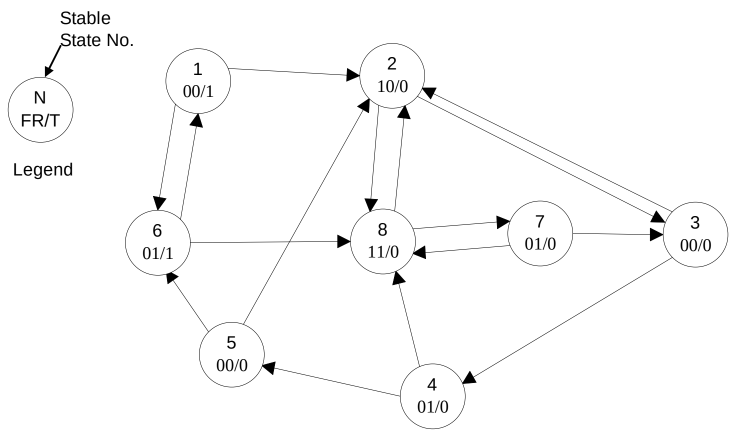
Industrial Automation - Tutorial Set 3

Solution to Prob. 1.



Flow Diagram

Row	00	01	11	10	T
	X_1X_2				
1	①	6	-	2	1
2	3	-	8	②	0
3	③	4	-	2	0
4	5	④	8	-	0
5	⑤	6	-	2	0
6	1	⑥	8	-	1
7	3	⑦	8	-	0
8	-	7	⑧	2	0

Primitive Flow Table

Rows	00	01	11	10	$Y_1Y_2Y_3$
	X_1X_2				
2,3	③	4	8	②	0 1 0
4	5	④	8	-	0 0 0
5	⑤	6	-	2	1 0 0
1,6	①	⑥	8	2	1 1 0
7,8	3	⑦	⑧	2	0 1 1
-	-	-	-	-	0 0 1
-	-	-	-	-	1 0 1
-	-	-	-	-	1 1 1

Merged Flow Table

From the merged flow diagram shown above, it can be seen that "critical races" may occur in 3 instances, 2 involving transitions from unstable states 8 in rows (4) and (1,6) to stable state ⑧ and one from unstable state 2 in row(5) to stable state ②. Note that all these involves more than one change of state for $Y_1Y_2Y_3$.

To avoid these races, we can force the transitions to follow the arrows as shown in the mergred flow table. The excitations maps for Y_1, Y_2 and Y_3 are then filled up accordingly.

X1X2

00	01	11	10	Y1Y2Y3
0	0	0	0	0 1 0
1	0	0	-	0 0 0
-	-	-	-	1 0 0
-	-	0	0	1 1 0
0	0	0	0	0 1 1
-	-	-	-	0 0 1
-	-	-	-	1 0 1
-	-	-	-	1 1 1

$S_1 = \overline{X_2}\,\overline{Y_2}$

X1X2

00	01	11	10	Y1Y2Y3
-	-	-	-	0 1 0
0	-	-	-	0 0 0
0	0	-	0	1 0 0
0	0	1	1	1 1 0
-	-	-	-	0 1 1
-	-	-	-	0 0 1
-	-	-	-	1 0 1
-	-	-	-	1 1 1

$R_1 = X_1 Y_2$

X1X2

00	01	11	10	Y1Y2Y3
-	0	-	-	0 1 0
0	0	1	-	0 0 0
0	1	-	1	1 0 0
-	-	-	-	1 1 0
-	-	-	-	0 1 1
-	-	-	-	0 0 1
-	-	-	-	1 0 1
-	-	-	-	1 1 1

$S_2 = X_2 Y_1 + X_1$

X1X2

00	01	11	10	Y1Y2Y3
0	1	0	0	0 1 0
-	-	0	-	0 0 0
-	0	-	0	1 0 0
0	0	0	0	1 1 0
0	0	0	0	0 1 1
-	-	-	-	0 0 1
-	-	-	-	1 0 1
-	-	-	-	1 1 1

$R_2 = \overline{X_1} X_2 \overline{Y_1}\,\overline{Y_3}$

X1X2X1X2

00	01	11	10	Y1Y2Y3
0	0	1	0	0 1 0
0	0	0	-	0 0 0
0	0	-	0	1 0 0
0	0	0	0	1 1 0
0	-	-	0	0 1 1
-	-	-	-	0 0 1
-	-	-	-	1 0 1
-	-	-	-	1 1 1

$S_3 = X_1 X_2 \overline{Y_1} Y_2$

00	01	11	10	Y1Y2Y3
-	-	0	-	0 1 0
-	-	-	-	0 0 0
-	-	-	-	1 0 0
-	-	-	-	1 1 0
1	0	0	1	0 1 1
-	-	-	-	0 0 1
-	-	-	-	1 0 1
-	-	-	-	1 1 1

$R_3 = \overline{X}_2$

$Y_1Y_2Y_3$ \ X_1X_2	00	01	11	10
0 1 0	0	0	0	0
0 0 0	0	0	0	-
1 0 0	0	-	-	0
1 1 0	1	1	-	0
0 1 1	0	0	0	0
0 0 1	-	-	-	-
1 0 1	-	-	-	-
1 1 1	-	-	-	-

$$T = Y_1 Y_2 \overline{X}_1$$

Solution to Prob. 2.

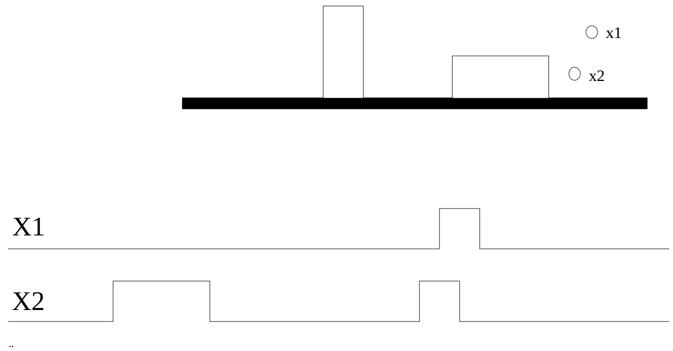


Figure 1.

In this problem, because of the arrangement of the sensors, X1 and X2, the inputs are not completely random inputs. Figure 1 above shows the changes in the sensor signals X1 and X2 when a DOWN part and then an UP part pass through. For a DOWN part passing through, the sensor pair, X1X2, goes through the sequence 00, 01, 00 whereas when an UP part passes through, the sequence is 00, 01, 11, 10, 00. These are the only two possible sequences that the sensor signals can have, unless they are not functioning properly.

The Flow Diagram is then

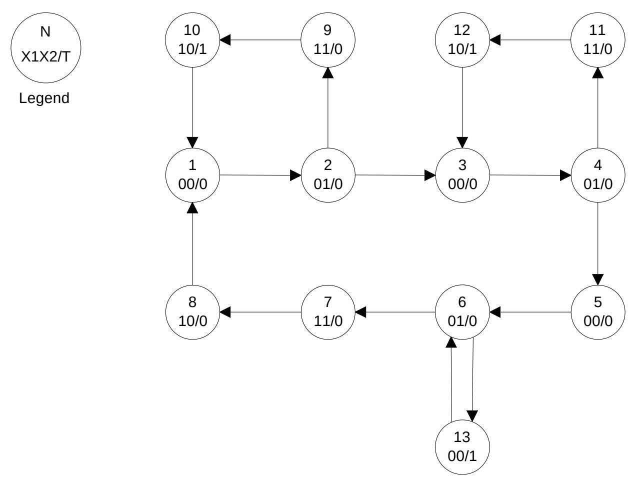


Figure 2.

In Figure 2, note that even though States 1, 3 and 5 have the same input/output states of 00/0, they are different in that they expect, for the normal sequence, 2, 1, and no lying down parts before the next upright part. The same reason applies to the other states in Figure 2 with the same input/output states.

From Figure 2, the Primitive Flow Table, Table 1 below, is then constructed and from this the Merged Flow Table, Table 2 below,without the state assignment column “$Y_1Y_2Y_3$”.

Table 1

X_1X_2

Row	00	01	11	10	T
1	①	2	-	-	0
2	3	②	9	-	0
3	③	4	-	-	0
4	5	④	11	-	0
5	⑤	6	-	-	0
6	13	⑥	7	-	0
7	-	-	⑦	8	0
8	1	-	-	⑧	0
9	-	-	⑨	10	0
10	1	-	-	⑩	1
11	-	-	⑪	12	0
12	3	-	-	⑫	1
13	⑬	6	-	-	1

Primitive Flow Table

Table 2

X_1X_2

Rows	00	01	11	10	$Y_1Y_2Y_3$
1,7,8	①	2	⑦	⑧	0 0 0
2,12	3	②	9	⑫	0 0 1
3,11	③	4	⑪	12	1 0 1
4	5	④	11	-	1 1 1
5	⑤	6	-	-	1 1 0
6,13	⑬	⑥	7	-	1 0 0
9,10	1	-	⑨	⑩	0 1 1
A	-	-	-	-	0 1 0

Merged Flow Table

To assist in assignment states, you can use a flow diagram to choose the “best” state assignments to avoid races: Note that it is possible to avoid races if, in going around a complete loop, there is an even number of transitions. If a complete loop has an odd number of transitions, it is not possible to avoid races. In such cases, adding an additional state (e.g. state A below) can resolve the problem. In the figure below, there is only one loop with an odd number of transitions, from (1,7,8) through (2,12) and (9,10) back to itself. From Figure 3 below, the state assignments column in Table 2 is completed.

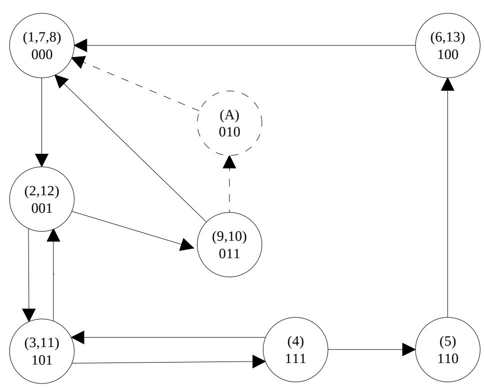


Figure 3.

Completing all states and rearranging:

Rows	X_1X_2 = 00	01	11	10	$Y_1Y_2Y_3$
1,7,8	①	2	⑦	⑧	0 0 0
2,12	3	②	9	⑫	0 0 1
9,10	1	-	⑨	⑩	0 1 1
A	-	-	-	-	0 1 0
6,13	⑬	⑥	7	-	1 0 0
3,11	③	4	⑪	12	1 0 1
4	5	④	11	-	1 1 1
5	⑤	6	-	-	1 1 0

Table 4

$Y_1Y_2Y_3$	X_1X_2 = 00	01	11	10	X_1X_2 = 00	01	11	10
0 0 0	0	0	0	0	-	-	-	-
0 0 1	1	0	0	0	0	-	-	-
0 1 1	0	-	0	0	-	-	-	-
0 1 0	0	-	-	-	-	-	-	-
1 0 0	-	-	0	-	0	0	1	-
1 0 1	-	-	-	0	0	0	0	1
1 1 1	-	-	-	-	0	0	0	-
1 1 0	-	-	-	-	0	0	-	-

$$S_1 = \overline{X}_1 \overline{X}_2 \overline{Y}_2 Y_3 \qquad R_1 = X_1 \overline{X}_2 + X_1 \overline{Y}_3$$

$Y_1Y_2Y_3$ \ X_1X_2	00	01	11	10
0 0 0	0	0	0	0
0 0 1	0	0	1	0
0 1 1	-	-	-	-
0 1 0	0	-	-	-
1 0 0	0	0	0	-
1 0 1	0	1	0	0
1 1 1	-	-	0	-
1 1 0	-	0	-	-

$$S_2 = X_1 X_2 \overline{Y}_1 Y_3 + \overline{X}_1 X_2 Y_1 Y_3$$

$Y_1Y_2Y_3$ \ X_1X_2	00	01	11	10
0 0 0	-	-	-	-
0 0 1	-	-	0	-
0 1 1	0	-	0	0
0 1 0	1	-	-	-
1 0 0	-	-	-	-
1 0 1	-	0	-	-
1 1 1	0	0	1	-
1 1 0	0	1	-	-

$$R_2 = \overline{Y}_1 \overline{Y}_3 + X_1 Y_1 + X_2 \overline{Y}_3$$

$Y_1Y_2Y_3$ \ X_1X_2	00	01	11	10
0 0 0	0	1	0	0
0 0 1	-	-	-	-
0 1 1	0	-	-	-
0 1 0	0	-	-	-
1 0 0	0	0	0	-
1 0 1	-	-	-	-
1 1 1	0	-	-	-
1 1 0	0	0	-	-

$$S_3 = \overline{X}_1 X_2 \overline{Y}_1$$

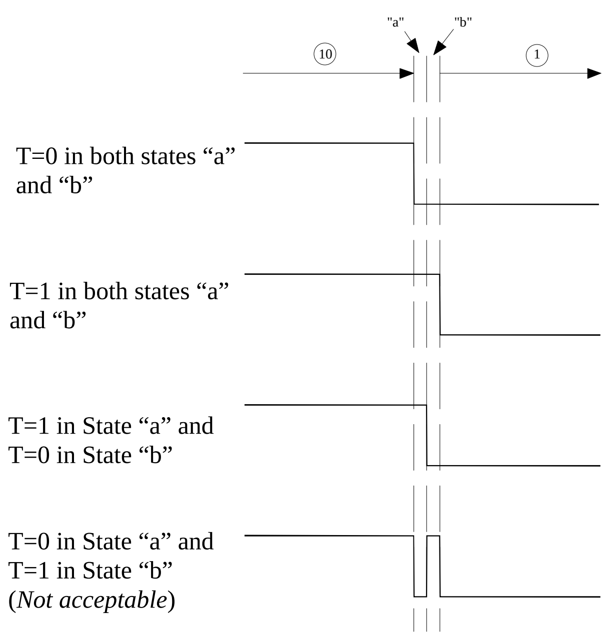
$Y_1Y_2Y_3$ \ X_1X_2	00	01	11	10
0 0 0	-	0	-	-
0 0 1	0	0	0	0
0 1 1	1	-	0	0
0 1 0	-	-	-	-
1 0 0	-	-	-	-
1 0 1	0	0	0	0
1 1 1	1	0	0	-
1 1 0	-	-	-	-

$$R_3 = \overline{X}_1 \overline{X}_2 Y_2$$

$$T = X_1 \overline{X}_2 Y_3 + \overline{X}_2 Y_1 \overline{Y}_2 \overline{Y}_3$$

$Y_1Y_2Y_3$	X_1X_2 = 00	01	11	10
0 0 0	0	0	0	0
0 0 1	0	0	0	1
0 1 1	a	-	0	1
0 1 0	b	-	-	-
1 0 0	1	0	0	-
1 0 1	0	0	0	-
1 1 1	0	0	0	-
1 1 0	0	0	-	-

From the rearranged merged flow table in Table 4, note that the output changes from T=1 in Stable State 10 through Unstable State 1 (square “a” above) and an intermediate state (square “b” above) to T=0 in Stable State 1. To prevent unnecessary switching back and forth, the values for squares “a” and “b” above, even though they are both “don’t cares”, should be the same, i.e. either both are “0” or both are “1”. If T=1 in State “a” and T=0 in State “b”, it would still be acceptable.



Once the logic equations are obtained for controlling the three “flip-flops” (or relays with holding contacts), the circuit can easily be constructed from either electromechanical or electronics logic circuits. The sensor signals for X1 and X2 will need to be “conditioned” so that they are suitable as inputs to the type of logic circuits used.