SOLUTIONS MANUAL

PART 1: CHAPTERS 1-5

Rev 10/02/2018

DIGITAL DESIGN

WITH AN INTRODUCTION to the VERILOG HDL, VHDL, and SystemVerilog
Sixth Edition

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Note: Solutions to problems requiring HDL code are presented in Verilog and VHDL

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CHAPTER 1

1.1 Base-10: 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Octal: 16 17 20 21 22 23 24 25 26 27 30 31 32 33 34 35 36 37 40
Hex: 10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F 20

Base-10: 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Base-12 8 9 0A 0B 10 11 12 13 14 15 16 17 18 19 1A 1B 20 21 22 23

24

1.2 **(a)** 32,768 **(b)** 67,108,864 **(c)** 6,871,947,674

1.3 $(4310)_5 = 4 * 5^3 + 3 * 5^2 + 1 * 5^1 = 580_{10}$

$(198)_{12} = 1 * 12^2 + 9 * 12^1 + 8 * 12^0 = 260_{10}$

$(445)_8 = 4 * 8^2 + 4 * 8^1 + 5 * 8^0 = 293_{10}$

$(345)_6 = 3 * 6^2 + 4 * 6^1 + 5 * 6^0 = 137_{10}$

1.4 16-bit binary: 1111_1111_1111_1111
Decimal equivalent: $2^{16} - 1 = 65{,}535_{10}$
Hexadecimal equivalent: $FFFF_{16}$

1.5 Let b = base

(a) 14/2 = (b + 4)/2 = 5, so b = 6

(b) 56/4 = (5*b + 6)/4 = 15 = 1*b + 5, so 5*b + 6 = 4*(1*b + 5) = 4*b + 20 so b = 14

(c) 32 + 12 = 28, 3*b + 2 + 1*b + 2 = 2*b + 8
4*b + 4 = 2*b + 8, 2*b = 4, so b = 2

1.6 $(x – 3)(x – 6) = x^2 –(6 + 3)x + 6*3 = x^2 -11x + 22$

Therefore: 6 + 3 = b + 1, so b = 8
Also, $6*3 = (18)_{10} = (22)_8$

1.7 $64CD_{16} = 0110\_0100\_1100\_1101_2 = 110\_010\_011\_001\_101 = (62315)_8$

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1.8 **(a)** Results of repeated division by 2 (quotients are followed by remainders):

431_{10} = 215(1); 107(1); 53(1); 26(1); 13(0); 6(1) 3(0) 1(1)
Answer: $1111\_1010_2 = FA_{16}$

(b) Results of repeated division by 16:

431_{10} = 26(15); 1(10) (Faster)
Answer: FA = 1111_1010

1.9 **(a)** $10110.0101_2 = 16 + 4 + 2 + .25 + .0625 = 22.3125$

(b) $16.5_{16} = 16 + 6 + 5*(.0615) = 22.3125$

(c) $26.24_8 = 2 * 8 + 6 + 2/8 + 4/64 = 22.3125$

(d) $DABA.B_{16} = 13*16^3 + 10*16^2 + 11*16 + 10 + 11/16 = 55{,}994.6875$

(e) $1011.1001_2 = 8 + 2 + 1 + .5 + .0625 = 11.5625$

1.10 **(a)** $1.10010_2 = 0001.1001_2 = 1.9_{16} = 1 + 9/16 = 1.563_{10}$

(b) $110.010_2 = 0110.0100_2 = 6.4_{16} = 6 + 4/16 = 6.25_{10}$

Reason: 110.010_2 is the same as 1.10010_2 shifted to the left by two places.

1.11

```
     1011.11
101 | 111011.0000
      101
     01001
       101
       1001
        101
        1000
         101
         0110
```

The quotient is carried to two decimal places, giving 1011.11
Checking: $111011_2 / 101_2 = 59_{10} / 5_{10} \cong 1011.11_2 = 58.75_{10}$

1.12 **(a)** 10000 and 110111

1011 1011

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```
     +101              x101
    10000 = 16_10       1011
                      1011
                      110111 = 55_10
```

(b) 62_h and 958_h

```
 2E_h  0010_1110          2E_h
+34_h  0011_0100          x34_h
 62_h  0110_0010 = 98_10   B^3 8
                         8^2 A
                         9 5 8_h = 2392_10
```

1.13 **(a)** Convert 27.315 to binary:

	Integer Quotient		Remainder	Coefficient
27/2 =	13	+	½	$a_0 = 1$
13/2	6	+	½	$a_1 = 1$
6/2	3	+	0	$a_2 = 0$
3/2	1	+	½	$a_3 = 1$
½	0	+	½	$a_4 = 1$

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$27_{10} = 11011_2$

	Integer		Fraction	Coefficient
.315 x 2 =	0	+	.630	$a_{-1} = 0$
.630 x 2 =	1	+	.26	$a_{-2} = 1$
.26 x 2 =	0	+	.52	$a_{-3} = 0$
.52 x 2 =	1	+	.04	$a_{-4} = 1$

$.315_{10} \cong .0101_2 = .25 + .0625 = .3125$

$27.315 \cong 11011.0101_2$

(b) 2/3 ≅ .6666666667

	Integer		Fraction	Coefficient
.6666_6666_67 x 2 =	1	+	.3333_3333_34	$a_{-1} = 1$
.3333333334 x 2 =	0	+	.6666666668	$a_{-2} = 0$
.6666666668 x 2 =	1	+	.3333333336	$a_{-3} = 1$
.3333333336 x 2 =	0	+	.6666666672	$a_{-4} = 0$
.6666666672 x 2 =	1	+	.3333333344	$a_{-5} = 1$
.3333333344 x 2 =	0	+	.6666666688	$a_{-6} = 0$
.6666666688 x 2 =	1	+	.3333333376	$a_{-7} = 1$
.3333333376 x 2 =	0	+	.6666666752	$a_{-8} = 0$

$.6666666667_{10} \cong .10101010_2 = .5 + .125 + .0313 + ..0078 = .6641_{10}$

$.101010102 = .1010\_1010_2 = .AA_{16} = 10/16 + 10/256 = .6641_{10}$ (Same as (b)).

1.14

	(a) 1001_0000	**(b)** 0000_0000	**(c)** 1101_1010
1s comp:	0110_1111	1111_1111	0010_0101
2s comp:	0111_0001	0000_0000	0010_0110

	(d) 1010_1011	**(e)** 1010_0101	**(f)** 1111_1111
1s comp:	0101_0100	0101_1010	0000_0000
2s comp:	0101_0111	0101_1011	0000_0001

`

1.15

	(a) 25,875,036	**(b)** 76,325,800
9s comp:	74,124,963	26,674,199
10s comp:	74,124,964	26,674,200

	(c) 25,101,236	**(d)** 00000000
9s comp:	74,898,763	99999999
10s comp:	74,898,764	100000000

1.16

	C3AF		C3AF: 1100_0011_1010_1111
15s comp:	3C50	1s comp:	0011_1100_0101_0000
16s comp:	3C51	2s comp:	0011_1100_0101_0001 = 3C51

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1.17 **(a)** 6,473 – 5297 = 1176
5297 → 05297 →94702 (9s comp) → 94703 (10s comp)
6473 – 5297 = 6473 + 94703 = 101,176 (positive)
Magnitude: 1,176
Result: 6,473 – 5297 = 1176

(b) 1,076 – 3,217 = -2,141
3,217 → 96,782 (9s comp) → 96,783 (10s comp)
1,076 – 3,217 = 1,076 + 96,783 = 97,858 (negative)
Magnitude: 2,141
Result: 1,076 – 3,217 = -2,141

(c) 4,361 → 04361 → 95638 (9s comp) → 95639 (10s comp)
2043 – 4361 = 02043 + 95639 = 97682 (Negative)
Magnitude: 2318
Result: 2043 – 6152 = -2318

(d) 745 → 00745 → 99254 (9s comp) → 99255 (10s comp)
1631 -745 = 01631 + 99255 = 0886 (Positive)
Result: 1631 – 745 = 886

1.18 **(a)**
0_10110(22)
1s comp: 1_01001
2s comp: 1_01010
0_10111(23)
Diff: 0_00001 (Positive)
Result: +1
Check: 23-22 = +1

(b)
0_100110
1s comp: 1_011001 with sign extension
2s comp: 1_011010
0_100010
1_111100 sign bit indicates that the result is negative
0_000011 1s complement
0_000100 2s complement
0_000100 magnitude
Result: -4
Check: 34 -38 = -4

(c)
0_110101
1s comp: 1_001010
2s comp: 1_001011
0_001001
Diff: 1_010100 (negative)
0_101011 (1s comp)
0_101100 (2s complement)
101100 (magnitude)
-44_{10} (result)

(d)
0_010101
1s comp: 1_101010 with sign extension
2s comp: 1_101011
0_101000
0_010011 sign bit indicates that the result is positive
Result: 19_{10}
Check: $40 – 21 = 19_{10}$

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1.19 +9286 → 009286; +801 → 000801; -9286 → 990714; -801 → 999199

(a) (+9286) + (_801) = 009286 + 000801 = 010087

(b) (+9286) + (-801) = 009286 + 999199 = 008485

(c) (-9286) + (+801) = 990714 + 000801 = 991515

(d) (-9286) + (-801) = 990714 + 999199 = 989913

1.20 +49 → 0_110001 (Needs leading zero extension to indicate + value);
+29 → 0_011101 (Leading 0 indicates + value)
-49 → 1_001110 + 0_000001→ 1_001111
-29 → 1_100011 (sign extension indicates negative value)

(a)(+29) + (-49) = 0_011101 + 1_001111 = 1_101100 (1 indicates negative value.)
Magnitude = 0_010011 + 0_000001 = 0_010100 = 20; Result (+29) + (-49) = -20

(b) (-29) + (+49) = 1_100011 + 0_110001 = 0_010100 (0 indicates positive value)
(-29) + (+49) = +20

(c) Must increase word size by 1 (sign extension) to accomodate overflow of values:
(-29) + (-49) = 11_100011 + 11_001111 = 10_110010 (1 indicates negative result)
Magnitude: 01_001110 = 78_{10}
Result: (-29) + (-49) = -78_{10}

1.21 +9742 → 009742 → 990257 (9's comp) → 990258 (10s) comp
+641 → 000641 → 999358 (9's comp) → 999359 (10s) comp

(a) (+9742) + (+641) → 010383

(b)(+9742) + (-641) →009742 + 999359 = 009101
Result: (+9742) + (-641) = 9101

(c) -9742) + (+641) = 990258 + 000641 = 990899 (negative)
Magnitude: 009101
Result: (-9742) + (641) = -9101

(d) (-9742) + (-641) = 990258 + 999359 = 989617 (Negative)
Magnitude: 10383
Result: (-9742) + (-641) = -10383

1.22 6,514

BCD**:** 0110_0101_0001_0100

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ASCII: 0_011_0110__0_011_0101__1_011_0001__1_011_0100
ASCII: 0011_0110__0011_0101__1011_0001__1011_0100

3,274
BCD: 0011_0010_0111_0100
ASCII: 0011_0011_1011_0010_1011_0111_1011_0100

1.23

```
       0111   1001    0001 (  791)
       0110   0101    1000 (+658)
       1101  1110   1001
       0110  0110
   0001 0011    0100
  0001    0001
  0001    0100  0100   1001  (1,449)
```

1.24 **(a) See text**

(b)

6	4	2	1	Decimal
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	1	0	8
1	0	1	1	9

1.25 **(a)** $6{,}428_{10}$ BCD: 0110_0100_0010_1000
(b) Excess-3: 1001_0111_0101_1011

(c) 2421: 1100_0100_0010_1110
2421: 0110_0100_1000_1110

(d) 6311: 1000_0110_0010_1011

1.26 6,428 9s Comp: 3,571
6 4 2 8
2421 code: 0011_1011_0111_0001

1.25(c): 1100_0100_0010_1110 (2421 code – alternative #1)
1s comp: 0011_1011_1101_0001 (2421 code - alternative #2)

6 4 2 8

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$6,428_{2421}$ 0110_0100_1000_1110 (2421 code alternative #2)
1s comp 1001_1011_0111_0001 Match

5,736 9s Comp: 4,263
2421 code: 0100_0010_1100_0011
1s comp: 1011_1101_0011_1100

1.27 For a deck with 52 cards, we need 6 bits ($2^5 = 32 < 52 < 64 = 2^6$). Let the msb's select the suit (e.g., diamonds, hearts, clubs, spades are encoded respectively as 00, 01, 10, and 11. The remaining four bits select the "number" of the card. Example: 0001 (ace) through 1011 (9), plus 101 through 1100 (jack, queen, king). This a jack of spades might be coded as 11_1010. (Note: only 52 out of 64 patterns are used.)

1.28 G (dot) (space) B o o l e

11000111_11101111_01101000_01101110_00100000_11000100_11101111_11100101

1.29 Steve Jobs

1.30 73 F4 E5 76 E5 4A EF 62 73

73:	0_111_0011	s
F4:	1_111_0100	t
E5:	1_110_0101	e
76:	0_111_0110	v
E5:	1_110_0101	e
4A:	0_100_1010	j
EF:	1_110_1111	o
62:	0_110_0010	b
73:	0_111_0011	s

Even parity

1.31 62 + 32 = 94 printing characters; 34 special characters

1.32 Complement bit 6 (from the right)

1.33 **(a)** 897 **(b)** 564 **(c)** 871 **(d)** 2,199

1.34 ASCII for decimal digits with even parity:

(0):	00110000	(1):	10110001	(2):	10110010	(3):	00110011
(4):	10110100	(5):	00110101	(6):	00110110	(7):	10110111
(8):	10111000	(9):	00111001				

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CHAPTER 2

2.1 **(a)**

x y z	$x + y + z$	$(x + y + z)'$	x'	y'	z'	$x'y'z'$
0 0 0	0	1	1	1	1	1
0 0 1	1	0	1	1	0	0
0 1 0	1	0	1	0	1	0
0 1 1	1	0	1	0	0	0
1 0 0	1	0	0	1	1	0
1 0 1	1	0	0	1	0	0
1 1 0	1	0	0	0	1	0
1 1 1	1	0	0	0	0	0

x y z	(xyz)	$(xyz)'$	x'	y'	z'	$x' + y' + z'$
0 0 0	0	1	1	1	1	1
0 0 1	0	1	1	1	0	1
0 1 0	0	1	1	0	1	1
0 1 1	0	1	1	0	0	1
1 0 0	0	1	0	1	1	1
1 0 1	0	1	0	1	0	1
1 1 0	0	1	0	0	1	1
1 1 1	1	0	0	0	0	0

(b)

x y z	$x + yz$	$(x + y)$	$(x + z)$	$(x + y)(x + z)$
0 0 0	0	0	0	0
0 0 1	0	0	1	0
0 1 0	0	1	0	0
0 1 1	1	1	1	1
1 0 0	1	1	1	1
1 0 1	1	1	1	1
1 1 0	1	1	1	1
1 1 1	1	1	1	1

(c)

x y z	$x(y + z)$	xy	xz	$xy + xz$
0 0 0	0	0	0	0
0 0 1	0	0	0	0
0 1 0	0	0	0	0
0 1 1	0	0	0	0
1 0 0	0	0	0	0
1 0 1	1	0	1	1
1 1 0	1	1	0	1
1 1 1	1	1	1	1

(c)

x y z	x	$y + z$	$x + (y + z)$	$(x + y)$	$(x + y) + z$
0 0 0	0	0	0	0	0
0 0 1	0	1	1	0	1
0 1 0	0	1	1	1	1
0 1 1	0	1	1	1	1
1 0 0	1	0	1	1	1
1 0 1	1	1	1	1	1
1 1 0	1	1	1	1	1
1 1 1	1	1	1	1	1

(d)

x y z	yz	$x(yz)$	xy	$(xy)z$
0 0 0	0	0	0	0
0 0 1	0	0	0	0
0 1 0	0	0	0	0
0 1 1	1	0	0	0
1 0 0	0	0	0	0
1 0 1	0	0	0	0
1 1 0	0	0	1	0
1 1 1	1	1	1	1

2.2 **(a)** $xy + xy' = x(y + y') = x$

(b) $(x + y)(x + y') = x + yy' = x(x + y') + y(x + y') = xx + xy' + xy + yy' = x$

(c) $xyz + x'y + xyz' = xy(z + z') + x'y = xy + x'y = y$

(d) $(x + y)'(x' + y')' = (x'y')(xy) = (x'y')(yx) = x'(y'y)x = 0$

(e) $(a + b + c')(a'b' + c) = aa'b' + ac + ba'b' + bc + c'a'b' + c'c = ac + bc + a'b'c'$

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(f) $a'bc + abc' + abc + a'bc' = a'b(c + c') + ab(c + c') = a'b + ab = (a' + a)b = b$

2.3 **(a)** $xyz + x'y + xyz' = xy + x'y = y$

(b) $x'yz + xz = (x'y + x)z = z(x + x')(x + y) = z(x + y)$

(c) $(x + y)'(x' + y') = x'y'(x' + y') = x'y'$

(d) $xy + x(wz + wz') = x(y + wz + wz') = x(w + y)$

(e) $(yz' + x'w)(xy' + zw') = yz'xy' + yz'zw' + x'wxy' + x'wzw' = 0$

(f) $(x' + z')(x + y' + z') = x'x + x'y' + x'z' + z'x + z'y' + z'z' = x'y' + x'z' + xz' + y'z' = z' + y'(x' + z')$
$= z' + y'z' + x'y' = z' + x'y'$

2.4 **(a)** $A'C' + ABC + AC' = C' + ABC = (C + C')(C' + AB) = AB + C'$

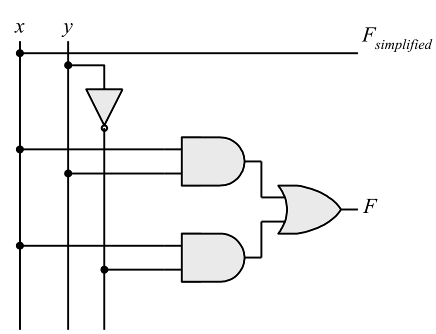
(b) $(B'C' + D)' + D + BC + AD = (B'C')'D' + D + BC + AD =[(B + C)D' + D] + BC + AD =$
$= (D + D')(D + B + C) + BC + AD = D + AD + B + BC + C = D(1 + A) + B(1 + C) + C$
$= B + C + D$

(c) $A'B(D' + C'D) + B(A + A'CD) = B(A'D' + A'C'D + A + A'CD)$
$= B(A'D' + A + A'D(C + C') = B(A + A'(D' + D)) = B(A + A') = B$

(d) $(A' + C)(A' + C')(A + B + C'D) = (A' + CC')(A + B + C'D) = A'(A + B + C'D)$
$= AA' + A'B + A'C'D = A'(B + C'D)$

(e) $ABC'D + A'BD + ABCD = AB(C + C')D + A'BD = ABD + A'BD = BD$

2.5 **(a)**



(b)

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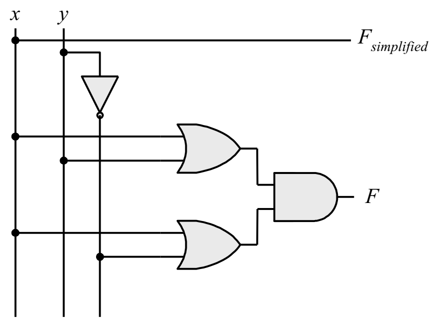

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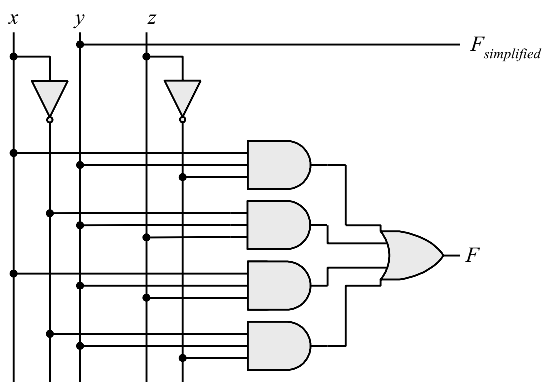

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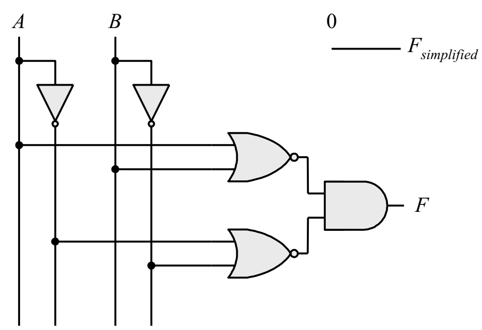

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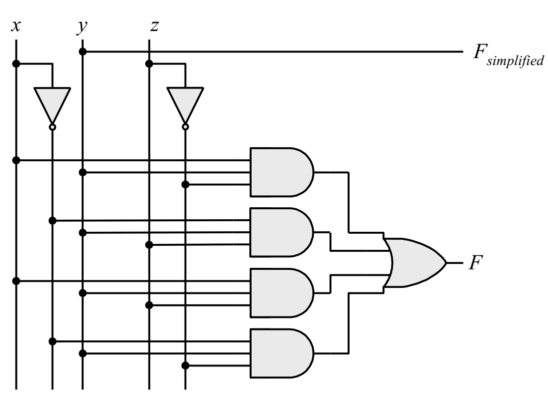

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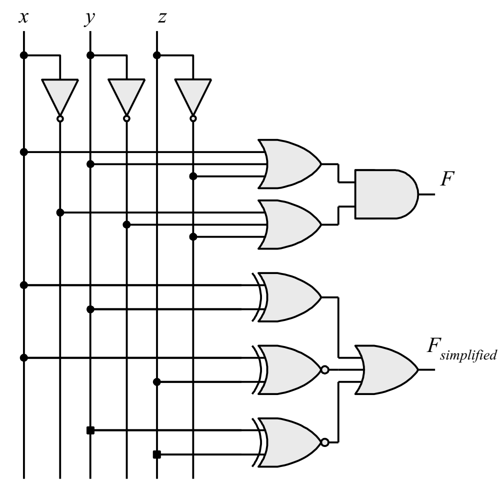
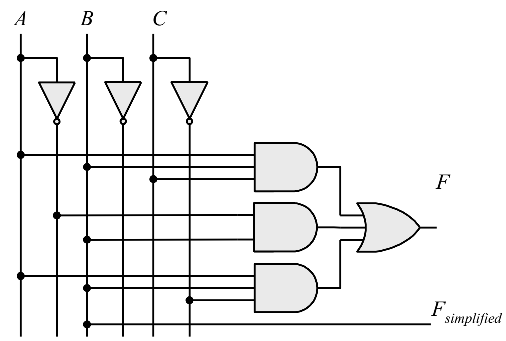


2.6 **(a)**



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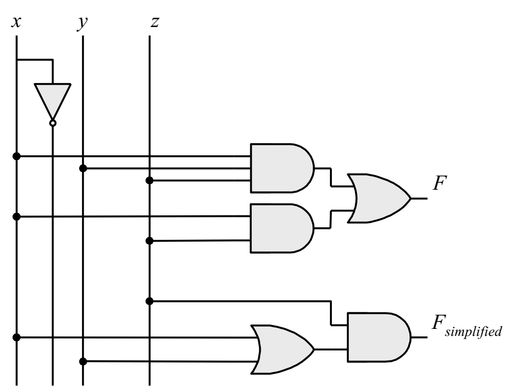

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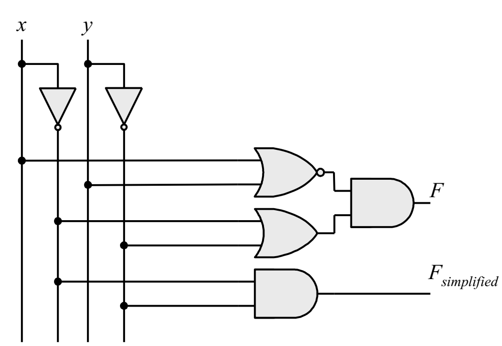

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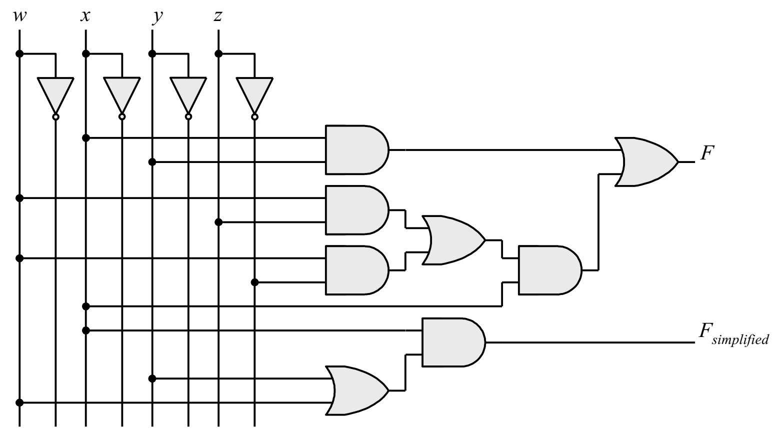
(d)



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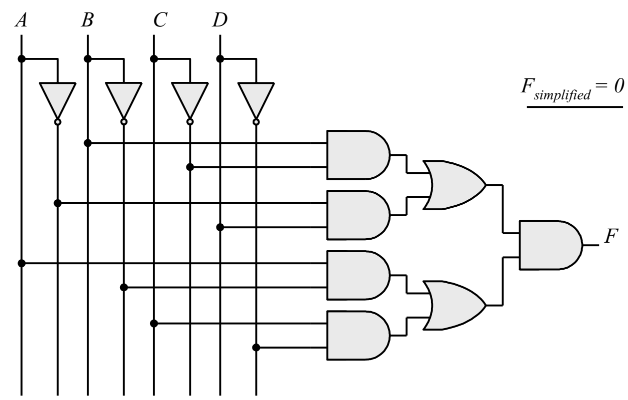

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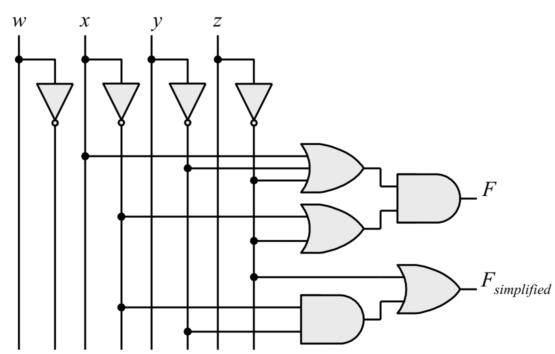

2.7 **(a)**

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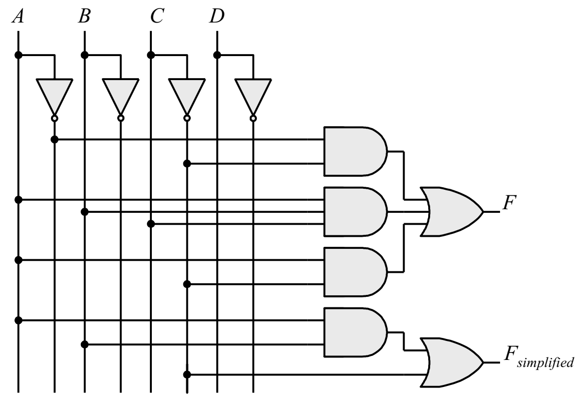
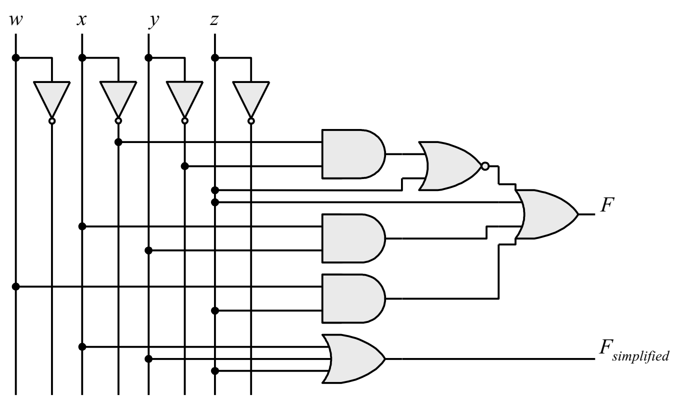
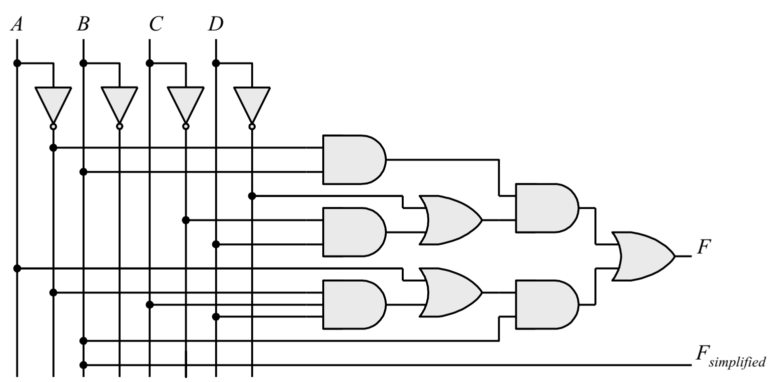


(b)



(c)



(d)

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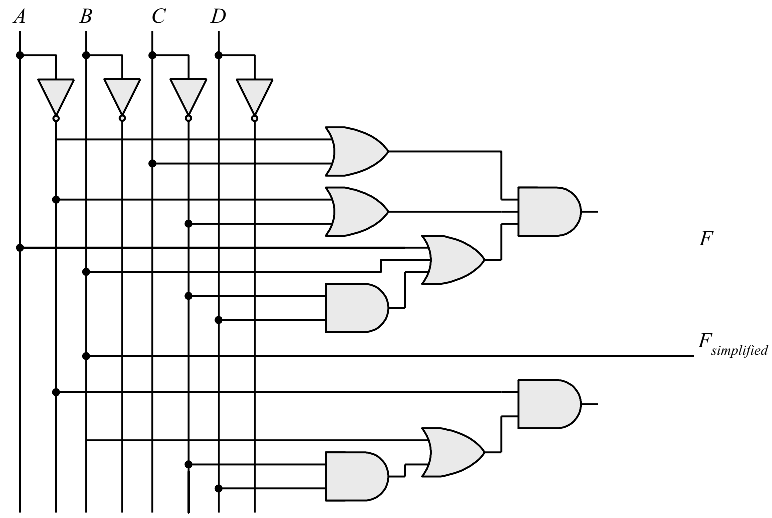

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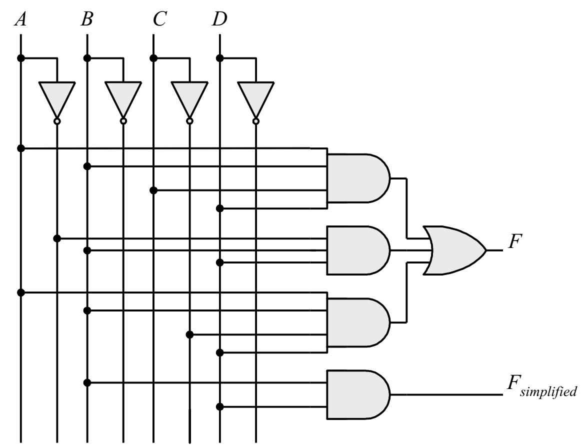
(e)



2.8 $F' = (wx + yz)' = (wx)'(yz)' = (w' + x')(y' + z')$

$FF' = wx(w' + x')(y' + z') + yz(w' + x')(y' + z') = 0$
$F + F' = wx + yz + (wx + yz)' = A + A' = 1 \text{ with } A = wx + yz$

2.9 **(a)** $F' = (xy' + x'y)' = (xy')'(x'y)' = (x' + y)(x + y') = xy + x'y'$

(b) $F' = [(a + c) (a + b')(a' + b + c')]' = (a + c)' + (a + b')' + (a' + b + c')'$
$= a'c' + a'b + ab'c$

(c) $F' = [z + z'(v'w + xy)]' = z'[z'(v'w + xy)]' = z'[z'v'w + xyz']'$
$= z'[(z'v'w)'(xyz')'] = z'[(z + v + w') + (x' + y' + z)]$
$= z'z + z'v + z'w' + z'x' + z'y' + z'z = z'(v + w' + x' + y')$

2.10 **(a)** $F_1 + F_2 = \Sigma m_{1i} + \Sigma m_{2i} = \Sigma (m_{1i} + m_{2i})$

(b) $F1\ F2 = \Sigma m_i \Sigma m_j$ where $m_i m_j = 0$ if $i \neq j$ and $m_i m_j = 1$ if $i = j$

2.11 **(a)** $F(x, y, z) = \Sigma(1, 4, 5, 6, 7)$

(b) $F(a, b, c) = \Sigma(0, 2, 3, 4, 5, 7)$

$F = xy + xy' + y'z$

x y z	F
0 0 0	0
0 0 1	1
0 1 0	0
0 1 1	0
1 0 0	1
1 0 1	1
1 1 0	1
1 1 1	1

$F = ac + b'c'$
$= \Sigma(0, 2, 3, 4, 5, 7)$

a b c	F
0 0 0	1
0 0 1	0
0 1 0	1
0 1 1	1
1 0 0	1
1 0 1	1
1 1 0	0
1 1 1	1

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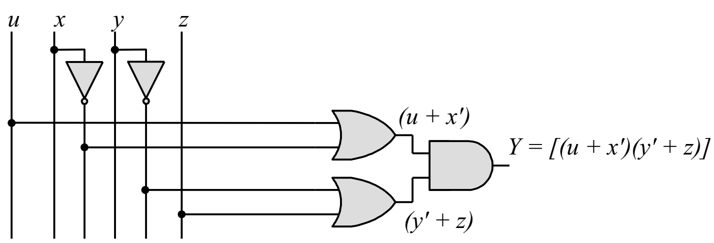
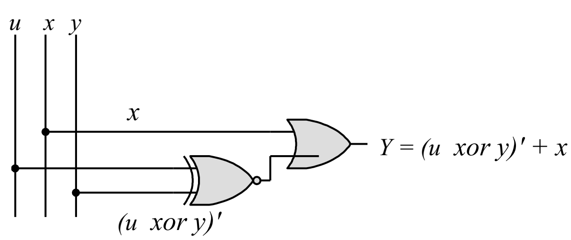
2.12 *A = 1011_0001*
B = 1010_1100

(a) *A AND B = 1010_0000*
(b) *A OR B = 1011_1101*
(c) *A XOR B = 0001_1101*
(d) *NOT A = 0100_1110*
(e) *NOT B = 0101_0011*

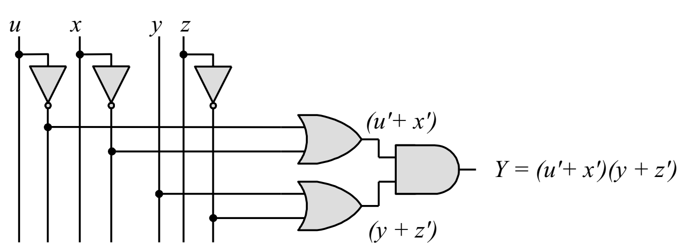
2.13 **(a)**



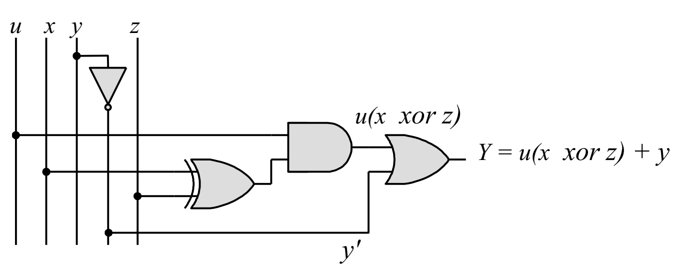
(b)



(c)



(d)



(e)

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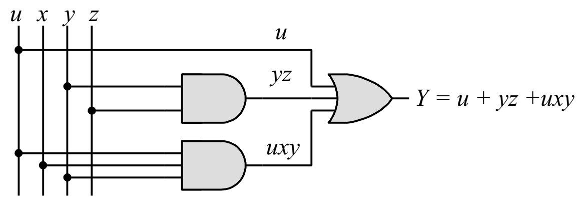
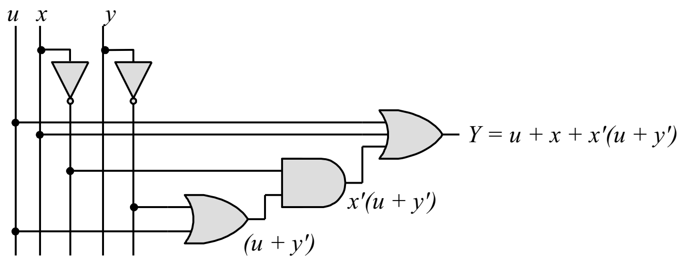
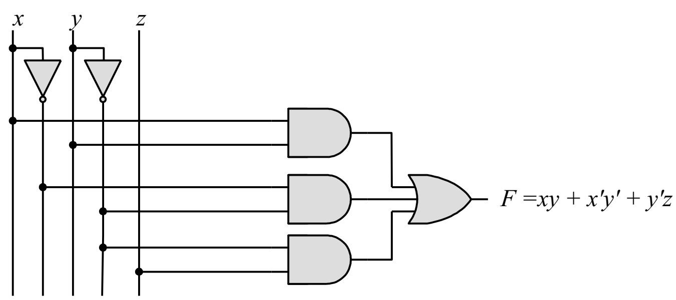


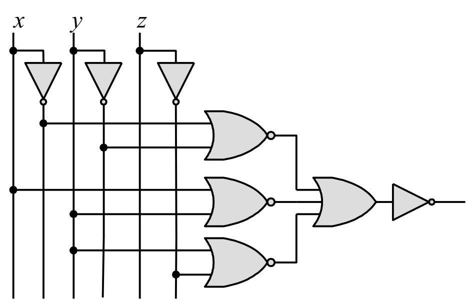
(f)



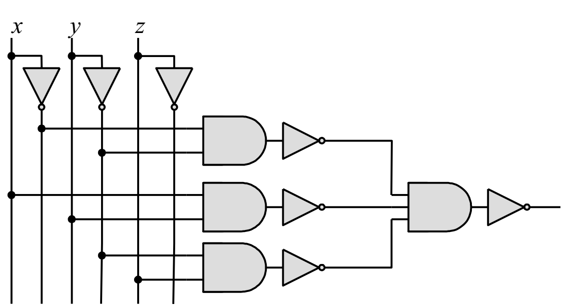
2.14 **(a)**



(b)



(c)



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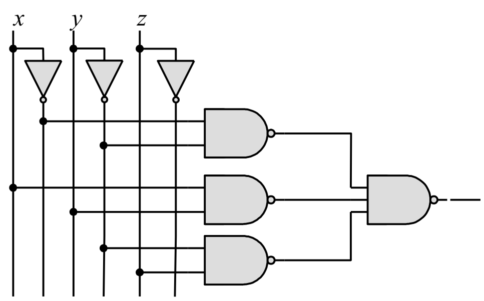
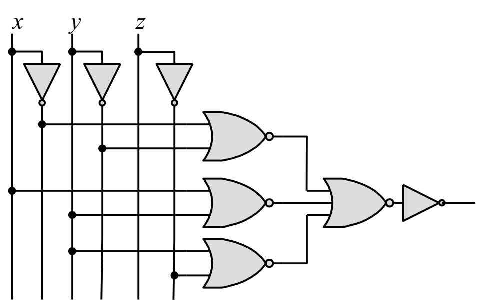
(d)



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

$= [(xy)' (x'y')' (y'z)']'$

(e)



F = xy + x'y' + y'z

$= (x' + y')' + (x + y)' + (y + z')'$

2.15 **(a)** $T_1 = A'B'C' + A'B'C + A'BC' = A'B'(C' + C) + A'C'(B' + B) = A'B' + A'C' = A'(B' + C')$

(b) $T_2 = T_1' = A'BC + AB'C' + AB'C + ABC' + ABC$
$= BC(A' + A) + AB'(C' + C) + AB(C' + C)$
$= BC + AB' + AB = BC + A(B' + B) = A + BC$

$\sum(3, 5, 6, 7) = \Pi(0, 1, 2, 4)$

$T_1 = A'B'C' + A'B'C + A'BC'$

$A'B'$ $\quad$ $A'C'$

$T_1 = A'B'\ A'C' = A'(B' + C')$

$T_2 = A'BC + AB'C' + AB'C + ABC' + ABC$

AC' $\quad$ AC

BC

$T_2 = AC' + BC + AC = A + BC$

.Digital Design With An Introduction to the Verilog HDL, VHDL, and SystemVerilog, Sixth Edition – Solution Manual.
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2.16 **(a)** $F(A, B, C) = A'B'C' + A'B'C + A'BC' + A'BC + AB'C' + AB'C + ABC' + ABC$
$= A'(B'C' + B'C + BC' + BC) + A((B'C' + B'C + BC' + BC)$
$= (A' + A)(B'C' + B'C + BC' + BC) = B'C' + B'C + BC' + BC$
$= B'(C' + C) + B(C' + C) = B' + B = 1$

(b) $F(x_1, x_2, x_3, \ldots, x_n) = \Sigma m_i$ has $2^n/2$ minterms with x_1 and $2^n/2$ minterms with x'_1, which can be factored and removed as in (a). The remaining 2^{n-1} product terms will have $2^{n-1}/2$ minterms with x_2 and $2^{n-1}/2$ minterms with x'_2, which and be factored to remove x_2 and x'_2. continue this process until the last term is left and $x_n + x'_n = 1$. Alternatively, by induction, F can be written as $F = x_nG + x'_nG$ with $G = 1$. So $F = (x_n + x'_n)G = 1$.

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2.17 **(a)** $F = (b + cd)(c + bd) = bc + bd + cd + bcd$
$= \Sigma(3, 5, 6, 7, 11, 13, 14, 15)$
$F' = \Sigma(0, 1, 2, 4, 8, 9, 10, 12)$
$F = \Pi(0, 1, 2, 4, 8, 9, 10, 12)$

a b c d	F
0 0 0 0	0
0 0 0 1	0
0 0 1 0	0
0 0 1 1	1
0 1 0 0	0
0 1 0 1	1
0 1 1 0	1
0 1 1 1	1
1 0 0 0	0
1 0 0 1	0
1 0 1 0	0
1 0 1 1	1
1 1 0 0	0
1 1 0 1	1
1 1 1 0	1
1 1 1 1	1

(b) $(cd + b'c + bd')(b + d) = bcd + bd' + cd + b'cd = cd + bd'$
$= \Sigma$ (3, 4, 7, 11, 12,14, 15)
$= \Pi$ (0, 1, 2, 5, 6, 8, 9, 10, 13)

a b c d	F
0 0 0 0	0
0 0 0 1	0
0 0 1 0	0
0 0 1 1	1
0 1 0 0	1
0 1 0 1	0
0 1 1 0	0
0 1 1 1	1
1 0 0 0	0
1 0 0 1	0
1 0 1 0	0
1 0 1 1	1
1 1 0 0	1
1 1 0 1	0
1 1 1 0	1
1 1 1 1	1

(c) $(c' + d)(b + c') = bc' + c' + bd + c'd = (c' + bd)$
$= \Sigma$ (0, 1, 4, 5, 7, 8, 12, 13, 15)
$= \Pi$ (2, 3, 6, 9, 10, 11, 14)

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(d) $bd' + acd' + ab'c + a'c' = \Sigma(0, 1, 4, 5, 10, 11, 14)$

$F' = \Sigma(2, 3, 6, 7, 8, 9, 12, 13, 15)$

$F = \Pi(0, 2, 3, 6, 7, 8, 12, 13, 15)$

a b c d	F
0 0 0 0	1
0 0 0 1	1
0 0 1 0	0
0 0 1 1	0
0 1 0 0	1
0 1 0 1	1
0 1 1 0	0
0 1 1 1	0
1 0 0 0	0
1 0 0 1	0
1 0 1 0	1
1 0 1 1	1
1 1 0 0	1
1 1 0 1	0
1 1 1 0	1
1 1 1 1	0

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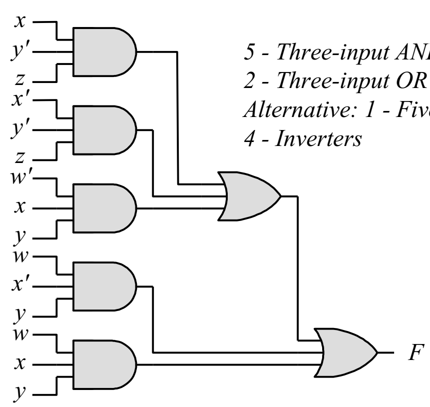
2.18 (a)

wx y z	F
00 0 0	0
00 0 1	1
00 1 0	0
00 1 1	0
01 0 0	0
01 0 1	1
01 1 0	1
01 1 1	1
10 0 0	0
10 0 1	1
10 1 0	1
10 1 1	1
11 0 0	0
11 0 1	1
11 1 0	1
11 1 1	1

$F = xy'z + x'y'z + w'xy + wx'y + wxy$

$F = \Sigma(1, 5, 6, 7, 9, 10\ 11, 13, 14, 15\ )$

(b)

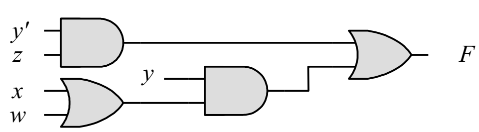


5 - Three-input AND gates
2 - Three-input OR gates
Alternative: 1 - Five-input OR gate
4 - Inverters

(c) $F = xy'z + x'y'z + w'xy + wx'y + wxy = y'z + xy + wy = y'z + y(w + x)$

(d) $F = y'z + yw + yx) = \Sigma(1, 5, 9, 13\ , 10, 11, 13, 15, 6, 7, 14, 15)$
$= \Sigma(1, 5, 6, 7, 9,\ \ 10, 11, 13, 14, 15)$

(e)



1 – Inverter, 2 – Two-input AND gates, 2 – Two-input OR gates

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2.19 $F = B'D + A'D + BD$

ABCD	*ABCD*	*ABCD*
-B'-D	*A'--D*	*-B-D*
0001 = 1	*0001 = 1*	*0101 = 5*
0011 = 3	*0011 = 3*	*0111 = 7*
1001 = 9	*0101 = 5*	*1101 = 13*
1011 = 11	*0111 = 7*	*1111 = 15*

$F = \Sigma(1, 3, 5, 7, 9, 11,13, 15) = \Pi(0, 2, 4, 6, 8, 10, 12, 14)$

2.20 **(a)** $F(A, B, C, D) = \Sigma(2, 4, 6, 8, 12, 14)$
$F'(A, B, C, D) = \Sigma(0, 1, 3, 5, 7, 9, 10, 11, 13, 15)$
$F(A, B, C, D) = \Pi(0, 1, 3, 5, 7, 9, 10, 11, 13, 15)$

(b) $F(x, y, z) = \Pi(3, 5, 7)$
$F' = \Pi(0, 1, 2, 4, 6)$
$F = \Sigma (0, 1, 2, 4, 6)$

2.21 ***(a)*** $F(x, y, z) = \Sigma(1, 3, 5) = \Pi(0, 2, 4, 6, 7)$

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

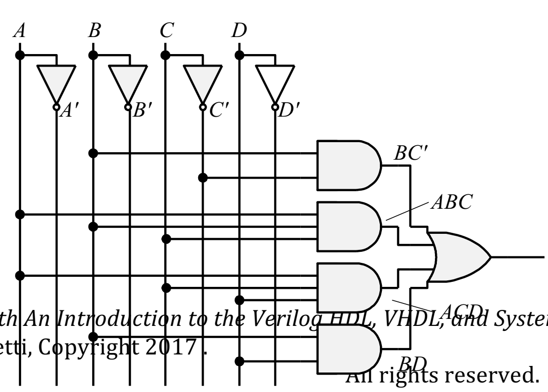
(c) $F(x, y, z) = \Pi(0, 2, 4, 6) = \Sigma(1, 3, 5, 7)$

(d) $F(w, x, y, z) = \Sigma(1, 3, 5, 7, 9) = \Pi(0, 2, 4, 6, 8, 10, 11, 12, 13, 14, 15)$

2.22 **(a)** $(u + xw)(x + u'v) = ux + uu'v + xxw + xwu'v = ux + xw + xwu'v$
$= ux + xw = x(u + w)$
$= ux + xw$ (SOP form)
$= x(u + w)$ (POS form)

(b) $x' + x(x + y')(y + z') = x' + x(xy + xz' + y'y + y'z')$
$= x' + xy + xz' + xy'z' = x' + xy +xz'$ *(SOP form)*
$= (x' + y + z')$ *(POS form)*

2.23 **(a)** $BC' +ABC + ACD + BD$



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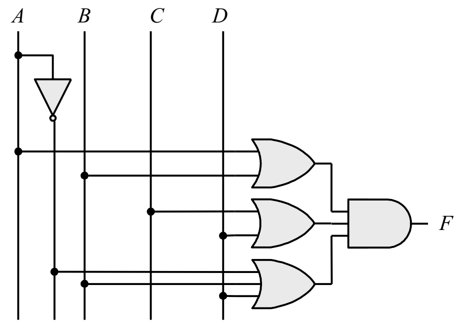
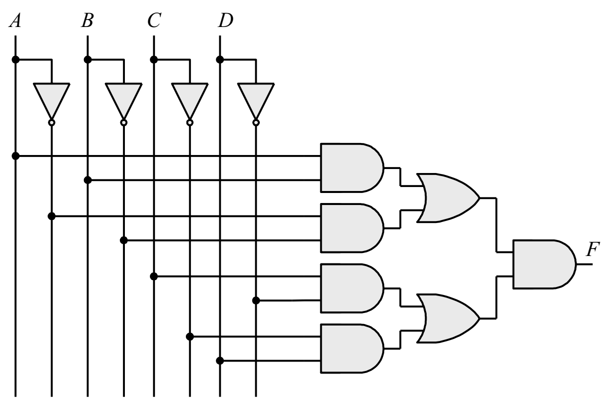
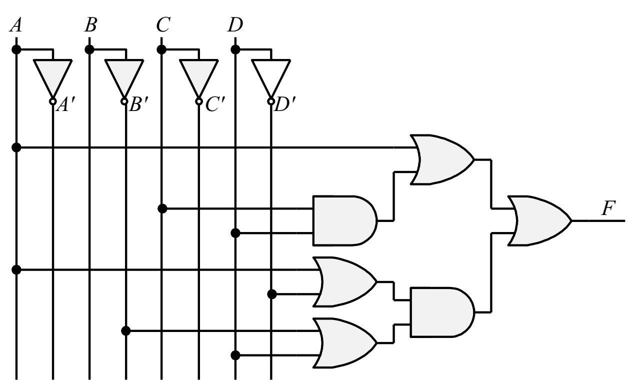
(b) *(A + B)(C + D)(A′ + B + D)*



(c) *(AB + A'B')(CD' + C'D)*



(d) *A + CD + (A + D')(B′ + D)*



2.24 $x \oplus y = x'y + xy'$ and $(x \oplus y)' = (x + y')(x' + y)$

Dual of $x'y + xy' = (x' + y)(x + y') = (x \oplus y)'$

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2.25 **(a)** $x | y = xy' \neq y | x = x'y$ Not commutative

$(x | y) | z = xy'z' \neq x | (y | z) = x(yz')' = xy' + xz$ Not associative

(b) $(x \oplus y) = xy' + x'y = y \oplus x = yx' + y'x$ Commutative

$(x \oplus y) \oplus z = \sum(1, 2, 4, 7) = x \oplus (y \oplus z)$ Associative

2.26

Gate		NAND (Positive logic)		NOR (Negative logic)	
x y	z	x y	z	x y	z
L L	H	0 0	1	1 1	0
L H	H	0 1	1	1 0	0
H L	H	1 0	1	0 1	0
H H	L	1 1	0	0 0	1

Gate		NOR (Positive logic)		NAND (Negative logic)	
x y	z	x y	z	x y	z
L L	H	0 0	1	1 1	0
L H	L	0 1	0	1 0	1
H L	L	1 0	0	0 1	1
H H	L	1 1	0	0 0	1

2.27 $f_1 = a'b'c' + a'bc' + a'bc + ab'c' + abc = a'c' + bc + a'bc' + ab'c'$

$f_2 = a'b'c' + a'b'c + a'bc + ab'c' + abc = a'b' + bc + ab'c'$

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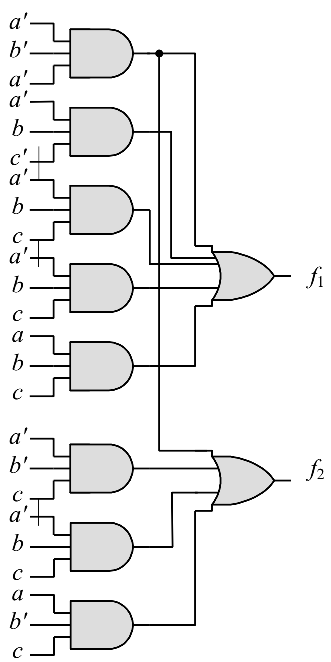

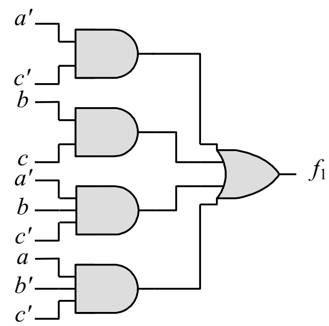

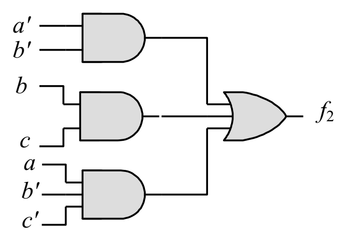

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2.28 **(a)** $y = a(bcd)'e = a(b' + c' + d')e$

$y = a(b' + c' + d')e = ab'e + ac'e + ad'e$
$= \Sigma(17, 19, 21, 23, 25, 27, 29)$

a bcde	y	a bcde	y
0 0000	0	1 0000	0
0 0001	0	**1 0001**	1
0 0010	0	1 0010	0
0 0011	0	**1 0011**	1
0 0100	0	1 0100	0
0 0101	0	**1 0101**	1
0 0110	0	1 0110	0
0 0111	0	**1 0111**	1
	0		0
0 1000	0	1 1000	0
0 1001	0	**1 1001**	1
0 1010	0	1 1010	0
0 1011	0	**1 1011**	1
0 1100	0	1 1100	0
0 1101	0	**1 1101**	1
0 1110	0	1 1110	0
0 1111	0	1 1111	0

(b) $y_1 = a \oplus (c + d + e) = a'(c + d + e) + a(c'd'e') = a'c + a'd + a'e + ac'd'e'$

$y_2 = b'(c + d + e)f = b'cf + b'df + b'ef$

$y_1 = a \ (c + d + e) = a'(c + d + e) + a(c'd'e') = a'c + a'd + a'e + ac'd'e'$

$y_2 = b'(c + d + e)f = b'cf + b'df + b'ef$

a'-c---	*a'--d--*	*a'---e-*	*a-c'd'e'-*
001000 = 8	000100 = 8	000010 = 2	100000 = 32
001001 = 9	000101 = 9	000011 = 3	100001 = 33
001010 = 10	000110 = 10	000110 = 6	110000 = 34
001011 = 11	000111 = 11	000111 = 7	110001 = 35
001100 = 12	001100 = 12	001010 = 10	
001101 = 13	001101 = 13	001011 = 11	
001110 = 14	001110 = 14	001110 = 14	
001111 = 15	001111 = 15	001111 = 15	
011000 = 24	010100 = 20	010010 = 18	
011001 = 25	010101 = 21	010011 = 19	
011010 = 26	010110 = 22	010110 = 22	
011011 = 27	010111 = 23	010111 = 23	
011100 = 28	011100 = 28	011010 = 26	
011101 = 29	011101 = 29	011001 = 27	
011110 = 30	011110 = 30	011110 = 30	
011111 = 31	011111 = 31	011111 = 31	

-b' c--f	-b' -d-f	-b' --ef
001001 = 9	001001 = 9	000011 = 3
001011 = 11	001011 = 11	000111 = 7
001101 = 13	001101 = 13	001011 = 11
001111 = 15	001111 = 15	001111 = 15
101001 = 41	101001 = 41	100011 = 35
101011 = 43	101011 = 43	100111 = 39
101101 = 45	101101 = 45	101011 = 51
101111 = 47	101111 = 47	101111 = 55

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$y_1 = \Sigma$ (2, 3, 6, 7, 8, 9, 10 ,11, 12, 13, 14, 15, 18, 19, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35)

$y_2 = \Sigma$ (3, 7, 9, 13, 15, 35, 39, 41, 43, 45, 47, 51, 55)

ab cdef	y_1 y_2	*ab cdef*	y_1 y_2	*ab cdef*	y_1 y_2	*ab cdef*	y_1 y_2
00 0000	0 0	01 0000	0 0	10 0000	1 0	11 0000	0 0
00 0001	0 0	01 0001	0 0	10 0001	1 0	11 0001	0 0
00 0010	1 0	01 0010	1 0	10 0010	1 0	11 0010	0 0
00 0011	1 1	01 0011	1 0	10 0011	1 1	11 0011	0 1
00 0100	0 0	01 0100	0 0	10 0100	0 0	11 0100	0 0
00 0101	0 0	01 0101	0 0	10 0101	0 0	11 0101	0 0
00 0110	1 0	01 0110	1 0	10 0110	0 0	11 0110	0 0
00 0111	1 1	01 0111	1 0	10 0111	0 1	11 0111	0 1
00 1000	1 0	01 1000	1 0	10 1000	0 0	11 1000	0 0
00 1001	1 1	01 1001	1 0	10 1001	0 1	11 1001	0 0
00 1010	1 0	01 1010	1 0	10 1010	0 0	11 1010	0 0
00 1011	1 0	01 1011	1 0	10 1011	0 1	11 1011	0 0
00 1100	1 0	01 1100	1 0	10 1100	0 0	11 1100	0 0
00 1101	1 1	01 1101	1 0	10 1101	0 1	11 1101	0 0
00 1110	1 0	01 1110	1 0	10 1110	0 0	11 1110	0 0
00 1111	1 1	01 1111	1 0	10 1111	0 1	11 1111	0 0

2.29 x'y' + x'z + x'z' = x'z' + y'z' + x'z

x'y' + x' = x' + y'z'

x' = x' + y'z' FALSE

2.30 (b + d)(a' + b' + c) = a'b + bb' + bc + a'd + b'd + cd = a'b + bc + a'd + b'd + cd

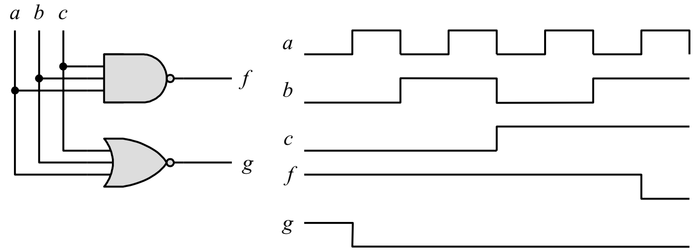
2.31 a'b + a'c' + abc = a'bc + a'bc' + a'bc' + a'b'c' + abc = Σ ($m_3 + m_2 + m_0 + m_7$)

(a'b + a'c' + abc)' = Σ ($m_1 + m_4 + m_5 + m_6$)

(a'b + a'c' + abc) = Π ($M_1 + M_4 + M_5 + M_6$)

(a'b + a'c' + abc) = (a' + b' + c)(a + b' + c')(a + b' + c)(a + b + c')

2.32



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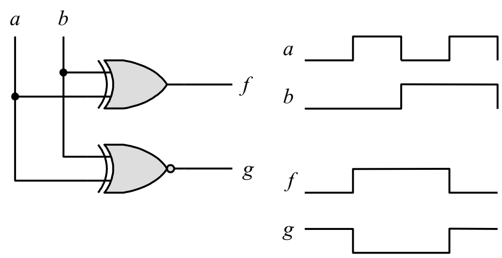
2.33



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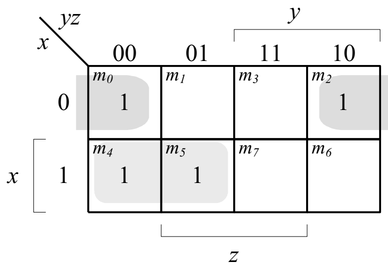
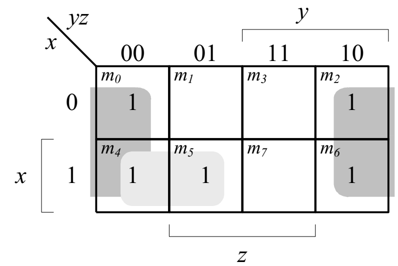
Chapter 3

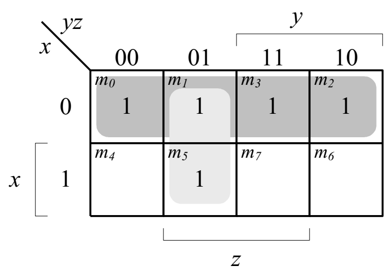
3.1



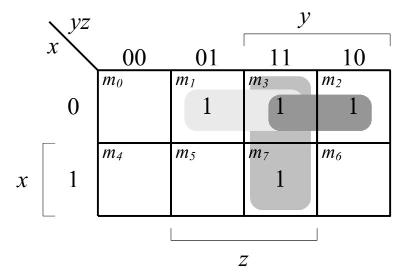
$F = xy' + x'z'$



$F = z' + xy'$

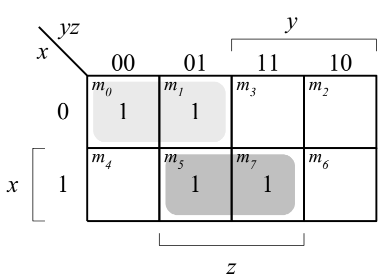


$F = x' + y'z$

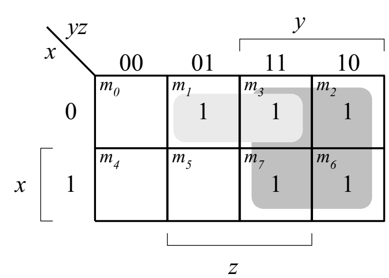


$F = x'z + yz + x'y$

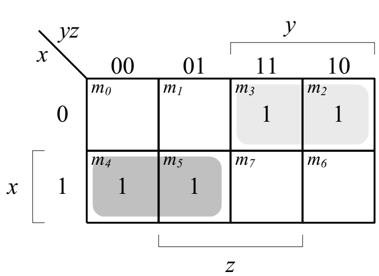
3.2



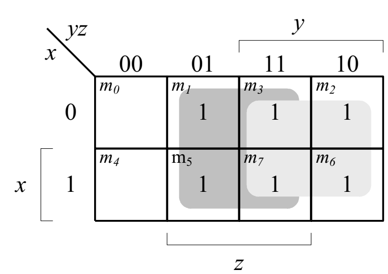
(a) $F = x'y' + xz$



(b) $F = y + x'z$



$F = xy' + x'y$



$F = y + z$

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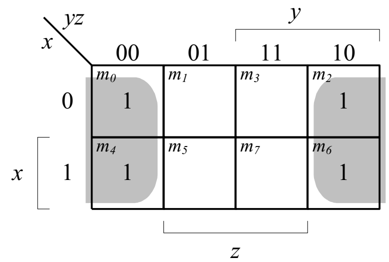
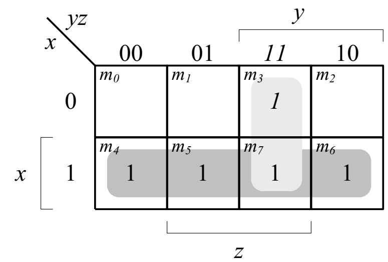
(c) **(d)**



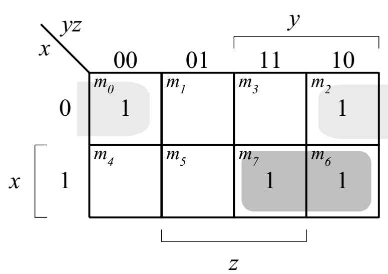
$F = z'$



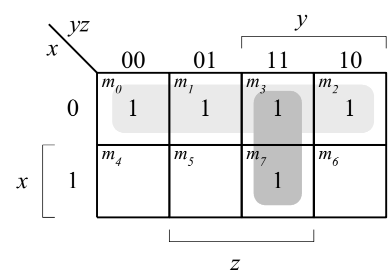
$F = x + y z$

(e) **(f)**

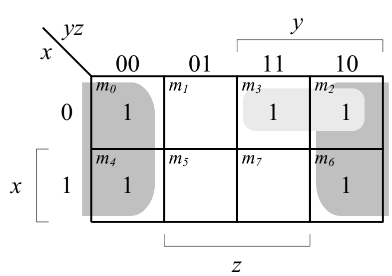
3.3



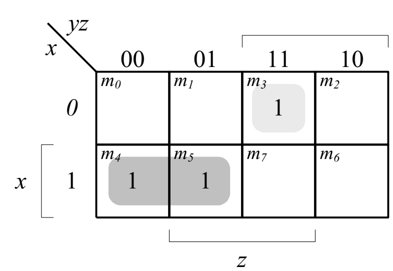
(a) $F = xy + x'y'z' + x'yz'$
$F = xy + x'z'$



(b) $F = x'y' + yz + x'yz'$
$F = x' + yz$



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



$F = x'yz + xy'z' + xy'z$
$F = x'yz + xy'$

(c) **(d)**

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