

- Commutative laws: $A + B = B + A$
 $AB = BA$
- Associative laws: $A + (B + C) = (A + B) + C$
 $A(BC) = (AB)C$
- Distributive law: $A(B + C) = AB + AC$
- Boolean rules:

1. $A + 0 = A$	7. $A \cdot A = A$
2. $A + 1 = 1$	8. $A \cdot \bar{A} = 0$
3. $A \cdot 0 = 0$	9. $\bar{\bar{A}} = A$
4. $A \cdot 1 = A$	10. $A + AB = A$
5. $A + A = A$	11. $A + \bar{A}B = A + B$
6. $A + \bar{A} = 1$	12. $(A + B)(A + C) = A + BC$
- DeMorgan's theorems:
 - The complement of a product is equal to the sum of the complements of the terms in the product.
$$\overline{XY} = \bar{X} + \bar{Y}$$
 - The complement of a sum is equal to the product of the complements of the terms in the sum.
$$\overline{X + Y} = \bar{X}\bar{Y}$$
- Karnaugh maps for 3 variables have 8 cells and for 4 variables have 16 cells.
- Quinn-McCluskey is a method for simplification of Boolean expressions.
- The three levels of abstraction in VHDL are data flow, structural, and behavioral.

KEY TERMS

Key terms and other bold terms in the chapter are defined in the end-of-book glossary.

Complement The inverse or opposite of a number. In Boolean algebra, the inverse function, expressed with a bar over a variable. The complement of a 1 is 0, and vice versa.

“Don’t care” A combination of input literals that cannot occur and can be used as a 1 or a 0 on a Karnaugh map for simplification.

Karnaugh map An arrangement of cells representing the combinations of literals in a Boolean expression and used for a systematic simplification of the expression.

Minimization The process that results in an SOP or POS Boolean expression that contains the fewest possible literals per term.

Product-of-sums (POS) A form of Boolean expression that is basically the ANDing of ORed terms.

Product term The Boolean product of two or more literals equivalent to an AND operation.

Sum-of-products (SOP) A form of Boolean expression that is basically the ORing of ANDed terms.

Sum term The Boolean sum of two or more literals equivalent to an OR operation.

Variable A symbol used to represent an action, a condition, or data that can have a value of 1 or 0, usually designated by an italic letter or word.

TRUE/FALSE QUIZ

Answers are at the end of the chapter.

- Variable, complement, and literal are all terms used in Boolean algebra.
- Addition in Boolean algebra is equivalent to the NOR function.
- Multiplication in Boolean algebra is equivalent to the AND function.
- The commutative law, associative law, and distributive law are all laws in Boolean algebra.
- The complement of 0 is 0 itself.
- When a Boolean variable is multiplied by its complement, the result is the variable.

7. "The complement of a product of variables is equal to the sum of the complements of each variable" is a statement of DeMorgan's theorem.
8. SOP means sum-of-products.
9. Karnaugh maps can be used to simplify Boolean expressions.
10. A 3-variable Karnaugh map has six cells.
11. VHDL is a type of hardware definition language.
12. A VHDL program consists of an entity and an architecture.

SELF-TEST

Answers are at the end of the chapter.

1. A variable is a symbol in Boolean algebra used to represent
 - (a) data
 - (b) a condition
 - (c) an action
 - (d) answers (a), (b), and (c)
2. The Boolean expression $A + B + C$ is
 - (a) a sum term
 - (b) a literal term
 - (c) an inverse term
 - (d) a product term
3. The Boolean expression \overline{ABCD} is
 - (a) a sum term
 - (b) a literal term
 - (c) an inverse term
 - (d) a product term
4. The domain of the expression $\overline{ABCD} + \overline{AB} + \overline{CD} + B$ is
 - (a) A and D
 - (b) B only
 - (c) A, B, C, and D
 - (d) none of these
5. According to the associative law of addition,
 - (a) $A + B = B + A$
 - (b) $A = A + A$
 - (c) $(A + B) + C = A + (B + C)$
 - (d) $A + 0 = A$
6. According to commutative law of multiplication,
 - (a) $AB = BA$
 - (b) $A = AA$
 - (c) $(AB)C = A(BC)$
 - (d) $A0 = A$
7. According to the distributive law,
 - (a) $A(B + C) = AB + AC$
 - (b) $A(BC) = ABC$
 - (c) $A(A + 1) = A$
 - (d) $A + AB = A$
8. Which one of the following is *not* a valid rule of Boolean algebra?
 - (a) $A + 1 = 1$
 - (b) $A = \overline{A}$
 - (c) $AA = A$
 - (d) $A + 0 = A$
9. Which of the following rules states that if one input of an AND gate is always 1, the output is equal to the other input?
 - (a) $A + 1 = 1$
 - (b) $A + A = A$
 - (c) $A \cdot A = A$
 - (d) $A \cdot 1 = A$
10. According to DeMorgan's theorems, the complement of a product of variables is equal to
 - (a) the complement of the sum
 - (b) the sum of the complements
 - (c) the product of the complements
 - (d) answers (a), (b), and (c)
11. The Boolean expression $X = (A + B)(C + D)$ represents
 - (a) two ORs ANDed together
 - (b) two ANDs ORed together
 - (c) A 4-input AND gate
 - (d) a 4-input OR gate
12. An example of a sum-of-products expression is
 - (a) $A + B(C + D)$
 - (b) $\overline{AB} + \overline{AC} + \overline{ABC}$
 - (c) $(\overline{A} + B + C)(A + \overline{B} + C)$
 - (d) both answers (a) and (b)
13. An example of a product-of-sums expression is
 - (a) $A(B + C) + \overline{AC}$
 - (b) $(A + B)(\overline{A} + B + \overline{C})$
 - (c) $\overline{A} + \overline{B} + BC$
 - (d) both answers (a) and (b)
14. An example of a standard SOP expression is
 - (a) $\overline{AB} + \overline{ABC} + \overline{ABD}$
 - (b) $\overline{ABC} + \overline{ACD}$
 - (c) $\overline{AB} + \overline{AB} + \overline{AB}$
 - (d) $\overline{ABCD} + \overline{AB} + \overline{A}$

15. A 4-variable Karnaugh map has
 - (a) four cells
 - (b) eight cells
 - (c) sixteen cells
 - (d) thirty-two cells
16. In a 4-variable Karnaugh map, a 2-variable product term is produced by
 - (a) a 2-cell group of 1s
 - (b) an 8-cell group of 1s
 - (c) a 4-cell group of 1s
 - (d) a 4-cell group of 0s
17. The Quine-McCluskey method can be used to
 - (a) replace the Karnaugh map method
 - (b) simplify expressions with 5 or more variables
 - (c) both (a) and (b)
 - (d) none of the above
18. VHDL is a type of
 - (a) programmable logic
 - (b) hardware description language
 - (c) programmable array
 - (d) logical mathematics
19. In VHDL, a port is
 - (a) a type of entity
 - (b) a type of architecture
 - (c) an input or output
 - (d) a type of variable
20. Using VHDL, a logic circuit's inputs and outputs are described in the
 - (a) architecture
 - (b) component
 - (c) entity
 - (d) data flow

PROBLEMS

Answers to odd-numbered problems are at the end of the book.

Section 4-1 Boolean Operations and Expressions

1. Using Boolean notation, write an expression that is a 0 only when all of its variables (A , B , C , and D) are 0s.
2. Write an expression that is a 1 when one or more of its variables (A , B , C , D , and E) are 0s.
3. Write an expression that is a 0 when one or more of its variables (A , B , and C) are 0s.
4. Evaluate the following operations:
 - (a) $0 + 0 + 0 + 0$
 - (b) $0 + 0 + 0 + 1$
 - (c) $1 + 1 + 1 + 1$
 - (d) $1 \cdot 1 + 0 \cdot 0 + 1$
 - (e) $1 \cdot 0 \cdot 1 \cdot 0$
 - (f) $1 \cdot 0 + 1 \cdot 0 + 0 \cdot 1 + 0 \cdot 1$
5. Find the values of the variables that make each product term 1 and each sum term 0.
 - (a) ABC
 - (b) $A + B + C$
 - (c) $\overline{A}\overline{B}C$
 - (d) $\overline{A} + \overline{B} + C$
 - (e) $A + \overline{B} + \overline{C}$
 - (f) $\overline{A} + \overline{B} + \overline{C}$
6. Find the value of X for all possible values of the variables.
 - (a) $X = A + B + C$
 - (b) $X = (A + B)C$
 - (c) $X = (A + B)(\overline{B} + \overline{C})$
 - (d) $X = (A + B) + (\overline{AB} + \overline{BC})$
 - (e) $X = (\overline{A} + \overline{B})(A + B)$

Section 4-2 Laws and Rules of Boolean Algebra

7. Identify the law of Boolean algebra upon which each of the following equalities is based:
 - (a) $A + AB + ABC + \overline{ABCD} = \overline{ABCD} + ABC + AB + A$
 - (b) $A + \overline{AB} + ABC + \overline{ABCD} = \overline{DCBA} + CBA + \overline{BA} + A$
 - (c) $AB(CD + \overline{CD} + EF + \overline{EF}) = ABCD + \overline{ABCD} + ABEF + \overline{ABEF}$
8. Identify the Boolean rule(s) on which each of the following equalities is based:
 - (a) $\overline{AB} + \overline{CD} + \overline{EF} = AB + CD + \overline{EF}$
 - (b) $A\overline{A}B + A\overline{B}C + A\overline{B}\overline{B} = A\overline{B}C$
 - (c) $A(BC + \overline{BC}) + AC = A(BC) + AC$
 - (d) $AB(C + \overline{C}) + AC = AB + AC$
 - (e) $A\overline{B} + A\overline{B}C = A\overline{B}$
 - (f) $ABC + \overline{AB} + \overline{ABCD} = ABC + \overline{AB} + D$

Section 4-3 DeMorgan's Theorems

9. Apply DeMorgan's theorems to each expression:
 - (a) $A + \overline{B}$
 - (b) \overline{AB}
 - (c) $\overline{A + B + C}$
 - (d) \overline{ABC}
 - (e) $\overline{A(B + C)}$
 - (f) $\overline{AB} + \overline{CD}$
 - (g) $\overline{AB + CD}$
 - (h) $\overline{(A + B)(C + D)}$

10. Apply DeMorgan's theorems to each expression:

(a) $\overline{AB(C + \overline{D})}$

(b) $\overline{AB(CD + EF)}$

(c) $\overline{(A + \overline{B} + C + \overline{D}) + ABCD}$

(d) $\overline{(\overline{A} + B + C + D)(\overline{A}\overline{B}\overline{C}\overline{D})}$

(e) $\overline{AB(CD + \overline{EF})(\overline{AB} + \overline{CD})}$

11. Apply DeMorgan's theorems to the following:

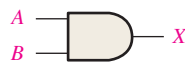
(a) $\overline{(ABC)(\overline{EFG}) + (\overline{HIJ})(\overline{KLM})}$

(b) $\overline{(A + \overline{BC} + CD) + \overline{BC}}$

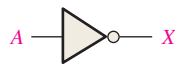
(c) $\overline{(A + B)(C + D)(E + F)(G + H)}$

Section 4-4 Boolean Analysis of Logic Circuits

12. Write the Boolean expression for each of the logic gates in Figure 4-56.



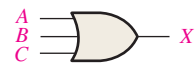
(a)



(b)



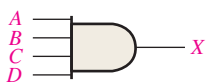
(c)



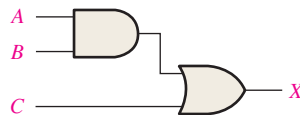
(d)

FIGURE 4-56

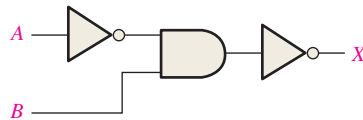
13. Write the Boolean expression for each of the logic circuits in Figure 4-57.



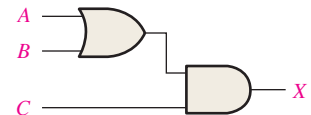
(a)



(b)



(c)



(d)

FIGURE 4-57

14. Draw the logic circuit represented by each of the following expressions:

(a) $A + B + C + D$

(b) $ABCD$

(c) $A + BC$

(d) $ABC + D$

15. Draw the logic circuit represented by each expression:

(a) $AB + \overline{AB}$

(b) $ABCD$

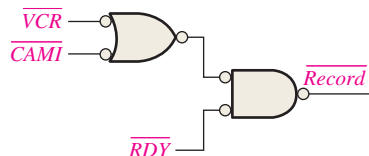
(c) $A + BC$

(d) $ABC + D$

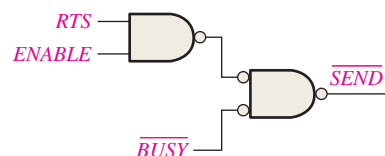
16. (a) Draw a logic circuit for the case where the output, ENABLE, is HIGH only if the inputs, ASSERT and READY, are both LOW.

(b) Draw a logic circuit for the case where the output, HOLD, is HIGH only if the input, LOAD, is LOW and the input, READY, is HIGH.

17. Develop the truth table for each of the circuits in Figure 4-58.



(a)



(b)

FIGURE 4-58

18. Construct a truth table for each of the following Boolean expressions:

(a) $A + B + C$

(b) ABC

(c) $AB + BC + CA$

(d) $(A + B)(B + C)(C + A)$

(e) $\overline{AB} + \overline{BC} + \overline{CA}$

Section 4-5 Logic Simplification Using Boolean Algebra

19. Using Boolean algebra techniques, simplify the following expressions as much as possible:

(a) $A(A + B)$

(b) $A(\overline{A} + AB)$

(c) $BC + \overline{BC}$

(d) $A(A + \overline{AB})$

(e) $\overline{A}BC + \overline{A}BC + \overline{A}BC$

20. Using Boolean algebra, simplify the following expressions:

- (a) $(\bar{A} + B)(A + C)$ (b) $A\bar{B} + A\bar{B}C + A\bar{B}CD + A\bar{B}CDE$
 (c) $BC + \overline{BCD} + B$ (d) $(B + \bar{B})(BC + B\bar{C})$
 (e) $BC + (\bar{B} + \bar{C})D + BC$

21. Using Boolean algebra, simplify the following expressions:

- (a) $CE + C(E + F) + \bar{E}(E + G)$ (b) $\bar{B}\bar{C}D + (\bar{B} + \bar{C} + \bar{D}) + \bar{B}\bar{C}\bar{D}E$
 (c) $(C + CD)(C + \bar{C}D)(C + E)$ (d) $BCDE + BC(\bar{D}E) + (\bar{B}C)DE$
 (e) $BCD[BC + \bar{D}(CD + BD)]$

22. Determine which of the logic circuits in Figure 4–59 are equivalent.

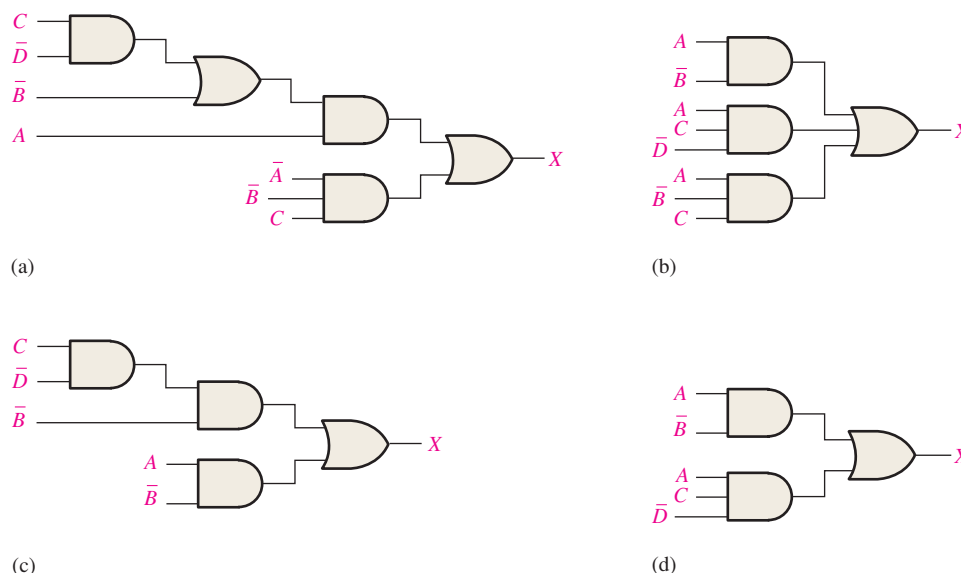


FIGURE 4–59

Section 4–6 Standard Forms of Boolean Expressions

23. Convert the following expressions to sum-of-product (SOP) forms:

- (a) $(C + D)(A + \bar{D})$ (b) $A(\bar{A}\bar{D} + C)$ (c) $(A + C)(CD + AC)$

24. Convert the following expressions to sum-of-product (SOP) forms:

- (a) $BC + DE(\bar{B}C + DE)$ (b) $BC(\bar{C}\bar{D} + CE)$ (c) $B + C[BD + (C + \bar{D})E]$

25. Define the domain of each SOP expression in Problem 23 and convert the expression to standard SOP form.

26. Convert each SOP expression in Problem 24 to standard SOP form.

27. Determine the binary value of each term in the standard SOP expressions from Problem 25.

28. Determine the binary value of each term in the standard SOP expressions from Problem 26.

29. Convert each standard SOP expression in Problem 25 to standard POS form.

30. Convert each standard SOP expression in Problem 26 to standard POS form.

Section 4–7 Boolean Expressions and Truth Tables

31. Develop a truth table for each of the following standard SOP expressions:

- (a) $ABC + \bar{A}\bar{B}C + \bar{A}BC$ (b) $\bar{X}\bar{Y}\bar{Z} + \bar{X}Y\bar{Z} + X\bar{Y}\bar{Z} + \bar{X}YZ + XY\bar{Z}$

32. Develop a truth table for each of the following standard SOP expressions:

- (a) $A\bar{B}\bar{C}\bar{D} + \bar{A}B\bar{C}\bar{D} + \bar{A}\bar{B}CD + \bar{A}\bar{B}\bar{C}\bar{D}$
 (b) $WXYZ + \bar{W}\bar{X}\bar{Y}Z + \bar{W}\bar{X}YZ + \bar{W}X\bar{Y}Z + W\bar{X}\bar{Y}\bar{Z}$

33. Develop a truth table for each of the SOP expressions:

- (a) $\bar{A}B + \bar{A}B\bar{C} + \bar{A}\bar{C} + \bar{A}BC$ (b) $\bar{X} + Y\bar{Z} + WZ + \bar{X}\bar{Y}Z$

34. Develop a truth table for each of the standard POS expressions:
- (a) $(\bar{A} + \bar{B} + \bar{C})(A + B + C)(A + B + \bar{C})$
- (b) $(A + \bar{B} + C + \bar{D})(\bar{A} + B + \bar{C} + D)(A + B + \bar{C} + \bar{D})(\bar{A} + \bar{B} + C + D)$
35. Develop a truth table for each of the standard POS expressions:
- (a) $(A + B)(A + C)(A + B + C)$
- (b) $(A + \bar{B})(A + \bar{B} + \bar{C})(B + C + \bar{D})(\bar{A} + B + \bar{C} + D)$
36. For each truth table in Table 4–15, derive a standard SOP and a standard POS expression.

TABLE 4–15

				$ABCD$	X	$ABCD$	X
				0000	1	0000	0
				0001	1	0001	0
				0010	0	0010	1
				0011	1	0011	0
				0100	0	0100	1
				0101	1	0101	1
				0110	1	0110	0
				0111	0	0111	1
ABC	X	ABC	X	1000	0	1000	0
000	0	000	0	1001	1	1001	0
001	1	001	0	1010	0	1010	0
010	0	010	0	1011	0	1011	1
011	0	011	0	1100	1	1100	1
100	1	100	0	1101	0	1101	0
101	1	101	1	1110	0	1110	0
110	0	110	1	1111	0	1111	1
111	1	111	1				
(a)		(b)		(c)		(d)	

Section 4–8 The Karnaugh Map

37. Draw a 3-variable Karnaugh map and label each cell according to its binary value.
38. Draw a 4-variable Karnaugh map and label each cell according to its binary value.
39. Write the standard product term for each cell in a 3-variable Karnaugh map.

Section 4–9 Karnaugh Map SOP Minimization

40. Use a Karnaugh map to find the minimum SOP form for each expression:
- (a) $\bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C + \bar{A}BC$ (b) $AC(\bar{B} + C)$
- (c) $\bar{A}(BC + \bar{B}\bar{C}) + A(BC + \bar{B}\bar{C})$ (d) $\bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C + \bar{A}BC + ABC$
41. Use a Karnaugh map to simplify each expression to a minimum SOP form:
- (a) $\bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C + \bar{A}BC + ABC$ (b) $AC[\bar{B} + B(B + \bar{C})]$
- (c) $DEF + \bar{D}\bar{E}\bar{F} + \bar{D}E\bar{F}$
42. Expand each expression to a standard SOP form:
- (a) $AB + \bar{A}\bar{B}C + ABC$ (b) $A + BC$
- (c) $\bar{A}\bar{B}\bar{C}D + A\bar{C}\bar{D} + B\bar{C}D + \bar{A}BC\bar{D}$ (d) $\bar{A}\bar{B} + \bar{A}\bar{B}\bar{C}D + CD + \bar{B}\bar{C}D + ABCD$
43. Minimize each expression in Problem 42 with a Karnaugh map.
44. Use a Karnaugh map to reduce each expression to a minimum SOP form:
- (a) $A + \bar{B}\bar{C} + CD$
- (b) $\bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D + ABCD + ABC\bar{D}$
- (c) $\bar{A}B(\bar{C}\bar{D} + \bar{C}D) + AB(\bar{C}\bar{D} + \bar{C}D) + \bar{A}\bar{B}\bar{C}D$
- (d) $(\bar{A}\bar{B} + \bar{A}\bar{B})(CD + \bar{C}\bar{D})$
- (e) $\bar{A}\bar{B} + \bar{A}\bar{B} + \bar{C}\bar{D} + \bar{C}\bar{D}$

45. Reduce the function specified in truth Table 4–16 to its minimum SOP form by using a Karnaugh map.
46. Use the Karnaugh map method to implement the minimum SOP expression for the logic function specified in truth Table 4–17.
47. Solve Problem 46 for a situation in which the last six binary combinations are not allowed.

TABLE 4–16

Inputs			Output
A	B	C	X
0	0	0	1
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

TABLE 4–17

Inputs				Output
A	B	C	D	X
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	0
1	0	1	0	1
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	1

Section 4–10 Karnaugh Map POS Minimization

48. Use a Karnaugh map to find the minimum POS for each expression:
- $(A + B + C)(\bar{A} + \bar{B} + \bar{C})(A + \bar{B} + C)$
 - $(X + \bar{Y})(\bar{X} + Z)(X + \bar{Y} + \bar{Z})(\bar{X} + \bar{Y} + Z)$
 - $A(B + \bar{C})(\bar{A} + C)(A + \bar{B} + C)(\bar{A} + B + \bar{C})$
49. Use a Karnaugh map to simplify each expression to minimum POS form:
- $(A + \bar{B} + C + \bar{D})(\bar{A} + B + \bar{C} + D)(\bar{A} + \bar{B} + \bar{C} + \bar{D})$
 - $(X + \bar{Y})(W + \bar{Z})(\bar{X} + \bar{Y} + \bar{Z})(W + X + Y + Z)$
50. For the function specified in Table 4–16, determine the minimum POS expression using a Karnaugh map.
51. Determine the minimum POS expression for the function in Table 4–17.
52. Convert each of the following POS expressions to minimum SOP expressions using a Karnaugh map:
- $(A + \bar{B})(A + \bar{C})(\bar{A} + \bar{B} + C)$
 - $(\bar{A} + B)(\bar{A} + \bar{B} + \bar{C})(B + \bar{C} + D)(A + \bar{B} + C + \bar{D})$

Section 4–11 The Quine-McCluskey Method

53. List the minterms in the expression
- $$X = ABC + \bar{A}\bar{B}C + A\bar{B}\bar{C} + \bar{A}BC + \bar{A}BC$$
54. List the minterms in the expression
- $$X = \bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D + \bar{A}B\bar{C}\bar{D} + A\bar{B}\bar{C}\bar{D} + \bar{A}B\bar{C}D + \bar{A}B\bar{C}\bar{D} + \bar{A}\bar{B}C\bar{D}$$
55. Create a table for the number of 1s in the minterms for the expression in Problem 54 (similar to Table 4–10).
56. Create a table of first level minterms for the expression in Problem 54 (similar to Table 4–11).

57. Create a table of second level minterms for the expression in Problem 54 (similar to Table 4–12).
58. Create a table of prime implicants for the expression in Problem 54 (similar to Table 4–13).
59. Determine the final reduced expression for the expression in Problem 54.

Section 4–12 Boolean Expressions with VHDL

60. Write a VHDL program for the logic circuit in Figure 4–60.

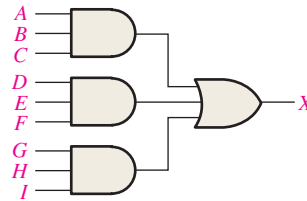


FIGURE 4–60

61. Write a program in VHDL for the expression

$$Y = \overline{A}BC + \overline{A}\overline{B}C + \overline{A}\overline{B}\overline{C} + \overline{A}BC$$

Applied Logic

62. If you are required to choose a type of digital display for low light conditions, will you select LED or LCD 7-segment displays? Why?
63. Explain the purpose of the invalid code detector.
64. For segment *c*, how many fewer gates and inverters does it take to implement the minimum SOP expression than the standard SOP expression?
65. Repeat Problem 64 for the logic for segments *d* through *g*.

Special Design Problems

66. The logic for segments *b* and *c* in Figure 4–53 produces LOW outputs to activate the segments. If a type of 7-segment display is used that requires a HIGH to activate a segment, modify the logic accordingly.
67. Redesign the logic for segment *a* in the Applied Logic to include the letter F in the display.
68. Repeat Problem 67 for segments *b* through *g*.
69. Design the invalid code detector.



Multisim Troubleshooting Practice

70. Open file P04-70. For the specified fault, predict the effect on the circuit. Then introduce the fault and verify whether your prediction is correct.
71. Open file P04-71. For the specified fault, predict the effect on the circuit. Then introduce the fault and verify whether your prediction is correct.
72. Open file P04-72. For the observed behavior indicated, predict the fault in the circuit. Then introduce the suspected fault and verify whether your prediction is correct.

ANSWERS

SECTION CHECKUPS

Section 4–1 Boolean Operations and Expressions

1. $\overline{\overline{A}} = \overline{0} = 1$
2. $A = 1, B = 1, C = 0; \overline{A} + \overline{B} + C = \overline{1} + \overline{1} + 0 = 0 + 0 + 0 = 0$
3. $A = 1, B = 0, C = 1; \overline{A}BC = 1 \cdot \overline{0} \cdot 1 = 1 \cdot 1 \cdot 1 = 1$

Section 4–2 Laws and Rules of Boolean Algebra

1. $A + (B + C + D) = (A + B + C) + D$
2. $A(B + C + D) = AB + AC + AD$