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) Signed-magnitude form
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) Ones complement form
$+48 = 0011\ 0000_2$
$-48 = 1100\ 1111_2$
$+52 = 0011\ 0100_2$

2.6(c) Two's complement form
$-48 = 1101\ 0000_2$
$+52 = 0011\ 0100_2$

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 ≈ 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*

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

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

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

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

2.14(b)

1024 512 128 16 ← *weighing*

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

$= 1024 + 512 + 128 + 16$

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

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

2.15

$\ 1011.01$

$+\ \underline{0110.01\ 1}$

$1\ 0001.10\ 1_2$

$=16+1+0.5+0.125$

$= 17.625_{10}$

2.16(a)

$14 = 0000\ 1110$

$\underline{+17} = \underline{0001\ 0001}$

$3110 = 0001\ 1111_2$

2.16(b)

$34 = 0010\ 0010$

$\underline{+28} = \underline{0001\ 1100}$

$62_{10} = 0011\ 1110_2$

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 → $1\ \ 0001\ 0010 = 18_{10}$

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 → $1111\ 1000$

Result $= -$ (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 → 1 $\underbrace{0000}_{0}\ \underbrace{1011}_{B}\ \underbrace{1101}_{D}\ \underbrace{1100}_{C_{16}}$

2.18(a) 9's complement of 132 :

999 − 132 = 867

Hence, 254 - 132 = 254 + 867 + 1

= 1 122

ignore carry (1) answer (122)

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

254 - 132 = 254 + 868 = 1122

ignore carry (1) 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
           19
         -(-12)
          + 31
                         19 =   010 011
-2's complement of -12 = +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
                  -(-16) = 010 000
                     -1  =  111 111
```
$-1 = 111\ 111 = -1_{10}$

C_5=0 C_4=0   no overflow

```
2.20                12 =     1 100
                    52 = 110 100

        52          52 = 110 100
        x12        x12 =     1 100
        624                000 000
                         0  000 00x
                        11  010 0x
                       110  100 x
                  1 001  110 000     = 512 + 64 + 32 + 16
                                     = 624
```

2.21   3 = 11_2

   14 = 1110_2

```
                         100   =  4 = Quotient
                     11 |  111 0
                           11
                           001 0 = 2 = Remainder
```

```
2.22 (a)    54 =    0101  0100
                   +48 = + 0100  1000
                   102 =    1001  1100
                                  0110    add 6
                            1010  0010
                            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
Using repeated Addition :
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).