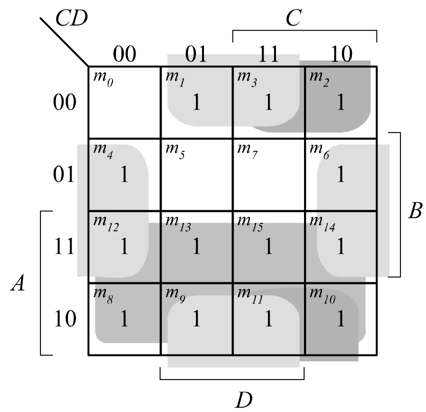
CHAPTER 4

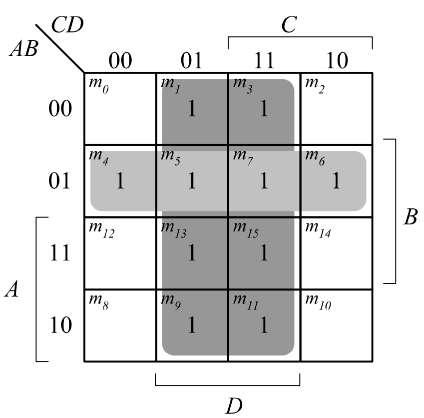
4.1 (a) $T_1 = B'C,\ T_2 = A'B,\ T_3 = A + T_1 = A + B'C,$
$T_4 = D \oplus T_2 = D \oplus (A'B) = A'BD' + D(A + B') = A'BD' + AD + B'D$
$F_1 = T_3 + T_4 = A + B'C + A'BD' + AD + B'D$
With $A + AD = A$ and $A + A'BD' = A + BD'$:
$F_1 = A + B'C + BD' + B'D$
Alternative cover: $F_1 = A + CD' + BD' + B'D$

$F_2 = T_2 + D = A'B + D$

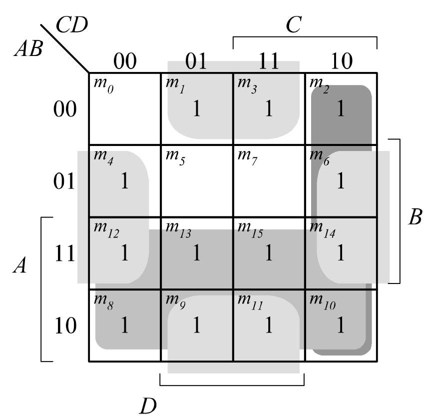
$ABCD$	T_1	T_2	T_3	T_4	F_1	F_2
0000	0	0	0	0	0	0
0001	0	0	0	1	1	1
0010	1	0	1	0	1	0
0011	1	0	1	1	1	1
0100	0	1	0	1	1	1
0101	0	1	0	0	0	1
0110	0	1	0	1	1	1
0111	0	1	0	0	0	1
1000	0	0	1	0	1	0
1001	0	0	1	1	1	1
1010	1	0	1	0	1	0
1011	1	0	1	1	1	1
1100	0	0	1	0	1	0
1101	0	0	1	1	1	1
1110	0	0	1	0	1	0
1111	0	0	1	1	1	1



$F_1 = A + B'C + B'D + BD'$



$F_2 = A'B + D$



$F_1 = A + CD' + B'D + BD'$

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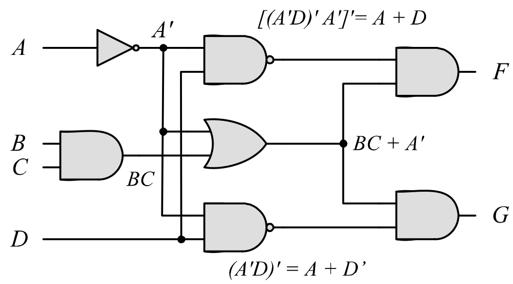
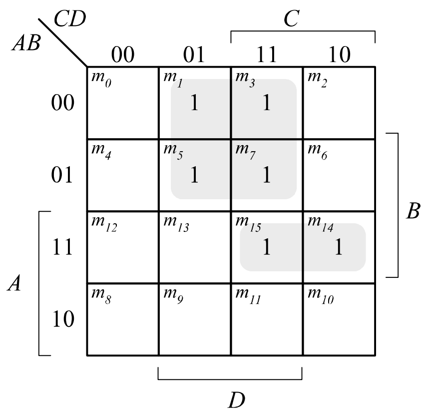
4.2

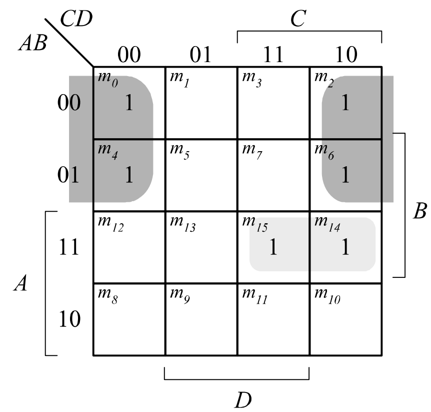


$F = (A + D)(A' + BC) = A'D + ABC + BCD += A'D + ABC$

$F = (A + D')(A' + BC) = A'D' + ABC + BCD' = A'D' + ABC$



$F = A'D + ABC + BCD = A'D + ABC$



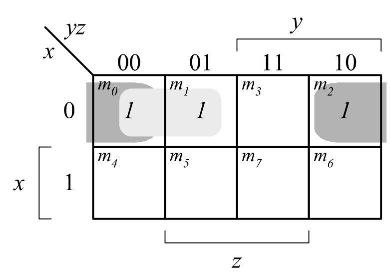
$G = A'D' + ABC + BCD' = A'D' + ABC$

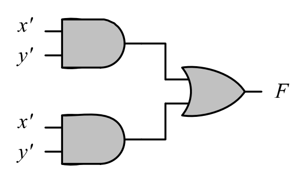
4.3 **(a)** $Y_i = (A_iS' + B_iS)E'$ *for* $i = 0, 1, 2, 3$

(b) 1024 rows and 14 columns

4.4 **(a)**

xyz	F
000	1
001	1
010	1
011	0
100	0
101	0
110	0
111	0





$F = x'y' + x'z'$

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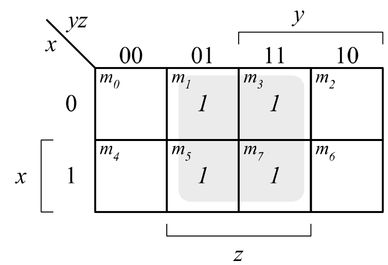
(b)

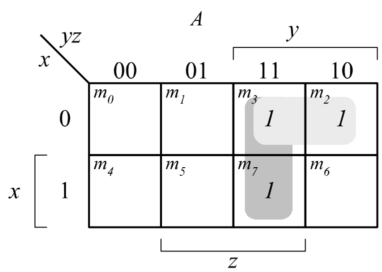
xyz	F
000	0
001	1
010	0
011	0
100	0
101	0
110	0
111	0



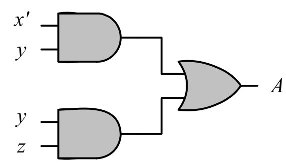
$F = z$

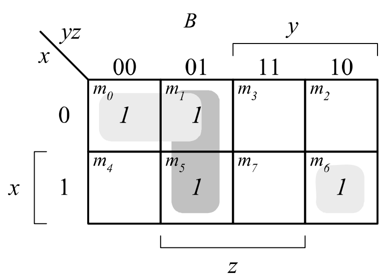
4.5

xyz	ABC
000	010
001	011
010	100
011	101
100	001
101	010
110	011
111	100

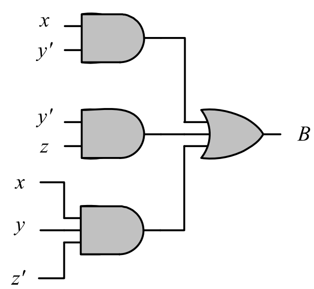


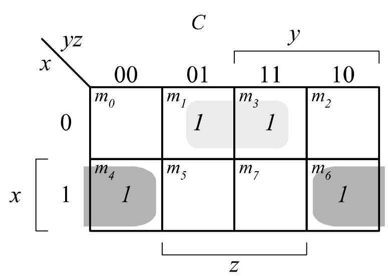
$A = x'y + yz$



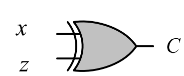


$B = x'y' + y'z + xyz'$



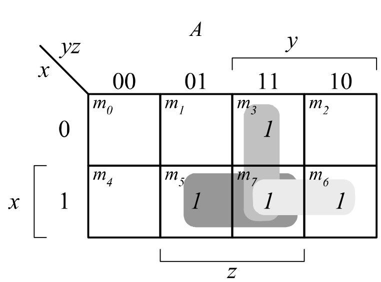


$C = x'z + xz'$

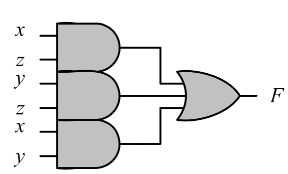


4.6

xyz	F
000	0
001	0
010	0
011	1
100	0
101	1
110	1
111	1



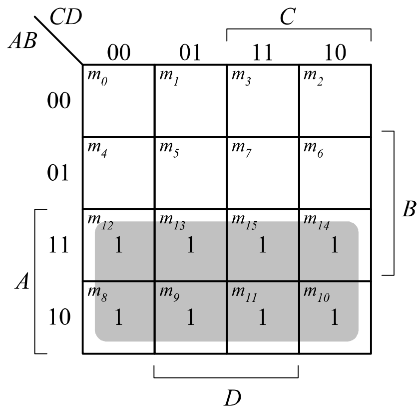
$F = xz + yz + xy$



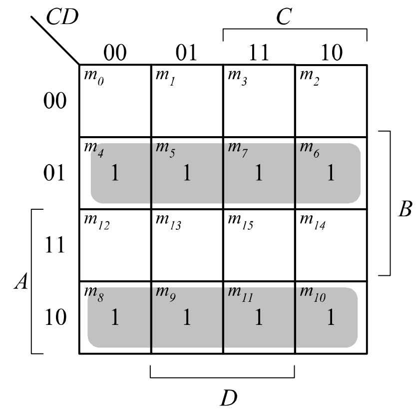
```
module Prob_4_6 (output F, input x, y, z);
  assign F = (x & z) | (y & z) | (x & y);
endmodule
```

4.7 **(a)**

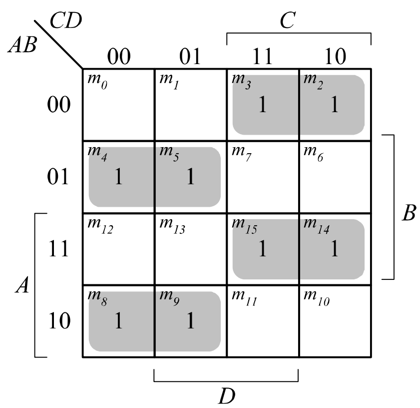
ABCD	wxyz
0000	0000
0001	0001
0011	0010
0010	0011
0110	0100
0111	0101
0101	0110
0100	0111
1100	1000
1101	1001
1111	1010
1110	1011
1010	1100
1011	1101
1001	1110
1000	1111



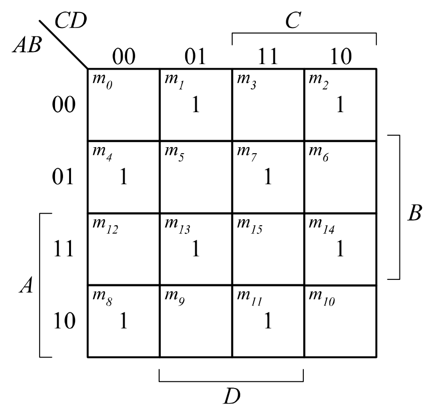
$w = A$



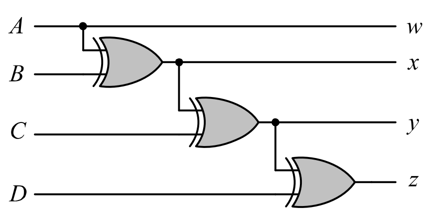
$x = AB' + A'B = A \oplus B$



$y = A'B'C \; A'BC' + ABC + AB'C'$
$= A'(A \oplus B) + A(B \oplus C)'$
$= A \oplus B \oplus C$
$= X \oplus C$



$z = A \oplus B \oplus C \oplus D$
$= y \oplus D$



(b)

```
module Prob_4_7(output w, x, y, z, input A, B, C, D);
  always @ (A, B, C, D)
    case ({A, B, C, D})
      4'b0000:       {w, x, y, z} = 4'b0000;
```

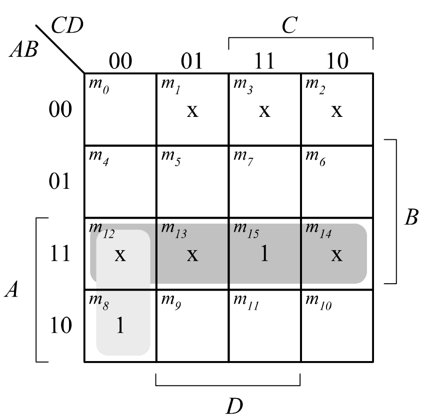
```
        4'b0001:     {w, x, y, z} = 4'b1111;
        4'b0010:     {w, x, y, z} = 4'b1110;
        4'b0011:     {w, x, y, z} = 4'b1101;
        4'b0100:     {w, x, y, z} = 4'b1100;
        4'b0101:     {w, x, y, z} = 4'b1011;
        4'b0110:     {w, x, y, z} = 4'b1010;
        4'b0111:     {w, x, y, z} = 4'b1001;

        4'b1000:     {w, x, y, z} = 4'b1000;
        4'b1001:     {w, x, y, z} = 4'b0111;
        4'b1010:     {w, x, y, z} = 4'b0110;
        4'b1011:     {w, x, y, z} = 4'b0101;
        4'b1100:     {w, x, y, z} = 4'b0100;
        4'b1101:     {w, x, y, z} = 4'b0011;
        4'b1110:     {w, x, y, z} = 4'b0010;
        4'b1111:     {w, x, y, z} = 4'b0001;
      endcase
    endmodule
```

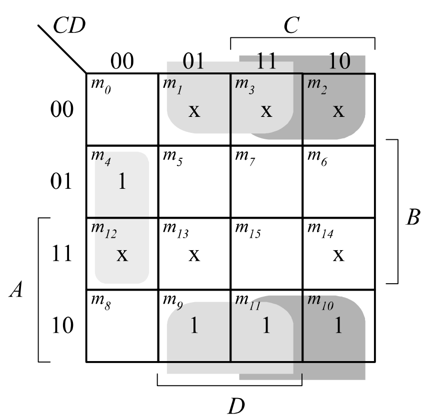
Alternative model:

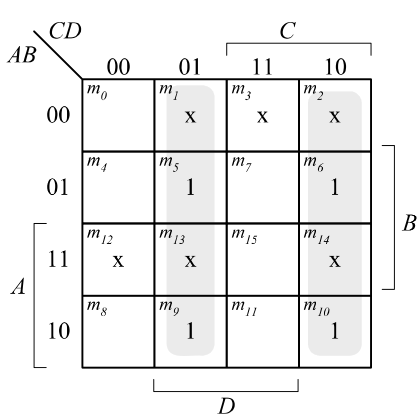
```
    module Prob_4_7(output w, x, y, z, input A, B, C, D);
      assign w = A;
      assign x = A ^ B);
      assign y = x ^ C;
      assign z = y ^ D;
    endmodule
```

4.8

ABCD	*wxyz*
0000	0000
0001	0001
0011	0010
0010	0011
0110	0100
0111	0101
0101	0110
0100	0111
1100	1000
1101	1001
1111	1010
1110	1011
1010	1100
1011	1101
1001	1110
1000	1111







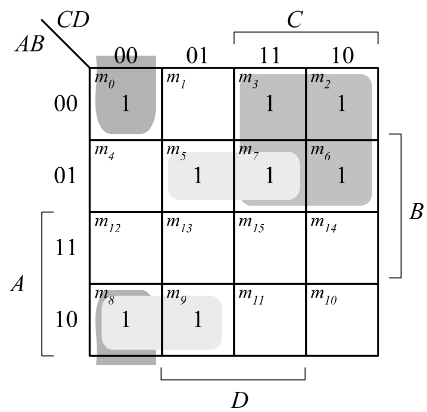
$w = AB+AC'D'$
$x = B'C + B'D +BC'D'$
$y = CD' +C'D$
$z = D$

Alternative model:

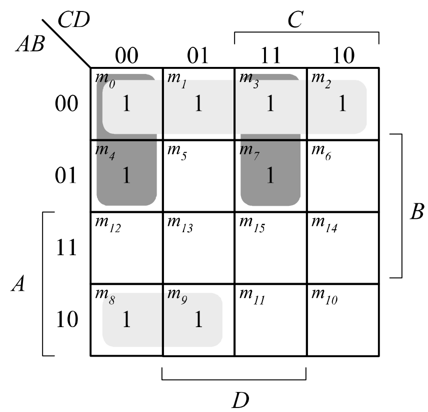
```
module Prob_4_8(output w, x, y, z, input A, B, C, D);
  assign w = (A&B) | (A & (~C)) & (~D) ;
  assign x = ( (~B) & C)  | ((~B) & D) | (B & (~C)) & (~D);
  assign y = C ^ D;
  assign z = D;
endmodule
```

4.9

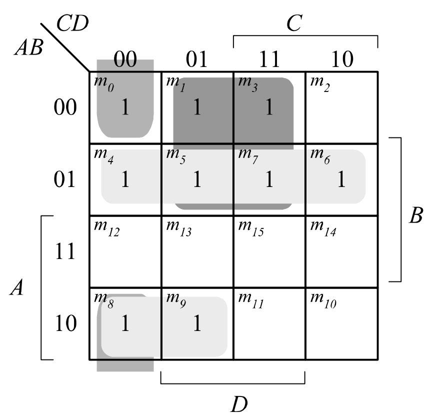
ABCD	*a*	*b*	*c*	*d*	*e*	*f*	*g*
0000	1	1	1	1	1	1	0
0001	0	1	1	0	0	0	0
0010	1	1	0	1	1	0	1
0011	1	1	1	1	0	0	1
0100	0	1	1	0	0	1	1
0101	1	0	1	1	0	1	1
0110	1	0	1	1	1	1	1
0111	1	1	1	0	0	0	0
1000	1	1	1	1	1	1	1
1001	1	1	1	1	0	1	1



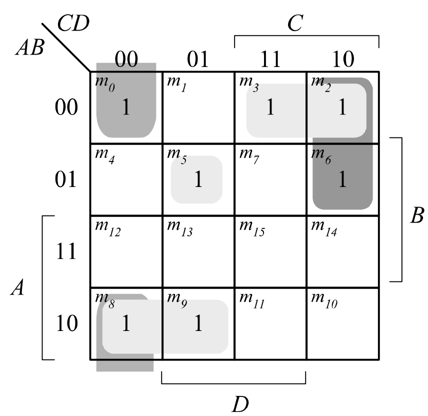
a = A'C + A'BD + B'C'D' + AB'C'



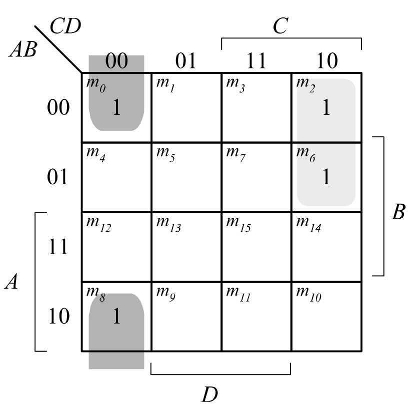
b = A'B' + A'C'D' + A'CD + AB'C'



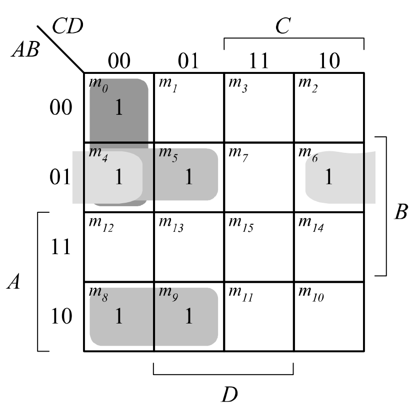
c = A'B + A'D + B'C'D' + AB'C'



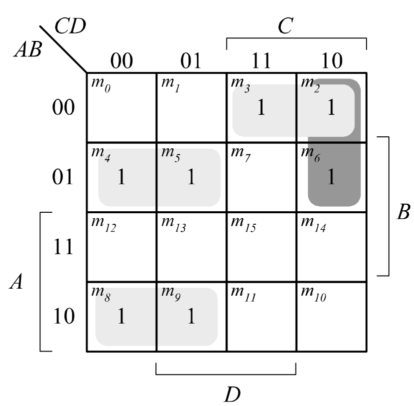
d = A'CD' + A'B' C+ B'C'D' + AB'C' + A'BC'D



e = A'CD' + B'C'D'



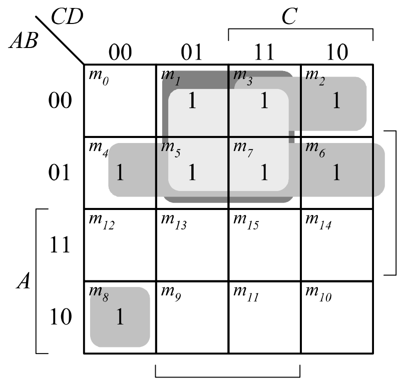
f = A'BC' + A'C'D' + A'BD + AB'C'



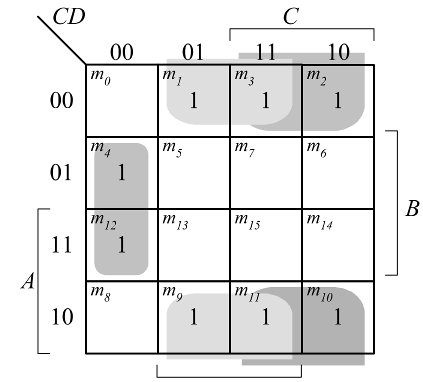
g = A'CD' + A'B'C + A'BC' + AB'C'

4.10

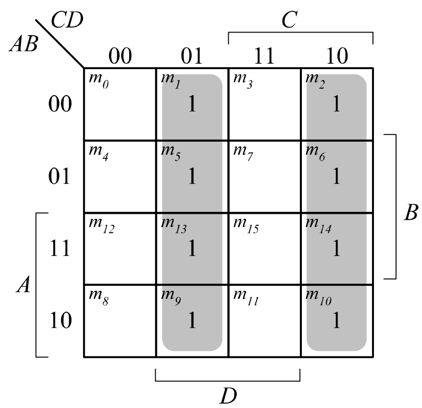
ABCD	wxyz
0000	0000
0001	1111
0010	1110
0011	1101
0100	1100
0101	1011
0110	1001
0111	1000
1000	1000
1001	0111
1010	0110
1011	0101
1100	0100
1101	0011
1110	0010
1111	0001



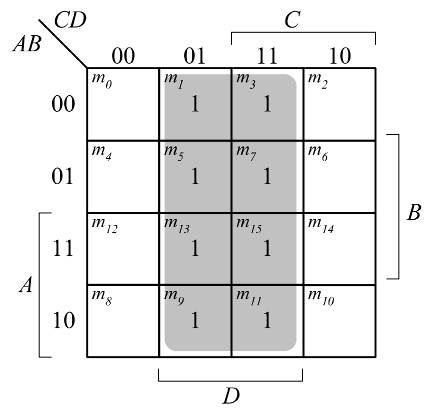
$w = A'(B + C + D) + AB'C'D'$
$= A \oplus (B + C + D)$



$x = B'(C + D) + CB'D'$
$= B \oplus (C + D)$



$y = CD' + C'D = C \oplus D$

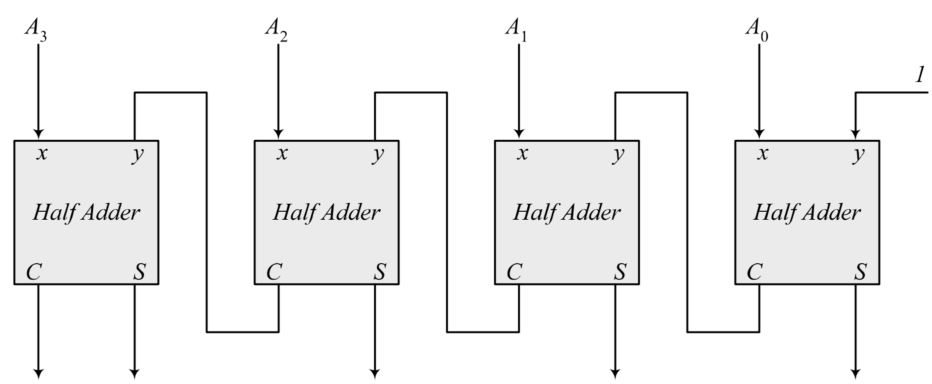


$z = D$

For a 5-bit 2's complementer with input E and output v:

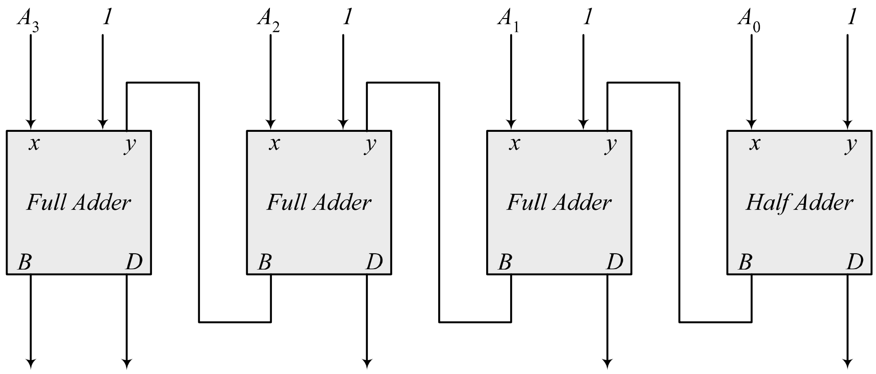
$v = E \oplus (A + B + C + D)$

4.11 **(a)**



Note: 5-bit output

(b)



Note: To decrement the 4-bit number, add -1 to the number. In 2's complement format (add F_h) to the number. An attempt to decrement 0 will assert the borrow bit. For waveforms, see solution to Problem 4.52.

4.12

(a)

x	y	B	D
0	0	0	0
0	1	1	1
1	0	0	1
1	1	0	0

$D = x'y + xy'$
$B = x'y$

(b)

x	y	B_{in}	B	D
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	1	0
1	0	0	0	1
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

$Diff = x \oplus y \oplus z$
$B_{out} = x'y + x'z + yz$

4.13

	Sum	C	V
(a)	1101	0	1
(b)	0001	1	1
(c)	0100	1	0
(d)	1011	0	1
(e)	1111	0	0

4.14 xor AND OR XOR

10 + 5 + 5 + 10 = 30 ns

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4.15 $C_4 = G_3 + P_3C_3 = G_3 + P_3(G_2 + P_2G_1 + P_2P_1G_0 + P_2P_1P_0C_0)$

$= G_3 + P_3G_2 + P_3P_2G_1 + P_3P_2P_1G_0 + P_3P_2P_1P_0C_0$

4.16 **(a)**

$(C'G'_i + p'_i)' = (C_i + G_i)P_i = G_iP_i + P_iC_i$
$= A_iB_i(A_i + B_i) + P_iC_i$
$= A_iB_i + P_iC_i = G_i + P_iC_i$
$= A_iB_i + (A_i + B_i)C_i = A_iB_i + A_iC_i + B_iC_i = C_{i+1}$
$(P_iG'_i) \oplus C_i = (A_i + B_i)(A_iB_i)' \oplus C_i = (A_i + Bi)(A'_i + B'_i) \oplus C_i$
$= (A'_iB_i + A_iB'_i) \oplus C_i = A_i \oplus B_i \oplus C_i = S_i$

(b)

Output of NOR gate = $(A_0 + B_0)' = P'_0$
Output of NAND gate = $(A_0B_0)' = G'_0$
$S_1 = (P_0G'_0) \oplus C_0$
$C_1 = (C'_0G'_0 + P'_0)'$ as defined in part (a)

4.17 **(a)**
$(C'_iG'_i + P'_i)' = (C_i + G_i)P_i = G_iP_i + P_iC_i = A_iB_i(A_i + B_i) + P_iC_i$
$= A_iB_i + P_iC_i = G_i + P_iC_i$
$= A_iB_i + (A_i + B_i)C_i = A_iB_i + A_iC_i + B_iC_i = C_{i+1}$

$(P_iG'_i) \oplus C_i = (A_i + B_i)(A_iB_i)' \oplus C_i = (A_i + B_i)(A'_i + B'_i) \oplus C_i$
$= (A'_iB_i + A_iB'_i) \oplus C_i = A_i \oplus B_i \oplus C_i = S_i$
(b)
Output of NOR gate = $(A_0 + B_0)' = P'_0$
Output of NAND gate = $(A_0B_0)' = G'_0$

$S_0 = (P_0G'_0) \oplus C_0$
$C_1 = (C'_0G'_0 + P'_0)'$ as defined in part (a)

4.18

Inputs *ABCD*	Outputs *wxyz*
0000	1001
0001	1000
0010	0111
0011	0110
0100	0101
0101	0100
0110	0011
0111	0010
1000	0001
1001	0000

$d(A, b, c, d) = \Sigma(10, 11, 12, 13, 14, 15)$

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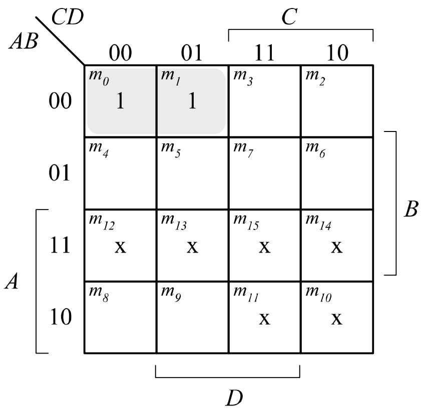
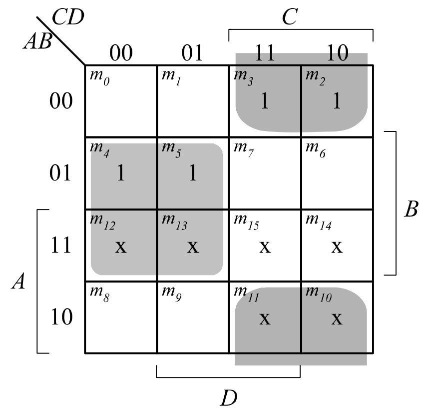
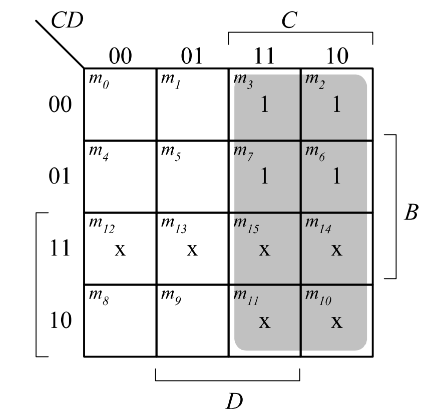


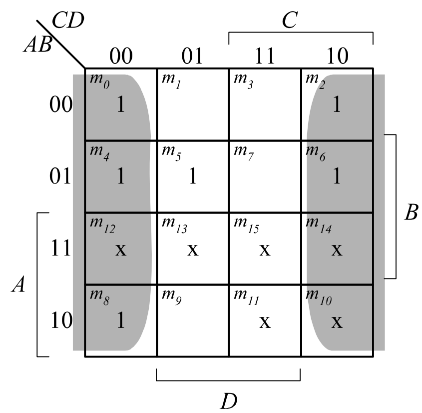
$w = A'B'C'$



$x = BC' + B'C = B \oplus C$

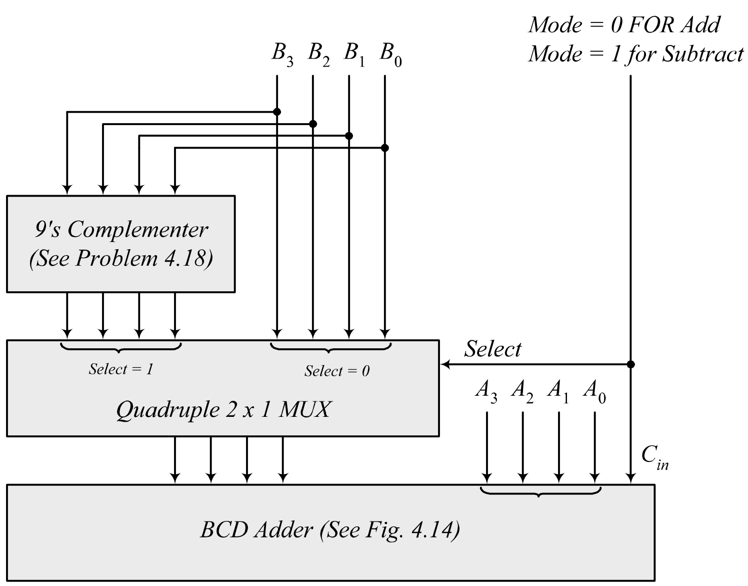


$y = C$

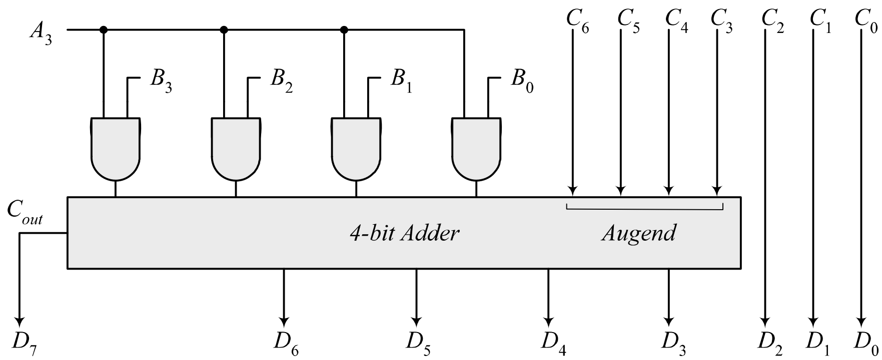


$z = D'$

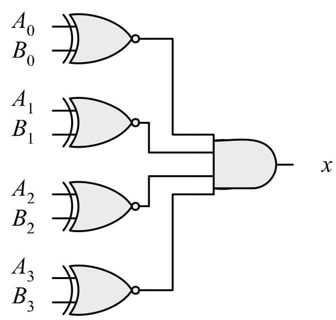
4.19



4.20 Combine the following circuit with the 4-bit binary multiplier circuit of Fig. 4.16.



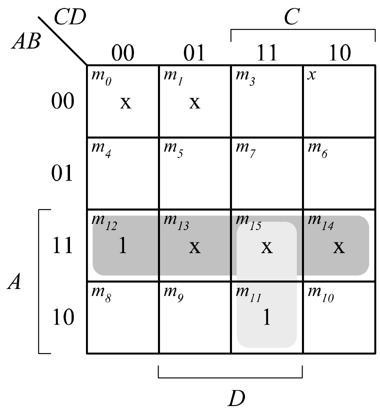
4.21



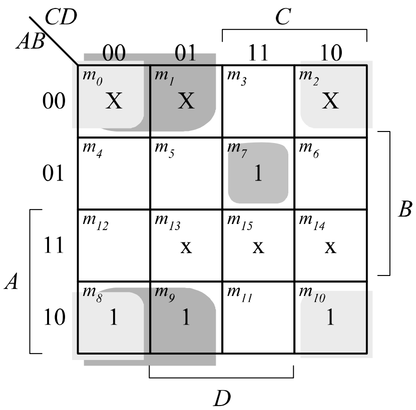
$$x = (A_0 \oplus B_0)'(A_1 \oplus B_1)'(A_2 \oplus B_2)'(A_3 \oplus B_3)'$$

4.22

XS-3 *ABCD*	Binary *wxyz*
0011	0000
0100	0001
0101	0010
0110	0011
0111	0100
1000	0101
1001	0110
1010	0111
1011	1000
1100	1001

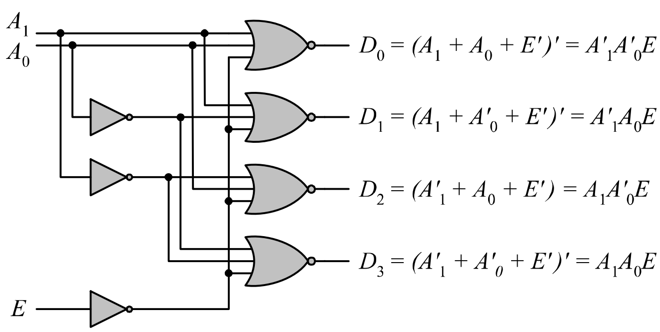


$w = AB + ACD$



$x = B'C' + B'D' + BCD$
$y = C'D + CD'$
$z = D'$

4.23

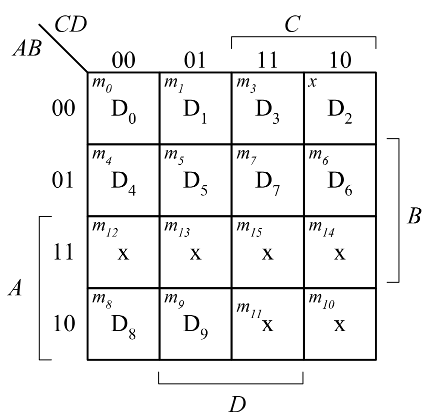


4.24

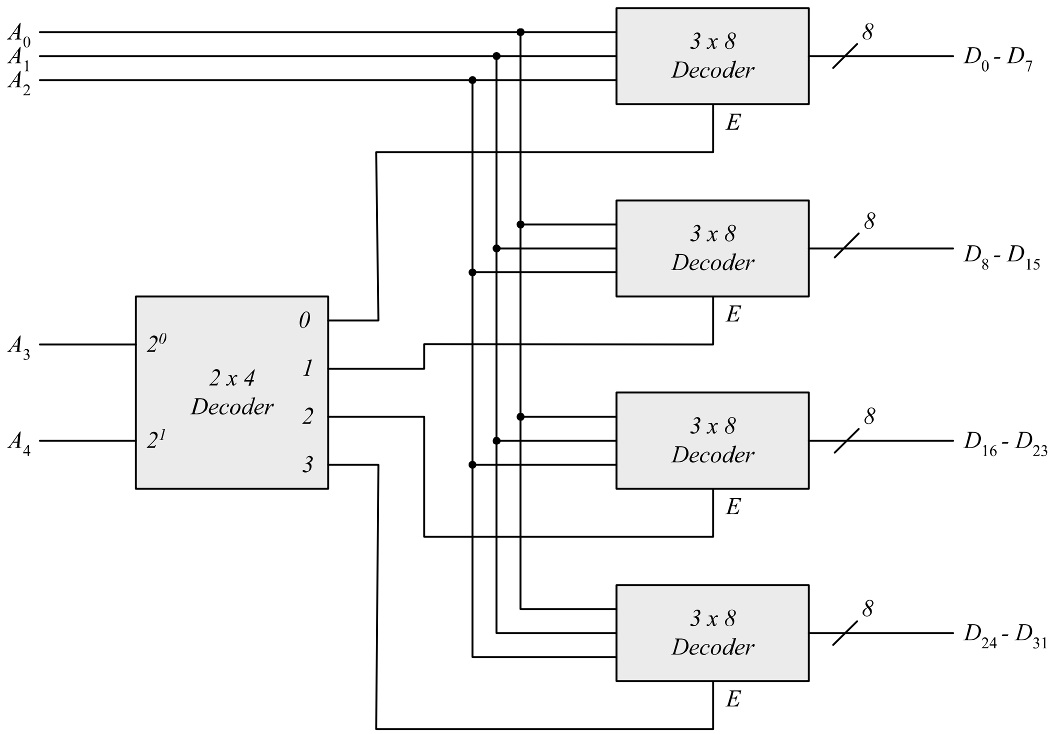
Inputs: A, B, C, D

Outputs: $D_0, D_1, \ldots D_9$

$D_0 = A'B'C'D'$
$D_1 = A'B'C'D$
$D_2 = B'CD'$
$D_3 = B'CD$
$D_4 = BC'D'$
$D_5 = BC'D$
$D_6 = BCD'$
$D_7 = BCD$
$D_8 = AD'$
$D_9 = AD$

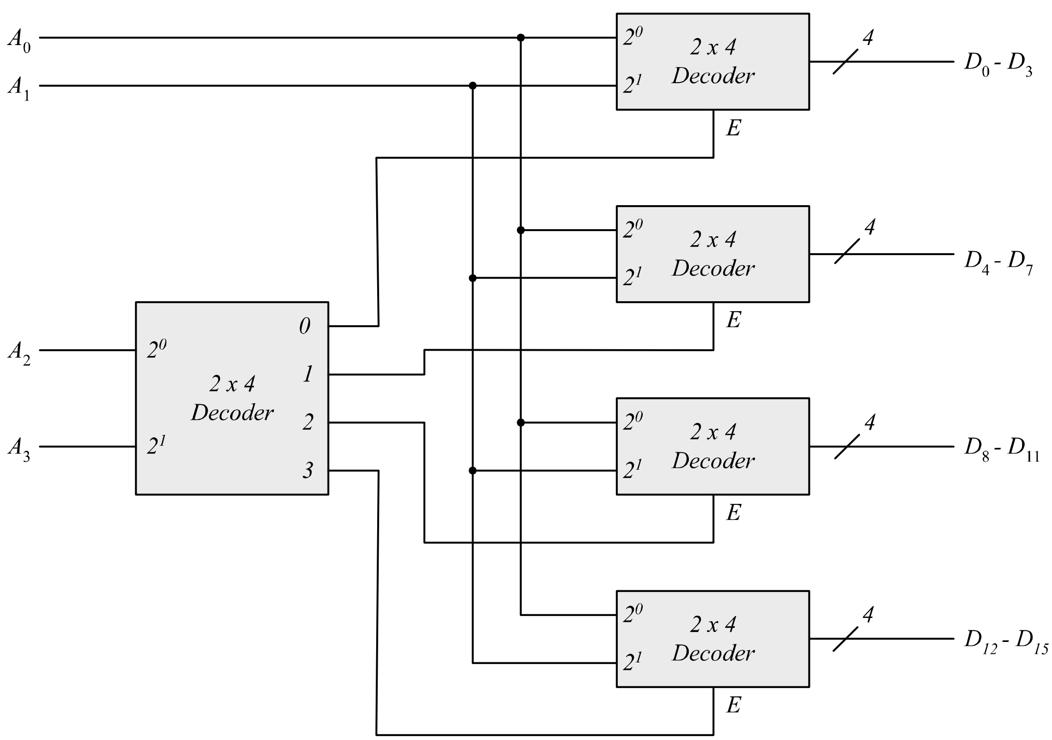


4.25



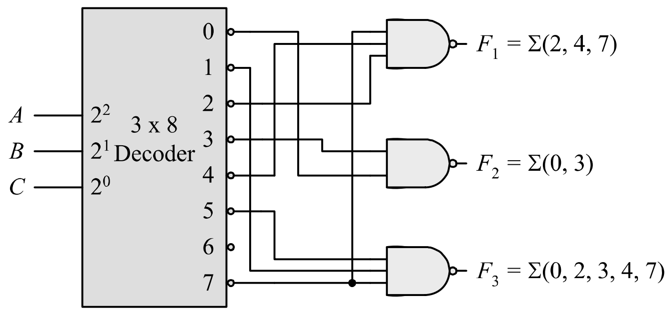
A_0
A_1
A_2
A_3
A_4
2^0
2^1
2 x 4 Decoder
0
1
2
3
3 x 8 Decoder
E
8
D_0 - D_7
D_8 - D_{15}
D_{16} - D_{23}
D_{24} - D_{31}

4.26



A_0
A_1
A_2
A_3
2^0
2^1
2 x 4 Decoder
0
1
2
3
E
4
D_0 - D_3
D_4 - D_7
D_8 - D_{11}
D_{12} - D_{15}

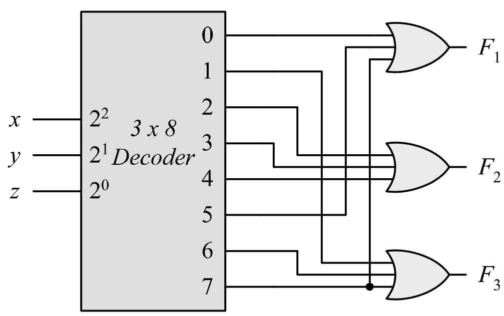
4.27



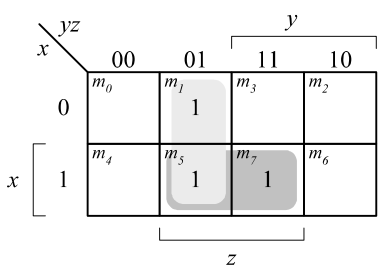
$(F'_3 = \Sigma(1, 5, 6))$

4.28 **(a)**

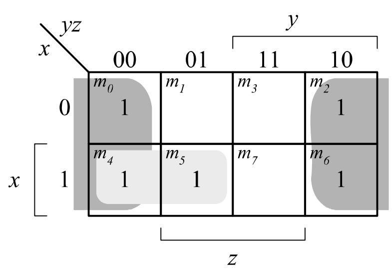
$$F_1 = x(y + y')z = x'y'z' = \Sigma(0, 5, 7)$$
$$F_2 = xy'z' + x'y + x'y(z + z') = \Sigma(2, 3, 4)$$
$$F_3 = x'y'z + xy(z + z') = \Sigma(1, 6, 7)$$



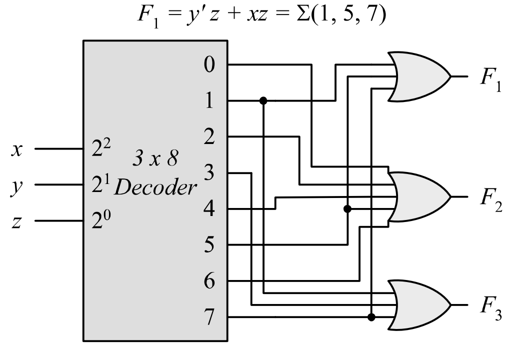
(b)

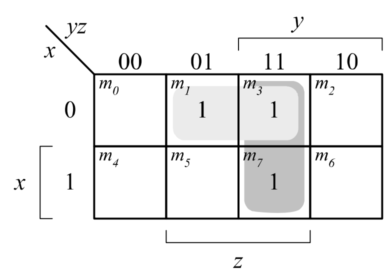


$F_1 = y'z + xz = \Sigma(1, 5, 7)$



$F_2 = y'z' + xy' + yz' = \Sigma(0, 2, 4, 5, 6)$





$F_3 = x'z + yz = \Sigma(1, 3, 7)$

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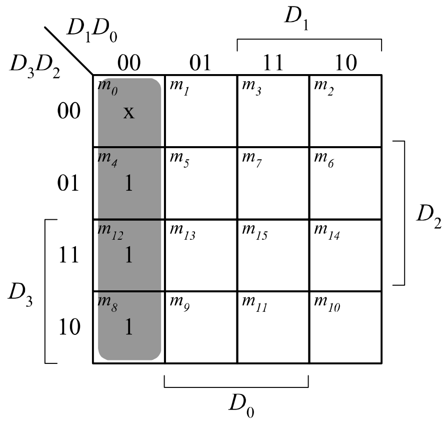
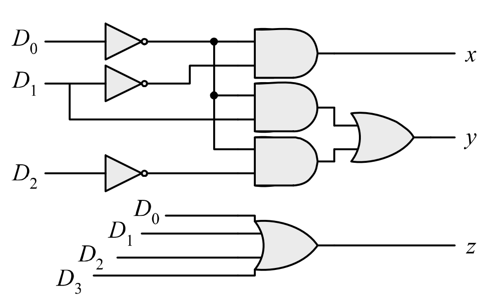
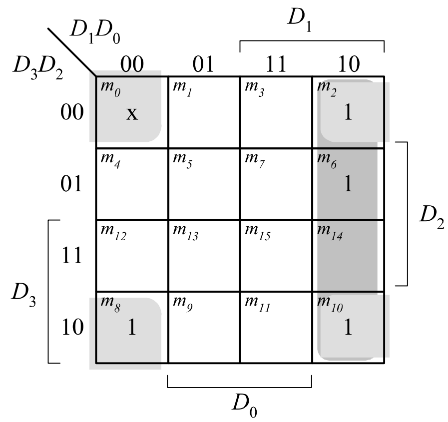
4.29

Inputs D_3	D_2	D_1	D_0	Outputs X	Y	Z
0	0	0	0	x	x	0
x	x	x	1	0	0	1
x	x	1	0	0	1	1
x	1	0	0	1	0	1
1	0	0	0	1	1	1



$v = D_0 + D_1 + D_2 + D_3$





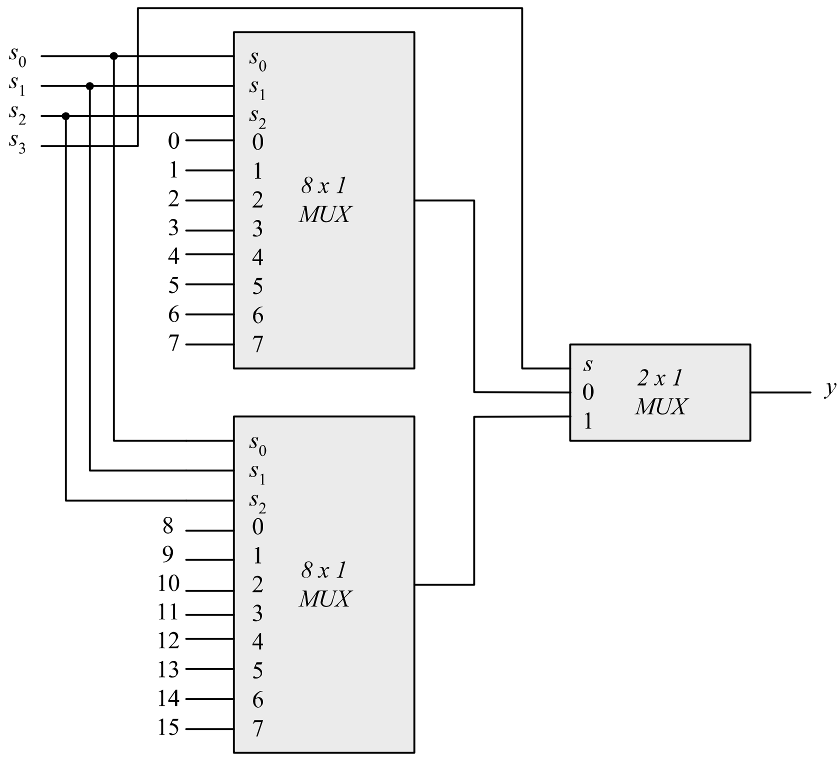
$y = D'_0D_1 + D'_0D'_2$

4.30

Inputs D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Outputs x	y	z	V
0	0	0	0	0	0	0	0	x	x	x	0
1	0	0	0	0	0	0	0	0	0	0	1
x	1	0	0	0	0	0	0	0	0	1	1
x	x	1	0	0	0	0	0	0	1	0	1
x	x	x	1	0	0	0	0	0	1	1	1
x	x	x	x	1	0	0	0	1	0	0	1
x	x	x	x	x	1	0	0	1	0	1	1
x	x	x	x	x	x	1	0	1	0	0	1
x	x	x	x	x	x	x	1	1	1	1	1

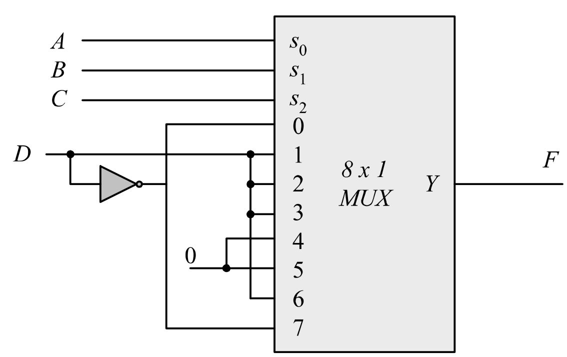
If $D_2 = 1$, $D_6 = 1$, all others = 0
Output xyz = 100 and V = 1

4.31



4.32 **(a)** $F = \Sigma\,(0, 2, 5, 7, 11, 14)$

Inputs ABCD	F	
0000	1	$F = D'$
0001	0	
0010	1	$F = D$
0011	0	
0100	0	$F = D$
0101	1	
0110	0	$F = D$
0111	1	
1000	0	$F = 0$
1001	0	
1010	0	$F = 0$
1011	0	
1100	0	$F = D$
1101	1	
1110	1	$F = D'$
1111	0	



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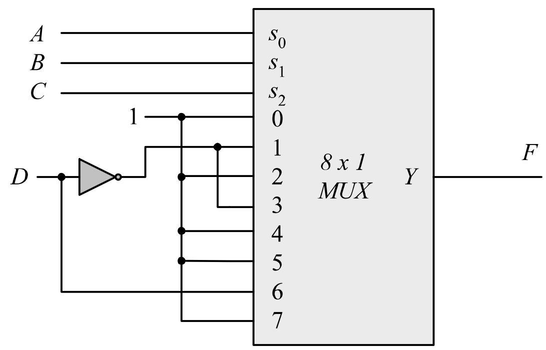
(b) $F = \Pi\,(3, 8, 12) = (A' + B' + C + D)(A + B' + C' + D')(A + B + C' + D')$
$F' = ABC'D' + A'BCD + A'B'CD = \Sigma(12, 7, 3)$
$F = \Sigma(0, 1, 2, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15)$

Inputs ABCD	F	
0000	1	$F = 1$
0001	1	
0010	1	$F = D'$
0011	0	
0100	1	$F = 1$
0101	1	
0110	1	$F = D'$
0111	0	
1000	1	$F = 1$
1001	1	
1010	1	$F = 1$
1011	1	
1100	0	$F = D$
1101	1	
1110	1	$F = 1$
1111	1	

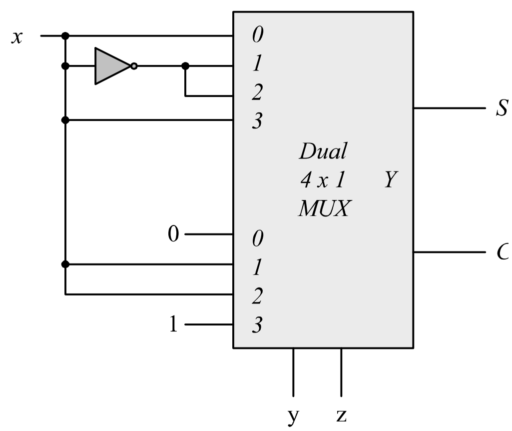


4.33

$S(x, y, z) = \Sigma(1, 2, 4, 7)$
$C(x, y, z) = \Sigma(3, 5, 6, 7)$

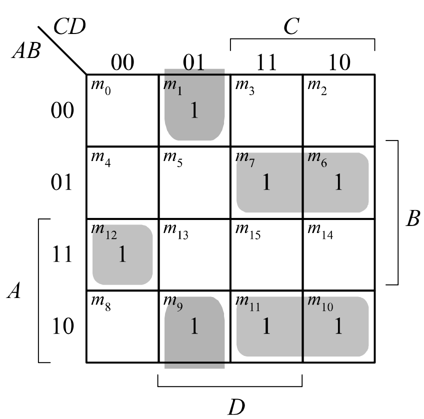
S	I_0	I_1	I_2	I_3
x'	0	1	2	3
x	4	5	6	7
	x	x'	x'	x

C	I_0	I_1	I_2	I_3
x'	0	1	2	3
x	4	5	6	7
	0	x'	x'	1



4.34 **(a)**

	A	B	C	D	F
$I_3 = 1$	0	1	1	0	1
	0	1	1	1	1
$I_5 = 1$	1	0	1	0	1
	1	0	1	1	1
$I_0 = D$	0	0	0	0	0
	0	0	0	1	1
$I_4 = D$	1	0	0	0	0
	1	0	0	1	1
$I_6 = D'$	1	1	0	0	1
	1	1	0	1	0



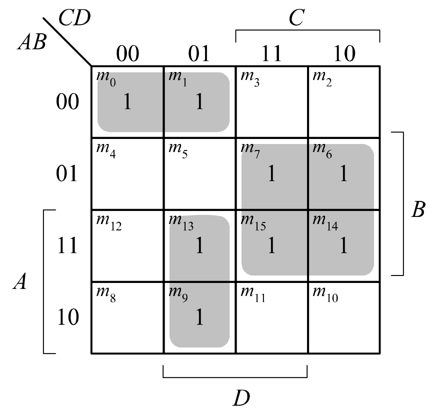
Other minterms = 0
since $I_1 = I_2 = I_7 = 0$

$F(A, B, C, D) = \Sigma(1, 6, 7, 9, 10, 11, 12)$

(b)

	A	B	C	D	F
$I_1 = 0$	0	0	1	0	0
	0	0	1	1	0
$I_2 = 0$	0	1	0	0	0
	0	1	0	1	0
$I_3 = 1$	0	1	1	0	1
	0	1	1	1	1
$I_7 = 1$	1	1	1	0	1
	1	1	1	1	1
$I_4 = D$	1	0	0	0	0
	1	0	0	1	1
$I_0 = D'$	0	0	0	0	1
	0	0	0	1	0
$I_6 = D'$	1	1	0	0	1
	1	1	0	1	0

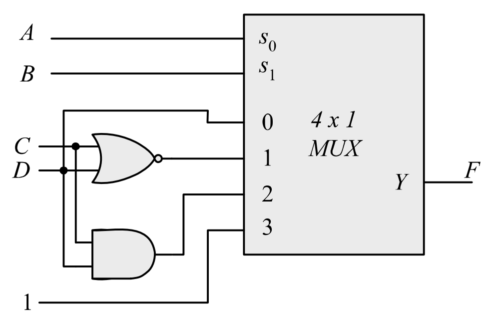
Other minterms = 0
since $I_1 = I_2 = 0$



$F(A, B, C, D) = \Sigma(0, 1, 6, 7, 9, 13, 14, 15)$

4.35 **(a)**

Inputs ABCD	F	
0000	0	
0001	1	$AB = 00$
0010	0	$F = D$
0011	1	
0100	1	$AB = 01$
0101	0	$F = C'D'$
0110	0	$= (C + D)'$
0111	0	
1000	0	
1001	0	$AB = 10$
1010	0	$F = CD$
1011	1	
1100	1	$AB = 11$
1101	1	$F = 1$
1110	1	
1111	1	



(b)

Inputs ABCD	F	
0000	0	
0001	1	$AB = 00$
0010	1	$F = C'D + CD'$
0011	0	
0100	1	$AB = 01$
0101	0	$F = C'D' + CD$
0110	0	
0111	1	
1000	1	
1001	1	$AB = 10$
1010	1	$F = 1$
1011	1	
1100	0	$AB = 11$
1101	1	$F = D$
1110	0	
1111	1