INSTRUCTOR'S MANUAL

to accompany

Sixth Edition

Fundamentals of Digital Logic and Microcontrollers

Sixth Edition

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CHAPTER 2

2.1 (a)

128	64	32	16	8	4	2	1	← weighting
0	1	1	1	0	1	0	1_2	$= 64+32+16+4+1 = 117_{10}$

(b)

8	4	2	1	.5	.25	.125	← weighting
1	1	0	1 .	1	0	1_2	$= 8+4+1+.5+.125 = 13.625_{10}$

(c)

8	4	2	1	.5	.25	.125	← weighting
1	0	0	0 .	1	1	1_2	$= 8+.5+.25+.125 = 8.875_{10}$

2.2(a)

		Quotient	+	Remainder
152/2	=	76	+	0
76/2	=	38	+	0
38/2	=	19	+	0
19/2	=	9	+	1
9/2	=	4	+	1
4/2	=	2	+	0
2/2	=	1	+	0
1/2	=	0	+	1
152_{10}	=	$1001\ 1000_2$		

2.2(b)

		Quotient	+	Remainder
343/2	=	171	+	1
171/2	=	85	+	1
85/2	=	42	+	1
42/2	=	21	+	0
21/2	=	10	+	1
10/2	=	5	+	0
5/2	=	2	+	1
2/2	=	1	+	0
1/2	=	0	+	1
343_{10}	=	101010111_2		

2.3(a)

		Quotient	+	Remainder
1843/8	=	230	+	3
230/8	=	28	+	6
28/8	=	3	+	4
3/8	=	0	+	3
1843_{10}	=	3463_8		

2.3(b)

		Quotient	+	Remainder
1766/8	=	220 +	6	
220/8	=	27 +	4	
27/8	=	3 +	3	
3/8	=	0 +	3	
1766_{10}	=	3346_8		

2.4(a)

		Quotient	+	Remainder
1987/16	=	124	+	3
124/16	=	7	+	C
7/16	=	0	+	7
1987_{10}	=	$7C3_{16}$		

2.4 (b)

		Quotient	+	Remainder
3072/16	=	192	+	0
192/16	=	12	+	0
12/16	=	0	+	C
3072_{10}	=	$C00_{16}$		

2.5(a) Add leading zeros

$$\underbrace{001}\ \underbrace{101}\ \underbrace{011}\ \underbrace{100}\ \underbrace{101} = 15345_8$$

Add 3 leading zeros

$$\underbrace{0001}\ \underbrace{1010}\ \underbrace{1110}\ \underbrace{0101} = 1AE5_{16}$$

(b) Add leading zero

$$\underbrace{011}\ \underbrace{000}\ \underbrace{011}\ \underbrace{100}\ \underbrace{110}\ \underbrace{000}\ \underbrace{011} = 3034603_8$$

$$\underbrace{1100}\ \underbrace{0011}\ \underbrace{1001}\ \underbrace{1000}\ \underbrace{0011} = C3983_{16}$$

2.6(a) <u>Signed-magnitude form</u>

48 in 7-bit can be represented as: $48 = 0110000_2$

Therefore, - 48 = 10110000 in sign magnitude form.

52 in 7-bit = 0110100_2

Hence, $+52 = 00110100_2$ in sign magnitude form

2.6(b) <u>Ones complement form</u>

$+48 = 0011\ 0000_2$

$- 48 = 1100\ 1111_2$

$+52 = 0011\ 0100_2$

2.6(c) <u>Two's complement form</u>

$-48 = 1101\ 0000_2$

$+52 = 0011\ 0100_2$

2.7 $1100\ 1100_2$ is an even number since the least significant bit is 0.

$0010\ 0100_2$ is an even number since the least significant bit is 0.

$0111\ 1001_2$ is an odd number since the least significant bit is 1.

2.8 532.372_{10}

		Quotient	+	Remainder
532/2	=	266	+	0
266/2	=	133	+	0
133/2	=	66	+	1
66/2	=	33	+	0
33/2	=	16	+	1
16/2	=	8	+	0
8/2	=	4	+	0
4/2	=	2	+	0
2/2	=	1	+	0
1/2	=	0	+	1

Hence, $532_{10} = 10\ 0001\ 0100_2$

0.372	0.744	0.488	
x2	x2	x2	
0.744	1.488	0.976	$\approx$ 1.000
↓	↓		↓
0	1		1

$0.372_{10} \cong .011_2$

$532.372_{10} \cong 100\ 001\ 0100.011_2$

2.9 $15FD_{16} = 0001\ 0101\ 1111\ 1101_2$

$26EA_{16} = 0010\ 0110\ 1110\ 1010_2$

2.10(a) $11264 = 0001\ 0001\ 0010\ 0110\ 0100_2$

2.10(b) $8192 = 1000\ 0001\ 1001\ 0010_2$

2.11(a) Excess-3 Code

6	7	8_{10}
↓	↓	↓
1001	1010	1011

2.11(b)

3	2	8	7	4_{10}
↓	↓	↓	↓	↓
0110	0101	1011	1010	0111

2.11(c)

6	1	4	4	0_{10}
↓	↓	↓	↓	↓
1001	0100	0111	0111	0011

2.12 Octal $1543 = 1 \times 8^3 + 5 \times 8^2 + 4 \times 8^1 + 3 \times 8^0$

$= 512 + 320 + 32 + 3$

= 8 6 7

↓ ↓ ↓

Excess-3 Code → $1011\ 1001\ 1010_2$

2.13(a) $0001\ 1001\ 0101\ 0001_2 = 4096 + 2048 + 256 + 64 + 16 + 1 = 6481 = 0110\ 0100\ 1000\ 0001$ BCD

2.13(b) $0110\ 0001\ 0100\ 0100\ 0000_2 = 262144 + 131072 + 4096 + 1024 + 64 = 398400$

398400 = 0011 1001 1000 0100 0000 0000 BCD

2.14(a)

1024 256 128 16 4 2 1 ← *weighing*

$0\ 1\ 0\ 1\ \ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 1_2$

$= 1024 + 256 + 128 + 16 + 4 + 2 + 1$

$= 1\ \ 4\ \ 3\ \ 1_{10}$

Excess-3 = $0100\ 0111\ 0110\ 0100_2$

2.14(b)

$$\begin{array}{cccccccccccc} & 1024 & 512 & & 128 & & & 16 & & & & \leftarrow \textit{weighing} \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0_2 \end{array}$$

$= 1024 + 512 + 128 + 16$

$= 1 \quad 6 \quad 8 \quad 0_{10}$

Excess-3 $= 0100 \ 1001 \ 1011 \ 0011_2$

2.15

$$\begin{array}{r} 1011.01 \\ +\ \underline{0110.01\ 1} \\ 1\ 0001.10\ 1_2 \end{array}$$

$=16+1+0.5+0.125$

$= 17.625_{10}$

2.16(a)

$$\begin{array}{rl} 14 & = 0000\ 1110 \\ \underline{+17} & = \underline{0001\ 0001} \\ 3110 & = 0001\ 1111_2 \end{array}$$

2.16(b)

$$\begin{array}{rl} 34 & = 0010\ 0010 \\ \underline{+28} & = \underline{0001\ 1100} \\ 62_{10} & = 0011\ 1110_2 \end{array}$$

2.16(c)

$32 = 0010\ 0000$

$14 = 0000\ 1110_2$

2's Complem.of $14 = 1111\ 0010_2$

$32_{10} - 14_{10} = 0010\ 0000$

$\underline{+\ 1111\ 0010}$

ignore $\rightarrow$ 1 $\quad 0001\ 0010 = 18_{10}$

2.16(d)

$34 = 0010\ 0010$

$42 = 0010\ 1010_2$

2's Complem.of $42 = 1101\ 0110_2$

$34_{10} - 42_{10} = 0010\ 0010$

$+\ \underline{1101\ 0110}$

No Carry $\rightarrow$ $\quad 1111\ 1000$

Result $= -(\text{ 2's complement of } 1111\ 1000_2)$

$= -(0000\ 1000_2) = -8_{10}$

2.17

$3AFA_{16} = 0011\ 1010\ 1111\ 1010_2$

$2F1E_{16} = 0010\ 1111\ 0001\ 1110_2$

2's complement of $2FIE_{16} = 1101\ 0000\ 1110\ 0010_2$

$3AFA_{16} - 2FIE_{16} = 0011\ 1010\ 1111\ 1010$

$\underline{+\ 1101\ 0000\ 1110\ 0010}$

ignore $\rightarrow 1$ $\quad \underbrace{0000}_{0}\ \underbrace{1011}_{B}\ \underbrace{1101}_{D}\ \underbrace{1100}_{C_{16}}$

2.18(a) 9's complement of 132 :

999 − 132 = 867

Hence, 254 - 132 = 254 + 867 + 1

$= 1\ \underbrace{122}$

ignore carry answer

10's complement of 132 = 1000 - 132 = 868

$254 - 132 = 254 + 868 = 1\underbrace{122}$

ignore carry Result = 122

2.18(b) 9's complement of 807 = 999 - 807

= 192

783 - 807 = 783 + 192 + 1

= 976

since there is no carry, result = - (1000 - 976)

= - 24

10's complement of 807 = 1000 - 807

= 193

783 - 807 = 783 + 193 = 976

since there is no carry, result of subtraction = - (1000 - 976) = - 24

2.19(a)

```
      14 = 001110
       8 = 001000
       ----------
    0  010110 = + 22
```

$C_5 = 0$ $C_4 = 0$

No overflow

2.19(b) 7 = 000111

-7 = 2's complement of 7 = 111001

```
    7  =   000 111
  (- 7) =  +111 001      no overflow
    0    1   000 000 = 0
```

Ignore $C_5 = 1$ $C_4 = 1$

2.19 (c) 27 +(-19) 8

27 = 011011 , 19 = 010011

-19 = 101101

```
    27   =   01101 1
  +(-19) = + 10110 1   no overflow
     8      1 00100 0
```

$C_5=1$ $C_4=1$

2.19 (d) +24 = 011 000

- 24 = 101 000

19 = 010 011

- 19 = 101 101

```
   (-24) = 101 000
 + (-19) = 101 101
 - 43  =  1 010 101  ?     overflow = 1 ⊕ 0 = 1
```

$C_5=1$ $C_4=0$ Hence, wrong result

2.19 (e) 19 = 010 011
12 = 001 100
- 12 = 110 100

$$\begin{array}{r} 19 \\ \underline{-(-12)} \\ +31 \end{array}$$

19 = 010 011
-2's complement of -12 = $\underline{+001\ 100}$
011 111 = 31
$C_5 = 0$ $C_4 = 0$ no overflow

2.19 (f) 17 = 010 001
- 17 = 101 111
16 = 010 000
- 16 = 110 000
2's complement of -16 = 010 000
(-17) = 101 111
$\underline{-(-16)}$ = $\underline{010\ 000}$
-1 = 111 111 = -1_{10}
$C_5=0$ $C_4=0$ no overflow

2.20 12 = 1 100
52 = 110 100

$$\begin{array}{rr} 52 & 52 = 110\ 100 \\ x12 & x12 = \underline{\ \ 1\ 100} \\ 624 & 000\ 000 \\ & 0\ \ 000\ 00x \\ & 11\ \ 010\ 0x\ \ \\ & \underline{110\ \ 100\ x\ \ \ \ } \\ & 1\ 001\ \ 110\ 000 \end{array}$$

= 512 + 64 + 32 + 16
= 624

2.21 3 = 11_2
14 = 1110_2

$\underline{\ \ 100\ \ =}$ 4 = Quotient
11 | 111 0
$\underline{11\ \ \ }$
001 0 = 2 = Remainder

2.22 (a) 54 = 0101 0100
$\underline{+48}$ = + $\underline{0100\ \ 1000}$
102 = 1001 1100
$\underline{\ \ \ \ \ \ 0110}$ add 6
1010 0010
$\underline{0110\ \ \ \ \ \ \ \ }$add 6
0001 0000 0010 = 102 in BCD

```
2.22 (b)    782 = 0111  1000  0010
           +219 = 0010  0001  1001
           1001    1001  1001  1011
                               0110
                   1001  1010  0001
                               0110
                   1010  0000  0001
                   0110
          0001     0000  0000  0001 = 1001 in BCD
```

```
2.22 (c)    82  =  1000  0010
           -58  = -0101 1000
            24
2's complement of each digit of        58 =    1011   1000
addition factor to find 10's complement =  +1001   1010
               10's complement of of 58 =    1 0100 1 0010
                                           ignore carries
10's complement of 58 = 0100  0010
                   82 = 1000  0010
                        1100  0100
                        0110
                     1   0010   0100
             ignore        2       4
```

```
2.23                    999 =     1001 1001 1001
               PLUS 999  =     1001 1001 1001
                   -------      ----------------------------
                    1998     1   0011 0011 0010
        BCD Corrections        0110 0110 0110
                             ------------------------------
                               0001  1001 1001  1000 = 1998
```

2.24 Data with odd parity bit in MSB = 0 1011 0000

odd parity bit = 0

2.25 By conventional method (i.e. paper & pencil):
12 x 52 = 624
<u>Using repeated Addition</u> :
Assume initial product to be zero. Add 52 twelve times to itself:

$$\left.\begin{array}{r} 0 + 52 = 52 \\ 52 + 52 = 104 \\ 104 + 52 = 156 \\ 156 + 52 = 208 \\ 208 + 52 = 260 \\ 260 + 52 = 312 \\ 312 + 52 = 364 \\ 364 + 52 = 416 \\ 416 + 52 = 468 \\ 468 + 52 = 520 \\ 520 + 52 = 572 \\ 572 + 52 = 624 \end{array}\right\} \text{12 times}$$

2.26

Divided	Divisor	Subtraction Result	Counter
14	3	14-3 = 11	1
		11-3 = 8	1 +1 = 2
		8-3 = 5	2 +1 = 3
		5-3 = 2	3 +1 = 4

Quotient = 4, Remainder = 2

2.27
M = $1111\ 1111_2$, Q = $1111\ 1100_2$
Since M and Q are both negative numbers.
2's complement of M = $0000\ 0001_2$
2's complement of Q = $0000\ 0100_2$
Multiplying the 2's complement of M and Q using unsigned multiplication method,
product = $0000\ 0000\ 0000\ 0100_2 = +\ 4_{10}$.
The sign of the product,
$S_n = M_n \oplus Q_n = 1 \oplus 1 = 0$
Hence, the result is $+\ 4_{10}$

2.28
Quotient = -8, Remainder = -1. The sign of the remainder is the same as the sign of the dividend unless remainder is zero.

2.29 9-bit data with even Parity

= 1 1100 0111 = Transmitted data has even parity.

Parity bit

Received data

= 1 1000 0111 = Wrong data with odd parity.

Bit 6 changed from 1 to 0 .

2.30 0000 1111 = +15 in decimal

Plus 1111 1100 = - 4 in decimal

0000 1011 = +11 decimal

Sign bit = 0, Overflow bit = 0 since the final carry and the previous carry are the same (1's).