APPENDIX
Answers to Selected Problems

Chapter 1

1-1. 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, 10, 11, 12, 13

1-2. 65,535

1-3. 46; 117.75; 436

1-4. 151; 580; 35; 260

1-5. 10011001111; 1010100001.0011101; 10011100010000; 11111001110

1-6. (a) 16612.34631. . .
(b) 792.41CAC. . .
(c) 10101111.001011. . .

1-7. $(11110011101001111000010)_2 = (74723702)_8$

1-8.

Decimal	Binary	Octal	Hexadecimal
225	11100001	341	E1
215	11010111	327	D7
403	110010011	623	193
10949	10101011000101	25305	2AC5

1-9. (a) 1304; 336313
(b) 206; E4F9
(c) 1101011; 101100101110

1-10. 110011 (255/5 = 51)

1-11. $x = 7$

1-12. $(73642815)_9$

1-13. 87650123; 99019899; 09990048; 99999999

1-14. 876100; 909343; 900000; 000000

1-15.

Number	1's complement	2's complement
10101110	01010001	01010010
10000001	01111110	01111111
10000000	01111111	10000000
00000001	11111110	11111111
00000000	11111111	00000000

1-17. (a) 01010; (b) 01101; (c) −101100; (d) 0000000

1-19. (a) 100011 (−29); (b) 000000; (c) 101111 (−17); (d) 000101

1-20. 0001 0011 0101 1001 0111
1001 0011 0010 1000 0110
1001 1001 1000 1000 0000

1-21.

	7421	
0	0000	
1	0001	
2	0010	
3	0011	
4	0100	
5	0101	
6	0110	
7	0111	(or 1000)
8	1001	
9	1010	

1-22. (b) 012345
(c) 000, 001, 010, 101, 110, 111; for digits 0, 1, 2, 3, 4, 5, respectively

1-23. (a) 1000 0110 0010 0000
(b) 1011 1001 0101 0011
(c) 1110 1100 0010 0000
(d) 100001101011 00

1-24. 3864: 0011 1110 1100 0100
6135: 1100 0001 0011 1011

1-28. John Doe

1-29. (a) 100100111
(b) 001010010101
(c) 011001001110010110101

1-30. 94 printing characters; 32 special characters

1-31. (a) 597 in BCD
(b) 264 in excess-3 code
(c) Not valid for the 2, 4, 2, 1 code of Table 1-2

1-32. 0100000001 + 1000000010 = 1100000011

1-34. $L = (A + B) \cdot C$

Chapter 2

2-2. (a) $x' + y$
(b) x

(c) 1
(d) $x' + y + z'$
(e) $xy' + x'z'$

2-3. (a) B
(b) $z(x + y)$
(c) $x'y'$
(d) $x(y + w)$
(e) 0

2-4. (a) $AB + C'$
(b) $x + y + z$
(c) B
(d) $A'(B + C'D)$

2-6. (a) $xy + x'y'$
(b) $(A' + B + D)(C' + D)E'$
(d) $x'yz' + xz + x'y'$

2-7. (a) $F = (x + y)' + (x + z')' + (y + z')'$
(b) $F = [(y + z')' + (x + y)' + (y' + z)']'$

2-8. (a) $F = [(x'y')'(x'z)'(y'z)']'$
(b) $F = (y'z)'(x'y')'(yz')'$

2-9. (a) $\Sigma(3, 5, 6, 7) = \Pi(0, 1, 2, 4)$
(b) $\Sigma(0, 1, 3, 7) = \Pi(2, 4, 5, 6)$

2-10. (a) $F = \Sigma(2, 3, 6, 7)$
(b) $F' = \Sigma(0, 1, 4, 5)$
(d) $F = y$

2-11. (c) $F = y'z + y(w + x)$

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

2-16. (a) $AB + BC$; $(A + C)B$
(b) $x' + y + z'$

2-18. $F' = (x'y + xy')' = xy + x'y'$ Dual of F is $(x' + y)(x + y') = xy + x'y'$

2-21. (a) 4; (b) 3; (c) 2; (d) 2; (e) 1

Chapter 3

3-1. (a) $x'y' + xz$
(b) $y + x'z$
(c) $xy + xz + yz$
(d) $A'B + C'$

3-2. (a) $xy + x'z'$
(b) $x' + yz$
(c) $C' + A'B$

3-3. (a) $BCD + A'BD'$
(b) $wx + w'x'y$
(c) $ABD + ABC + CD$

3-4. (a) $xz' + w'y'z + wxy$
(b) $A'C' + A'B'D' + ACD + A'BD$ (or BCD)
(c) $wx + x'y$
(d) $BD + B'D' + A'B$ (or $A'D'$)

3-5. (a) $x'y + z$
(b) $BC' + B'D + AB'C$

(c) $AC + B'D' + A'BD + B'C$ (or CD)
(d) $xz + wy + x'y$

3-6. (a) $F(x, y, z) = \Sigma(3, 5, 6, 7)$
(b) $F(A, B, C, D) = \Sigma(1, 3, 5, 9, 12, 13, 14)$
(c) $F(w, x, y, z) = \Sigma(0, 2, 5, 7, 8, 10, 14, 15)$

3-7. (a) The essential prime implicants are xz and $x'z'$;
$F = xz + x'z' + w'x$ (or $w'z'$)
(b) The essential prime implicants are AC, $B'D'$ and $A'BD$;
$F = AC + B'D' + A'BD + CD$ (or $B'C$)
(c) The essential prime implicants are BC' and AC;
$F = BC' + AC + A'B'D$

3-8. (a) $A'B'D' + AD'E + B'C'D'$
(b) $DE + A'B'C + B'C'E'$
(c) $A'B'D' + B'D'E' + B'CD' + CDE' + BDE'$

3-9. (a) $(w' + x')(x + z')(x' + y + z)$
(b) $(A + D')(B' + D')$
(c) y
(d) $(B + C')(A + B)(A + C + D)$

3-10. (a) $xy + z' = (x + z')(y + z')$
(b) $AC' + CD + B'D = (A + D)(C' + D)(A + B' + C)$
(c) $B'D' + AD' + A'C' = (A' + D')(C' + D')(A + B' + C')$

3-11. $F = B'D' + A'BD + A'BC = (A' + B')(B + D')(B' + C + D)$

3-12. (a) $A + BC' + C'D'$
(b) $BD + BC + AB'C'D'$

3-13. $F' = BD + BC + AC$

3-15. (a) $F = (w + z')(x' + z')(w' + x' + y')$
(b) $F = (w + x)(w' + x')(y + z)(w' + z')$

3-18. $F = B'D'(A' + C) + BD(A' + C')$
$= [B' + D(A' + C')][B + D'(A' + C)]$
$= [D' + B(A' + C')][D + B'(A' + C)]$

3-21.

AND–AND = AND	OR–OR = OR
AND–NAND = NAND	OR–NOR = NOR
NOR–NAND = OR	NAND–NOR = AND
NOR–AND = NOR	NAND–OR = NAND

3.22. (a) $F = 1 = \Sigma(0, 1, 2, 3, 4, 5, 6, 7)$
(b) $F = B'D' + CD' + ABC'D = \Sigma(0, 2, 6, 8, 10, 13, 14)$
(c) $F = A'D + BD + C'D = \Sigma(1, 3, 5, 7, 9, 13, 15)$

3-23. (a) $F = x'z' + w'z = (x' + z)(w' + z')$

3-24. $F = C + AD'$

3-27. (a) $A'CEF'G'$
(b) $ABCDEFG + A'CEF'G' + BC'D'EF$
(c) $A'B'C'DEF' + A'BC'D'E + CE'F + A'BD'EF$ (or $A'BCD'F$)

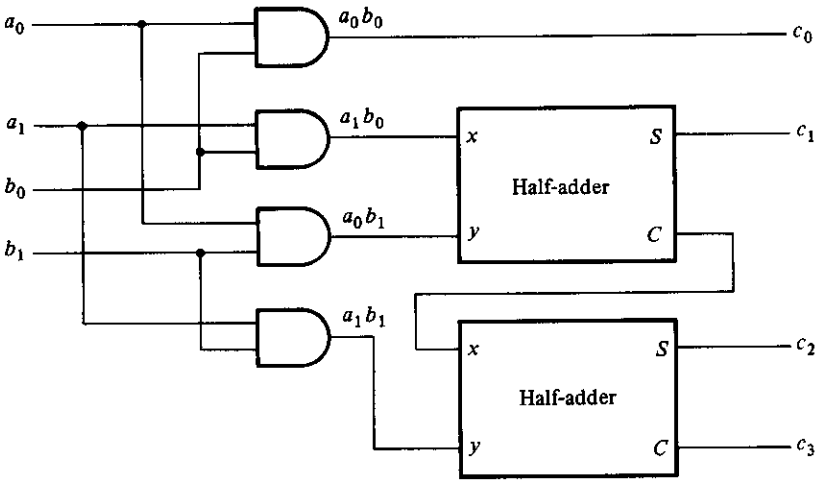
Chapter 4

4-1. $F = x'y' + x'z'$

4-2. $A = xy + xz + yz$; $B = x \oplus y \oplus z$; $C = z'$

4-3. $F = xy + xz + yz$

4-7.



4-9. Inputs: x, y, z; outputs: A, B, C, D, E, F

$A = xy \qquad D = yz'$
$B = xy' + xz \qquad E = 0$
$C = z(x \oplus y) \qquad F = z$

4-10. Inputs: A, B, C, D; outputs: w, x, y, z; $d = \Sigma(10, 11, 12, 13, 14, 15)$;

$w = A'B'C'$
$x = B \oplus C$
$y = C$
$z = D'$

4-11. Inputs: A, B, C, D; outputs: w, x, y, z;

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

4-12. Inputs: A, B, C, D; output: $E = AB + AC$

4-13. Inputs: A, B, C, D; outputs: w, x, y, z; $d = \Sigma(1, 2, 3, 12, 13, 14)$;

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

4-14. Inputs: A, B, C, D; outputs: w, x, y, z; $d = \Sigma(5, 6, 7, 8, 9, 10)$;

$w = A$
$x = A'C + A'B + A'D + BCD$
$y = ACD + AC'D' + A'C'D + A'CD'$
$z = D$

4-15. Inputs: w, x, y, z; outputs: E, A, B, C, D;

$E = wx + wy$
$A = wx'y'$
$B = w'x + xy$
$C = w'y + wxy'$
$D = z$

4-16. Inputs: A, B, C, D; outputs: a, b, c, d, e, f, g;

$a = A'C + A'BD + B'C'D' + AB'C'$
$b = A'B' + A'C'D' + A'CD + AB'C'$
$c = A'B + A'D + B'C'D' + AB'C'$
$d = A'CD' + A'B'C + B'C'D' + AB'C' + A'BC'D$
$e = A'CD' + B'C'D'$
$f = A'BC' + A'C'D' + A'BD' + AB'C'$
$g = A'CD' + A'B'C + A'BC' + AB'C'$

4-17. Full-adder circuit

4-21. $F = ABC + A'D$
$G = ABC + A'D'$

4-28. Inputs: A, B, C, D; outputs: w, x, y, z

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

4-30. $(A \oplus B)(C \oplus D)$

Chapter 5

5-3. (a) $A = 0110$; $B = 1001$; $M = 1$
(b) $S = 1101$ (2's complement of 0011); $C_5 = 0$ (because $A < B$)

5-4.

	Sum	C_4	
(a)	1101	0	$7 + 6 = 13$
(b)	0001	1	$8 + 9 = 16 + 1$
(c)	0100	1	$12 - 8 = 4$
(d)	1011	0	$5 - 10 = -5$ (in 2's complement)
(e)	1111	0	$0 - 1 = -1$ (in 2's complement)

5-5. (b) $C_4 = (G_3'P_3' + G_3'G_2'P_2' + G_3'G_2'G_1'P_1' + G_3'G_2'G_1'C_1')'$

5-6. (c) $C_4 = (P_3' + G_3'P_2' + G_3'G_2'P_1' + G_3'G_2'G_1'C_1')'$

5-7. 60 ns

5-8. $C_5 = G_4 + P_4G_3 + P_4P_3G_2 + P_4P_3P_2G_1 + P_4P_3P_2P_1C_1$

5-9. 312

5-10. See the answer to Problem 4-10.

5-13. $x = (A_0 \odot B_0)(A_1 \odot B_1)(A_2 \odot B_2)(A_3 \odot B_3)$

5-15. $F_1(x, y, z) = \Sigma(0, 5, 7)$
$F_2(x, y, z) = \Sigma(2, 3, 4)$
$F_3(x, y, z) = \Sigma(1, 6, 7)$

5-16. Use NAND gates for F_1 and F_2; AND gate for F_3.

5-20. $x = D_0'D_1'$
$y = D_0'D_1' + D_0'D_2'$
$V = D_0 + D_1 + D_2 + D_3$

5-21. For inputs $D_5 = D_3 = 1$, the outputs are $xyz = 101$; $V = 1$.

5-27. $F(A, B, C, D) = \Sigma(1, 6, 7, 9, 10, 11, 12)$

5-28. When $AB = 00$, $F = D$
When $AB = 01$, $F = (C + D)'$ (use a NOR gate)
When $AB = 10$, $F = CD$ (use an AND gate)
When $AB = 11$, $F = 1$

5-30. 24 pins

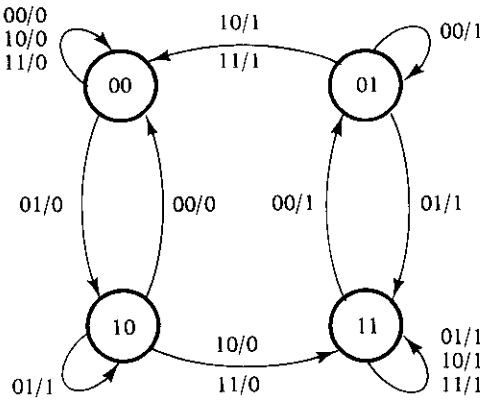
5-31. (a) 256 × 8; (b) 512 × 5; (c) 1024 × 4; (d) 32 × 7

5-33. Six product terms: yz', xz', $x'y'z$, xy', $x'y$, z

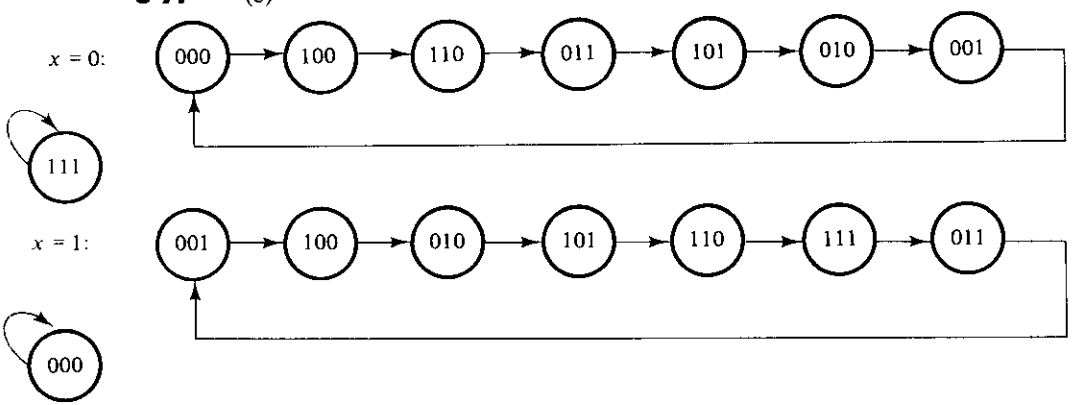
5-37. $A = yz' + xz' + x'y'z$
$B = x'y' + xy + yz$
$C = A + xyz$
$D = z + x'y$

Chapter 6

6-6. (c)



6-7. (b)



6-8.

Present State	Inputs		Next State	Output
Q	x	y	Q	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

6-9. A counter with a repeated sequence of 00, 01, 10.

6-10. (a)

J	N	$Q(t+1)$
0	0	0
0	1	$Q(t)$
1	0	$Q'(t)$
1	1	1

(b)

$Q(t)$	$Q(t+1)$	J	N
0	0	0	X
0	1	1	X
1	0	X	0
1	1	X	1

6-11.

Present State		Input	Next State		Output
A	B	x	A	B	y
0	0	0	0	1	0
0	0	1	0	0	1
0	1	0	1	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	0	1	0
1	1	0	1	1	0
1	1	1	1	0	1

6-12. (c)
$$A(t+1) = xB + x'A + yA + y'A'B'$$
$$B(t+1) = xA'B' + (x' + y')A'B$$

6-13.

Present state:	00	00	01	00	01	11	00	01	11	10	00	01	11	10	10
Input:	0	1	0	1	1	0	1	1	1	0	1	1	1	1	0
Output:	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1
Next state:	00	01	00	01	11	00	01	11	10	00	01	11	10	10	00

6-14.

	Next State		Output	
Present State	0	1	0	1
a	f	b	0	0
b	d	a	0	0
d	g	a	1	0
f	f	b	1	1
g	g	d	0	1

6-15.

State:	a	f	b	c	e	d	g	h	g	g	h	a
Input:	0	1	1	1	0	0	1	0	0	1	1	
Output:	0	1	0	0	0	1	1	1	0	1	0	

6-16.

State:	a	f	b	a	b	d	g	d	g	g	d	a
Input:	0	1	1	1	0	0	1	0	0	1	1	
Output:	0	1	0	0	0	1	1	1	0	1	0	

6-19. $DQ = Q'J + QK'$

6-20.
$DA = Ax' + Bx$
$DB = A'x + Bx'$

6-21.
$JA = KA = (Bx + B'x')E$
$JB = KB = E$

6-22.
(a) $DA = A'B'x$
$DB = A + C'x' + BCx$
$DC = Cx' + Ax + A'B'x'$
$y = A'x$

(b) $JA = B'x \qquad KA = 1$
$JB = A + C'x' \qquad KB = C'x + Cx'$
$JC = Ax + A'B'x' \qquad KC = x$
$y = A'x$

6-23.
$SA = BX' \qquad RA = BX$
$SB = B'x \qquad RB = A'x' + ABx$

6-24.
$TA = ABx + A'Bx'$
$TB = ABx + A'Bx' + B'x$

6-25.
(a) $JA = BC \qquad KA = B$
$JB = C \qquad KB = A + C$
$JC = A' + B' \qquad KC = 1$

(b) $DA = A \oplus B$
$DB = AB' + C$
$DC = A'B'C'$

(c) $TA = B$
$TB = C$
$TC = AB + C'$
(d) $TA = A \oplus B$
$TB = B \oplus C$
$TC = AC + A'C'$ (not self-correcting)
$TC = AC + A'B'C'$ (self-correcting)

Chapter 7

7-5. 1110; 0111; 1011; 1101; 0110; 1011

7-10. A = 0010, 0001, 1000, 1100; Q = 1, 1, 1, 0

7-11. $JQ = x'y$; $KQ = (x' + y)'$

7-16. 100 ns; 10 MHz

7-17. (a) 4; (b) 9

7-18. $1010 \rightarrow 1011 \rightarrow 0100$
$1100 \rightarrow 1101 \rightarrow 0100$
$1110 \rightarrow 1111 \rightarrow 0000$

7-20. $DA_1 = A_1$
$DA_2 = A_2 \oplus A_1$
$DA_3 = A_3 \oplus (A_1A_2)$
$DA_4 = A_4 \oplus (A_1A_2A_3)$

7-23. $JA_1 = KA_1 = 1$
$JA_2 = A_1A_8'$; $KA_2 = A_1A_8'$ (or $= A_1$)
$JA_4 = KA_4 = A_1A_2$
$JA_8 = A_1A_2A_4$; $KA_8 = A_1$

7-33. (a) 11, 16; (b) 16, 8
(c) 24, 32; (d) 17, 12

7-34. 1000010111; 0000100010100001

7-35. (a) 16; (b) 11, 7; (c) 4 × 16 decoder

7-36. (a) 8; (b) 128

7-37. (a) 10, 8; (b) 32; (c) 14, 16; (d) 4 × 16 decoder

7-38. 0001101110111

7-39. 1011100011001010

7-40. (a) 01011010; (b) 11000110; (c) 11110100

7-41. (a) 6; (b) 7; (c) 7

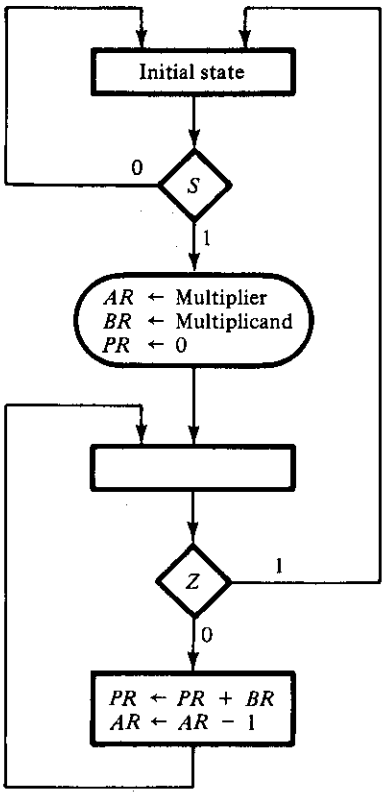
7-42. (a) 0101010

Chapter 8

8-8. MUX1: 0, A_3A_4, 0, 0
MUX2: S, 1, 0, 0

8-9. $DT_0 = S'T_0 + ZT_1$
$DT_1 = ST_0 + ET_3$
$DT_2 = Z'T_1 + E'T_3$
$DT_3 = T_2$

8-13.



8-14. $(2^n - 1)(2^n - 1) < (2^{2n} - 1)$ for $n \geq 1$

8-16. Product = 1010001011

8-17. $2t(n + 1)$

8-18. (a) $JG_1 = G_2$
$KG_1 = ZG_2$
$JG_2 = G_1 + S$
$KG_2 = 1$
(b) $DG_1 = T_1 + T_2 + Z'T_3$
$DG_2 = ST_0 + T_2$
(c) MUX1: 0, 1, 1, Z'
MUX2: S, 0, 1, 0
(d) $DT_0 = S'T_0 + ZT_3$
$DT_1 = ST_0$
$DT_2 = T_1 + Z'T_3$
$DT_3 = T_2$

Chapter 9

9-2. Sequence of $Y_1 Y_2$: 00, 00, 01, 11, 11, 01, 00.

9-3. (d) When the input is 01, the output is 0. When the input is 10, the output is 1. Whenever the input assumes one of the other two combinations, the output retains its previous value.

9-4. (c)

	00	01	11	10
a	ⓐ, 0	b, 1	c, 1	d, 0
b	a, 0	ⓑ, 1	c, 1	ⓑ, 0
c	ⓒ, 1	b, 1	ⓒ, 1	d, 1
d	c, 1	b, 1	c, 1	ⓓ, 1

9-5. (c) $Y_1 = x_1' x_2 + x_2 y_1$
$Y_2 = x_2 + x_1 y_2$
$z = x_1 x_2 y_1' + x_1 y_2'$

9-10. $S = x_1 x_2'$
$R = x_1' x_2$

9-13. (b) Two possible transition tables:

	00	01	11	10
a	ⓐ, 0	b, –	–, –	e, –
b	ⓑ, 1	ⓑ, 1	–, –	d, –
d	a, –	ⓓ, 1	–, –	ⓓ, 1
e	ⓔ, 1	d, –	–, –	ⓔ, 1

	00	01	11	10
a	ⓐ, 0	b, –	–, –	b, –
b	c, –	ⓑ, 1	–, –	ⓑ, 0
c	ⓒ, 1	d, –	–, –	d, –
d	a, –	ⓓ, 1	–, –	ⓓ, 1

9-18. 3a: $(a, b)(c, d)(e, f, g, h)$
3b: $(a, e, f)(b, j)(c, d)(g, h)(k)$

9-20. Add states g and h to binary assignment.

	00	01	11	10
0	a	g	b	f
1	c	h	d	e

9-22. $F = A'D' + AC'D' + A'BC + A'CD'$

9-23. $Y = (x_1 + x_2')(x_2 + x_3)(x_1 + x_3)$

Chapter 10

10-1. Fan-out = 10; power dissipation = 18.75 mW; propagation delay = 3 ns; noise margin = 0.3 V

10-2. (a) 1.058 V (b) 0.82 V (c) 0.238 V

10-3. $I_B = 0.44$ mA, $I_{CS} = 2.4$ mA

10-4. (a) 2.4 mA (b) 0.82 mA (c) $2.4 + 0.82N$ (d) 7.8 (e) 7

10-5. (b) 3.53 (c) 2.585 mA (d) 16 mA (e) 300 Ω

10-9. (a) 4.62 mA (b) 4 mA

10-10. 0.3 V