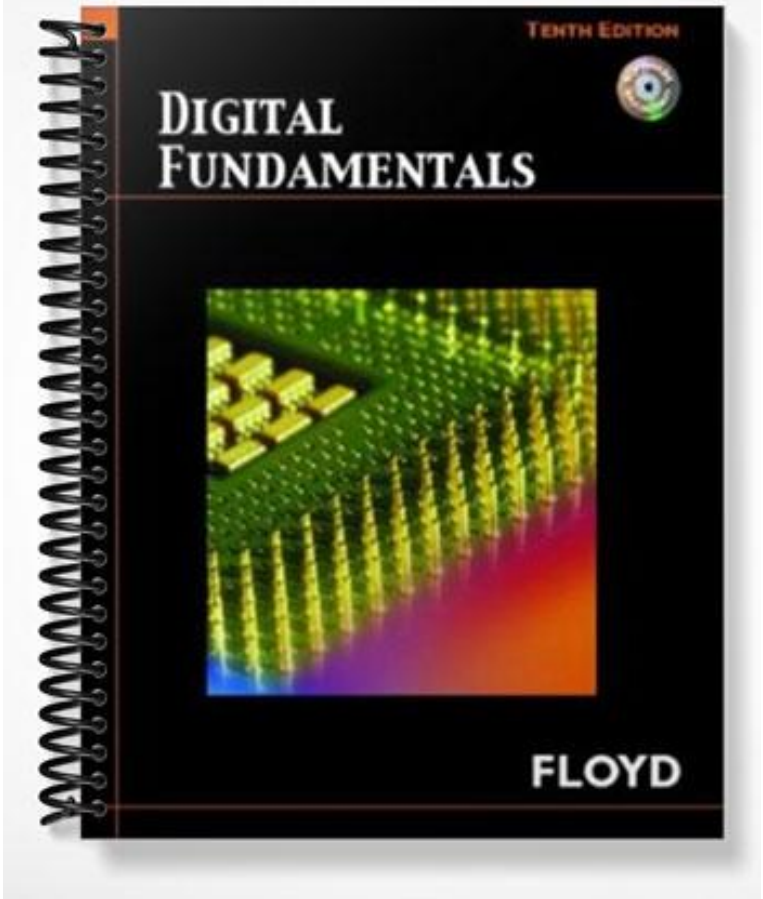
SOLUTIONS MANUAL



Online Instructor's Manual
to accompany

Digital Fundamentals
Tenth Edition

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PEARSON
Prentice Hall

Upper Saddle River, New Jersey
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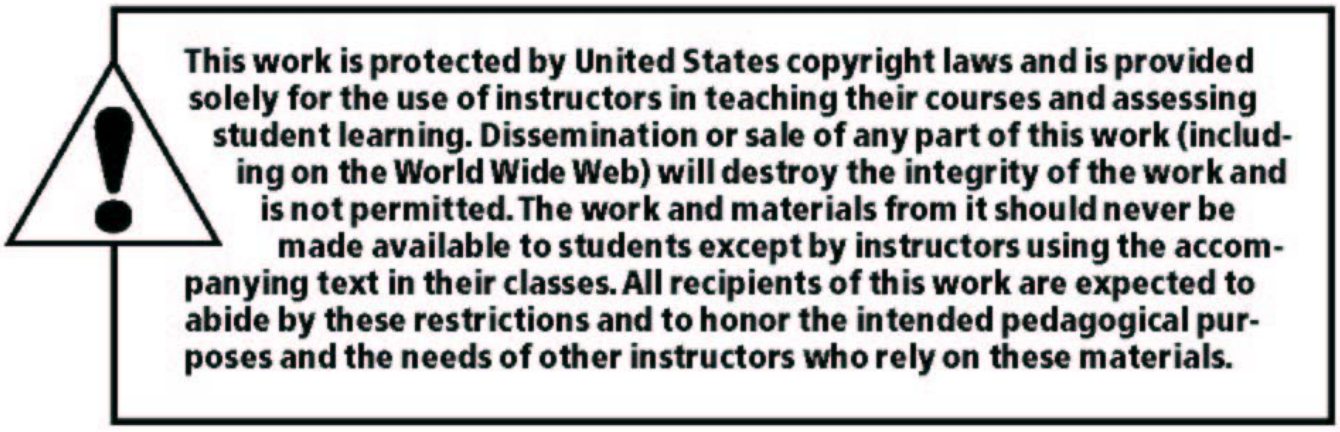

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NOTE: For access to hidden faults in Multisim circuits, the password is *book*.

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, a 1 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.

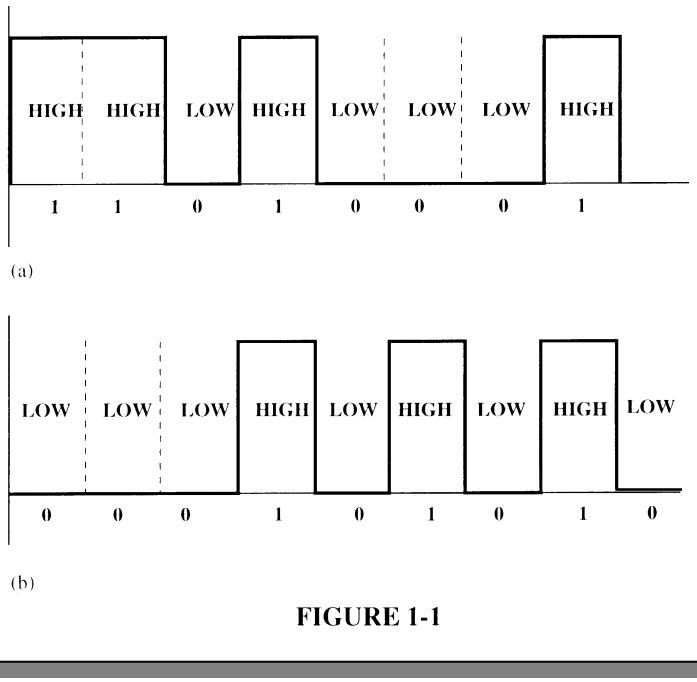

FIGURE 1-1

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.

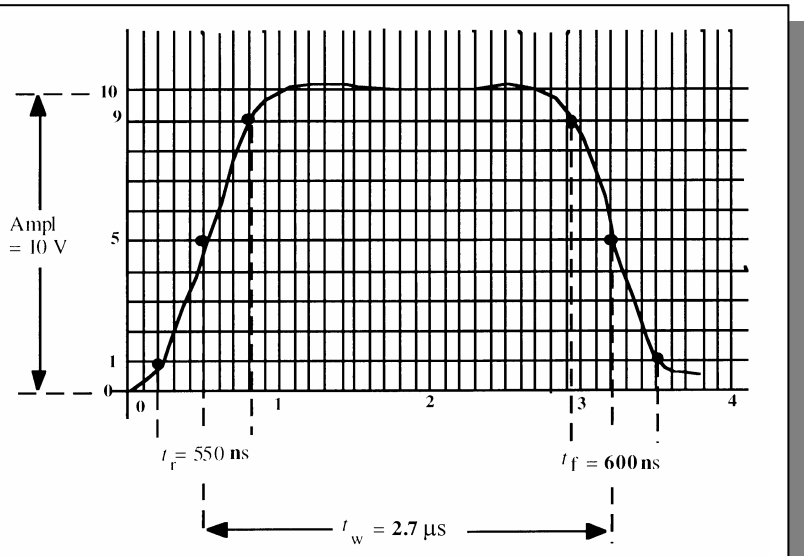

FIGURE 1-2

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

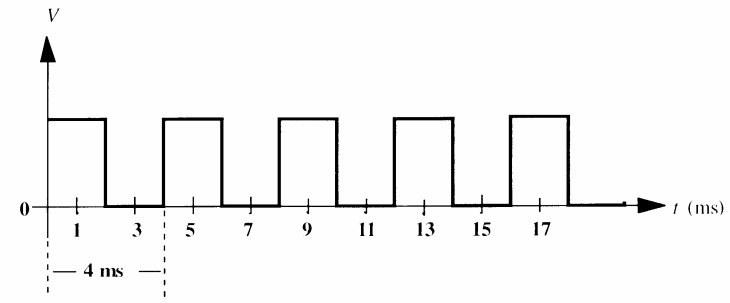

FIGURE 1-3

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.

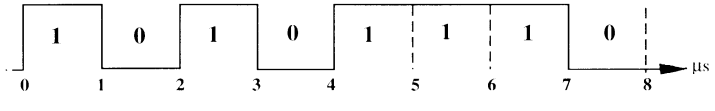

FIGURE 1-4

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. $T = \dfrac{1}{f} = \dfrac{1}{3.5\text{ GHz}} = \mathbf{0.286\text{ ns}}$

Section 1-3 Basic Logic Operations

15. $L_{ON} = SW1 + SW2 + SW1 \cdot SW2$

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

17. AND gate. See Figure 1-5.

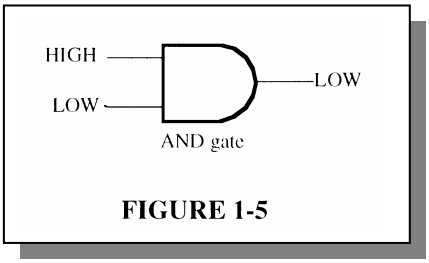

FIGURE 1-5

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 Introduction to the System Concept

19. See Figure 1-6.

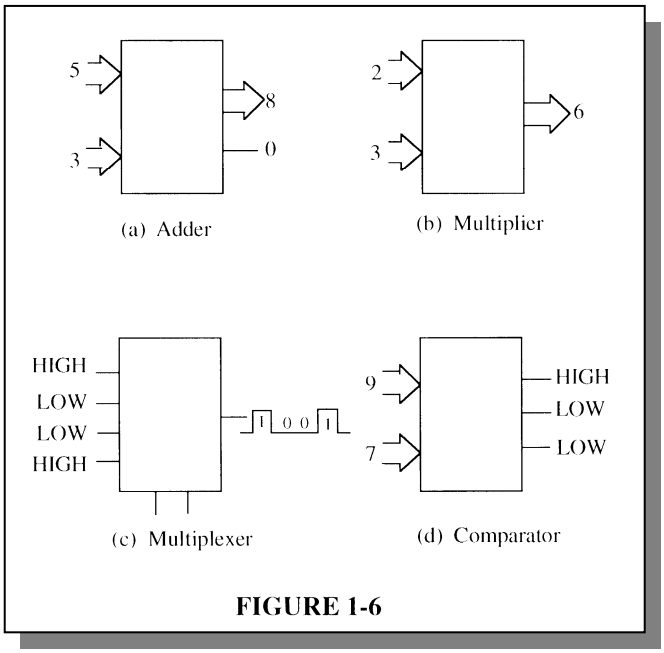

FIGURE 1-6

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

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

21. See Figure 1-7.

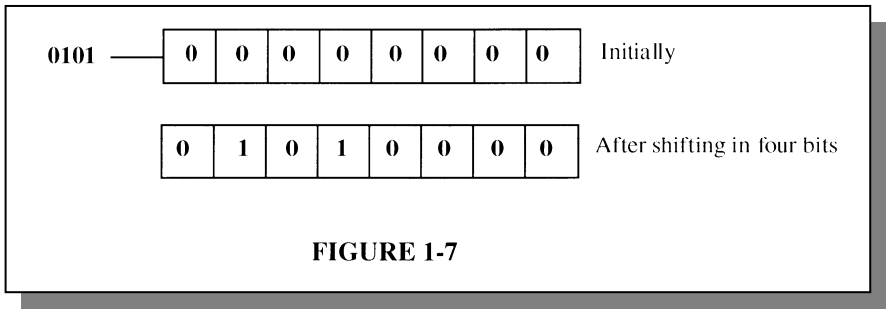

FIGURE 1-7

Section 1-5 Fixed-Function Integrated Circuits

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

23. 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.

24. See Figure 1-8.

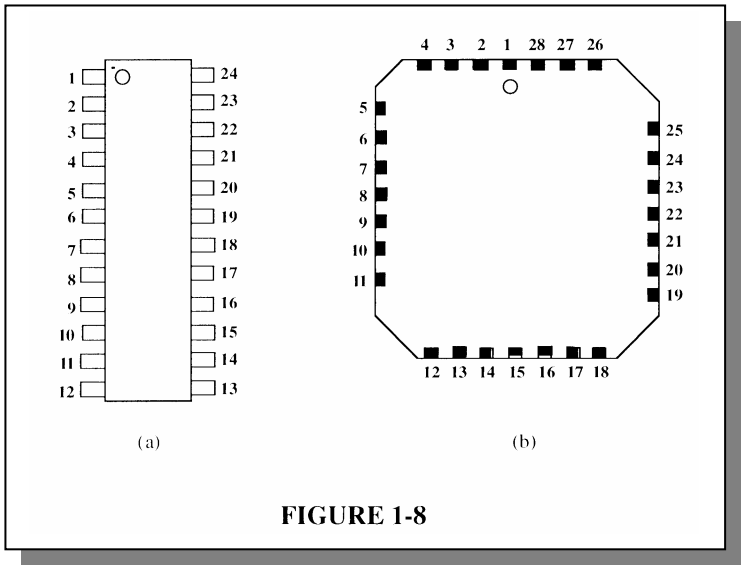

FIGURE 1-8

Section 1-6 Test and Measurement Instruments

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

26. A flashing probe lamp indicates a continuous sequence of pulses (pulse train).

Section 1-7 Introduction to Programmable Logic

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

28. SPLD: Simple Programmable Logic Device
CPLD: Complex Programmable Logic Device
HDL: Hardware Description Language
FPGA: Field-Programmable Gate Array
GAL: Generic Array Logic

29. (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.

30. 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.

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) $1111 = 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 8 + 4 + 2 + 1 = 15$

Chapter 2

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

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

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

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

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

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

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

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

Chapter 2

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 1's and 2's 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 = 11000001100000000000000
11000101011000001100000000000000

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
$1.100001111101001 \times 2^{77}$

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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)

$$\begin{array}{r} 00110011 \\ -\ 00010000 \end{array}$$

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

(b)

$$\begin{array}{r} 01100101 \\ -\ 11101000 \end{array}$$

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

35.

$$\begin{array}{r} 01101010 \\ \times\ 11110001 \end{array}$$

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

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) $FF_{16} + BB_{16} = 1BA_{16}$

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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)
```
  0010
+ 0001
  0011
```
(b)
```
  0101
+ 0011
  1000
```
(c)
```
  0111
+ 0010
  1001
```
(d)
```
  1000
+ 0001
  1001
```
(e)
```
  00011000
+ 00010001
  00101001
```
(f)
```
  01100100
+ 00110011
  10010111
```
(g)
```
  01000000
+ 01000111
  10000111
```
(h)
```
  10000101
+ 00010011
  10000111
```

53. (a)

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

(b)

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

(c)

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

(d)

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

(e)

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

(f)

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

(g)

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

(h)

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

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54. (a) 4 + 3

$$\begin{array}{r} 0100 \\ +\ 0011 \\ \hline 0111 \end{array}$$

(b) 5 + 2

$$\begin{array}{r} 0101 \\ +\ 0010 \\ \hline 0111 \end{array}$$

(c) 6 + 4

$$\begin{array}{r} 0110 \\ +\ 0100 \\ \hline 1010 \\ +\ 0110 \\ \hline 00010000 \end{array}$$

(d) 17 + 12

$$\begin{array}{r} 00010111 \\ +\ 00100010 \\ \hline 00101001 \end{array}$$

(e) 28 + 23

$$\begin{array}{r} 00101000 \\ +\ 00100011 \\ \hline 01001011 \\ +\ 0110 \\ \hline 01010001 \end{array}$$

(f) 65 + 58

$$\begin{array}{r} 01100101 \\ +\ 01011000 \\ \hline 10111101 \\ +\ 01100110 \\ \hline 000100100011 \end{array}$$

(g) 113 + 101

$$\begin{array}{r} 000100010011 \\ +\ 000100000001 \\ \hline 001000010100 \end{array}$$

(h) 295 + 157

$$\begin{array}{r} 001010010101 \\ +\ 000101010111 \\ \hline 001111101100 \\ +\ 01100110 \\ \hline 010001010010 \end{array}$$

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 Detection 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

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66. (a)
$$\begin{array}{r} 1100 \\ +1011 \\ \hline 0111 \end{array}$$
(b)
$$\begin{array}{r} 1111 \\ +0100 \\ \hline 1011 \end{array}$$
(c)
$$\begin{array}{r} 100011100 \\ +\ 10011001 \\ \hline 110000101 \end{array}$$

67. (a)
$$\begin{array}{r} 1100 \\ +0111 \\ \hline 1011 \end{array}$$
(b)
$$\begin{array}{r} 1111 \\ +1011 \\ \hline 0100 \end{array}$$
(c)
$$\begin{array}{r} 100011100 \\ +110000101 \\ \hline 010011001 \end{array}$$

In each case, you get the other number.

68.
$$\begin{array}{r} 101100100000 \\ \underline{1010} \\ 1001 \\ \underline{1010} \\ 1100 \\ \underline{1010} \\ 1100 \\ \underline{1010} \\ 1100 \\ \underline{1010} \\ 1100 \\ \underline{1010} \\ \text{Remainder} = 0110 \end{array}$$

$$\begin{array}{r} 101100100110 \\ \underline{1010} \\ 1001 \\ \underline{1010} \\ 1100 \\ \underline{1010} \\ 1101 \\ \underline{1010} \\ 1111 \\ \underline{1010} \\ 1010 \\ \underline{1010} \\ 0000 \end{array}$$

Append remainder to data. CRC is 101100100110.

69. Error in MSB of transmitted CRC:

$$\begin{array}{r} 001100100110 \\ \underline{1010} \\ 1001 \\ \underline{1010} \\ 1100 \\ \underline{1010} \\ 1101 \\ \underline{1010} \\ 1110 \\ \underline{1010} \\ 1000 \\ \underline{1010} \\ 1011 \\ \underline{1010} \\ 10 \end{array}$$

Remainder is 10, indicating an error.