(c) $2^2 + 2^1 + 2^0 = 7$

(d) $2^3 + \cancel{2^2} + \cancel{2^1} + \cancel{2^0} = 8$

(g) $2^3 + \cancel{2^2} + 2^1 + 2^0 = 11$

(h) $2^3 + 2^2 + 2^1 + 2^0 = 15$

6. convert the following binary numbers to decimal:

(a) 1110 (b) 1010 (c) 11100 (d) 10000 (e) 10101 (f) 11101 (g) 10111 (h) 11111

(a) $2^3 + 2^2 + 2^1 + \cancel{2^0} = 14$

(b) $2^3 + \cancel{2^2} + 2^1 + \cancel{2^0} = 10$

(c) $2^4 + 2^3 + 2^2 + \cancel{2^1} + \cancel{2^0} = 28$

(d) $2^4 + \cancel{2^3} + \cancel{2^2} + \cancel{2^1} + \cancel{2^0} = 16$

(e) $2^4 + \cancel{2^3} + 2^2 + \cancel{2^1} + 2^0 = 21$

(f) $2^4 + 2^3 + 2^2 + \cancel{2^1} + 2^0 = 29$

(g) $2^4 + \cancel{2^3} + 2^2 + 2^1 + 2^0 = 23$

(h) $2^4 + 2^3 + 2^2 + 2^1 + 2^0 = 31$

- 92.65625 113.0625

(g) $2^6 + \cancel{2^5} + 2^4 + 2^3 + \cancel{2^2} + 2^1 + \cancel{2^0} . 2^{-1} + \cancel{2^{-2}} + 2^{-3} + \cancel{2^{-4}}$

$= 90.625$

(h) $2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0 . 2^{-1} + 2^{-2}$

127.75

8. What is the highest decimal number that can be represented by each of the following numbers of binary digits (bits)?

(a) two (b) three (c) four (d) five (e) six (f) seven (g) eight (h) nine (i) ten (j) eleven

(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) $2^8 - 1 = 225$
(h) $2^9 - 1 = 511$
(i) $2^{10} - 1 = 1023$
(j) $2^{11} - 1 = 2047$

9. How many bits are required to represent the following decimal numbers?

(a) 17 (b) 35 (c) 49 (d) 68 (e) 81 (f) 114 (g) 132 (h) 205

10. Generate binary sequence for each decimal sequence:

(a) 0 through 7 (b) 8 through 15 (c) 16 through 31 (d) 32 through 63 (e) 64 through 75

Ⓐ 3 bits

0 = 000
1 = 001
2 = 010
3 = 011
4 = 100
5 = 101
6 = 110
7 = 111

Ⓑ 4 bits

8 = 1000
9 = 1001
10 = 1010
11 = 1011
12 = 1100
13 = 1101
14 = 1110
15 = 1111

Ⓒ 5 bits

16 = 10000
17 = 10001
18 = 10010
19 = 10011
20 = 10100
21 = 10101
22 = 10110
23 = 10111
24 = 11000
25 = 11001
26 = 11010
27 = 11011
28 = 11100
29 = 11101
30 = 11110
31 = 11111

ⓓ 6 bits

32 = 100000
33 = 100001
34 = 100010
35 = 100011
36 = 100100
37 = 100101
38 = 100110
39 = 100111
40 = 101000
41 = 101001
42 = 101010
43 = 101011
44 = 101100
45 = 101101
46 = 101110
47 = 101111
48 = 110000
49 = 110001
50 = 110010
51 = 110011
52 = 110100
53 = 110101
54 = 110110
55 = 110111
56 = 111000
57 = 111001
58 = 111010
59 = 111011
60 = 111100
61 = 111101
62 = 111110
63 = 111111

ⓔ

64 = 1000000
65 = 1000001
66 = 1000010
67 = 1000011
68 = 1000100
69 = 1000101
70 = 1000110
71 = 1000111
72 = 1001000
73 = 1001001
74 = 1001010
75 = 1001011

13. Convert each decimal number to binary using repeated division by 2:

(a) 15 (b) 21 (c) 28 (d) 34 (e) 40 (f) 59 (g) 65 (h) 73

remainders

(a)
$\frac{15}{2} = 7$ 1
$\frac{7}{2} = 3$ 1
$\frac{3}{2} = 1$ 1
$\frac{1}{2} = 0$ 1

MSB $\boxed{1111}$ LSB

(b)
$\frac{21}{2} = 10$ 1
$\frac{10}{2} = 5$ 0
$\frac{5}{2} = 2$ 1
$\frac{2}{2} = 1$ 0
$\frac{1}{2} = 0$ 1 $\boxed{10101}$

(c)
$\frac{28}{2} = 14$ 0
$\frac{14}{2} = 7$ 0
$\frac{7}{2} = 3$ 1
$\frac{3}{2} = 1$ 1
$\frac{1}{2} = 0$ 1 $\boxed{11100}$

(d)
$\frac{34}{2} = 17$ 0
$\frac{17}{2} = 8$ 1
$\frac{8}{2} = 4$ 0
$\frac{4}{2} = 2$ 0
$\frac{2}{2} = 1$ 0
$\frac{1}{2} = 0$ 1 $\boxed{100010}$

(e)
$\frac{40}{2} = 20$ 0
$\frac{20}{2} = 10$ 0
$\frac{10}{2} = 5$ 0
$\frac{5}{2} = 2$ 1
$\frac{2}{2} = 1$ 0
$\frac{1}{2} = 0$ 1 $\boxed{101000}$

(f)
$\frac{59}{2} = 29$ 1
$\frac{29}{2} = 14$ 1
$\frac{14}{2} = 7$ 0
$\frac{7}{2} = 3$ 1
$\frac{3}{2} = 1$ 1
$\frac{1}{2} = 0$ 1 $\boxed{111011}$

(g)
$\frac{65}{2} = 32$ 1
$\frac{32}{2} = 16$ 0
$\frac{16}{2} = 8$ 0
$\frac{8}{2} = 4$ 0
$\frac{4}{2} = 2$ 0
$\frac{2}{2} = 1$ 0
$\frac{1}{2} = 0$ 1 $\boxed{1000001}$

(h)
$\frac{73}{2} = 36$ 1
$\frac{36}{2} = 18$ 0
$\frac{18}{2} = 9$ 0
$\frac{9}{2} = 4$ 1
$\frac{4}{2} = 2$ 0
$\frac{2}{2} = 1$ 0
$\frac{1}{2} = 0$ 1

$\boxed{1001001}$

Section 2-4 Binary Arithmetic

15. Add the binary numbers:

F ?

(a) 11+01 (b) 10+10 (c) 101+11 (d) 111+10 (e) 1001+101 (f) 1101+1011

A $\begin{array}{r} 11 \\ +\ 01 \\ \hline 100 \end{array} \quad \begin{array}{r} 3 \\ +\ 1 \\ \hline 4 \end{array}$ B $\begin{array}{r} 10 \\ +\ 10 \\ \hline 100 \end{array} \quad \begin{array}{r} 2 \\ +\ 2 \\ \hline 4 \end{array}$ C $\begin{array}{r} 101 \\ +\ 11 \\ \hline 1000 \end{array} \quad \begin{array}{r} 5 \\ +\ 3 \\ \hline 8 \end{array}$ d $\begin{array}{r} 111 \\ +\ 10 \\ \hline 1001 \end{array} \quad \begin{array}{r} 7 \\ +\ 2 \\ \hline 9 \end{array}$

E $\begin{array}{r} 1001 \\ +\ 101 \\ \hline 1110 \end{array} \quad \begin{array}{r} 9 \\ +\ 5 \\ \hline 14 \end{array}$ F $\begin{array}{r} 1101 \\ +\ 1011 \\ \hline 111000 \end{array} \quad \begin{array}{r} 13 \\ +\ 11 \\ \hline 24 \end{array}$

Section 2-5 Complements of Binary Numbers

19. What are two ways of representing zero in 1's complement form?

- Two ways to rep. zero in 1's complement form is by using all 0's or by all 1's

20. Determine the 1's complement of each binary number

(a) 101 (b) 110 (c) 1010 (d) 11010111 (e) 1110101 (f) 00001

Ⓐ 101 → 010 Ⓒ 1010 → 0101 Ⓔ 1110101 → 0001010

28. Determine the decimal value of each signed binary number in the 2's complement form:

(a) 10011001 (b) 01110100 (c) 10111111

Ⓐ $-2^7\ \cancel{2^6}\ \cancel{2^5}\ 2^4\ 2^3\ \cancel{2^2}\ \cancel{2^1}\ 2^0$

$-2^7 + 2^4 + 2^3 + 2^0$

$-128 + 16 + 8 + 1 = -103$

Ⓑ $+\cancel{2^7}\ 2^6\ 2^5\ 2^4\ \cancel{2^3}\ 2^2\ \cancel{2^1}\ \cancel{2^0}$

$+2^6 + 2^5 + 2^4 + 2^2$

$+64 + 32 + 16 + 4 = +116$

Ⓒ $-2^7\ \cancel{2^6}\ 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0$

$-2^7 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0$

$-128 + 32 + 16 + 8 + 4 + 2 + 1 = -65$

29. Express each of the following sign-magnitude binary numbers in single-precision floating-point format: (a) 0111110000101011 (b) 100110000011000

Ⓐ $1.111110000101011 \times 2^{14}$ 141 = 10001101

111100000101011000000000 , 10001101 , 0

Ⓑ $1.100000011000 \times 2^{11}$ 138 = 10001010

1.10000001100000000000000000 , 10001010 , 1