

Fig. 9-1 Block Diagram of an Asynchronous Sequential Circuit

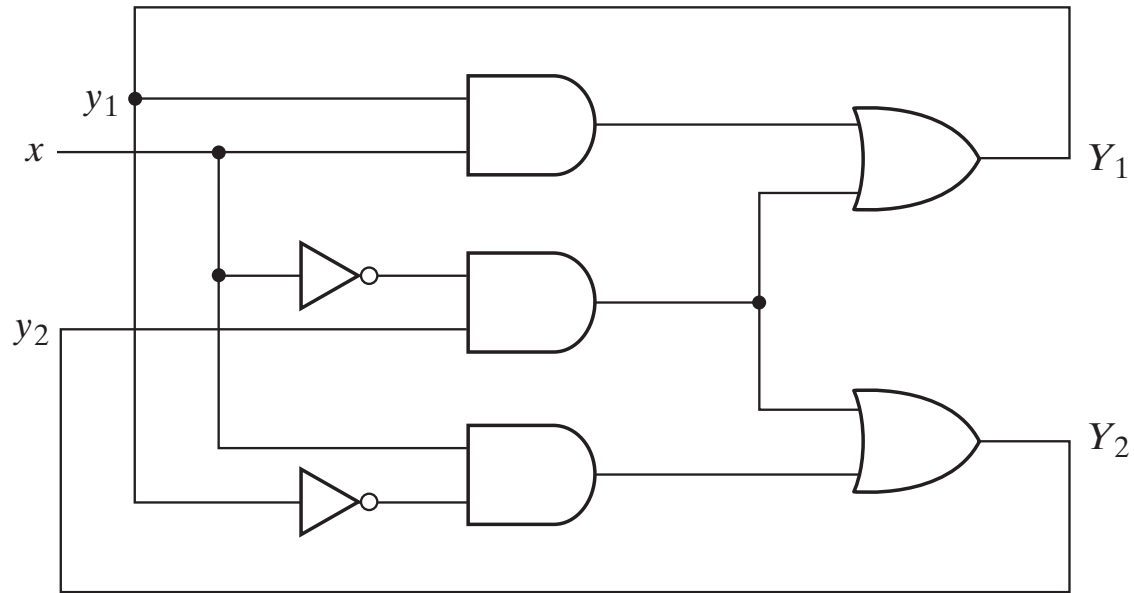


Fig. 9-2 Example of an Asynchronous Sequential Circuit

	$x$	
	0	1
$y_1 y_2$		
00	0	0
01	1	0
11	1	1
10	0	1

(a) Map for  
 $Y_1 = xy_1 + x'y_2$

	$x$	
	0	1
$y_1 y_2$		
00	0	1
01	1	1
11	1	0
10	0	0

(b) Map for  
 $Y_2 = xy'_1 + x'y_2$

	$x$	
	0	1
$y_1 y_2$		
00	00	01
01	11	01
11	11	10
10	00	10

(c) Transition table

Fig. 9-3 Maps and Transition Table for the Circuit of Fig. 9-2

	$x$	
	0	1
$a$	$a$	$b$
$b$	$c$	$b$
$c$	$c$	$d$
$d$	$a$	$d$

(a) Four states with one input

	$x_1 x_2$			
	00	01	11	10
$a$	$a, 0$	$a, 0$	$a, 0$	$b, 0$
$b$	$a, 0$	$a, 0$	$b, 1$	$b, 0$

(b) Two states with two inputs and one output

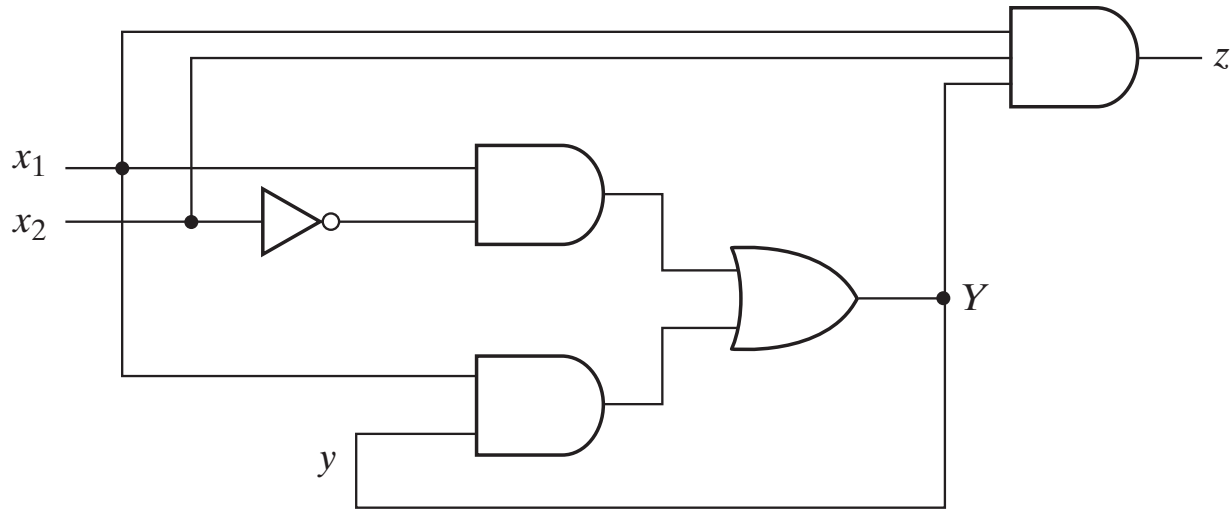
Fig. 9-4 Examples of Flow Tables

		$x_1 x_2$			
		00	01	11	10
$y$	0	0	0	0	1
	1	0	0	1	1

(a) Transition table  
 $Y = x_1x_2' + x_1y$

		$x_1 x_2$			
		00	01	11	10
$y$	0	0	0	0	0
	1	0	0	1	0

(b) Map for output  
 $z = x_1x_2y$



(c) Logic diagram

Fig. 9-5 Derivation of a Circuit Specified by the Flow Table of Fig. 9-4(b)

		$x$	
		0	1
$y_1 y_2$	00	00	11
	01		11
	11		11
	10		11

(a) Possible transitions:

$00 \rightarrow 11$   
 $00 \rightarrow 01 \rightarrow 11$   
 $00 \rightarrow 10 \rightarrow 11$

		$x$	
		0	1
$y_1 y_2$	00	00	11
	01		01
	11		01
	10		11

(b) Possible transitions:

$00 \rightarrow 11 \rightarrow 01$   
 $00 \rightarrow 01$   
 $00 \rightarrow 10 \rightarrow 11 \rightarrow 01$

Fig. 9-6 Examples of Noncritical Races

		$x$	
		0	1
$y_1 y_2$	00	00	11
	01		01
	11		11
	10		10

(a) Possible transitions:

$00 \rightarrow 11$   
 $00 \rightarrow 01$   
 $00 \rightarrow 10$

		$x$	
		0	1
$y_1 y_2$	00	00	11
	01		11
	11		11
	10		10

(b) Possible transitions:

$00 \rightarrow 11$   
 $00 \rightarrow 01 \rightarrow 11$   
 $00 \rightarrow 10$

Fig. 9-7 Examples of Critical Races

		$x$	
		0	1
$y_1 y_2$	00	00	01
	01		11
	11		10
	10		10

(a) State transition:  
 $00 \rightarrow 01 \rightarrow 11 \rightarrow 10$

		$x$	
		0	1
$y_1 y_2$	00	00	01
	01		11
	11		11
	10		10

(b) State transition:  
 $00 \rightarrow 01 \rightarrow 11$

		$x$	
		0	1
$y_1 y_2$	00	00	01
	01		11
	11		10
	10		01

(c) Unstable

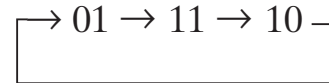
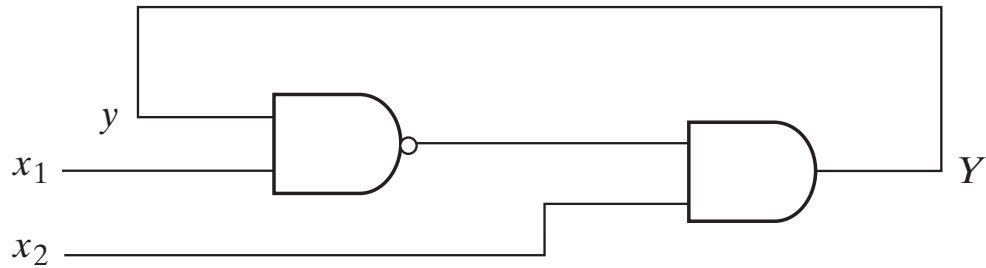


Fig. 9-8 Examples of Cycles



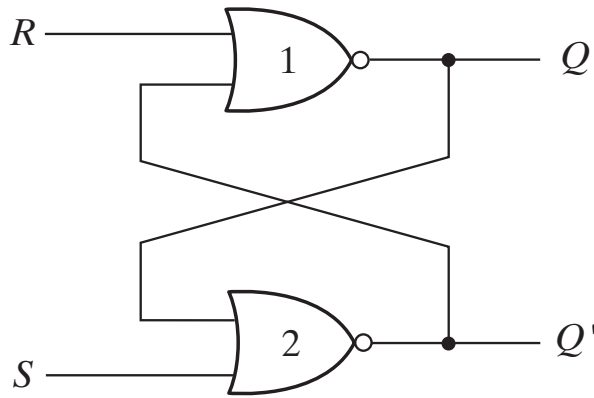


(a) Logic diagram

		$x_1 x_2$			
		00	01	11	10
$y$	0	0	1	1	0
	1	0	1	0	0

(b) Transition table

Fig. 9-9 Example of an Unstable Circuit



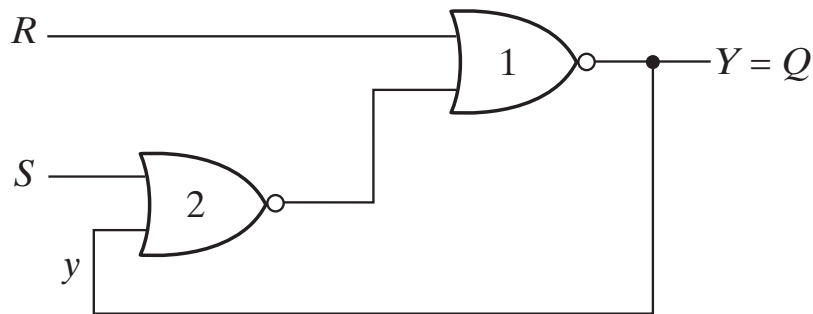
(a) Crossed-coupled circuit

$S$	$R$	$Q$	$Q'$
1	0	1	0
0	0	1	0
0	1	0	1
0	0	0	1
1	1	0	0

(After  $SR = 10$ )

(After  $SR = 01$ )

(b) Truth table



(c) Circuit showing feedback

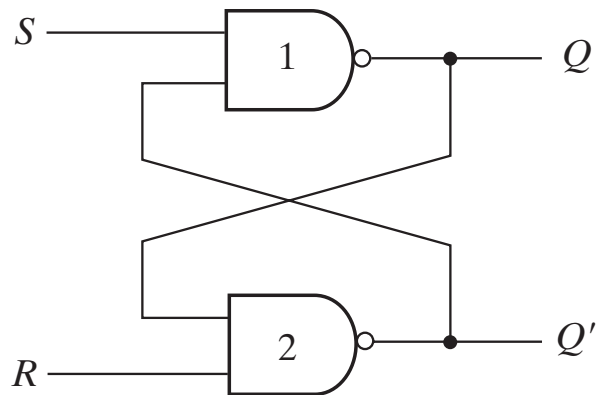
		$SR$			
		00	01	11	10
$y$	0	0	0	0	1
	1	1	0	0	1

$$Y = SR' + R'y$$

$$Y = S + R'y \text{ when } SR = 0$$

(d) Transition table

Fig. 9-10  $SR$  Latch with NOR Gates



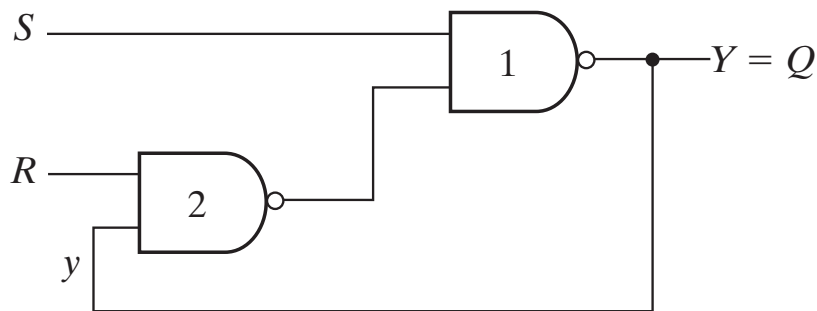
(a) Crossed-coupled circuit

$S$	$R$	$Q$	$Q'$
1	0	0	1
1	1	0	1
0	1	1	0
1	1	1	0
0	0	1	1

(After  $SR = 10$ )

(After  $SR = 01$ )

(b) Truth table



(c) Circuit showing feedback

		$SR$			
		00	01	11	10
$y$	0	1	1	0	0
	1	1	1	1	0

$$Y = S' + Ry \text{ when } S'R' = 0$$

(d) Transition table

Fig. 9-11  $SR$  Latch with NAND Gates

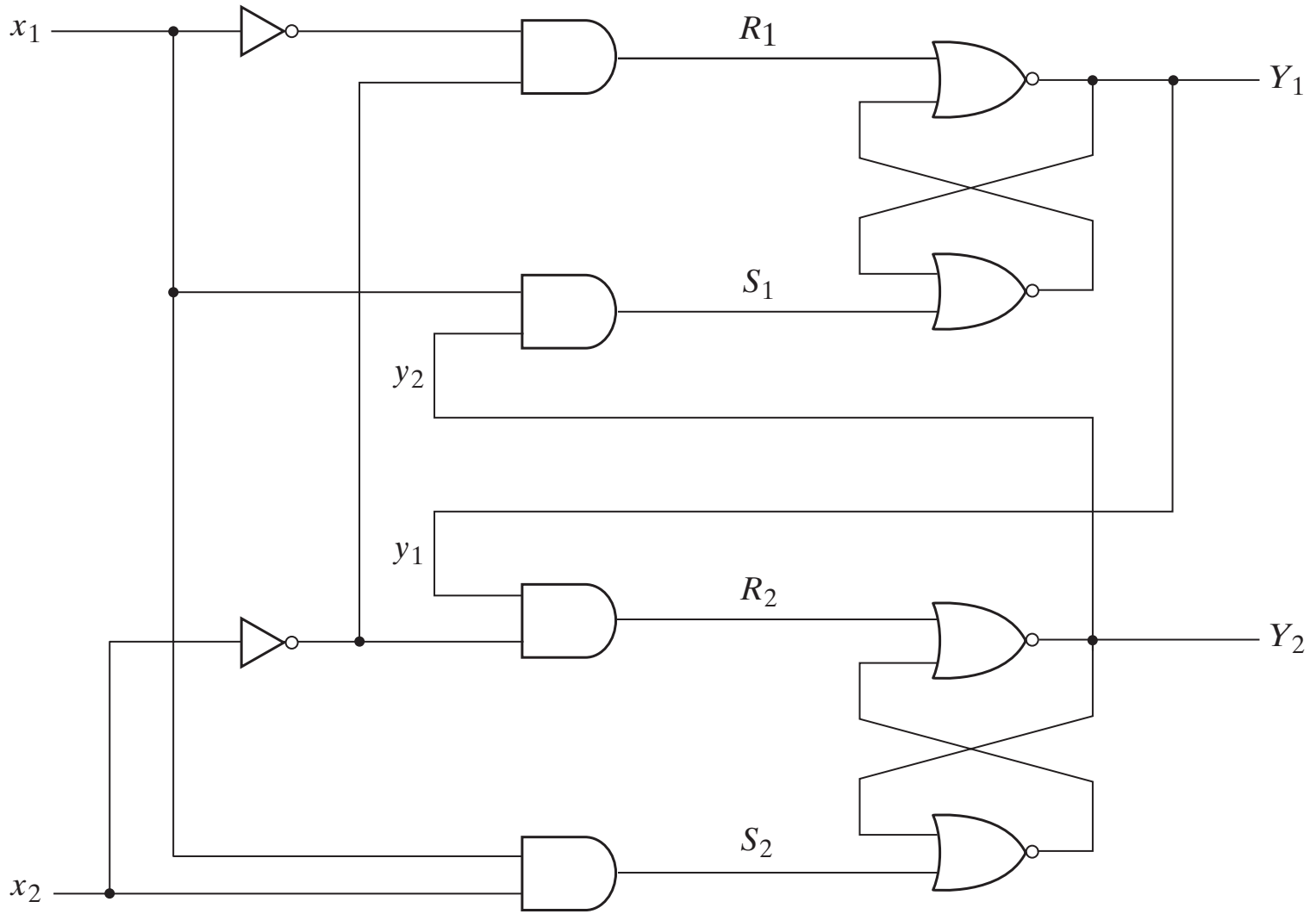


Fig. 9-12 Example of a Circuit with *SR* Latches

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

Fig. 9-13 Transition Table for the Circuit of Fig. 9-12

	$x_1x_2$			
	00	01	11	10
$y$				
0	0	0	0	1
1	0	0	1	1

(a) Transition table

$$Y = x_1x'_2 + x_1y$$

$y$	$Y$	$S$	$R$
0	0	0	$X$
0	1	1	0
1	0	0	1
1	1	$X$	1

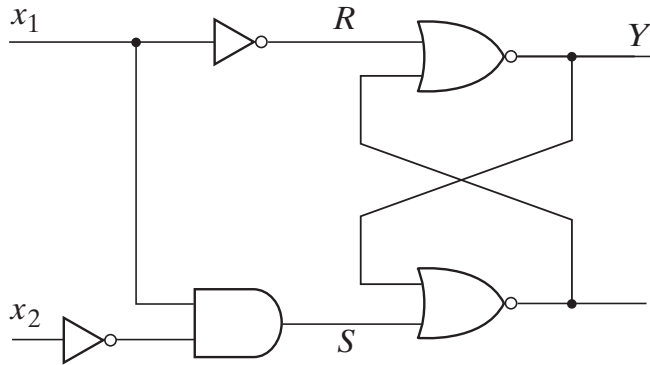
(b) Latch excitation table

	$x_1x_2$			
	00	01	11	10
$y$				
0	0	0	0	1
1	0	0	$X$	$X$

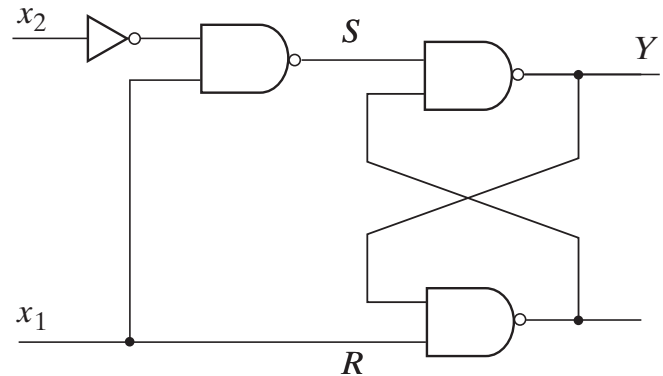
(c) Map for  $S = x_1x'_2$

	$x_1x_2$			
	00	01	11	10
$y$				
0	$X$	$X$	$X$	0
1	1	1	0	0

(d) Map for  $R = x'_1$



(e) Circuit with NOR latch



(f) Circuit with NAND latch

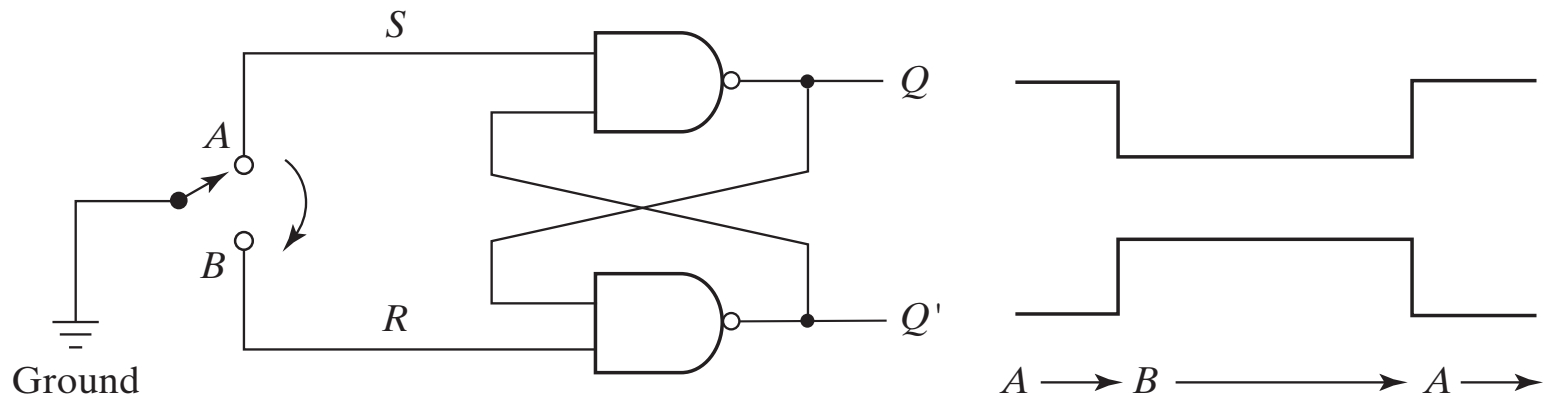


Fig. 9-15 Debounce Circuit

		<i>DG</i>			
		00	01	11	10
<i>a</i>	<i>c</i> , -	<i>a</i>	, 0	<i>b</i> , -	-, -
<i>b</i>	-, -	<i>a</i> , -	<i>b</i>	, 1	<i>e</i> , -
<i>c</i>	<i>c</i>	, 0	<i>a</i> , -	-, -	<i>d</i> , -
<i>d</i>	<i>c</i> , -	-, -	<i>b</i> , -	<i>d</i>	, 0
<i>e</i>	<i>f</i> , -	-, -	<i>b</i> , -	<i>e</i>	, 1
<i>f</i>	<i>f</i>	, 1	<i>a</i> , -	-, -	<i>e</i> , -

Fig. 9-16 Primitive Flow Table



		<i>DG</i>			
		00	01	11	10
<i>a</i>	<i>c</i> , -	<i>a</i> , 0	<i>b</i> , -	- , -	
<i>c</i>	<i>c</i> , 0	<i>a</i> , -	- , -	<i>d</i> , -	
<i>d</i>	<i>c</i> , -	- , -	<i>b</i> , -	<i>d</i> , 0	

		<i>DG</i>			
		00	01	11	10
<i>b</i>	- , -	<i>a</i> , -	<i>b</i> , 1	<i>e</i> , -	
<i>e</i>	<i>f</i> , -	- , -	<i>b</i> , -	<i>e</i> , 1	
<i>f</i>	<i>f</i> , 1	<i>a</i> , -	- , -	<i>e</i> , -	

(a) States that are candidates for merging

		<i>DG</i>			
		00	01	11	10
<i>a, c, d</i>	<i>c</i> , 0	<i>a</i> , 0	<i>b</i> , -	<i>d</i> , 0	
<i>b, e, f</i>	<i>f</i> , 1	<i>a</i> , -	<i>b</i> , 1	<i>e</i> , 1	

		<i>DG</i>			
		00	01	11	10
<i>a</i>	<i>a</i> , 0	<i>a</i> , 0	<i>b</i> , -	<i>a</i> , 0	
<i>b</i>	<i>b</i> , 1	<i>a</i> , -	<i>b</i> , 1	<i>b</i> , 1	

(b) Reduced table (two alternatives)

Fig. 9-17 Reduction of the Primitive Flow Table

		<i>DG</i>			
		00	01	11	10
<i>y</i>	0	0	0	1	0
	1	1	0	1	1

(a)  $Y = DG + G'y$

		<i>DG</i>			
		00	01	11	10
<i>y</i>	0	0	0	1	0
	1	1	0	1	1

(b)  $Q = Y$

Fig. 9-18 Transition Table and Output Map for Gated Latch

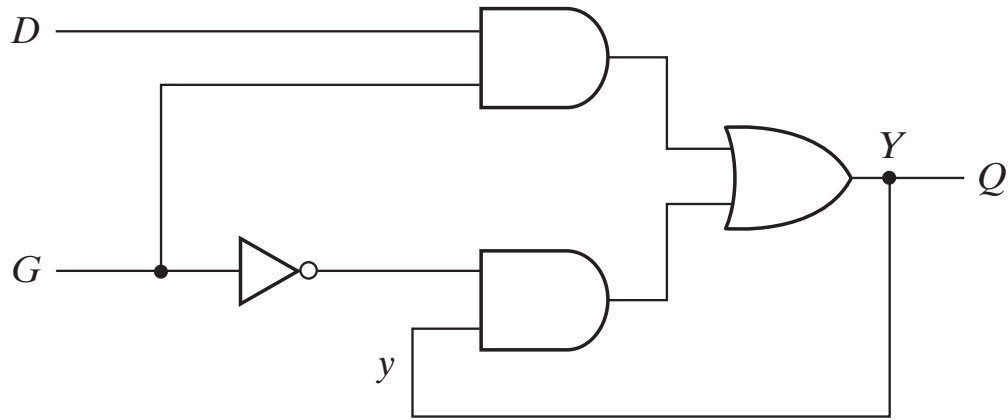


Fig. 9-19 Gated-Latch Logic Diagram

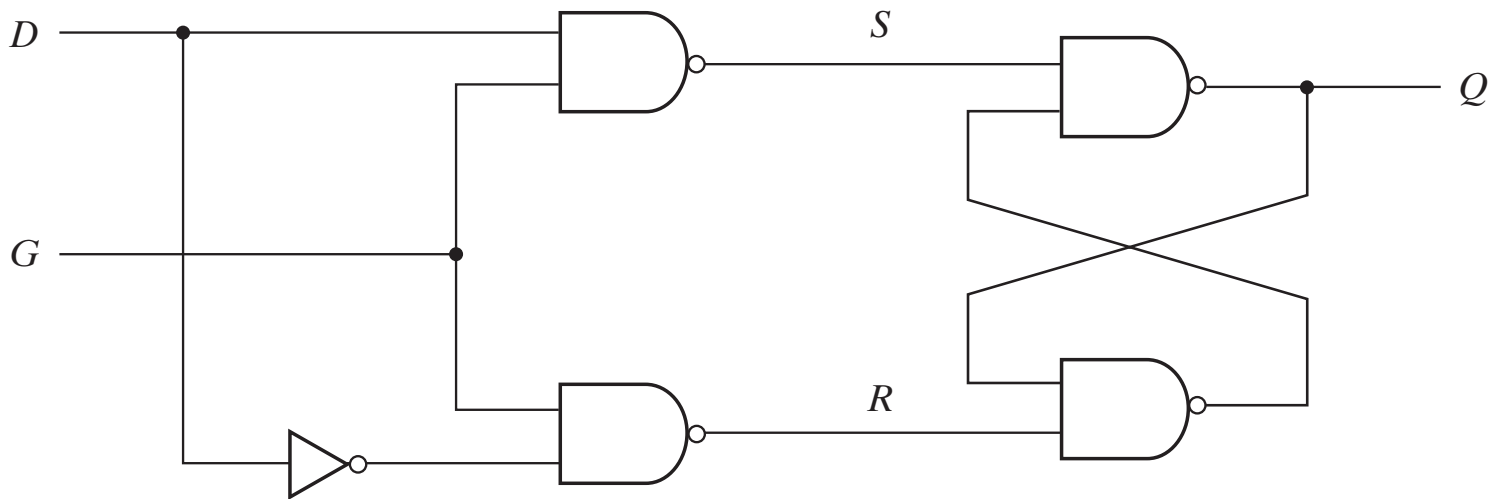
		$DG$			
		00	01	11	10
$y$	0	0	0	1	0
	1	$X$	0	$X$	$X$

(a)  $S = DG$

		$DG$			
		00	01	11	10
$y$	0	$X$	$X$	0	$X$
	1	0	1	0	0

$R = D'G$

(a) Maps for  $S$  and  $R$



(b) Logic diagram

<i>a</i>	$\textcircled{a}, 0$	<i>b</i> , -
<i>b</i>	<i>c</i> , -	$\textcircled{b}, 0$
<i>c</i>	$\textcircled{c}, 1$	<i>d</i> , -
<i>d</i>	<i>a</i> , -	$\textcircled{d}, 1$

(a) Flow table

0	0
<i>X</i>	0
1	1
<i>X</i>	1

(b) Output assignment

Fig. 9-21 Assigning Output Values to Unstable States

<i>b</i>	<i>d, e</i> ✓					
<i>c</i>	×	×				
<i>d</i>	×	×	×			
<i>e</i>	×	×	×	✓		
<i>f</i>	<i>c, d</i> ×	<i>c, e</i> × <i>a, b</i>	×	×	×	
<i>g</i>	×	×	×	<i>d, e</i> ✓	<i>d, e</i> ✓	×
	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>

Fig. 9-22 Implication Table

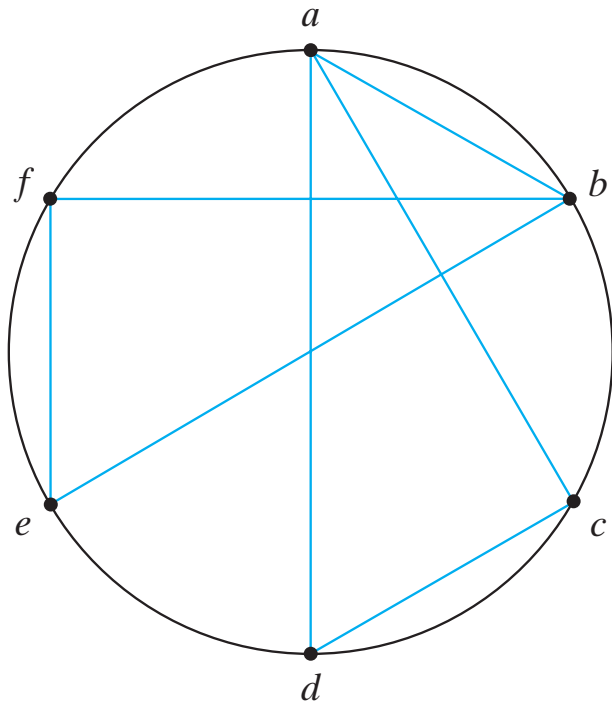
	00	01	11	10
<i>a</i>	<i>c</i> , -	<b><i>a</i></b> , 0	<i>b</i> , -	- , -
<i>b</i>	- , -	<i>a</i> , -	<b><i>b</i></b> , 1	<i>e</i> , -
<i>c</i>	<b><i>c</i></b> , 0	<i>a</i> , -	- , -	<i>d</i> , -
<i>d</i>	<i>c</i> , -	- , -	<i>b</i> , -	<b><i>d</i></b> , 0
<i>e</i>	<i>f</i> , -	- , -	<i>b</i> , -	<b><i>e</i></b> , 1
<i>f</i>	<b><i>f</i></b> , 1	<i>a</i> , -	- , -	<i>e</i> , -

(a) Primitive flow table

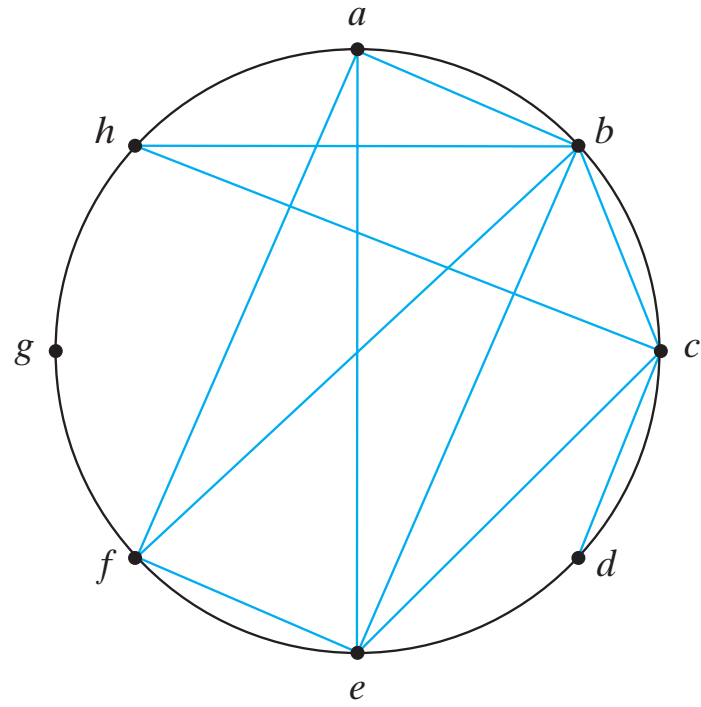
<i>b</i>	✓				
<i>c</i>	✓	<i>d</i> , <i>e</i> ×			
<i>d</i>	✓	<i>d</i> , <i>e</i> ×	✓		
<i>e</i>	<i>c</i> , <i>f</i> ×	✓	<i>d</i> , <i>e</i> × <i>c</i> , <i>f</i> ×	×	
<i>f</i>	<i>c</i> , <i>f</i> ×	✓	×	<i>d</i> , <i>e</i> × <i>c</i> , <i>f</i> ×	✓
	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>

(b) Implication table

Fig. 9-23 Flow and Implication Tables



(a) Maximal compatible:  
 $(a, b,)$   $(a, c, d)$   $(b, e, f)$



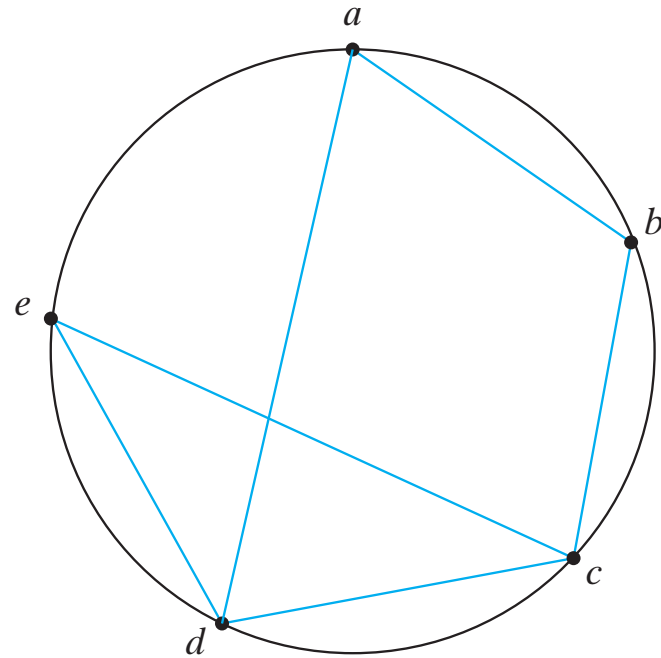
(b) Maximal compatible:  
 $(a, b, e, f)$   $(b, c, h)$   $(c, d)$   $(g)$

Fig. 9-24 Merger Diagrams



<i>b</i>	<i>b, c</i> ✓			
<i>c</i>	×	<i>d, e</i> ✓		
<i>d</i>	<i>b, c</i> ✓		×	<i>a, d</i> ✓
<i>e</i>	×	×	✓	<i>b, c</i> ✓
	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>

(a) Implication table



(b) Merger diagram

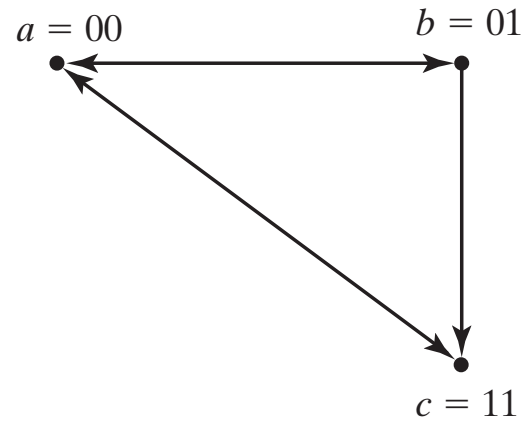
Compatibles	<i>(a, b)</i>	<i>(a, d)</i>	<i>(b, c)</i>	<i>(c, d, e)</i>
Implied states	<i>(b, c)</i>	<i>(b, c)</i>	<i>(d, e)</i>	<i>(a, d,)</i> <i>(b, c,)</i>

(c) Closure table

Fig. 9-25 Choosing a Set of Compatibles

		$x_1 x_2$			
		00	01	11	10
$a$	$a$	$b$	$c$	$a$	
$b$	$a$	$b$	$b$	$c$	
$c$	$a$	$c$	$c$	$c$	

(a) Flow table

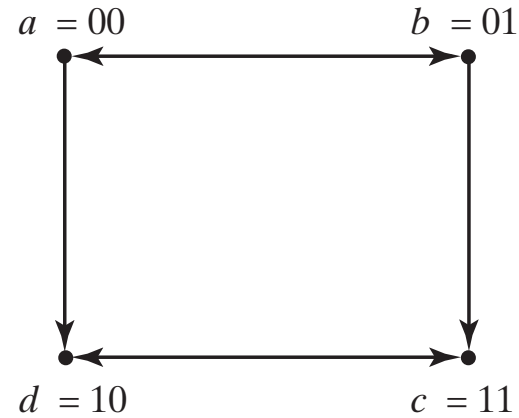


(b) Transition diagram

Fig. 9-26 Three-Row Flow-Table Example

		$x_1x_2$			
		00	01	11	10
$a$	$a$	$b$	$d$	$a$	
$b$	$a$	$b$	$b$	$c$	
$c$	$d$	$c$	$c$	$c$	
$d$	$a$	-	$c$	-	

(a) Flow table



(b) Transition diagram

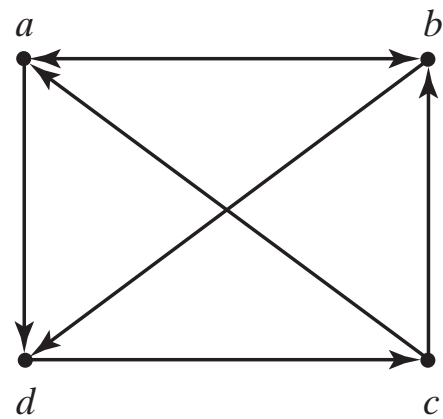
Fig. 9-27 Flow Table with an Extra Row

		$x_1x_2$			
		00	01	11	10
$a = 00$	00	01	10	00	
$b = 01$	00	01	01	11	
$c = 11$	10	11	11	11	
$d = 10$	00	-	11	-	

Fig. 9-28 Transition Table

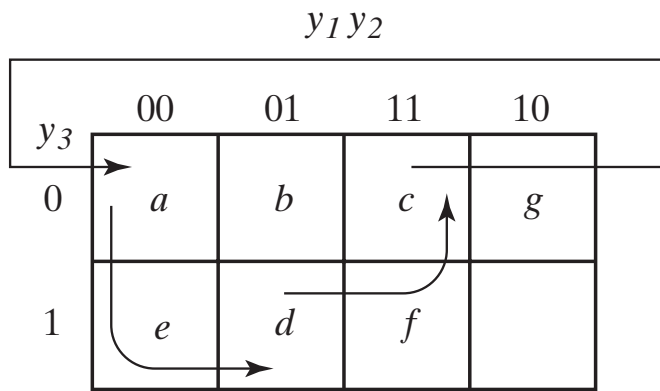
	00	01	11	10
<i>a</i>	<i>b</i>	<i>a</i>	<i>d</i>	<i>a</i>
<i>b</i>	<i>b</i>	<i>d</i>	<i>b</i>	<i>a</i>
<i>c</i>	<i>c</i>	<i>a</i>	<i>b</i>	<i>c</i>
<i>d</i>	<i>c</i>	<i>d</i>	<i>d</i>	<i>c</i>

(a) Flow table

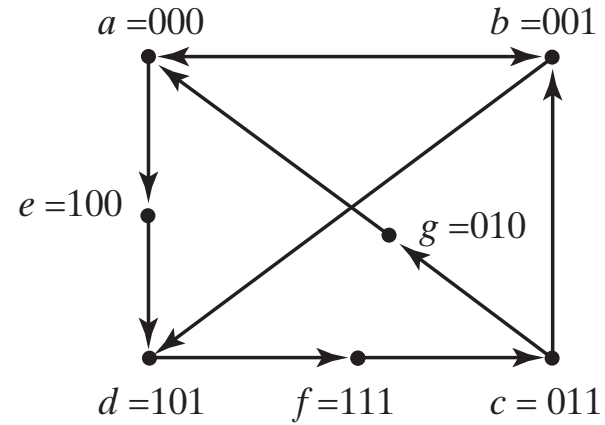


(b) Transition diagram

Fig. 9-29 Four-Row Flow-Table Example



(a) Binary assignment



(b) Transition diagram

Fig. 9-30 Choosing Extra Rows for the Flow Table

	00	01	11	10
000 = <i>a</i>	<i>b</i>	<i>a</i>	<i>e</i>	<i>a</i>
001 = <i>b</i>	<i>b</i>	<i>d</i>	<i>b</i>	<i>a</i>
011 = <i>c</i>	<i>c</i>	<i>g</i>	<i>b</i>	<i>c</i>
010 = <i>g</i>	–	<i>a</i>	–	–
110 –	–	–	–	–
111 = <i>f</i>	<i>c</i>	–	–	<i>c</i>
101 = <i>d</i>	<i>f</i>	<i>d</i>	<i>d</i>	<i>f</i>
100 = <i>e</i>	–	–	<i>d</i>	–

Fig. 9-31 State Assignment to Modified Flow Table

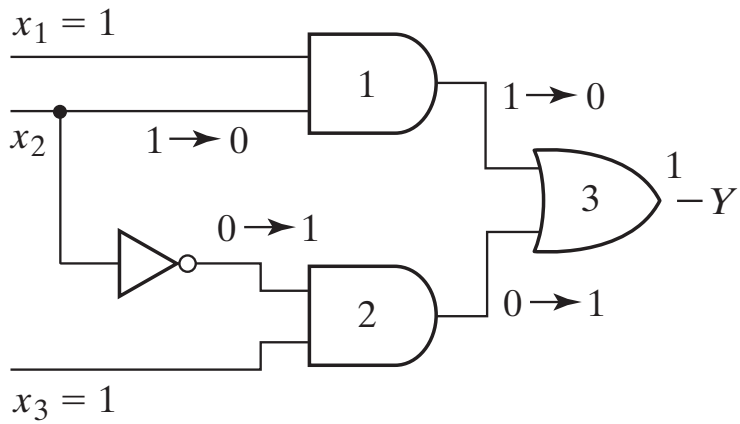
		$y_2 y_3$			
		00	01	11	10
$y_1$	0	$a_1$	$b_1$	$c_1$	$d_1$
	1	$c_2$	$d_2$	$a_2$	$b_2$

(a) Binary assignment

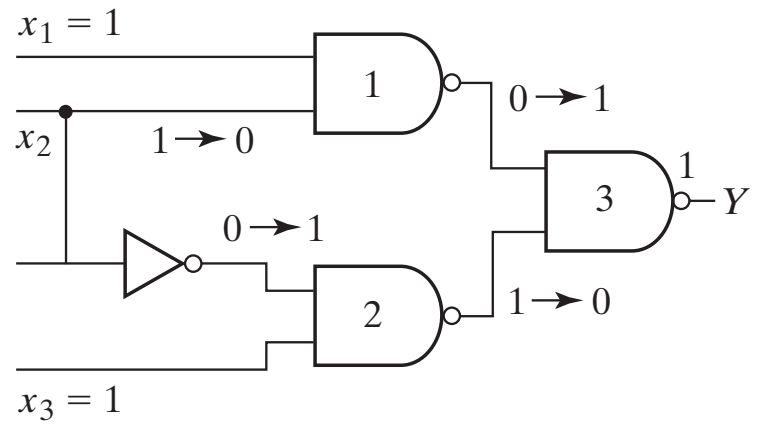
	00	01	11	10
$000 = a_1$	$b_1$	$a_1$	$d_1$	$a_1$
$111 = a_2$	$b_2$	$a_2$	$d_2$	$a_2$
$001 = b_1$	$b_1$	$d_2$	$b_1$	$a_1$
$110 = b_2$	$b_2$	$d_1$	$b_2$	$a_2$
$011 = c_1$	$c_1$	$a_2$	$b_1$	$c_1$
$100 = c_2$	$c_2$	$a_1$	$b_2$	$c_2$
$010 = d_1$	$c_1$	$d_1$	$d_1$	$c_1$
$101 = d_2$	$c_2$	$d_2$	$d_2$	$c_2$

(b) Flow table



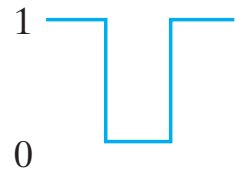


(a) AND-OR circuit

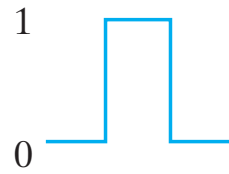


(b) NAND circuit

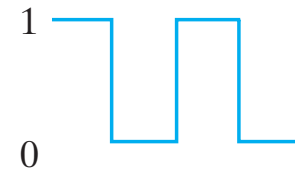
Fig. 9-33 Circuits with Hazards



(a) Static 1-hazard

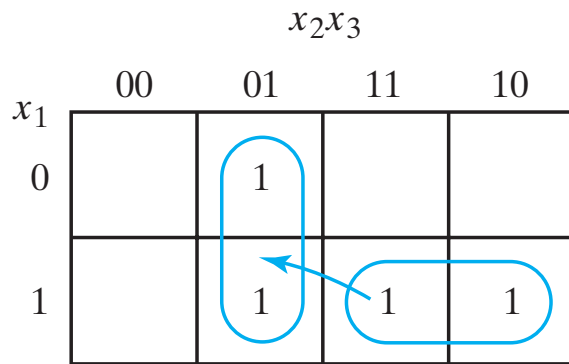


(b) Static 0-hazard

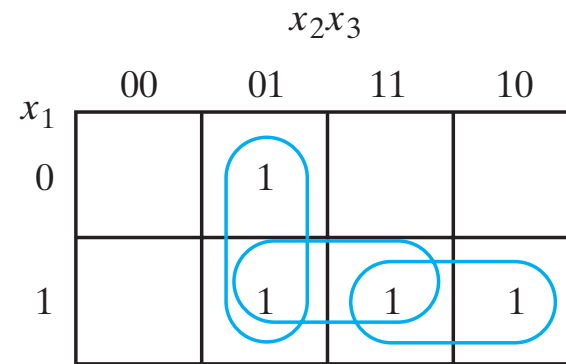


(c) Dynamic hazard

Fig. 9-34 Types of Hazards



(a)  $Y = x_1 x_2 + x'_2 x_3$



(b)  $Y = x_1 x_2 + x'_2 x_3 + x_1 x_3$

Fig. 9-35 Maps Demonstrating a Hazard and its Removal

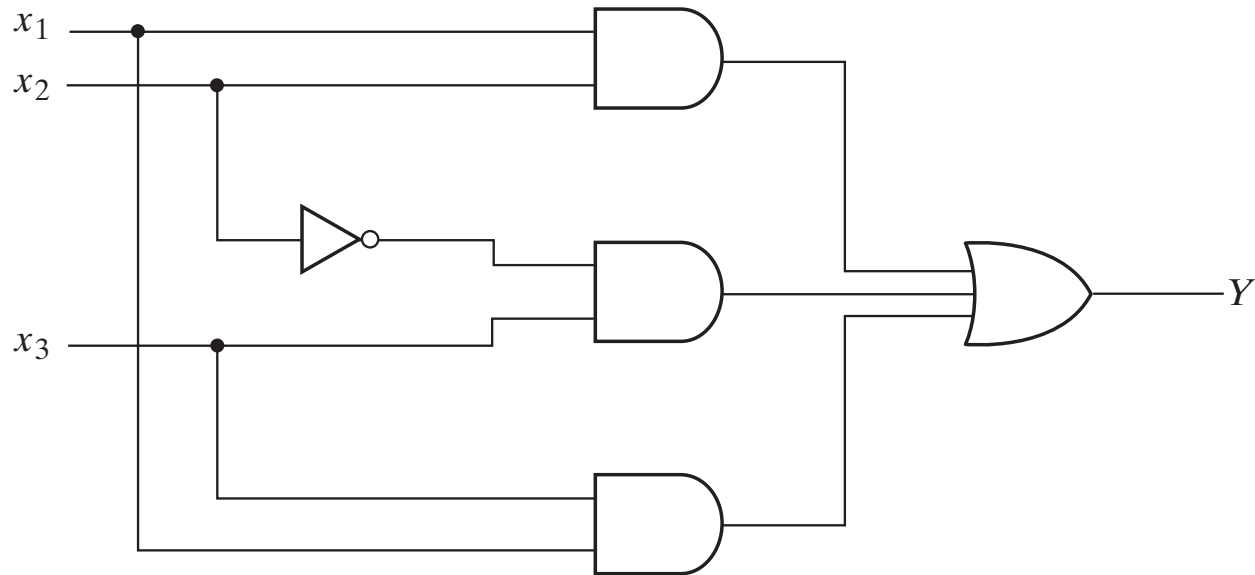
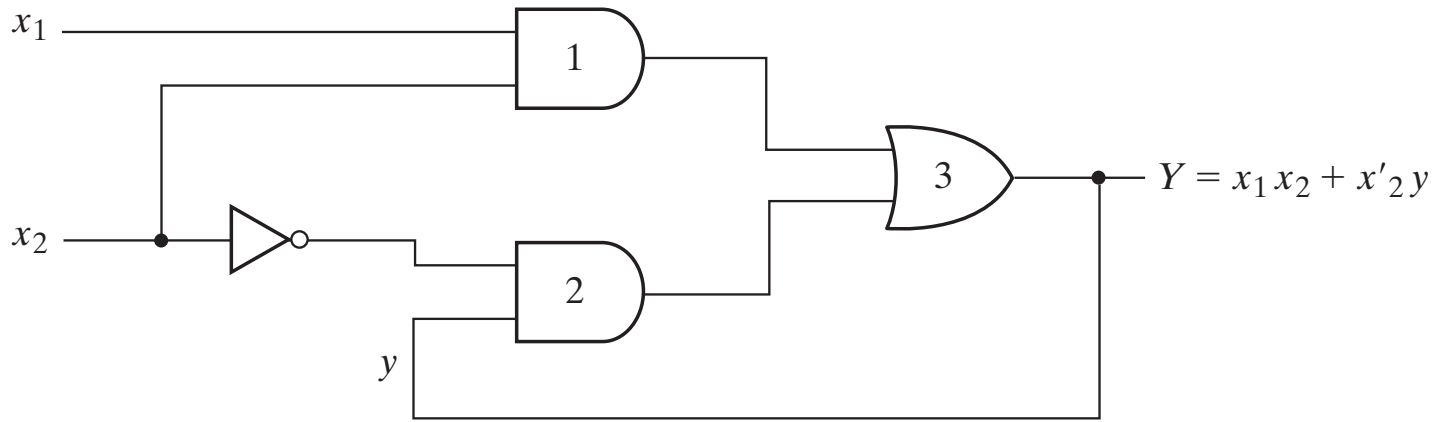


Fig. 9-36 Hazard-Free Circuit



(a) Logic diagram

		$x_1x_2$			
		00	01	11	10
$y$	0	0	0	1	0
	1	1	0	1	1

(b) Transition table

		$x_1x_2$			
		00	01	11	10
$y$	0			1	
	1	1		1	1

(c) Map for  $Y$

Fig. 9-37 Hazard in an Asynchronous Sequential Circuit

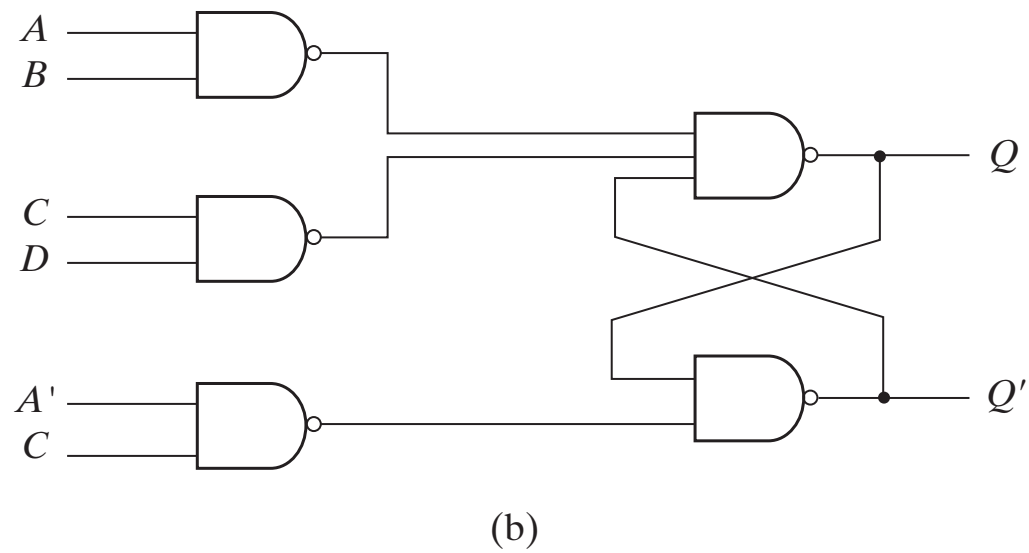
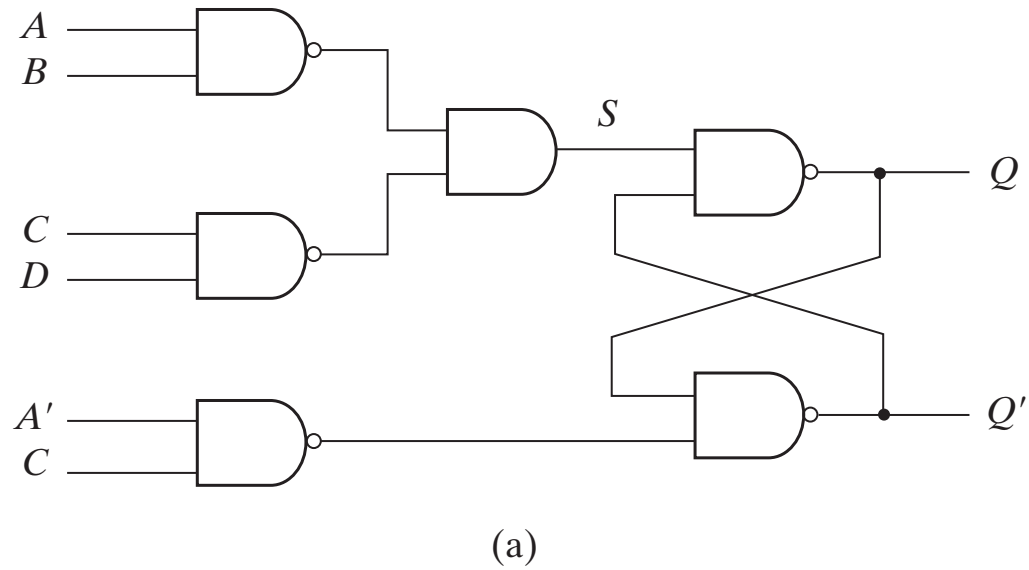


Fig. 9-38 Latch Implementation

		$TC$			
		00	01	11	10
$a$	- , -	$f$ , -	$a$ , 0	$b$ , -	
$b$	$g$ , -	- , -	$c$ , -	$b$ , 1	
$c$	- , -	$h$ , -	$c$ , 1	$d$ , -	
$d$	$e$ , -	- , -	$a$ , -	$d$ , 0	
$e$	$e$ , 0	$f$ , -	- , -	$d$ , -	
$f$	$e$ , -	$f$ , 0	$a$ , -	- , -	
$g$	$g$ , 1	$h$ , -	- , -	$b$ , -	
$h$	$g$ , -	$h$ , 1	$c$ , -	- , -	

Fig. 9-39 Primitive Flow Table

<i>b</i>	<i>a, c</i> ×						
<i>c</i>	×	<i>b, d</i> ×					
<i>d</i>	<i>b, d</i> ×		×	<i>a, c</i> ×			
<i>e</i>	<i>b, d</i> ×	<i>e, g</i> × <i>b, d</i> ×	<i>f, h</i> ×	✓			
<i>f</i>	✓	<i>e, g</i> × <i>a, c</i> ×	<i>f, h</i> × <i>a, c</i> ×	✓	✓		
<i>g</i>	<i>f, h</i> ×	✓	<i>b, d</i> ×	<i>e, g</i> × <i>b, d</i> ×	×	<i>e, g</i> × <i>f, h</i> ×	
<i>h</i>	<i>f, h</i> × <i>a, c</i> ×	✓	✓	<i>d, e</i> × <i>c, f</i> ×	<i>e, g</i> × <i>f, h</i> ×	×	✓
	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>

Fig. 9-40 Implication Table



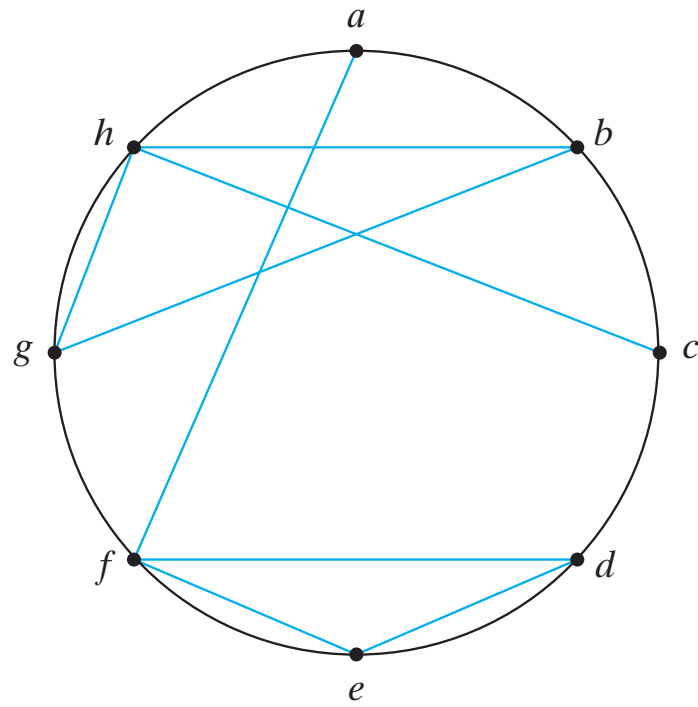


Fig. 9-41 Merger Diagram

	<i>TC</i>			
	00	01	11	10
<i>a, f</i>	<i>e</i> , -	<i>f</i> , 0	<i>a</i> , 0	<i>b</i> , -
<i>b, g, h</i>	<i>g</i> , 1	<i>h</i> , 1	<i>c</i> , -	<i>b</i> , 1
<i>c, h</i>	<i>g</i> , 1	<i>h</i> , 1	<i>c</i> , 1	<i>d</i> , -
<i>d, e, f</i>	<i>e</i> , 0	<i>f</i> , 0	<i>a</i> , -	<i>d</i> , 0

(a)

	<i>TC</i>			
	00	01	11	10
<i>a</i>	<i>d</i> , -	<i>a</i> , 0	<i>a</i> , 0	<i>b</i> , -
<i>b</i>	<i>b</i> , 1	<i>b</i> , 1	<i>c</i> , -	<i>b</i> , 1
<i>c</i>	<i>b</i> , -	<i>c</i> , 1	<i>c</i> , 1	<i>d</i> , -
<i>d</i>	<i>d</i> , 0	<i>d</i> , 0	<i>a</i> , -	<i>d</i> , 0

(b)

Fig. 9-42 Reduced Flow Table

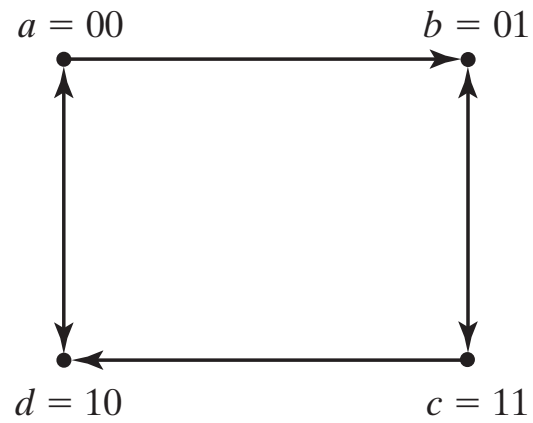


Fig. 9-43 Transition Diagram

		<i>TC</i>			
		00	01	11	10
$y_1 y_2$	$a = 00$	10	00	00	01
$b = 01$	01	01	11	01	
$c = 11$	01	11	11	10	
$d = 10$	10	10	00	10	

(a) Transition table

		<i>TC</i>			
		00	01	11	10
$y_1 y_2$	00	0	0	0	<i>X</i>
01	1	1	1	1	
11	1	1	1	<i>X</i>	
10	0	0	0	0	

(b) Output map  $Q = y_2$

Fig. 9-44 Transition Table and Output Map

*TC*

	00	01	11	10
$y_1y_2$				
00	1	0	0	0
01	0	0	1	0
11	0	X	X	X
10	X	X	0	X

(a)  $S_1 = y_2 TC + y'_2 T'C'$

*TC*

	00	01	11	10
$y_1y_2$				
00	0	X	X	X
01	X	X	0	X
11	1	0	0	0
10	0	0	1	0

(b)  $R_1 = y_2 T'C' + y'_2 TC$

*TC*

	00	01	11	10
$y_1y_2$				
00	0	0	0	1
01	X	X	X	X
11	X	X	X	0
10	0	0	0	0

(c)  $S_2 = y'_1 TC'$

*TC*

	00	01	11	10
$y_1y_2$				
00	X	X	X	0
01	0	0	0	0
11	0	0	0	1
10	X	X	X	X

(d)  $R_2 = y_1 TC'$

Fig. 9-45 Maps for Latch Inputs

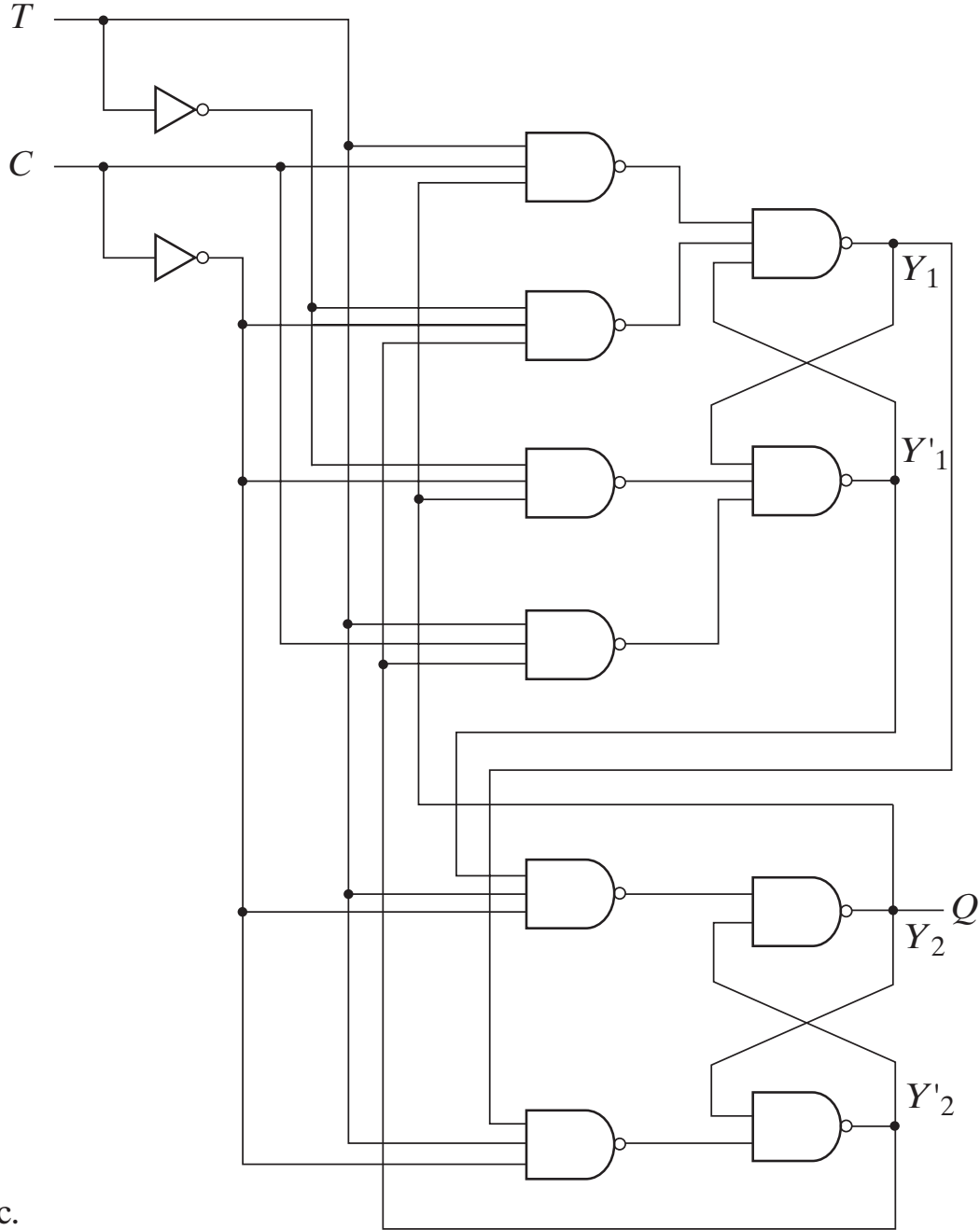


Fig. 9-46 Logic Diagram of Negative-Edge-Triggered  $T$  Flip-Flop

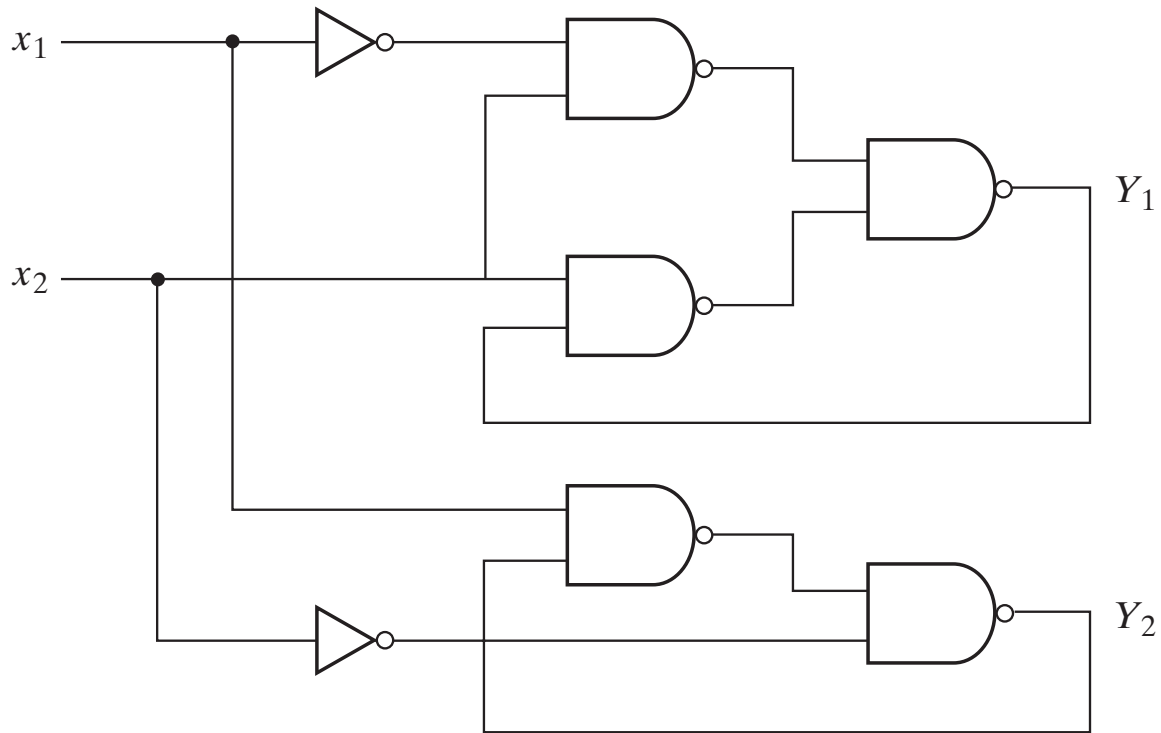


Fig. P9-2

		$x_1x_2$			
		00	01	11	10
$a$	$\textcircled{a}, 0$	$b, -$	$c, -$	$\textcircled{a}, 1$	
$b$	$a, -$	$\textcircled{b}, 0$	$\textcircled{b}, 0$	$c, -$	
$c$	$a, -$	$b, -$	$\textcircled{c}, 1$	$\textcircled{c}, 0$	

Fig. P9-5



		$x_1x_2$			
		00	01	11	10
$y_1y_2$	00	10	00	11	10
	01	01	00	10	10
	11	01	00	11	11
	10	11	00	10	10

Fig. P9-6

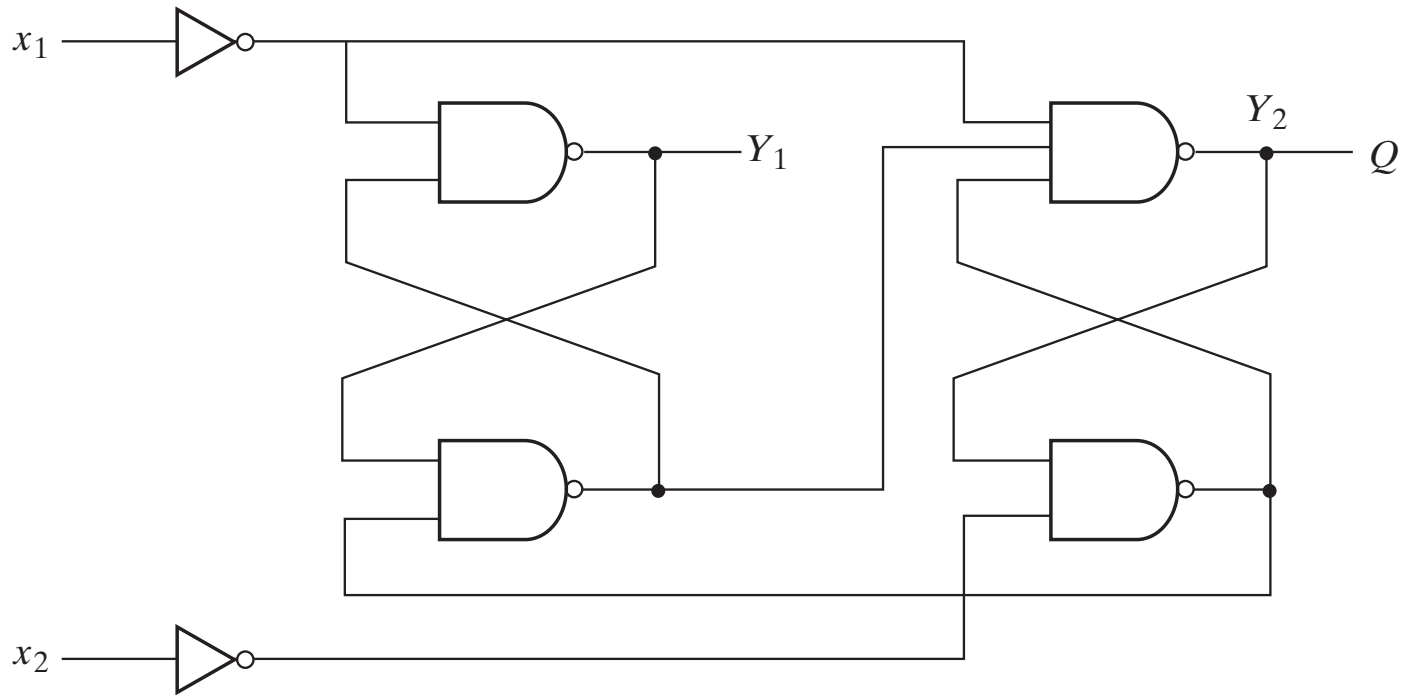


Fig. P9-9

	00	01	11	10
<i>a</i>	$\textcircled{a}, 0$	$\textcircled{a}, 1$	$b, -$	$\textcircled{a}, 1$
<i>b</i>	$a, -$	$\textcircled{b}, 0$	$\textcircled{b}, 0$	$\textcircled{b}, 0$

Fig. P9-14

	00	01	11	10
<i>a</i>	$\textcircled{a}, 0$	$b, -$	$-, -$	$d, -$
<i>b</i>	$a, -$	$\textcircled{b}, 1$	$\textcircled{b}, 1$	$c, -$
<i>c</i>	$b, -$	$-, -$	$b, -$	$\textcircled{c}, 0$
<i>d</i>	$c, -$	$\textcircled{d}, 1$	$c, -$	$\textcircled{d}, 1$

(a)

	00	01	11	10
<i>a</i>	$\textcircled{a}, 0$	$b, -$	$b, -$	$\textcircled{a}, 0$
<i>b</i>	$a, -$	$\textcircled{b}, 0$	$\textcircled{b}, 1$	$c, -$
<i>c</i>	$b, -$	$d, -$	$\textcircled{c}, 1$	$\textcircled{c}, 1$
<i>d</i>	$\textcircled{d}, 0$	$\textcircled{d}, 1$	$c, -$	$a, -$

(b)

Fig. P9-15

	00	01	11	10
<i>a</i>	$\textcircled{a}, 0$	$b, -$	$- , -$	$e , -$
<i>b</i>	$a , -$	$\textcircled{b}, 0$	$c , -$	$- , -$
<i>c</i>	$- , -$	$d , -$	$\textcircled{c}, 0$	$h , -$
<i>d</i>	$a , -$	$\textcircled{d}, 1$	$- , -$	$- , -$
<i>e</i>	$a , -$	$- , -$	$f , -$	$\textcircled{e}, 0$
<i>f</i>	$- , -$	$g , -$	$\textcircled{f}, 0$	$h , -$
<i>g</i>	$a , -$	$\textcircled{g}, 0$	$- , -$	$- , -$
<i>h</i>	$a , -$	$- , -$	$- , -$	$\textcircled{h}, 0$

(a)

	00	01	11	10
<i>a</i>	$\textcircled{a}, 1$	$f , -$	$- , -$	$e , -$
<i>b</i>	$c , -$	$- , -$	$j , -$	$\textcircled{b}, 0$
<i>c</i>	$\textcircled{c}, 0$	$d , -$	$- , -$	$b , -$
<i>d</i>	$c , -$	$\textcircled{d}, 0$	$g , -$	$- , -$
<i>e</i>	$a , -$	$- , -$	$g , -$	$\textcircled{e}, 1$
<i>f</i>	$a , -$	$\textcircled{f}, 1$	$g , -$	$- , -$
<i>g</i>	$- , -$	$d , -$	$\textcircled{g}, 0$	$k , -$
<i>h</i>	$\textcircled{h}, 0$	$d , -$	$- , -$	$k , -$
<i>j</i>	$- , -$	$f , -$	$\textcircled{j}, 1$	$b , -$
<i>k</i>	$a , -$	$- , -$	$j , 1$	$\textcircled{k}, 0$

(b)

		$x_1x_2$			
		00	01	11	10
$a$	$(a), 0$	$(a), 1$	$b, -$	$d, -$	
$b$	$a, -$	$(b), 0$	$(b), 0$	$c, -$	
$c$	$a, -$	$-, -$	$d, -$	$(c), 0$	
$d$	$a, -$	$a, -$	$(d), 1$	$(d), 1$	

Fig. P9-19

	00	01	11	10
<i>a</i>	<i>a</i>	<i>d</i>	<i>a</i>	<i>c</i>
<i>b</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>d</i>
<i>c</i>	<i>d</i>	<i>c</i>	<i>b</i>	<i>c</i>
<i>d</i>	<i>d</i>	<i>d</i>	<i>e</i>	<i>d</i>
<i>e</i>	<i>f</i>	<i>c</i>	<i>e</i>	<i>c</i>
<i>f</i>	<i>f</i>	<i>b</i>	<i>a</i>	<i>f</i>

Fig. P9-20

	00	01	11	10
<i>a</i>	<i>a</i>	<i>c</i>	<i>a</i>	<i>d</i>
<i>b</i>	<i>a</i>	<i>b</i>	<i>c</i>	<i>b</i>
<i>c</i>	<i>c</i>	<i>c</i>	<i>c</i>	<i>d</i>
<i>d</i>	<i>d</i>	<i>b</i>	<i>a</i>	<i>d</i>

Fig. P9-21