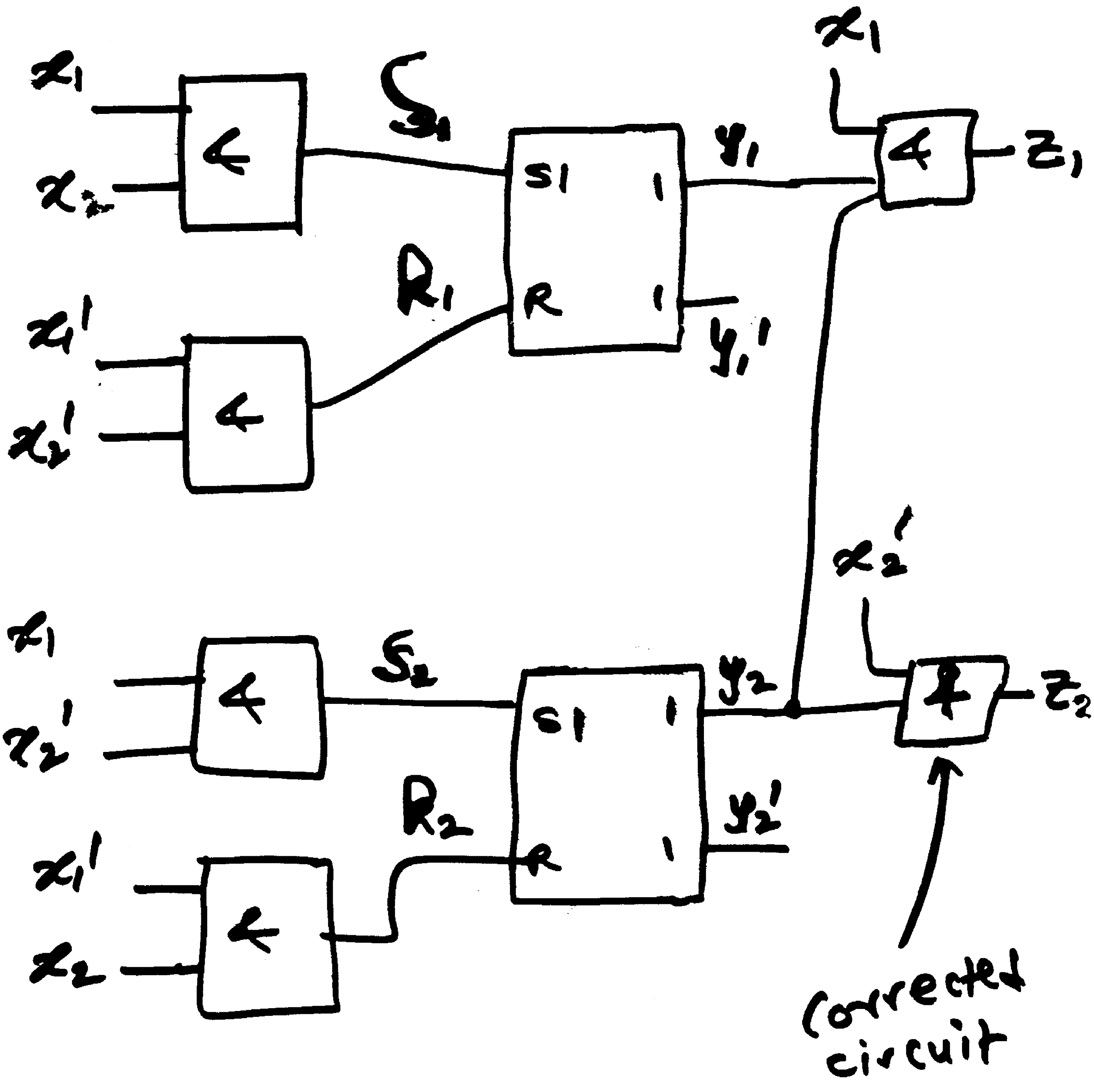
Analysis of sequential circuits with latches



Excitation table + characteristic function ⇒ transition table

stable states

x_1	x_2	y_1	y_2	Y_1	Y_2	z_1	z_2
0	0	0	0	0	0	0	0
0	0	0	1	0	1	0	1
0	0	1	1	0	1	0	1
0	0	1	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	0	1	0	0	0	0
0	1	1	1	1	0	0	0
0	1	1	0	1	0	0	0
1	1	0	0	1	0	0	0
1	1	0	1	1	1	0	0
1	1	1	1	1	1	1	0
1	1	1	0	1	0	0	0
1	0	0	0	0	1	0	0
1	0	0	1	0	1	0	1
1	0	1	1	1	1	1	1
1	0	1	0	1	1		

stable state

The table on previous slide can be presented differently to obtain the so-called <u>transition table</u> shown below, and <u>output table</u> shown later

$y_1 y_2$ \ $x_1 x_2$	00	01	11	10
00	00	00	10	01
01	01	00	11	01
11	01	10	11	11
10	00	10	10	11

$Y_1 Y_2$

← transition table

$y_1 y_2$ \ $x_1 x_2$	00	01	11	10
00	00	00	00	00
01	01	00	00	01
11	01	00	10	11
10	00	00	00	00

$x_1 x_2$

← output table

$z_1 z_2$

A total state

$$x_1 x_2 y_1 y_2$$

is stable if in this state

$$Y_1 Y_2 = y_1 y_2$$

<u>Otherwise, the total state is unstable.</u>

In the transition table, if we replace binary "code" for each state by a letter or name of some sort, the resulting table is called a <u>state table</u>.

internal state s

s \ $x_1 x_2$	00	01	11	10
A	A	A	D	B
B	B	A	C	B
C	B	D	C	C
D	A	D	D	C

state S

A : 00
B : 01
C : 11
D : 10

The transition table shows the "next" state $\Longrightarrow$ when the total state is not stable, the circuit will not stay in the "next" state for long, and will make another transition. These transitions will continue until a stable state is reached.

A "flow table" shows, for each total state, the final stable state that will be reached.

see next slide

Transition table:

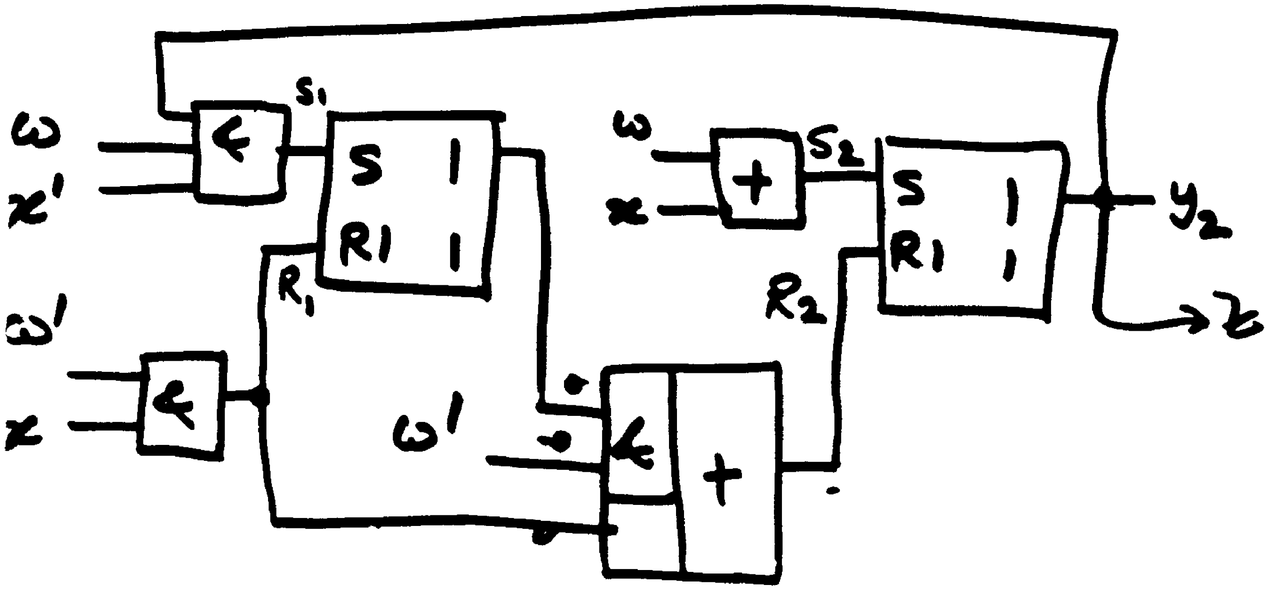
$y_1y_2 \backslash x_1x_2$	00	01	11	10
00	00	00	10	01
01	01	00	11	01
11	01	10	11	11
10	00	10	10	11

Flow table:

$y_1y_2 \backslash x_1x_2$	00	01	11	10
00	00	00	10	01
01	01	00	11	01
11			11	11
10		10	10	

For this example, transition table and flow table <u>happen to</u> be identical.

Another Example :



Excitation functions : $\left(\begin{array}{l} S_1 = y_2\, w\, x' \\ R_1 = w' x \end{array}\right.$

$S_2 = w + x$

$R_2 = y_1 w' + R_1 = w'(x + y_1)$

Next state functions obtained using the characteristic function

$Y = R'(S + y)$

$Y_1 = R_1'(S_1 + y_1) = \underline{w x' y_2 + x' y_1 + w y_1}$

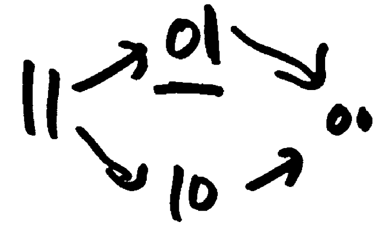
$Y_2 = R_2'(S_2 + y_2) = \underline{w + x' y_1' y_2}$

Transition table

y_1y_2 \ wx	00	01	11	10
00	00	00	01	01
01	01	00	01	11
11	10	00*	11	11
10	10	00	11	11

$Y_1 Y_2$

$11 \rightarrow 00$



* denotes a race

$\Downarrow$

both y_1 & y_2 change together

$wx = 01$

$11 \rightarrow 01 \rightarrow 00$

$11 \rightarrow 10 \rightarrow 00$

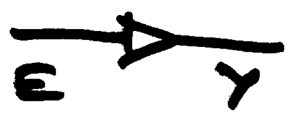
A race is a critical race if the order in which y_1 and y_2 change affects the final state.

Otherwise, it is not a critical race.

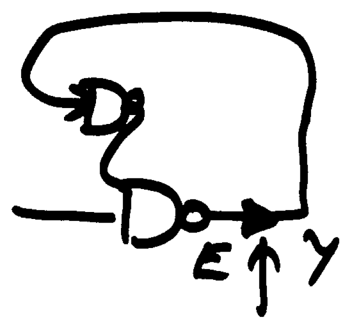
Analysis of Sequential Circuits with Feedback Loops

Break feedback loops with inserting hypothetical amplifiers

Characteristic function of



$\boxed{Y = E}$



Excitation functions : Y_1: $E_1 = x_1 x_2 + y_1(x_1 + x_2)$

$E_2 = x_1 x_2' + y_2(x_1 + x_2')$

Next state functions $Y_1 = E_1$ $Y_2 = E_2$

Transition Table

Can be obtained using above equations.

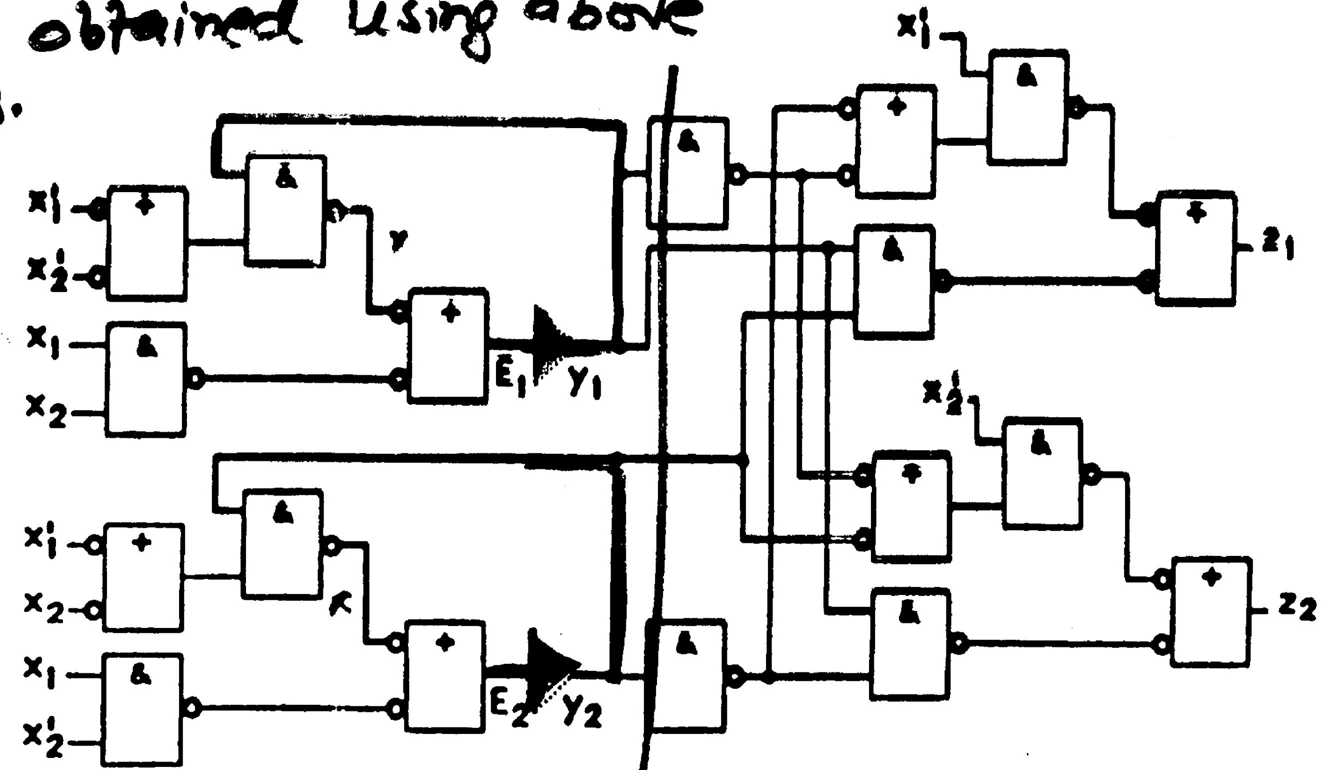


Figure 7.5-5 Sequential circuit constructed of NAND gates.

$x_1 x_2$

$y_1 y_2$ \ $x_1 x_2$	00	01	11	10
00	00	00	10	01
01	01	00	11	01
11	01	10	11	11
10	00	10	10	11

$Y_1 Y_2$

Transition Table (Since $E = Y$, excitation table is identical to transition table)

Outputs: Write equations from the circuit:

$Z_1 =$

$Z_2 =$

Exercise

Obtain output table using these equations

Transition table.

$y_1 y_2$ \ $x_1 x_2$	00	01	11	10
00	00	00	10	01
01	01	00	11	01
11	01	10	11	11
10	00	10	10	11

$Y_1 Y_2$

⇓

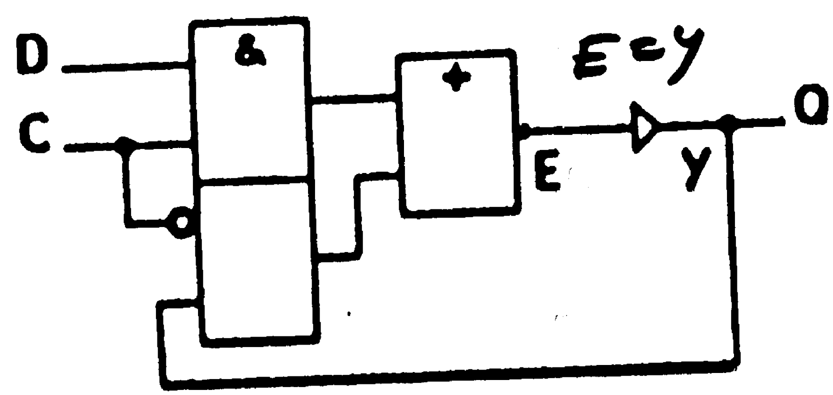
State table

S \ $x_1 x_2$	00	01	11	10
1	1	1	4	2
2	2	1	3	2
3	2	4	3	3
4	1	4	4	3

S

00 ⇒ 1
01 ⇒ 2
11 ⇒ 3
10 ⇒ 4

⊙ denotes Stable state



$\underline{E} = Y = \underline{DC + C'y}$

(a)

y \ CD	00	01	11	10	Q
0	0	0	1	0	0
1	1	1	1	0	1

Y

(b)

Figure 7.5-6 *D* latch analysis: (a) latch circuit; (b) transition table.

$\boxed{E = DC + C'y}$

excitation function

$\boxed{Y = E}$ (characteristic)

next state function

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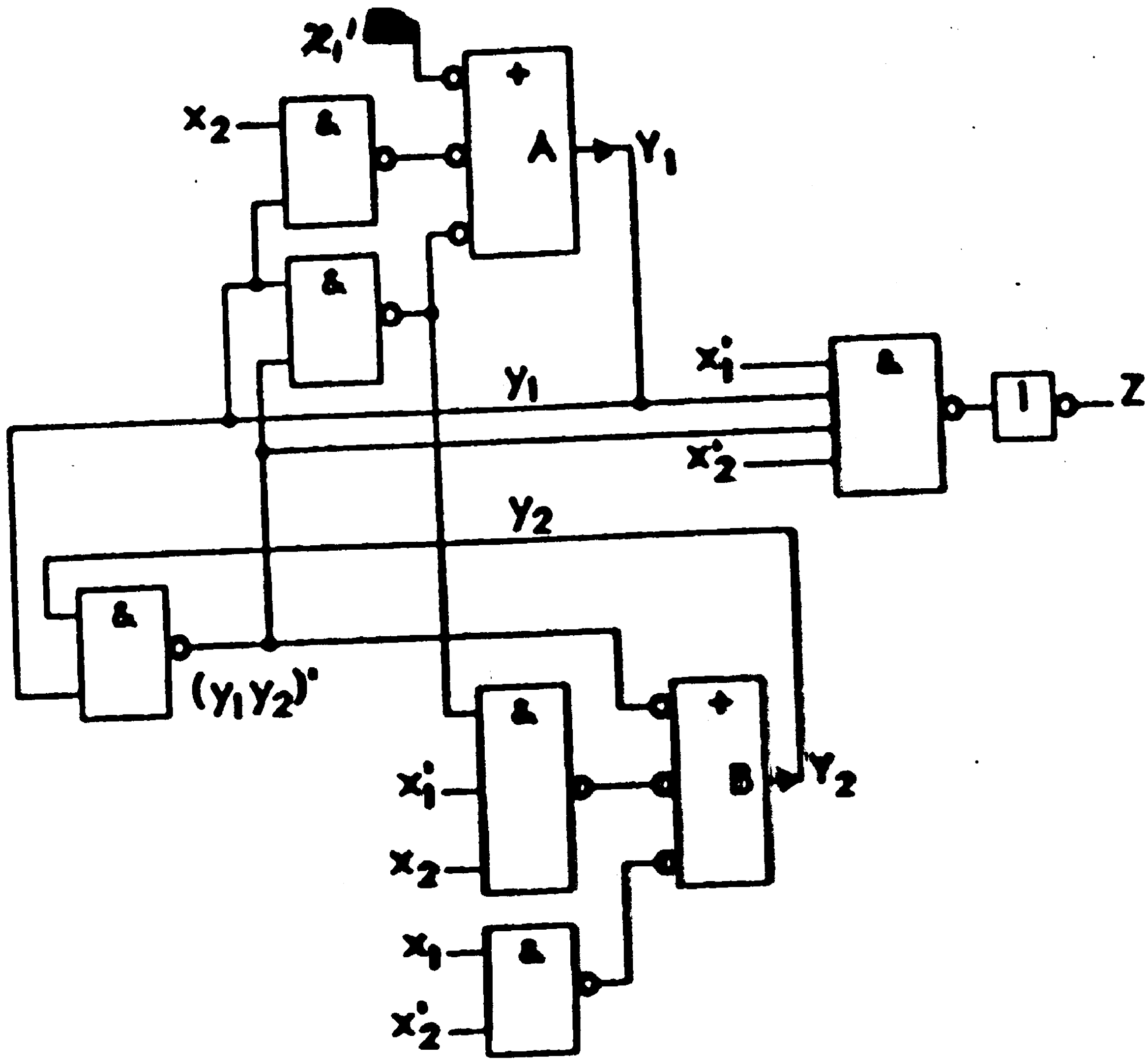

$$Y_1 = x_1' + x_2 y_1 + y_1(y_1' y_2)' = x_1 + x_2 y_1 + y_1 y_2'$$
$$Y_2 = y_1 y_2 + (y_1' + y_1 y_2) x_1' x_2 + x_1 x_2' = y_1 y_2 + x_1' x_2 y_1' + x_1 x_2'$$
$$Z = x_1' x_2' y_1 (y_1' + y_2') = x_1' x_2' y_1 y_2'$$

Figure 7.6-1 Sequential circuit illustrating races.

Excitation table and transition table identical because $Y = E$.

$y_1 y_2$ \ $x_1 x_2$	00	01	11	10
00	00	01	10	11
01	00	01	10*	11
11	01	11	11	11
10	10	10	10	11

* denotes a race