v	0	0 → 1	0 → 0	0

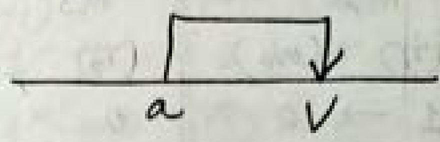
→ Thus, we see that the aggressor cell (a) is sensitized in w_0 of M_2 and is detected in r_1 of M_2.

The 4 subtypes of CFid: < ↑; 0 >, < ↑; 1 >, < ↓; 0 >, < ↓; 1 >

①. addr. of a-cell < addr. of v-cell.

②. addr. of a-cell > addr. of v-cell.

Case 1: <u>addr. of a-cell < addr. of v-cell</u> :



1. **Fault** : $<\uparrow ; 0>$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
v	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0
a	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus; from the above; we can see that the fault <u>cannot be detected</u>.

2. **Fault** : $<\downarrow ; 0>$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
v	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0
a	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus; from the above; we can see that the fault <u>cannot be detected</u>.

③. **Fault**: $\langle \uparrow ; 1 \rangle$

	M0	M1	M2	M3
	(w_0)	(r_0) (w_1)	(r_1) (w_0)	(r_0)
V	0	$1 \rightarrow 1$	$1 \rightarrow 0$	0
a	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0

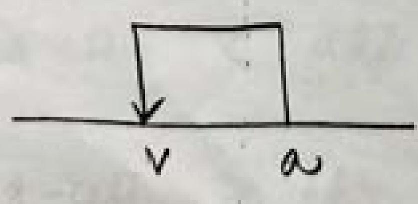
→ Thus, we see that the aggressor cell (a) is sensitized in w_1 of M1 and is detected in r_0 of M1.

④. **Fault**: $\langle \downarrow ; 1 \rangle$

	M0	M1	M2	M3
	(w_0)	(r_0) (w_1)	(r_1) (w_0)	(r_0)
V	0	$0 \rightarrow 1$	$1 \rightarrow 0 \rightarrow 1$	1
a	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus, we see that the aggressor cell (a) is sensitized in w_0 of M2 and is detected in r_0 of M3.

Case 2: addr. of a-cell > addr. of v-cell.



1). **Fault**: < ↑; 0 >

	M0	M1		M2		M3
	(w0)	(r0)	(w1)	(r1)	(w0)	(r0)
a	0	0 →	1	1 →	0	0
v	0	0 →	1 → 0	0 →	0	0

→ Thus, we see that the aggressor cell (a) is sensitized in w_1 of M1 and is detected in r_1 of M_2.

2). **Fault**: < ↓; 0 >

	M_0	M_1		M2		M3
	(w0)	(r0)	(w_1)	(r1)	(w0)	(r0)
a	0	0 →	1	1 →	0	0
v	0	0 →	1	0 →	0	0

→ Thus, we see that the aggressor cell (a) is sensitized in w_0 of M_2 and is detected in r_1 of M_2.

3). **Fault**: < ↑; 1 >

	M0	M1		M2		M3
	(w0)	(r0)	(w_1)	(r1)	(w0).	(r0).
a	0	0 →	1	1 →	0	0
v	0	0 →	1	1 →	0	0

→ Thus, from the above, we can see that the fault cannot be detected.

④. <u>Fault</u> : $\langle \downarrow ; 1 \rangle$

	M0	M1		M2		M3
	(w_0)	(r_0)	(w_1)	(r_1)	(w_0)	(r_0)
a	0	0 →	1	1 →	0	0
v	0	0 →	1	1 →	0	0

→ Thus, from the above, we can see that the **fault cannot be detected**.

(c). **State Coupling faults : (CF_{st}) :**

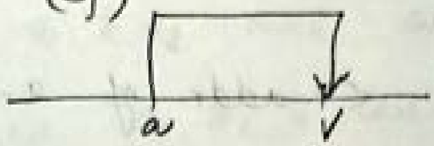
The state of the a-cell forces a fixed value in the v-

The 4 subtypes are : $\langle 1;0 \rangle$, $\langle 1;1 \rangle$, $\langle 0;0 \rangle$, $\langle 0;1 \rangle$

(1). addr. of a-cell $<$ addr. of v-cell.

(2). addr. of a-cell $>$ addr. of v-cell.

Case 2: addr of a-cell < addr of v-cell
(C_j) (C_i)



a v

Step	March element	State S_{ij} before operation	Operation	State S_{ij} after operation
1	M_0	–	w_0 into i	–
2		–	w_0 into j	S_{00}
3	M_1	S_{00}	r_0 from j	S_{00}
4		S_{00}	w_1 into j	S_{01}
5		S_{01}	r_0 from i	S_{01}
6		S_{01}	w_1 into i	S_{11}
7	M_2	S_{11}	r_1 from i	S_{11}
8		S_{11}	w_0 into i	S_{01}
9		S_{01}	r_1 from j	S_{01}
10		S_{01}	w_0 into j	S_{00}
11	M_3	S_{00}	r_0 from i	S_{00}
12		S_{00}	r_0 from j	S_{00}

∴ The fault at state S_{11} is partially detected. There is No transition to the state S_{10}. Thus, CF_{st} is not detectable.

(C). State Coupling Faults (CF_{st}):

Case 1 : addr. of v-cell < addr. of a-cell.
(C_i) (C_j).

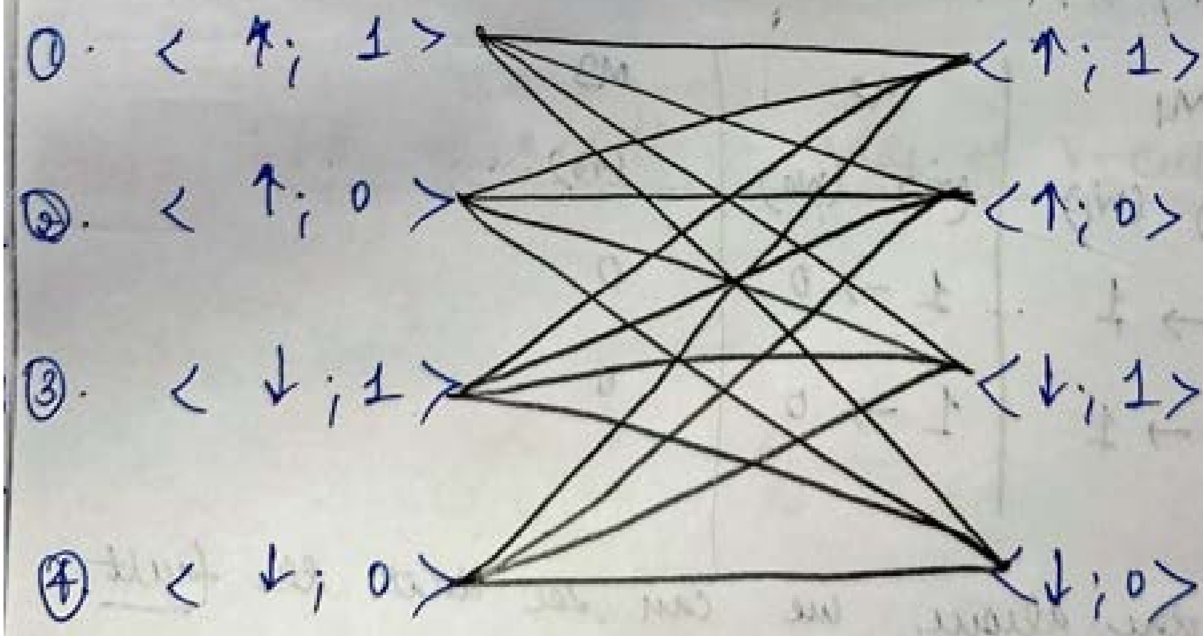
Step	March Element	State S_{ij} before operation	Operation	State S_{ij} after operation
1	M0	–	w_0 into i	–
2		–	w_0 into j	S_{00}
3	M_1	S_{00}	r_0 from i	S_{00}
4		S_{00}	w_1 into i	S_{10}
5		S_{10}	r_0 from j	S_{10}
6		S_{10}	w_1 into j	S_{11}
7	M_2	S_{11}	r_1 from j	S_{11}
8		S_{11}	w_0 into j	S_{10}
9		S_{10}	r_1 from i	S_{10}
10		S_{10}	w_0 into i	S_{00}
11	M_3	S_{00}	r_0 from i	S_{00}
12		S_{00}	r_0 from j	S_{00}

∴ The fault at state S_{11} is partially detected. There is No transition to state S_{01}. Thus; CF_{st} is not detectable.

Linked Coupling fault : For linked faults; we would have 2 aggressors say a_1 & a_2 and one victim (V). The way in which a_1, a_2, V can be arranged in $3! = 6$ ways.

→ The total no. of fault combinations would be 16 (4×4) as below, each matched with another;

For aggressor 1 (a1) : For aggressor 2 (a2).

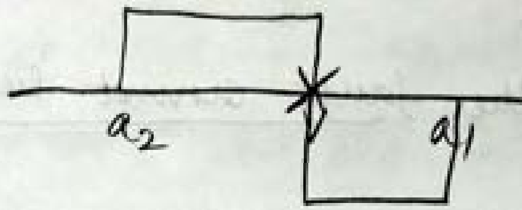


the 6 diff-combinations of a_1, a_2, V would be;

1. $a_1 < V < a_2$ 2. $a_1 < a_2 < V$ 3. $V < a_1 < a_2$

4. $V < a_2 < a_1$ 5. $a_2 < a_1 < V$ 6. $a_2 < V < a_1$.

Let's consider the 6th case as; $\boxed{a_2 < V < a_1}$ and check for all 16 combinations;



Case 1: $a_1: \langle \uparrow; 1 \rangle$ + $a_2: \langle \uparrow; 1 \rangle$

March Sequence: $\{ \Updownarrow (w0) ; \Uparrow (r0, w1) ; \Downarrow (r1, w0) ; \Updownarrow (r0) \}$

M0 M1 M2 M3

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
a_1	0	$0 \to 1$	$1 \to 0$	0
V	0	$1 \to 1$	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ thus; the aggressor cell (a_2) is <u>sensitized</u> in <u>w_1 of M1</u> and detected in r_0 <u>of M_1</u>

Case 2: $a_1 : \langle \uparrow ; 1 \rangle$ & $a_2 : \langle \uparrow ; 0 \rangle$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
a_1	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0
v	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0
a_2	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus; we see that the fault cannot be detected.

Case 3: $a_1 : \langle \uparrow ; 1 \rangle$ & $a_2 : \langle \downarrow ; 1 \rangle$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
a_1	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0
v	0	$0 \rightarrow 1$	$1 \rightarrow 0 \rightarrow 1$	1
a_2	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus; here we see that the aggressor cell (a_2) is sensitized at w_0 of M_2 and is detected in r_0 of M_3.

Case 4: $a_1 : \langle \uparrow ; 1 \rangle$ & $a_2 : \langle \downarrow ; 0 \rangle$

	M0 (w0)	M1 (r0) (w1)	M2 (r1) (w0)	M3 (r0)
a_1	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0
v	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0
a_2	0	$0 \rightarrow 1$	$1 \rightarrow 0$	0

→ Thus; we see that the fault cannot be detected.

Case 5 : $a_1 : <\uparrow; 0>$ & $a_2 : <\uparrow; 1>$.

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	0
V	0	$1 \to 1 \to 0$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor cell a_2 is sensitized in w_1 of M_1 and detected in r_0 of M_1.

→ Also; the aggressor cell (a_1) is sensitized in w_1 of M_1 and detected in r_1 of M_2.

Case 6 : $a_1 : <\uparrow; 0>$ & $a_2 : <\uparrow; 0>$.

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1 \to 0$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus; the aggressor cell a_1 is sensitized in w_1 of M_1 and is detected in r_1 of M_2.

Case 7 : $a_1 : \langle \uparrow ; 0 \rangle$ & $a_2 : \langle \downarrow ; 1 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	0
V	0	$0 \to 1 \to 0$	$0 \to 0 \to 1$	1
a_2	0	$0 \to 1$	$1 \to 0$	0

→ thus; we see that the aggressor cell (a_1) is <u>sensitized</u> at <u>w_1 of M_1</u> and detected in <u>r_1 of M_2</u>.

→ Also; the aggressor cell (a_2) is <u>sensitized</u> at <u>w_0 of</u> and detected in <u>r_0 of M_3</u>.

Case 8 : $a_1 : \langle \uparrow ; 0 \rangle$ & $a_2 : \langle \downarrow ; 0 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	0
V	0	$0 \to 1 \to 0$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ thus, we see that the aggressor cell (a_1) is <u>sensitized</u> at <u>w_1 of M_1</u> and detected in <u>r_1 of M_2</u>.

Case 9 : $a_1 : \langle \downarrow ; 1 \rangle$ & $a_2 : \langle \uparrow ; 1 \rangle$.

	M_0 (w0)	M_1 (r0) (w1)	M_2 (r1) (w0)	M_3 (r0)
a_1	0	$0 \to 1$	$1 \to 0$	0
V	0	$1 \to 1$	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus, we see that the aggressor cell (a_2) is sensitized at w_1 of M_1 and is detected in r_0 of M_1.

Case 10 : $a_1 : \langle \downarrow ; 1 \rangle$ & $a_2 : \langle \uparrow ; 0 \rangle$

	M_0 (w0)	M_1 (r0) (w1)	M_2 (r1) (w0)	M_3 (r0)
a_1	0	$0 \to 1$	$1 \to 0$.	0
V	0	$0 \to 1$.	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus, we see that the fault cannot be detected.

Case 11 : $a_1 : \langle \downarrow ; 1 \rangle$ & $a_2 : \langle \downarrow ; 1 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1$	$1 \to 0 \to 1$	1
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus, we see that the aggressor a_2 is sensiti[zed] at w_0 of M_2 and is detected in r_0 of M_3.

Case 12 : $a_1 : \langle \downarrow ; 1 \rangle$ & $a_2 : \langle \downarrow ; 0 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1$	$1 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus, from the above we see that the fault cannot be detected.

Case 13: $a_1 : \langle \downarrow ; 0 \rangle$ & $a_2 : \langle \uparrow ; 1 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	0
V	0	$1 \to 1$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor a_2 is sensitized at w_1 of M_1 and is detected in r_0 of M_1. Also; a_1 is sensitized in w_0 of M_2 & detected in r_1 of M_2.

Case 14: $a_1 : \langle \downarrow ; 0 \rangle$ & $a_2 : \langle \uparrow ; 0 \rangle$

	M_0 (w_0)	M_1 (r_0) (w_1)	M_2 (r_1) (w_0)	M_3 (r_0)
a_1	0	$0 \to 1$	$1 \to 0$	0
V	0	$0 \to 1$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus; we see that the aggressor a_1 is sensitized at w_0 of M_2 and is detected in r_1 of M_2.

Case 15 : $a_1 : \langle \downarrow ; 0 \rangle$ & $a_2 : \langle \downarrow ; 1 \rangle$

	M_0 (w0)	M_1 (r0) (w1)	M_2 (r1) (w0)	M_3 (r0)
a_1	0	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1$	$0 \to 0 \to 1$	1
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus; the aggressor a_1 is sensitized at w_0 of M_2 and is detected in r_1 of M_2.

→ Also; the aggressor a_2 is sensitized at w_0 of M_2 and is detected in r_0 of M_3.

Case 16 : $a_1 : \langle \downarrow ; 0 \rangle$ & $a_2 : \langle \downarrow ; 0 \rangle$

	M_0 (w0)	M_1 (r0) (w1)	M_2 (r1) (w0)	M_3 (r0)
a_1	0	$0 \to 1$	$1 \to 0$	0
v	0	$0 \to 1$	$0 \to 0$	0
a_2	0	$0 \to 1$	$1 \to 0$	0

→ Thus; the aggressor a_1 is sensitized at w_0 of M_2 & is detected in r_1 of M_2.

Solution 3:

For 2 more address combinations:

Summarizing the remaining few combinations of Linked Idempotent Faults for MARCH X:

As mentioned earlier, we would obtain a total of 16 * 6 = 96 combinations for linked faults which constitutes 6 different aggressor-victim combinations (a1, a2, v) namely;

1) A1 < a2 < v
2) A1 < v < a2
3) A2 < a1 < v
4) **A2 < v < a1**
5) V < a1 < a2
6) V < a2 < a1

Apart from case 4 which is a2 < v < a1 as solved above, the below for 2 more address combinations has also been checked and is tabulated as shown below: (A total of 16 * 2 = 32 combinations for 2 different address combinations is shown below):

a1 < v < a2

Fault (a1 , a2)	Condition	Sensitizing	Detection	Comment
<↑;1> <↑;1>	a 1<v< a 2	aggressor a1 is sensitized in M1	M1	
<↑;1> <↑;0>	a 1<v< a 2	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M1 and detected in M2
<↑;1> <↓;1>	a 1<v< a 2	aggressor a1 is sensitized in M1	M1	
<↑;1> <↓;0>	a 1<v< a 2	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M2 and detected in M2
<↑;0> <↑;1>	a 1<v< a 2	Fault not detected	Fault not detected	Fault not detected
<↑;0> <↑;0>	a 1<v< a 2	aggressor a2 is sensitized in M1	M3	
<↑;0> <↓;1>	a 1<v< a 2	Fault not detected	Fault not detected	Fault not detected
<↑;0> <↓;0>	a 1<v< a 2	aggressor a2 is sensitized in M2	M2	
<↓;1> <↑;1>	a 1<v< a 2	aggressor a1 is sensitized in M2	M3	
<↓;1> <↑;0>	a 1<v< a 2	aggressor a1 is sensitized in M2	M3	aggressor a2 can also be sensitized in M1 and detected in M2
<↓;1> <↓;1>	a 1<v< a 2	aggressor a2 is sensitized in M2	M3	
<↓;1> <↓;0>	a 1<v< a 2	aggressor a1 is sensitized in M2	M3	aggressor a2 can also be sensitized in M2 and detected in M2

<↓;0> <↑;1>	a 1<v< a 2	Fault not detected	Fault not detected	Fault not detected
<↓;0> <↑;0>	a 1<v< a 2	aggressor a2 is sensitized in M1	M2	
<↓;0> <↓;1>	a 1<v< a 2	Fault not detected	Fault not detected	Fault not detected
<↓;0> <↓;0>	a 1<v< a 2	aggressor a2 is sensitized in M2	M2	

a1 < a2 < v

Fault (a1 , a2)	Condition	Sensitizing	Detection	Comment
<↑;1> <↑;1>	a 1<a2< v	aggressor a2 is sensitized in M1	M1	
<↑;1> <↑;0>	a 1<a2< v	Fault not detected	Fault not detected	Fault not detected
<↑;1> <↓;1>	a 1<a2< v	aggressor a1 is sensitized in M1	M1	aggressor a2 can also be sensitized in M2 and detected in M3
<↑;1> <↓;0>	a 1<a2< v	Fault not detected	Fault not detected	Fault not detected
<↑;0> <↑;1>	a 1<a2< v	Fault not detected	Fault not detected	Fault not detected
<↑;0> <↑;0>	a 1<a2< v	Fault not detected	Fault not detected	Fault not detected
<↑;0> <↓;1>	a 1<a2< v	aggressor a2 is sensitized in M2	M2	
<↑;0> <↓;0>	a 1<a2< v	aggressor a2 is sensitized in M2	M2	
<↓;1> <↑;1>	a 1<a2< v	aggressor a2 is sensitized in M1	M1	aggressor a1 can also be sensitized in M2 and detected in M3
<↓;1> <↑;0>	a 1<a2< v	aggressor a1 is sensitized in M2	M3	
<↓;1> <↓;1>	a 1<a2< v	aggressor a1 is sensitized in M2	M3	
<↓;1> <↓;0>	a 1<a2< v	aggressor a1 is sensitized in M2	M3	
<↓;0> <↑;1>	a 1<a2< v	aggressor a2 is sensitized in M1	M1	
<↓;0> <↑;0>	a 1<a2< v	Fault not detected	Fault not detected	Fault not detected
<↓;0> <↓;1>	a 1<a2< v	Fault not detected	Fault not detected	Fault not detected
<↓;0> <↓;0>	a 1<a2< v	Fault not detected	Fault not detected	Fault not detected