Online Instructor's Manual
for

Digital Fundamentals

Eleventh Edition

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PART 1

Problem Solutions

CHAPTER 1
INTRODUCTORY CONCEPTS

Section 1-1 Digital and Analog Quantities

1. Digital data can be transmitted and stored more efficiently and reliably than analog data. Also, digital circuits are simpler to implement and there is a greater immunity to noisy environments.

2. Pressure is an analog quantity.

3. A clock, a thermometer, and a speedometer can have either an analog or a digital output.

Section 1-2 Binary Digits, Logic Levels, and Digital Waveforms

4. In positive logic, a1 is represented by a HIGH level and a 0 by a LOW level. In negative logic, a 1 is represented by a LOW level, and a 0 by a HIGH level.

5. HIGH = 1; LOW = 0. See Figure 1-1.

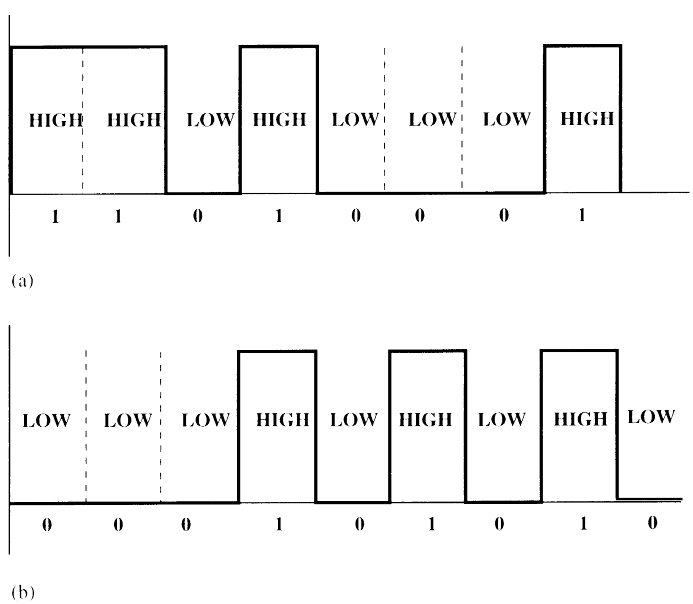

FIGURE 1-1

6. A 1 is a HIGH and a 0 is a LOW:
(a) HIGH, LOW, HIGH, HIGH, HIGH, LOW, HIGH
(b) HIGH, HIGH, HIGH, LOW, HIGH, LOW, LOW, HIGH

7. See Figure 1-2.

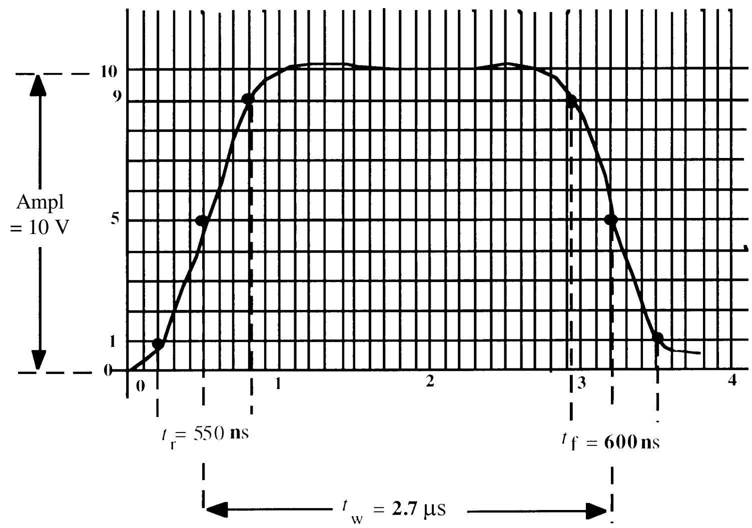

FIGURE 1-2

8. $T = 4$ ms. See Figure 1-3.

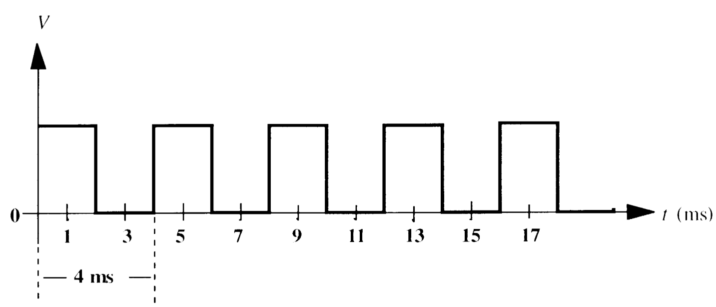

FIGURE 1-3

9. $f = \dfrac{1}{T} = \dfrac{1}{4\text{ ms}} = 0.25\text{ kHz} = 250\text{ Hz}$

10. The waveform in Figure 1-61 is **periodic** because it repeats at a fixed interval.

11. $t_W = 2$ ms; $T = 4$ ms

$$\%\text{ duty cycle} = \left(\frac{t_W}{T}\right)100 = \left(\frac{2\text{ ms}}{4\text{ ms}}\right)100 = 50\%$$

12. See Figure 1-4.

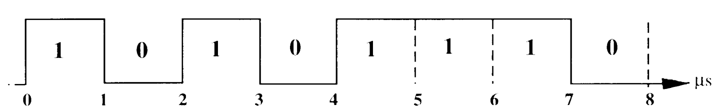

FIGURE 1-4

13. Each bit time = 1 μs
Serial transfer time = (8 bits)(1 μs/bit) = 8 μs

Parallel transfer time = 1 bit time = 1 μs

14. $T = \frac{1}{f} = \frac{1}{3.5\text{ GHz}}$ = **0.286 ns**

Section 1-3 Basic Logic Functions

15. L_{ON} = SW1 + SW2 + SW1 · SW2

16. An AND gate produces a HIGH output only when *all* of its inputs are HIGH.

17. AND gate. See Figure 1-5.

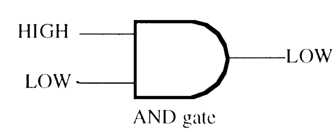

FIGURE 1-5

18. An OR gate produces a HIGH output when *either or both* inputs are HIGH. An exclusive-OR gate produces a HIGH if one input is HIGH and the other LOW.

Section 1-4 Combinational and Sequential Logic Functions

19. See Figure 1-6.

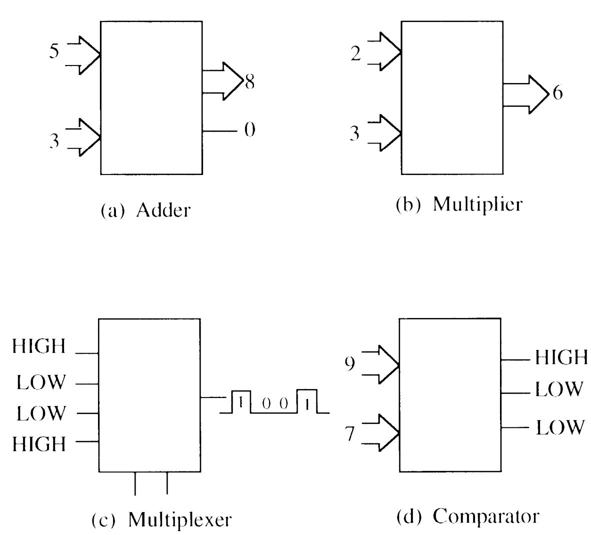

FIGURE 1-6

20. $T = \dfrac{1}{10\,\text{kHz}} = 100\ \mu\text{s}$

Pulses counted $= \dfrac{100\ \text{ms}}{100\ \mu\text{s}} = 1000$

21. See Figure 1-7.

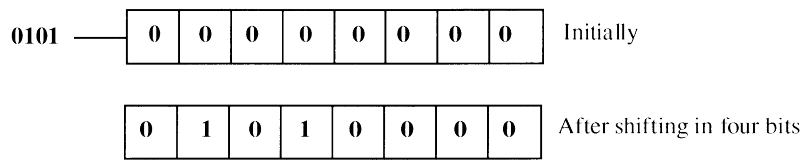

FIGURE 1-7

Section 1-5 Introduction to Programmable Logic

22. The following do not describe PLDs: VHDL, AHDL

23. (a) SPLD: Simple Programmable Logic Device
(b) CPLD: Complex Programmable Logic Device
(c) HDL: Hardware Description Language
(d) FPGA: Field-Programmable Gate Array
(e) GAL: Generic Array Logic

24. (a) Design entry: The step in a programmable logic design flow where a description of the circuit is entered in either schematic (graphic) form or in text form using an HDL.

(b) Simulation: The step in a design flow where the entered design is simulated based on defined input waveforms.

(c) Compilation: A program process that controls the design flow process and translates a design source code to object code for testing and downloading.

(d) Download: The process in which the design is transferred from software to hardware.

25. Place-and-route or fitting is the process where the logic structures described by the netlist are mapped into the actual structure of the specific target device. This results in an output called a bitstream.

Section 1-6 Fixed-Function Logic Devices

26. Circuits with complexities of from 100 to 10,000 equivalent gates are classified as large scale integration (LSI).

27. The pins of an SMT are soldered to the pads on the surface of a pc board, whereas the pins of a DIP feed through and are soldered to the opposite side. Pin spacing on SMTs is less than on DIPs and therefore SMT packages are physically smaller and require less surface area on a pc board.

28. See Figure 1-8.

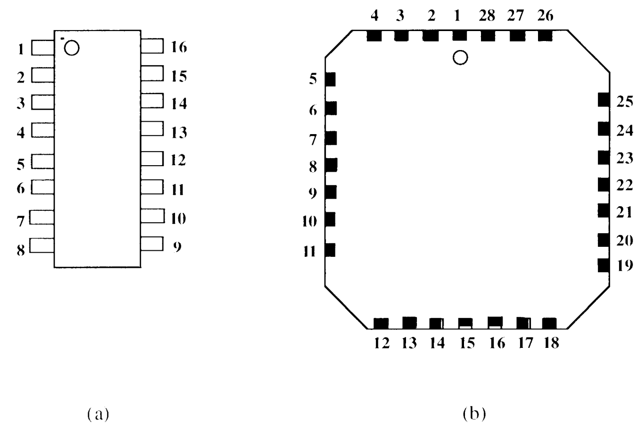

FIGURE 1-8

Section 1-7 Test and Measurement Instruments

29. Amplitude = top of pulse minus base line
$V = 8\text{ V} - 1\text{ V} = 7\text{ V}$

30. Amplitude = (3 div)(2 V /div) = **6 V**.

31. T = (4 div)(2 ms/div) = **8 ms**

$$f = \frac{1}{T} = \frac{1}{8\text{ ms}} = \mathbf{125\text{ Hz}}$$

32. Record length = (Acquisition time)(sample rate) = (2 ms) 12 Msamples/s = **24 ksamples**

Section 1-8 Introduction to Trouble Shooting

33. Troubleshooting is the process of recognizing, isolating, and correcting a fault or failure in a system.

34. In the half-splitting method, a point half way between the input and output is checked for the presence or absence of a signal.

35. In the signal-tracing method, a signal is tracked as it progresses through a system until a point is found where the signal disappears or is incorrect.

36. In signal subsitution, a generated signal replaces the normal input signal of a system or portion of s system. In signal injection a generated signal is injected into the system at a point where the normal signal has been determined to be faulty or missing.

37. When a failure **is** reported, determine when and how it failed and what are the symptoms.

38. No output signal can be caused by no dc power, no input signal, or a short or open that prevents the signal from getting to the output.

39. An incorrect output can be caused by an incorrect dc supply voltage, improper ground, incorrect component value, or a faulty component.

40. Some types of obvious things that you look for when a system fails are visible faults such as shorted wires, solder splashes, wire clippings, bad or open connections, burned components, Also look for a signal that is incorrect in terms of amplitude shape, or frequency or the absence of a signal.

41. To isolate a fault in a system, apply half-splitting or signal tracing.

42. Two common troubleshooting instruments are the oscilloscope and the DMM.

43. When a fault has been isolated to a particular circuit board, the options are to repair the board or replace the board with a known good board.

CHAPTER 2
NUMBER SYSTEMS, OPERATIONS, AND CODES

Section 2-1 Decimal Numbers

1. (a) $1386 = 1 \times 10^3 + 3 \times 10^2 + 8 \times 10^1 + 6 \times 10^0$
$= 1 \times 1000 + 3 \times 100 + 8 \times 10 + 6 \times 1$
The digit 6 has a weight of $10^0 = 1$

(b) $54{,}692 = 5 \times 10^4 + 4 \times 10^3 + 6 \times 10^2 + 9 \times 10^1 + 2 \times 10^0$
$= 5 \times 10{,}000 + 4 \times 1000 + 6 \times 100 + 9 \times 10 + 2 \times 1$
The digit 6 has a weight of $10^2 = 100$

(c) $671{,}920 = 6 \times 10^5 + 7 \times 10^4 + 1 \times 10^3 + 9 \times 10^2 + 2 \times 10^1 + 0 \times 10^0$
$= 6 \times 100{,}000 + 7 \times 10{,}000 + 1 \times 1000 + 9 \times 100 + 2 \times 10 + 0 \times 1$
The digit 6 has a weight of $10^5 = 100{,}000$

2. (a) $10 = 10^1$ (b) $100 = 10^2$
(c) $10{,}000 = 10^4$ (d) $1{,}000{,}000 = 10^6$

3. (a) $471 = 4 \times 10^2 + 7 \times 10^1 + 1 \times 10^0$
$= 4 \times 100 + 7 \times 10 + 1 \times 1$
$= 400 + 70 + 1$

(b) $9{,}356 = 9 \times 10^3 + 3 \times 10^2 + 5 \times 10^1 + 6 \times 10^0$
$= 9 \times 1000 + 3 \times 100 + 5 \times 10 + 6 \times 1$
$= 9{,}000 + 300 + 50 + 6$

(c) $125{,}000 = 1 \times 10^5 + 2 \times 10^4 + 5 \times 10^3$
$= 1 \times 100{,}000 + 2 \times 10{,}000 + 5 \times 1000$
$= 100{,}000 + 20{,}000 + 5{,}000$

4. The highest four-digit decimal number is 9999.

Section 2-2 Binary Numbers

5. (a) $11 = 1 \times 2^1 + 1 \times 2^0 = 2 + 1 = 3$
(b) $100 = 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0 = 4$
(c) $111 = 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 4 + 2 + 1 = 7$
(d) $1000 = 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 0 \times 2^0 = 8$
(e) $1001 = 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 8 + 1 = 9$
(f) $1100 = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0 = 8 + 4 = 12$
(g) $1011 = 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 8 + 2 + 1 = 11$
(h) $1111 = 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 8 + 4 + 2 + 1 = 15$

6. (a) $1110 = 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 = 8 + 4 + 2 = 14$
(b) $1010 = 1 \times 2^3 + 1 \times 2^1 = 8 + 2 = 10$
(c) $11100 = 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 = 16 + 8 + 4 = 28$
(d) $10000 = 1 \times 2^4 = 16$
(e) $10101 = 1 \times 2^4 + 1 \times 2^2 + 1 \times 2^0 = 16 + 4 + 1 = 21$
(f) $11101 = 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^0 = 16 + 8 + 4 + 1 = 29$
(g) $10111 = 1 \times 2^4 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 16 + 4 + 2 + 1 = 23$
(h) $11111 = 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 16 + 8 + 4 + 2 + 1 = 31$

7. (a) $110011.11 = 1 \times 2^5 + 1 \times 2^4 + 1 \times 2^1 + 1 \times 2^0 + 1 \times 2^{-1} + 1 \times 2^{-2}$
$= 32 + 16 + 2 + 1 + 0.5 + 0.25 = 51.75$
(b) $101010.01 = 1 \times 2^5 + 1 \times 2^3 + 1 \times 2^1 + 1 \times 2^{-2} = 32 + 8 + 2 + 0.25$
$= 42.25$
(c) $1000001.111 = 1 \times 2^6 + 1 \times 2^0 + 1 \times 2^{-1} + 1 \times 2^{-2} + 1 \times 2^{-3}$
$= 64 + 1 + 0.5 + 0.25 + 0.125 = 65.875$
(d) $1111000.101 = 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^{-1} + 1 \times 2^{-3}$
$= 64 + 32 + 16 + 8 + 0.5 + 0.125 = 120.625$
(e) $1011100.10101 = 1 \times 2^6 + 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^{-1} + 1 \times 2^{-3} + 1 \times 2^{-5}$
$= 64 + 16 + 8 + 4 + 0.5 + 0.125 + 0.03125$
$= 92.65625$
(f) $1110001.0001 = 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 1 \times 2^0 + 1 \times 2^{-4}$
$= 64 + 32 + 16 + 1 + 0.0625 = 113.0625$
(g) $1011010.1010 = 1 \times 2^6 + 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^1 + 1 \times 2^{-1} + 1 \times 2^{-3}$
$= 64 + 16 + 8 + 2 + 0.5 + 0.125 = 90.625$
(h) $1111111.11111 = 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1$
$+ 1 \times 2^0 + 1 \times 2^{-1} + 1 \times 2^{-2} + 1 \times 2^{-3} + 1 \times 2^{-4} + 1 \times 2^{-5}$
$= 64 + 32 + 16 + 8 + 4 + 2 + 1 + 0.5 + 0.25 + 0.125 + 0.0625 + 0.03125$
$= 127.96875$

8.

(a)	$2^2 - 1 = 3$	(b)	$2^3 - 1 = 7$
(c)	$2^4 - 1 = 15$	(d)	$2^5 - 1 = 31$
(e)	$2^6 - 1 = 63$	(f)	$2^7 - 1 = 127$
(g)	$2^8 - 1 = 255$	(h)	$2^9 - 1 = 511$
(i)	$2^{10} - 1 = 1023$	(j)	$2^{11} - 1 = 2047$

9. (a) $(2^4 - 1) < 17 < (2^5 - 1)$; 5 bits
(b) $(2^5 - 1) < 35 < (2^6 - 1)$; 6 bits
(c) $(2^5 - 1) < 49 < (2^6 - 1)$; 6 bits
(d) $(2^6 - 1) < 68 < (2^7 - 1)$; 7 bits
(e) $(2^6 - 1) < 81 < (2^7 - 1)$; 7 bits
(f) $(2^6 - 1) < 114 < (2^7 - 1)$; 7 bits
(g) $(2^7 - 1) < 132 < (2^8 - 1)$; 8 bits
(h) $(2^7 - 1) < 205 < (2^8 - 1)$; 8 bits

10. (a) 0 through 7:
000, 001, 010, 011, 100, 101, 110, 111

(b) 8 through 15:
1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111

(c) 16 through 31:
10000, 10001, 10010, 10011, 10100, 10101, 10110, 10111, 11000, 11001, 11010, 11011, 11100, 11101, 11110, 11111

(d) 32 through 63:
100000, 100001, 100010, 100011, 100100, 100101, 100110, 100111, 10100, 101001, 101010, 101011, 101100, 101101, 101110, 101111, 110000, 110001, 110010, 110011, 110100, 110101, 110110, 110111, 111000, 111001, 111010, 111011, 111100, 111101, 111110, 111111

(e) 64 through 75:
1000000, 1000001, 1000010, 1000011, 1000100, 1000101, 1000110, 1000111, 1001000, 1001001, 1001010, 1001011

Section 2-3 Decimal-to-Binary Conversion

11. (a) $10 = 8 + 2 = 2^3 + 2^1 = 1010$

(b) $17 = 16 + 1 = 2^4 + 2^0 = 10001$

(c) $24 = 16 + 8 = 2^4 + 2^3 = 11000$

(d) $48 = 32 + 16 = 2^5 + 2^4 = 110000$

(e) $61 = 32 + 16 + 8 + 4 + 1 = 2^5 + 2^4 + 2^3 + 2^2 + 2^0 = 111101$

(f) $93 = 64 + 16 + 8 + 4 + 1 = 2^6 + 2^4 + 2^3 + 2^2 + 2^0 = 1011101$

(g) $125 = 64 + 32 + 16 + 8 + 4 + 1 = 2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^0 = 1111101$

(h) $186 = 128 + 32 + 16 + 8 + 2 = 2^7 + 2^5 + 2^4 + 2^3 + 2^1 = 10111010$

12. (a) $0.32 \cong 0.00 + 0.25 + 0.0625 + 0.0 + 0.0 + 0.0078125 = 0.0101001$

(b) $0.246 \cong 0.0 + 0.0 + 0.125 + 0.0625 + 0.03125 + 0.015625 = 0.001111$

(c) $0.0981 \cong 0.0 + 0.0 + 0.0 + 0.0625 + 0.03125 + 0.0 + 0.0 + 0.00390625 = 0.0001101$

13. (a)

$$\frac{15}{2} = 7,\ R = 1\ (\text{LSB})$$
$$\frac{7}{2} = 3,\ R = 1$$
$$\frac{3}{2} = 1,\ R = 1$$
$$\frac{1}{2} = 0,\ R = 1\ (\text{MSB})$$

(b)

$$\frac{21}{2} = 10,\ R = 1\ (\text{LSB})$$
$$\frac{10}{2} = 5,\ R = 0$$
$$\frac{5}{2} = 2,\ R = 1$$
$$\frac{2}{2} = 1,\ R = 0$$
$$\frac{1}{2} = 0,\ R = 1\ (\text{MSB})$$

(c)

$$\frac{28}{2} = 14,\ R = 0\ (\text{LSB})$$
$$\frac{14}{2} = 7,\ R = 0$$
$$\frac{7}{2} = 3,\ R = 1$$
$$\frac{3}{2} = 1,\ R = 1$$
$$\frac{1}{2} = 0,\ R = 1\ (\text{MSB})$$

(d)

$$\frac{34}{2} = 17,\ R = 0\ (\text{LSB})$$
$$\frac{17}{2} = 8,\ R = 1$$
$$\frac{8}{2} = 4,\ R = 0$$
$$\frac{4}{2} = 2,\ R = 0$$
$$\frac{2}{2} = 1,\ R = 0$$
$$\frac{1}{2} = 0,\ R = 1\ (\text{MSB})$$

(e)

$$\frac{40}{2} = 20,\ R = 0\ (\text{LSB})$$
$$\frac{20}{2} = 10,\ R = 0$$
$$\frac{10}{2} = 5,\ R = 0$$
$$\frac{5}{2} = 2,\ R = 1$$
$$\frac{2}{2} = 1,\ R = 0$$
$$\frac{1}{2} = 0,\ R = 1\ (\text{MSB})$$

(f)

$$\frac{59}{2} = 29,\ R = 1\ (\text{LSB})$$
$$\frac{29}{2} = 14,\ R = 1$$
$$\frac{14}{2} = 7,\ R = 0$$
$$\frac{7}{2} = 3,\ R = 1$$
$$\frac{3}{2} = 1,\ R = 1$$
$$\frac{1}{2} = 0,\ R = 1\ (\text{MSB})$$

(g)

$$\frac{65}{2} = 32,\ R = 1\ (\text{LSB})$$
$$\frac{32}{2} = 16,\ R = 0$$
$$\frac{16}{2} = 8,\ R = 0$$
$$\frac{8}{2} = 4,\ R = 0$$
$$\frac{4}{2} = 2,\ R = 0$$
$$\frac{2}{2} = 1,\ R = 0$$
$$\frac{1}{2} = 0,\ R = 1\ (\text{MSB})$$

(h)

$$\frac{73}{2} = 36,\ R = 1\ (\text{LSB})$$
$$\frac{36}{2} = 18,\ R = 0$$
$$\frac{18}{2} = 9,\ R = 0$$
$$\frac{9}{2} = 4,\ R = 1$$
$$\frac{4}{2} = 2,\ R = 0$$
$$\frac{2}{2} = 1,\ R = 0$$
$$\frac{1}{2} = 0,\ R = 1\ (\text{MSB})$$

14. (a)

$0.98 \times 2 = 1.96$ 1 (MSB)
$0.96 \times 2 = 1.92$ 1
$0.92 \times 2 = 1.84$ 1
$0.84 \times 2 = 1.68$ 1
$0.68 \times 2 = 1.36$ 1
$0.36 \times 2 = 0.72$ 0
continue if more accuracy is desired
0.111110

(b)

$0.347 \times 2 = 0.694$ 0 (MSB)
$0.694 \times 2 = 1.388$ 1
$0.388 \times 2 = 0.776$ 0
$0.776 \times 2 = 1.552$ 1
$0.552 \times 2 = 1.104$ 1
$0.104 \times 2 = 0.208$ 0
$0.208 \times 2 = 0.416$ 0
continue if more accuracy is desired
0.0101100

(c)

$0.9028 \times 2 = 1.8056$ 1 (MSB)
$0.8056 \times 2 = 1.6112$ 1
$0.6112 \times 2 = 1.2224$ 1
$0.2224 \times 2 = 0.4448$ 0
$0.4448 \times 2 = 0.8896$ 0
$0.8896 \times 2 = 1.7792$ 1
$0.7792 \times 2 = 1.5584$ 1
continue if more accuracy is desired
0.1110011

Section 2-4 Binary Arithmetic

15.

(a) $$\begin{array}{r} 11 \\ +\,01 \\ \hline 100 \end{array}$$

(b) $$\begin{array}{r} 10 \\ +\,10 \\ \hline 100 \end{array}$$

(c) $$\begin{array}{r} 101 \\ +\,011 \\ \hline 1000 \end{array}$$

(d) $$\begin{array}{r} 111 \\ +\,110 \\ \hline 1101 \end{array}$$

(e) $$\begin{array}{r} 1001 \\ +\,0101 \\ \hline 1110 \end{array}$$

(f) $$\begin{array}{r} 1101 \\ +\,1011 \\ \hline 11000 \end{array}$$

16.

(a) $$\begin{array}{r} 11 \\ -\,01 \\ \hline 10 \end{array}$$

(b) $$\begin{array}{r} 101 \\ -\,100 \\ \hline 001 \end{array}$$

(c) $$\begin{array}{r} 110 \\ -\,101 \\ \hline 001 \end{array}$$

(d) $$\begin{array}{r} 1110 \\ -\,0011 \\ \hline 1011 \end{array}$$

(e) $$\begin{array}{r} 1100 \\ -\,1001 \\ \hline 0011 \end{array}$$

(f) $$\begin{array}{r} 11010 \\ -\,10111 \\ \hline 00011 \end{array}$$

17. (a)
$$\begin{array}{r} 11 \\ \times 11 \\ \hline 11 \\ 11 \\ \hline 1001 \end{array}$$

(b)
$$\begin{array}{r} 100 \\ \times 10 \\ \hline 000 \\ 100 \\ \hline 1000 \end{array}$$

(c)
$$\begin{array}{r} 111 \\ \times 101 \\ \hline 111 \\ 000 \\ 111 \\ \hline 100011 \end{array}$$

(d)
$$\begin{array}{r} 1001 \\ \times 110 \\ \hline 0000 \\ 1001 \\ 1001 \\ \hline 110110 \end{array}$$

(e)
$$\begin{array}{r} 1101 \\ \times 1101 \\ \hline 1101 \\ 0000 \\ 1101 \\ 1101 \\ \hline 10101001 \end{array}$$

(f)
$$\begin{array}{r} 1110 \\ \times 1101 \\ \hline 1110 \\ 0000 \\ 1110 \\ 1110 \\ \hline 10110110 \end{array}$$

18. (a) $\frac{100}{10} = 010$ (b) $\frac{1001}{0011} = 0011$ (c) $\frac{1100}{0100} = 0011$

Section 2-5 Complements of Binary Numbers

19. Zero is represented in 1's complement as all 0's (for +0) or all 1's (for −0).

20. Zero is represented by all 0's only in 2's complement.

21. (a) The 1's complement of 101 is 010.
(b) The 1's complement of 110 is 001.
(c) The 1's complement of 1010 is 0101.
(d) The 1's complement of 11010111 is 00101000.
(e) The 1's complement of 1110101 is 0001010.
(f) The 1's complement of 00001 is 11110.

22. Take the 1's complement and add 1:

(a) 01 + 1 = 10
(b) 000 + 1 = 001
(c) 0110 + 1 = 0111
(d) 0010 + 1 = 0011
(e) 00011 + 1 = 00100
(f) 01100 + 1 = 01101
(g) 01001111 + 1 = 01010000
(h) 11000010 + 1 = 11000011

Section 2-6 Signed Numbers

23. (a) Magnitude of 29 = 0011101
+ 29 = 00011101

(b) Magnitude of 85 = 1010101
−85 = 11010101

(c) Magnitude of 100_{10} = 1100100
+100 = 01100100

(d) Magnitude of 123 = 1111011
−123 = 11111011

24. (a) Magnitude of 34 = 0100010
−34 = 11011101

(b) Magnitude of 57 = 0111001
+57 = 00111001

(c) Magnitude of 99 = 1100011
−99 = 10011100

(d) Magnitude of 115 = 1110011
+115 = 01110011

25. (a) Magnitude of 12 = 1100
+12 = 00001100

(b) Magnitude of 68 = 1000100
−68 = 10111100

(c) Magnitude of 101_{10} = 1100101
+101_{10} = 01100101

(d) Magnitude of 125 = 1111101
−125 = 10000011

26. (a) 10011001 = −25 (b) 01110100 = +116 (c) 10111111 = −63

27. (a) 10011001 = −(01100110) = −102
(b) 01110100 = +(1110100) = +116
(c) 10111111 = −(1000000) = −64

28. (a) 10011001 = −(1100111) = −103
(b) 01110100 = +(1110100) = +116
(c) 10111111 = −(1000001) = −65

29. (a) 0111110000101011 $\rightarrow$ sign = 0
$1.11110000101011 \times 2^{14}$ $\rightarrow$ exponent = 127 + 14 + 141 = 10001101
Mantissa = 11110000101011000000000
01000110111110000101011000000000

(b) 100110000011000 $\rightarrow$ sign = 1
$1.10000011000 \times 2^{11}$ $\rightarrow$ exponent = 127 + 11 = 138 = 10001010
Mantissa = 10000011000000000000000
11000101010000011000000000000000

30. (a) 11000000101001001110001000000000
Sign = 1
Exponent = 10000001 = 129 − 127 = 2
Mantissa = $1.01001001110001 \times 2^{2}$ = 101.001001110001
−101.001001110001 = **−5.15258789**

(b) 01100110010000111110100100000000
Sign = 0
Exponent = 11001100 = 204 − 127 = 77
Mantissa = 1.100001111101001
$\mathbf{1.100001111101001 \times 2^{77}}$

Section 2-7 Arithmetic Operations with Signed Numbers

31. (a) 33 = 00100001, 15 = 00001111

$$\begin{array}{r} 00100001 \\ +\ 00001111 \\ \hline 00110000 \end{array}$$

(b) 56 = 00111000, 27 = 00011011, −27 = 11100101

$$\begin{array}{r} 00111000 \\ +\ 11100101 \\ \hline 00011101 \end{array}$$

(c) 46 = 00101110, −46 = 11010010, 25 = 00011001

$$\begin{array}{r} 11010010 \\ +\ 00011001 \\ \hline 11101011 \end{array}$$

(d) 110_{10} = 01101110, -110_{10} = 10010010, 84 = 01010100, −84 = 10101100

$$\begin{array}{r} 10010010 \\ +\ 10101100 \\ \hline 100111110 \end{array}$$

32. (a)

$$\begin{array}{r} 00010110 \\ +\ 00110011 \\ \hline 01001001 \end{array}$$

(b)

$$\begin{array}{r} 01110000 \\ +\ 10101111 \\ \hline 100011111 \end{array}$$

33. (a)

$$\begin{array}{r} 10001100 \\ +\ 00111001 \\ \hline 11000101 \end{array}$$

(b)

$$\begin{array}{r} 11011001 \\ +\ 11100111 \\ \hline 11000000 \end{array}$$

34. (a)

$$\begin{array}{r} 00110011 \\ -\ 00010000 \\ \hline \end{array} \qquad \begin{array}{r} 00110011 \\ +\ 11110000 \\ \hline \not{1}\ 00100011 \end{array}$$

(b)

$$\begin{array}{r} 01100101 \\ -\ 11101000 \\ \hline \end{array} \qquad \begin{array}{r} 01100101 \\ +\ 00011000 \\ \hline 01111101 \end{array}$$

35.

$$\begin{array}{r} 01101010 \\ \times\ 11110001 \\ \hline \end{array} \qquad \begin{array}{r} 01101010 \\ \times\ 00001111 \\ \hline 01101010 \\ 01101010 \\ \hline 100111110 \\ 01101010 \\ \hline 1011100110 \\ 01101010 \\ \hline 11000110110 \end{array}$$

Changing to 2's complement with sign: 100111001010

36. $\dfrac{01000100}{00011001} = 00000010$

$\dfrac{68}{25} = 2$, remainder of 18

Section 2-8 Hexadecimal Numbers

37.
- (a) 38_{16} = 0011 1000
- (b) 59_{16} = 0101 1001
- (c) $A14_{16}$ = 1010 0001 0100
- (d) $5C8_{16}$ = 0101 1100 1000
- (e) 4100_{16} = 0100 0001 0000 0000
- (f) $FB17_{16}$ = 1111 1011 0001 0111
- (g) $8A9D_{16}$ = 1000 1010 1001 1101

38. (a) $1110 = E_{16}$
(b) $10 = 2_{16}$
(c) $0001\ 0111 = 17_{16}$
(d) $1010\ 0110 = A6_{16}$
(e) $0011\ 1111\ 0000 = 3F0_{16}$
(f) $1001\ 1000\ 0010 = 982_{16}$

39. (a) $23_{16} = 2 \times 16^1 + 3 \times 16^0 = 32 + 3 = 35$
(b) $92_{16} = 9 \times 16^1 + 2 \times 16^0 = 144 + 2 = 146$
(c) $1A_{16} = 1 \times 16^1 + 10 \times 16^0 = 16 + 10 = 26$
(d) $8D_{16} = 8 \times 16^1 + 13 \times 16^0 = 128 + 13 = 141$
(e) $F3_{16} = 15 \times 16^1 + 3 \times 16^0 = 240 + 3 = 243$
(f) $EB_{16} = 14 \times 16^1 + 11 \times 16^0 = 224 + 11 = 235$
(g) $5C2_{16} = 5 \times 16^2 + 12 \times 16^1 + 2 \times 16^0 = 1280 + 192 + 2 = 1474$
(h) $700_{16} = 7 \times 16^2 = 1792$

40. (a) $\frac{8}{16} = 0$, remainder = 8
hexadecimal number = 8_{16}

(b) $\frac{14}{16} = 0$, remainder = $14 = E_{16}$
hexadecimal number = E_{16}

(c) $\frac{33}{16} = 2$, remainder = 1 (LSD)
$\frac{2}{16} = 0$, remainder = 2
hexadecimal number = 21_{16}

(d) $\frac{52}{16} = 3$, remainder = 4 (LSD)
$\frac{3}{16} = 0$, remainder = 3
hexadecimal number = 34_{16}

(e) $\frac{284}{16} = 17$, remainder = $12 = C_{16}$ (LSD)
$\frac{17}{16} = 1$, remainder = 1
$\frac{1}{16} = 0$, remainder = 1
hexadecimal number = $11C_{16}$

(f) $\frac{2890}{16} = 180$, remainder = $10 = A_{16}$ (LSD)
$\frac{180}{16} = 11$, remainder = 4
$\frac{11}{16} = 0$, remainder = $11 = B_{16}$
hexadecimal number = $B4A_{16}$

(g) $\frac{4019}{16} = 251$, remainder = 3 (LSD)
$\frac{251}{16} = 15$, remainder = $11 = B_{16}$
$\frac{15}{16} = 0$, remainder = $15 = F_{16}$
hexadecimal number = $FB3_{16}$

(h) $\frac{6500}{16} = 406$, remainder = 4 (LSD)
$\frac{406}{16} = 25$, remainder = 6
$\frac{25}{16} = 1$, remainder = 9
$\frac{1}{16} = 0$, remainder = 1
hexadecimal number = 1964_{16}

41. (a) $37_{16} + 29_{16} = 60_{16}$
(b) $A0_{16} + 6B_{16} = 10B_{16}$
(c) $FF_{16} + BB_{16} = 1BA_{16}$

42. (a) $51_{16} - 40_{16} = 11_{16}$
(b) $C8_{16} - 3A_{16} = 8E_{16}$
(c) $FD_{16} - 88_{16} = 75_{16}$

Section 2-9 Octal Numbers

43. (a) $12_8 = 1 \times 8^1 + 2 \times 8^0 = 8 + 2 = 10$
(b) $27_8 = 2 \times 8^1 + 7 \times 8^0 = 16 + 7 = 23$
(c) $56_8 = 5 \times 8^1 + 6 \times 8^0 = 40 + 6 = 46$
(d) $64_8 = 6 \times 8^1 + 4 \times 8^0 = 48 + 4 = 52$
(e) $103_8 = 1 \times 8^2 + 3 \times 8^0 = 64 + 3 = 67$
(f) $557_8 = 5 \times 8^2 + 5 \times 8^1 + 7 \times 8^0 = 320 + 40 + 7 = 367$
(g) $163_8 = 1 \times 8^2 + 6 \times 8^1 + 3 \times 8^0 = 64 + 48 + 3 = 115$
(h) $1024_8 = 1 \times 8^3 + 2 \times 8^1 + 4 \times 8^0 = 512 + 16 + 4 = 532$
(i) $7765_8 = 7 \times 8^3 + 7 \times 8^2 + 6 \times 8^1 + 5 \times 8^0 = 3584 + 448 + 48 + 5 = 4085$

44. (a) $\frac{15}{8} = 1$, remainder = 7 (LSD)
$\frac{1}{8} = 0$, remainder =1
octal number = 17_8

(b) $\frac{27}{8} = 3$, remainder = 3 (LSD)
$\frac{3}{8} = 0$, remainder = 3
octal number = 33_8

(c) $\frac{46}{8} = 5$, remainder = 6 (LSD)
$\frac{5}{8} = 0$, remainder = 5
octal number = 56_8

(d) $\frac{70}{8} = 8$, remainder = 6 (LSD)
$\frac{8}{8} = 1$, remainder = 0
$\frac{1}{8} = 0$, remainder = 1
octal number = 106_8

(e) $\frac{100}{8} = 12$, remainder = 4 (LSD)
$\frac{12}{8} = 1$, remainder = 4
$\frac{1}{8} = 0$, remainder = 1
octal number = 144_8

(f) $\frac{142}{8} = 17$, remainder = 6 (LSD)
$\frac{17}{8} = 2$, remainder = 1
$\frac{2}{8} = 0$, remainder = 2
octal number = 216_8

(g) $\frac{219}{8} = 27$, remainder = 3 (LSD)
$\frac{27}{8} = 3$, remainder = 3
$\frac{3}{8} = 0$, remainder = 3
octal number = 333_8

(h) $\frac{435}{8} = 54$, remainder = 3 (LSD)
$\frac{54}{8} = 6$, remainder = 6
$\frac{6}{8} = 0$, remainder = 6
octal number = 663_8

45. (a) 13_8 = 001 011
(b) 57_8 = 101 111
(c) 101_8 = 001 000 001
(d) 321_8 = 011 010 001
(e) 540_8 = 101 100 000
(f) 4653_8 = 100 110 101 011
(g) 13271_8 = 001 011 010 111 001
(h) 45600_8 = 100 101 110 000 000
(i) 100213_8 = 001 000 000 010 001 011

46. (a) 111 = 7_8
(b) 010 = 2_8
(c) 110 111 = 67_8
(d) 101 010 = 52_8
(e) 001 100 = 14_8
(f) 001 011 110 = 136_8
(g) 101 100 011 001 = 5431_8
(h) 010 110 000 011 = 2603_8
(i) 111 111 101 111 000 = 77570_8

Section 2-10 Binary Coded Decimal (BCD)

47. (a) 10 = 0001 0000
(b) 13 = 0001 0011
(c) 18 = 0001 1000
(d) 21 = 0010 0001
(e) 25 = 0010 0101
(f) 36 = 0011 0110
(g) 44 = 0100 0100
(h) 57 = 0101 0111
(i) 69 = 0110 1001
(j) 98 = 1001 1000
(k) 125 = 0001 0010 0101
(l) 156 = 0001 0101 0110

48.

(a)	10 = 1010_2	4 bits binary, 8 bits BCD
(b)	13 = 1101_2	4 bits binary, 8 bits BCD
(c)	18 = 10010_2	5 bits binary, 8 bits BCD
(d)	21 = 10101_2	5 bits binary, 8 bits BCD
(e)	25 = 11001_2	5 bits binary, 8 bits BCD
(f)	36 = 100100_2	6 bits binary, 8 bits BCD
(g)	44 = 101100_2	6 bits binary, 8 bits BCD
(h)	57 = 111001_2	6 bits binary, 8 bits BCD
(i)	69 = 1000101_2	7 bits binary, 8 bits BCD
(j)	98 = 1100010_2	7 bits binary, 8 bits BCD
(k)	125 = 1111101_2	7 bits binary, 12 ibts BCD
(l)	156 = 10011100_2	8 bits binary, 12 bits BCD

49. (a) 104 = 0001 0000 0100
(b) 128 = 0001 0010 1000
(c) 132 = 0001 0011 0010
(d) 150 = 0001 0101 0000
(e) 186 = 0001 1000 0110
(f) 210 = 0010 0001 0000
(g) 359 = 0011 0101 1001
(h) 547 = 0101 0100 0111
(i) 1051 = 0001 0000 0101 0001

50. (a) 0001 = 1
(b) 0110 = 6
(c) 1001 = 9
(d) 0001 1000 = 18
(e) 0001 1001 = 19
(f) 0011 0010 = 32
(g) 0100 0101 = 45
(h) 1001 1000 = 98
(i) 1000 0111 0000 = 870

51. (a) 1000 0000 = 80
(b) 0010 0011 0111 = 237
(c) 0011 0100 0110 = 346
(d) 0100 0010 0001 = 421
(e) 0111 0101 0100 = 754
(f) 1000 0000 0000 = 800
(g) 1001 0111 1000 = 978
(h) 0001 0110 1000 0011 = 1683
(i) 1001 0000 0001 1000 = 9018
(j) 0110 0110 0110 0111 = 6667

52.

(a)
$$\begin{array}{r} 0010 \\ \underline{+\ 0001} \\ 0011 \end{array}$$

(b)
$$\begin{array}{r} 0101 \\ \underline{+\ 0011} \\ 1000 \end{array}$$

(c)
$$\begin{array}{r} 0111 \\ \underline{+\ 0010} \\ 1001 \end{array}$$

(d)
$$\begin{array}{r} 1000 \\ \underline{+\ 0001} \\ 1001 \end{array}$$

(e)
$$\begin{array}{r} 00011000 \\ \underline{+\ 00010001} \\ 00101001 \end{array}$$

(f)
$$\begin{array}{r} 01100100 \\ \underline{+\ 00110011} \\ 10010111 \end{array}$$

(g)
$$\begin{array}{r} 01000000 \\ \underline{+\ 01000111} \\ 10000111 \end{array}$$

(h)
$$\begin{array}{r} 10000101 \\ \underline{+\ 01000111} \\ 10000111 \end{array}$$

53. (a)

$$\begin{array}{r} 1000 \\ +\,0110 \\ \hline 1110 \\ +\,0110 \\ \hline 00010100 \end{array} \quad \textit{invalid}$$

(b)

$$\begin{array}{r} 0111 \\ +\,0101 \\ \hline 1100 \\ +\,0110 \\ \hline 00010010 \end{array} \quad \textit{invalid}$$

(c)

$$\begin{array}{r} 1001 \\ +\,1000 \\ \hline 10001 \\ +\,0110 \\ \hline 00010111 \end{array} \quad \textit{invalid}$$

(d)

$$\begin{array}{r} 1001 \\ +\,0111 \\ \hline 10000 \\ +\,0110 \\ \hline 00010110 \end{array} \quad \textit{invalid}$$

(e)

$$\begin{array}{r} 00100101 \\ +\,00100111 \\ \hline 01001100 \\ +\,0110 \\ \hline 01010010 \end{array} \quad \textit{invalid}$$

(f)

$$\begin{array}{r} 01010001 \\ +\,01011000 \\ \hline 10101001 \\ +\,0110 \\ \hline 000100001001 \end{array} \quad \textit{invalid}$$

(g)

$$\begin{array}{r} 10011000 \\ +\,10010111 \\ \hline 100101111 \\ +\,01100110 \\ \hline 000110010101 \end{array} \quad \textit{invalid}$$

(h)

$$\begin{array}{r} 010101100001 \\ +\,011100001000 \\ \hline 110001101001 \\ +\,0110 \\ \hline 0001001001101001 \end{array} \quad \textit{invalid}$$

54. (a) 4 + 3
0100
+ 0011
0111

(b) 5 + 2
0101
+ 0010
0111

(c) 6 + 4
0110
+ 0100
1010
+0110
00010000

(d) 17 + 12
00010111
+ 00100010
00101001

(e) 28 + 23
00101000
+ 00100011
01001011
+0110
01010001

(f) 65 + 58
01100101
+ 01011000
10111101
+01100110
000100100011

(g) 113 + 101
000100010011
+ 000100000001
001000010100

(h) 295 + 157
001010010101
+ 000101010111
001111101100
+01100110
010001010010

Section 2-11 Digital Codes

55. The Gray code makes only one bit change at a time when going from one number in the sequence to the next number.
Gray for 1111_2 = 1000
Gray for 0000_2 = 0000

56. (a) 1 + 1 + 0 + 1 + 1 *Binary*
1 0 1 1 0 *Gray*

(b) 1 + 0 + 0 + 1 + 0 + 1 + 0 *Binary*
1 1 0 1 1 1 1 *Gray*

(c) 1 + 1 + 1 + 1 + 0 + 1 + 1 + 1 + 0 + 1 + 1 + 1 + 0 *Binary*
1 0 0 0 1 1 0 0 1 1 0 0 1 *Gray*

57. (a) 1 0 1 0 *Gray*
1 1 0 0 *Binary*

(b) 0 0 0 1 0 *Gray*
0 0 0 1 1 *Binary*

(c) 1 1 0 0 0 0 1 0 0 0 1 *Gray*
1 0 0 0 0 0 1 1 1 1 0 *Binary*

58. (a) 1 → 00110001
(b) 3 → 00110011
(c) 6 → 00110110
(d) 10 → 0011000100110000
(e) 18 → 0011000100111000
(f) 29 → 0011001000111001
(g) 56 → 0011010100110110
(h) 75 → 0011011100110101
(i) 107 → 001100010011000000110111

59. (a) 0011000 → CAN (b) 1001010 → **J**
(c) 0111101 → **=** (d) 0100011 → **#**
(e) 0111110 → **>** (f) 1000010 → **B**

60.

1001000	1100101	1101100	1101100	1101111	0101110	0100000
H	**e**	**l**	**l**	**o**	**.**	**#**
1001000	1101111	1110111	0100000	1100001	1110010	1100101
H	**o**	**w**	**#**	**a**	**r**	**e**
0100000	1111001	1101111	1110101	0111111		
#	**y**	**o**	**u**	**?**		

61.

1001000	1100101	1101100	1101100	1101111	0101110	0100000
48	**65**	**6C**	**6C**	**6F**	**2E**	**20**
1001000	1101111	1110111	0100000	1100001	1110010	1100101
48	**6F**	**77**	**20**	**61**	**72**	**65**
0100000	1111001	1101111	1110101	0111111		
20	**79**	**6F**	**75**	**3F**		

62. 30 INPUT A, B

3	0110011	33_{16}
0	0110000	30_{16}
SP	0100000	20_{16}
I	1001001	49_{16}
N	1001110	$4E_{16}$
P	1010000	50_{16}
U	1010101	55_{16}
T	1010100	54_{16}
SP	0100000	20_{16}
A	1000001	41_{16}
,	0101100	$2C_{16}$
B	1000010	42_{16}

Section 2-12 Error Codes

63. Code (b) 011101010 has five 1s, so it is in error.

64. Codes (a) 11110110 and (c) 01010101010101010 are in error because they have an even number of 1s.

65. (a) 1 10100100 (b) 0 00001001 (c) 1 11111110

66. (a)

```
  1100
+ 1011
------
  0111
```

(b)

```
  1111
+ 0100
------
  1011
```

(c)

```
  100011100
+  10011001
-----------
  110000101
```

67. (a)

```
  1100
+ 0111
------
  1011
```

(b)

```
  1111
+ 1011
------
  0100
```

(c)

```
  100011100
+ 110000101
-----------
  010011001
```

In each case, you get the other number.

68.

```
            101100100000        101100100110
            1010                1010
               1001                1001
               1010                1010
                 1100                1100
                 1010                1010
                  1100                1101
                  1010                1010
                   1100                1111
                   1010                1010
                    1100                1010
                    1010                1010
Remainder =         0110                0000
```

Append remainder to data. CRC is 101100100110.

69. Error in MSB of transmitted CRC:

```
001100100110
1010
1001
1010
  1100
  1010
   1101
   1010
    1110
    1010
     1000
     1010
       1011
       1010
          10
```

Remainder is 10, indicating an error.

CHAPTER 3
LOGIC GATES

Section 3-1 The Inverter

1. See Figure 3-1.

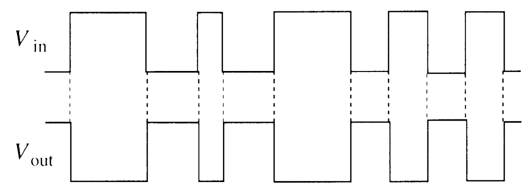

FIGURE 3-1

2. *B*: LOW, *C*: HIGH, *D*: LOW, *E*: HIGH, *F*: LOW

3. See Figure 3-2.

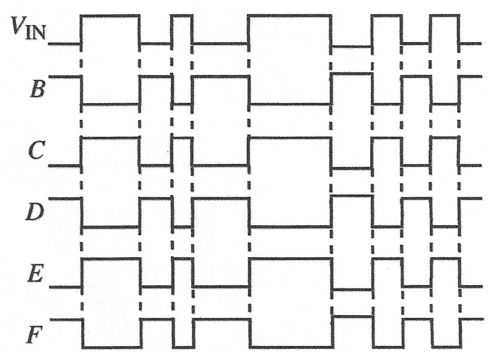

FIGURE 3-2

Section 3-2 The AND Gate

4. See Figure 3-3.

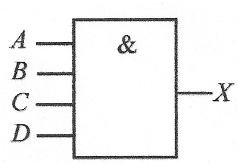

FIGURE 3-3

5. See Figure 3-4.

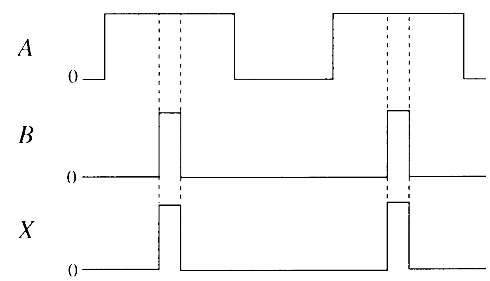

FIGURE 3-4

6. See Figure 3-5.

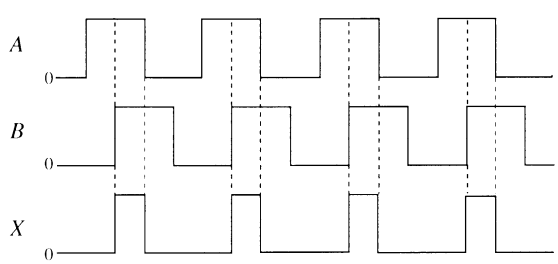

FIGURE 3-5

7. See Figure 3-6.

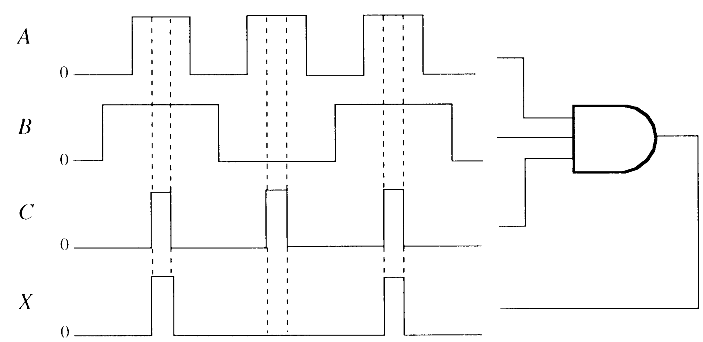

FIGURE 3-6

8. See Figure 3-7.

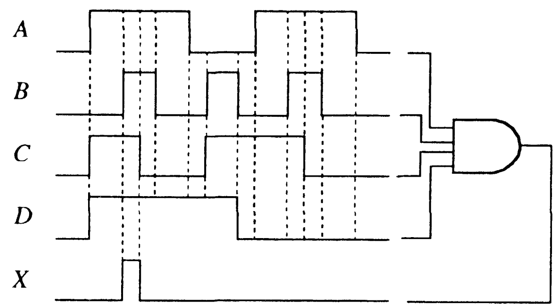

FIGURE 3-7

9. See Figure 3-8

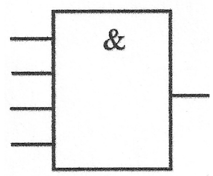

FIGURE 3-8

10. $X = A + B + C + D + E$

Section 3-3 The OR Gate

11. See Figure 3-9.

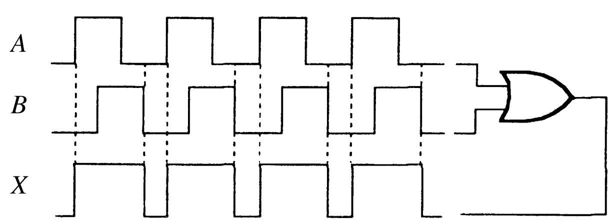

FIGURE 3-9

12. See Figure 3-10.

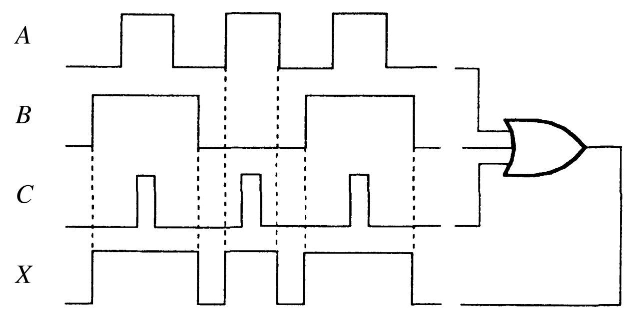

FIGURE 3-10

13. See Figure 3-11.

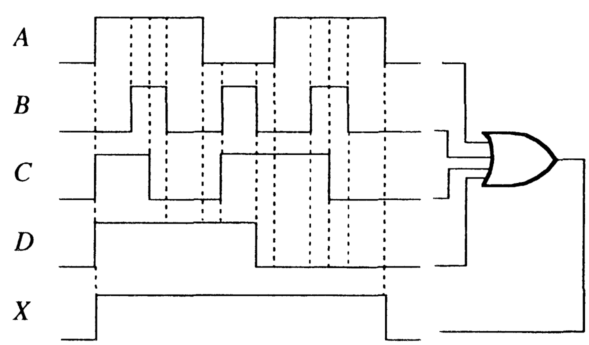

FIGURE 3-11

14. See Figure 3-12.

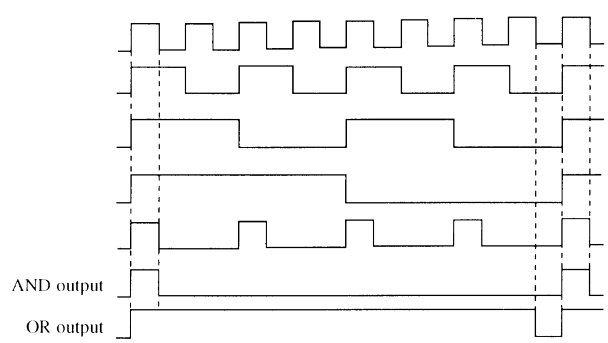

FIGURE 3-12