Multiplication in Number System 4

$$\boxed{\text{Result} = \text{Carry} \times \text{Base} + \text{Remainder}}$$

$$\begin{array}{r}
2\ 2\ 2 \\
4\ 5\ 5 \\
(5\,6\,7)_8 \\
\times\ (3\,6)_8 \\
\hline
4\,3\,1\,2 \\
2\,1\,4\,5\,\times \\
\hline
(2\,5\,7\,6\,2)_8
\end{array}$$

$42 = 5 \times 8 + 2$

$41 = 5 \times 8 + 1$

$35 = 4 \times 8 + 3$

$21 = 2 \times 8 + 5$

$20 = 2 \times 8 + 4$

$17 = 2 \times 8 + 1$

HW

$$\boxed{(327)_8 \times (65)_8 = (\ ?\ )_8}$$

$$\boxed{\text{Result} = \text{Carry} \times \text{Base} + \text{Remainder}}$$

$$\begin{array}{r}
(1\,0\,1\,1\,0)_2 \\
\times\ (1\,1\,0)_2 \\
1\,1\qquad\qquad \\
\hline
0\,0\,0\,0\,0 \\
1\,0\,1\,1\,0\,\times \\
1\,0\,1\,1\,0\,\times\,\times \\
\hline
1\,0\,0\,0\,0\,1\,0\,0
\end{array}$$

$\hookrightarrow (10000100)_2$

$2 = 1 \times 2 + 0$

HW

$$\boxed{(110110)_2 \times (1101)_2 = (\ ?\ )_2}$$

Decimal to Binary Conversion 5

$(231.25)_{10} \longrightarrow (\_\_)_? = (11100111.01)_2$

$\underline{231}$ ↓ Division

$\underline{25}$ ↓ Multiplication

2	231	R
2	115	1 (LSB)
2	57	1
2	28	1
2	14	0
2	7	0
2	3	1
	1 (MSB)	1

$(213)_{10} \rightarrow (11100111)_2$

$0.25 \times 2 = 0.5$ | 0 (MSB)

$0.5 \times 2 = 1.0$ | 1 (LSB)

0.0

$(0.25)_{10} \rightarrow (0.01)_2$

$(612.4)_{10} \longrightarrow (\_\_)_2 = (1001100100.0110\ldots)_2$

2	612	R
2	306	0 (LSB)
2	153	0
2	76	1
2	38	0
2	19	0
2	9	1
2	4	1
2	2	0
	1 (MSB)	0

$(612)_{10} = (1001100100)_2$

$0.4 \times 2 = 0.8$ | 0 (MSB)

$0.8 \times 2 = 1.6$ | 1

$0.6 \times 2 = 1.2$ | 1

$0.2 \times 2 = 0.4$ | 0 (LSB)

$\vdots$ | $\vdots$

$(0.4)_{10} \rightarrow (0.0110\cdots)_2$

$(361.4)_{10} \rightarrow (\ldots)_2$

Decimal to Octal Conversion 6

$(3952.4)_{10} \longrightarrow (\,?\,)_8 = (7560.3146\ldots)_8$

8	3952	R
8	494	0
8	61	6
	7	5

LSB ↑ (remainders read from bottom, 7 = MSB, 0 = LSB)

MSB

$(3952)_{10} = (7560)_8$

$0.4 \times 8 = 3.2$ — 3 (MSB)

$0.2 \times 8 = 1.6$ — 1

$0.6 \times 8 = 4.8$ — 4

$0.8 \times 8 = 6.4$ — 6 (LSB)

$(0.4)_{10} = (0.3146\ldots)_8$

$(76289.25)_{10} \rightarrow (\ldots)_8 = (225001.2)_8$

8	76289	R
8	9536	1
8	1192	0
8	149	0
8	18	5
	2	2

LSB

MSB

$(76289)_{10} = (225001)_8$

$0.25 \times 8 = 2.0$ — 2

$(0.25)_{10} = (0.2)_8$

$\boxed{(1629.3)_{10} \rightarrow (\,?\,)_8}$

HW

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Decimal to Hexadecimal Conversion

0, 1, 2, 3, 4, 5, 6, 7, 8, 9

A, B, C, D, E, F
↓ ↓ ↓ ↓ ↓ ↓
10 11 12 13 14 15

7

$(19628.2)_{10} \longrightarrow (\underline{\ ?\ })_{16}$

		R
16	19628	
16	1226	C
16	76	A
	4	C

↑ LSB

MSB

$(19628)_{10} = (4CAC)_{16}$

$0.2 \times 16 = 3.2$ | 3

$0.2 \times 16 = 3.2$ | 3

⋮

$(0.2)_{10} = (0.33\ldots)_{16}$

$(19628.2)_{10} =$

$(4CAC.33\ldots)_{16}$

$(76293.125)_{10} \longrightarrow (\ldots)_{16} = (12A05.2)_{16}$

		R
16	76293	
16	4768	5
16	298	0
16	18	A
	1	2

↑ LSB

MSB

$(76293)_{10} = (12A05)_{16}$

$0.125 \times 16 = 2.0$ | 2

$\times$

$(0.125)_{10} = (0.2)_{16}$

$$\boxed{\begin{array}{c}(96298.215)_{10} \\ \downarrow \\ (\underline{\ ?\ })_{16}\end{array}}$$

HW.

Number System to Decimal Conversion

8

$(3ACB.AB)_{16} \longrightarrow (\_\_\_)_{10}$

3 2 1 0 -1 -2

- 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

A → 10, B → 11, C → 12, D → 13, E → 14, F → 15

$= 3 \times 16^3 + 10 \times 16^2 + 12 \times 16^1 + 11 \times 16^0 + 10 \times 16^{-1} + 11 \times 16^{-2}$

$= (15051.66797)_{10}$

$\boxed{(ABCD.1F)_{16} \longrightarrow (\_\_\_)_{10}}$ HW

$(3765.65)_8 \longrightarrow (\_\_\_)_{10}$

3 2 1 0 -1 -2

$= 3 \times 8^3 + 7 \times 8^2 + 6 \times 8^1 + 5 \times 8^0 + 6 \times 8^{-1} + 5 \times 8^{-2}$

$= (2037.828125)_{10}$

$\boxed{(4561.35)_8 \longrightarrow (\_\_\_)_{10}}$ HW

$(11011.1011)_2 \longrightarrow (\_\_\_)_{10}$

4 3 2 1 0 -1 -2 -3 -4

$= 1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 + 1 \times 2^{-1} + 0 \times 2^{-2} + 1 \times 2^{-3} + 1 \times 2^{-4}$

$= (27.6875)_{10}$

$\boxed{(1101011.1101)_2 \longrightarrow (\_\_\_)_{10}}$ HW

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Hexadecimal to Binary to Octal Conversion & Visaversa

9

$(5ACD.BB)_{16} \longrightarrow (\ldots)_2 \longrightarrow (\ldots)_8$

$= [\,0101\ 1010\ 1100\ 1101\,.$

(x x x x)
8 4 2 1

$1011\ 1011\,0]_2$

$= [55315.566]_8$

$\boxed{(3ABC.AC)_{16} \longrightarrow (\ldots)_2 \longrightarrow (\ldots)_8}$ HW

$0(011\ 0111\ 1011.1011\ 1010)0_2 \longrightarrow (\ldots)_8 \longrightarrow (\quad)_{16}$

$= (1573.55)_8$

$= (37B.B4)_{16}$

$\boxed{(10110101101.1011101)_2 \longrightarrow (\ldots)_{16} \longrightarrow (\ldots)_8}$ HW.

$(3716.563)_8 \longrightarrow (\ldots)_2 \longrightarrow (\ldots)_{16}.$

$= (011\ 111\ 001\ 110.101\ 110\ 011\,00)_2$

$= (7CE.B98)_{16}$

$\boxed{(6576.562)_8 \longrightarrow (\ldots)_2 \longrightarrow (\ldots)_{16}}$ HW.

X Number System to Y Number System Conversion

$\rightarrow (\overset{2}{3}\overset{1}{2}\overset{0}{7}.)_8 \longrightarrow (\ldots\ldots)_5$ (10)

$\hookrightarrow (\ldots\ldots)_{10} \rightarrow$

$= 3 \times 8^2 + 2 \times 8^1 + 7 \times 8^0$

$= (215)_{10}$

		R
5	215	
5	43	0
5	8	3
	1	3

LSB

MSB

$(1330)_5$

$\rightarrow (\overset{4}{1}\ \overset{3}{2}\ \overset{2}{3}\ \overset{1}{3}\ \overset{0}{2}.)_4 \longrightarrow (\ldots\ldots)_3$

$\hookrightarrow (\ldots\ldots)_{10} \rightarrow$

$= 1 \times 4^4 + 2 \times 4^3 + 3 \times 4^2 + 3 \times 4^1 + 2 \times 4^0$

$= (446)_{10}$

		R
3	446	
3	148	2
3	49	1
3	16	1
3	5	1
	1	2

LSB

MSB

$(121112)_3$

$(5621)_7 \longrightarrow (\ldots\ldots)_9$

1's & 2's / 7's & 8's / 9's & 10's / 15's & 16's Compliment

11

- 1's & 2's Compliment in Binary System

HW $\boxed{(0110101100)_2}$

- $(110101)_2$

$(001010)_2$ ← 1's Compliment
$+1$
$(001011)_2$ ← 2's Compliment

$(1011010)_2$

$(0100101)_2$ ← 1's Compliment
$+1$
$(0100110)_2$ ← 2's Compliment

- 7's & 8's Compliment in Octal System

$(67123)_8$

HW $\boxed{(235400)_8}$

$$\begin{array}{r} 77777 \\ -\ 67123 \\ \hline (10654)_8 \end{array}$$ → 7's Compliment

$+1$

$(10655)_8$ → 8's Compliment

- 9's & 10's Compliment in Decimal System

$(169700)_{10}$

HW $\boxed{(235618)_{10}}$

$$\begin{array}{r} 999999 \\ -\ 169700 \\ \hline (830299)_{10} \end{array}$$ → 9's Compliment

$+1$

$(830300)_{16}$ → 10's Compliment

- 15's & 16's Compliment in Hexadecimal System

$(2BCDE)_{16}$

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

A ↓ 10, B ↓ 11, C ↓ 12, D ↓ 13, E ↓ 14, F ↓ 15

$$\begin{array}{rrrrr} 15 & 15 & 15 & 15 & 15 \\ -\ 2 & B & C & D & E \\ \hline (D & 4 & 3 & 2 & 1)_{16} \end{array}$$ → 15's Compliment

HW $\boxed{(7D1600)_{16}}$

$+1$

$(D\ 4\ 3\ 2\ 2)_{16}$ → 16's Compliment

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Signed Representation (12)

- Simple
- 1's Compliment
- 2's Compliment

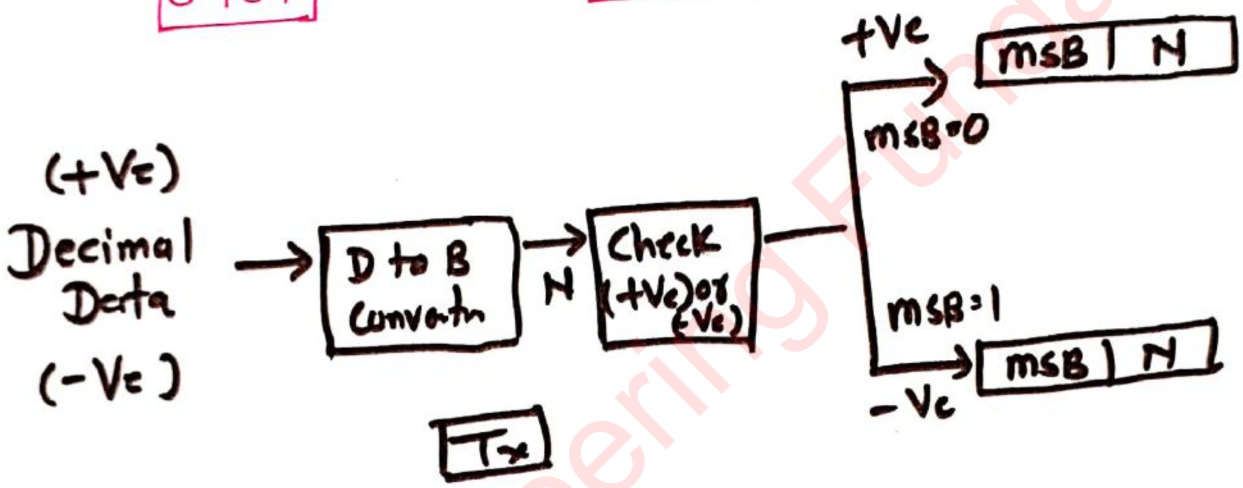
Simple

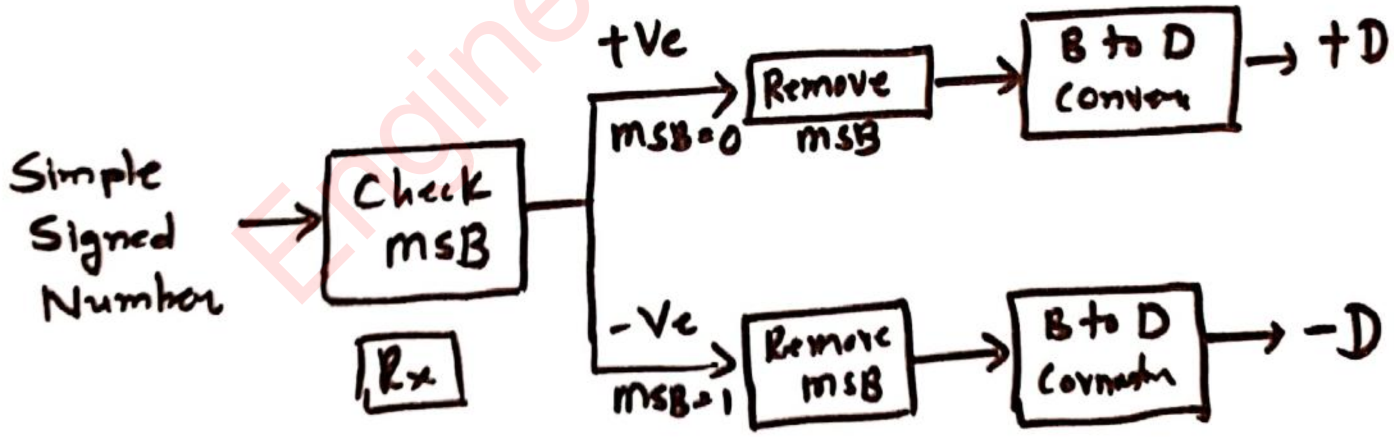
$+X$ → | 0 | D to B |

$-X$ → | 1 | D to B |

e.g. $+5$ → | 0 | 101 |

e.g. -6 → | 1 | 110 |





→ For $n = 3$

0	0	00
1	0	01
2	0	10
3	0	11
	1	00 ✕
−1	1	01
−2	1	10
−3	1	11

$\{0, 1, 2, 3\}$ → +Ve $(2^{n-1} - 1)$

$\{-1, -2, -3\}$ → −Ve $(2^{n-1} - 1)$

→ Range of number

$$-(2^{n-1}-1) \leq N \leq (2^{n-1}-1)$$

→ total Numbers

$$= (2^{n-1}-1) + (2^{n-1}-1) + 1$$

$$= 2^n - 1$$

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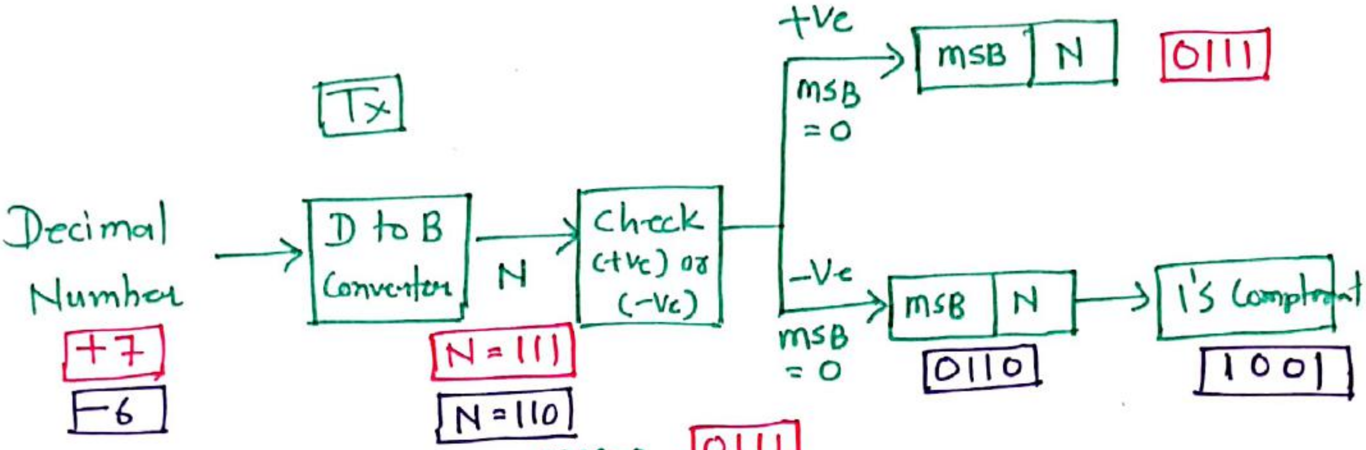
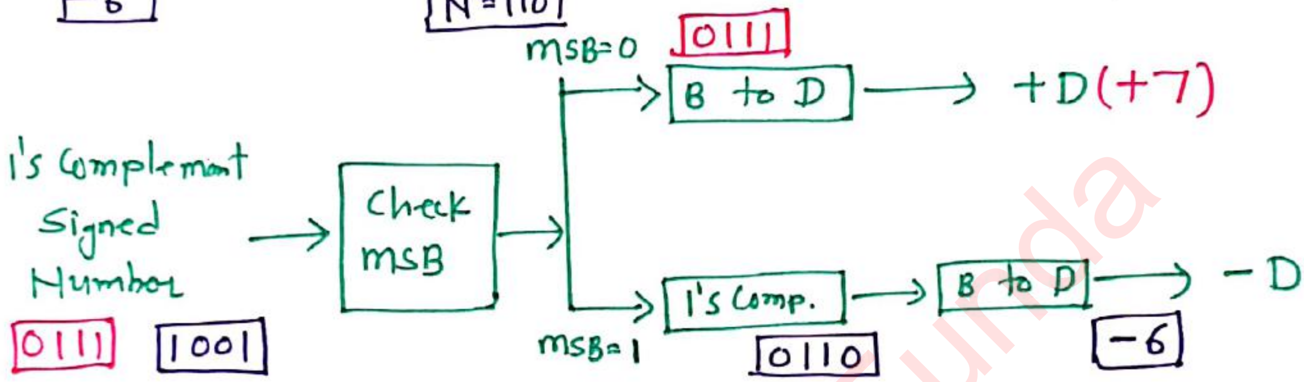
1's Compliment Signed Representation (B)





→ If n bits are given

0	0	0	0	+Ve 0
1	0	0	1	
2	0	1	0	$+Ve = (2^{n-1} - 1)$
3	0	1	1	
-3	1	0	0	
-2	1	0	1	$-Ve = (2^{n-1} - 1)$
-1	1	1	0	
×	1	1	1	-Ve 0

→ total Numbers

$= (2^{n-1} - 1) + (2^{n-1} - \cancel{1}) + \cancel{1}$

$= 2 \cdot 2^{n-1} - 1$

$= 2^n - 1$

→ Range of Numbers N

$-(2^{n-1} - 1) \leq N \leq (2^{n-1} - 1)$

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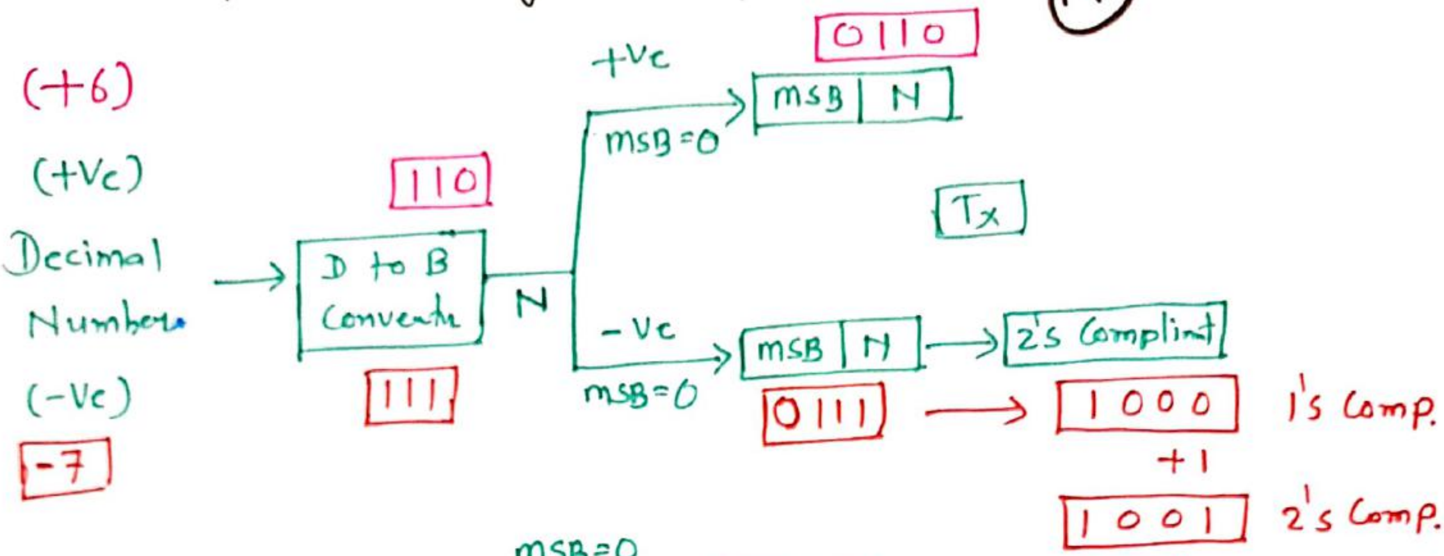
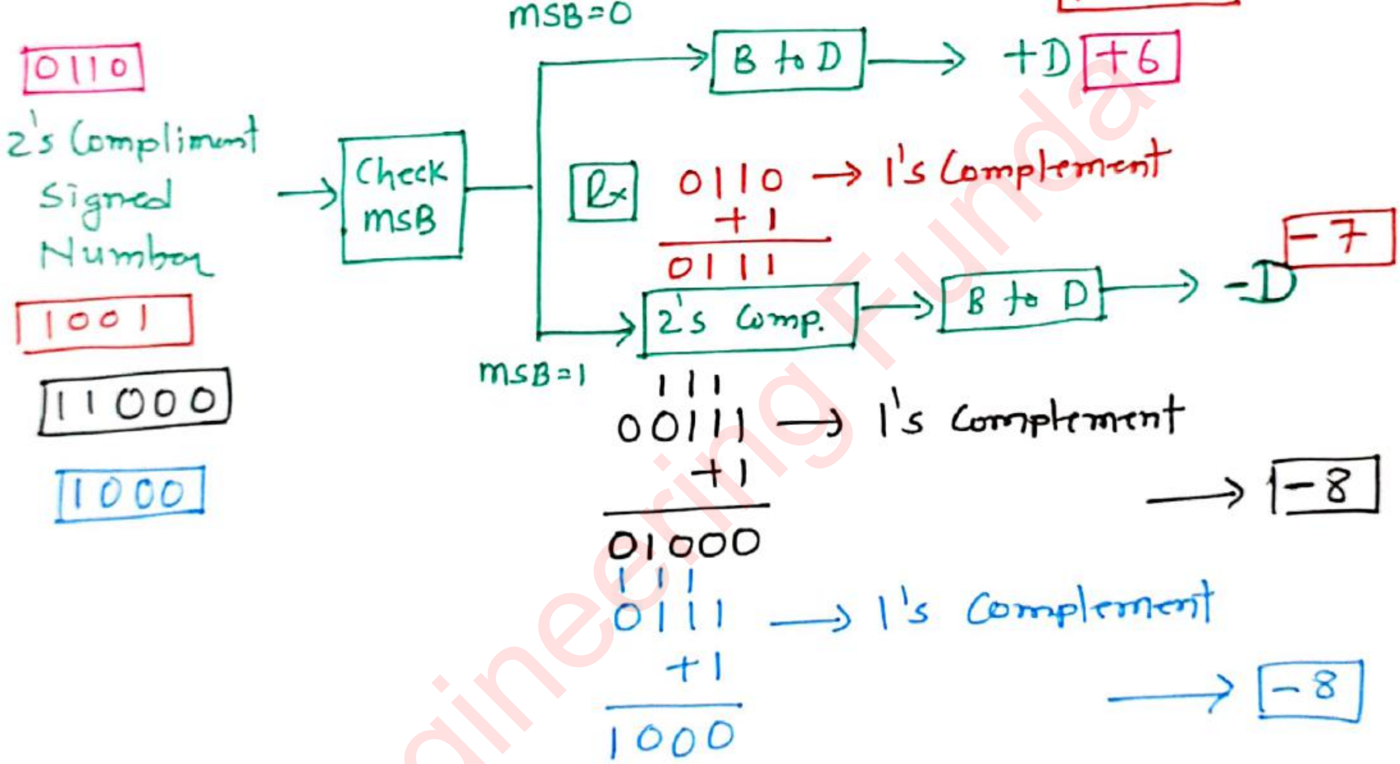
2's Compliment Signed Representation (13)





→ for 1's Complement

Range $(-(2^{n-1}-1)) \leq N \leq (2^{n-1}-1)$

total Numbers $= 2^{n}-1$

+Ve Numbers $= 2^{n-1}-1$

-Ve Numbers $= 2^{n-1}-1$

1 As n
100
1000
10000
100000
×

for 2's Complement

$-2^{n-1} \leq N \leq 2^{n-1}-1$

$= 2^{n}$

$= 2^{n-1}-1$ ✓

$= 2^{n-1}$

Examples on Simple, 1's Complement and 2's Complement Signed Representation

15

1011 → Simple $\underline{1}\,\underline{011} = -3$

→ 1's comp $\underline{1}011 = (0100) = -4$
sign (arrow to 1); 1's Comp (under 0100)

→ 2's Comp $\underline{1}011 = (0100) = 0100 + 1 = 0101 = -5$
sign; 1's comp

→ Binary to Decimal $= 1011 = 11$

1 HW

$\boxed{(1100)}$

	1's	2's	Simple
100	-3	-4	-0
1100	-3	-4	-4
11100	-3	-4	-12
111100	-3	-4	-28

1111111111|010   −5 ← 1's Comp Sign   −6 ← 2's Comp sign

→ A & B are given in 2's Complement, A = 0110 & B = 1001. Find A+B and A−B in Simple Sign, 1's Comp. & 2' comp sign.

$\boxed{A = 1100 \quad B = 1001}$ 2 HW

A = $\underline{0}110$ = +6

B = $\underline{1}001$ = (0110) = (0111) = −7
1's Comp; 2's Comp.

→ A+B = 6 − 7 = −1

Simple = (11)

1's Comp = 01 = (10)

2's Comp = 01 = (10) = (11)
1's Comp; 2's Comp

→ A−B = 6−(−7) = 13

Simple = 01101

1's Comp = 01101 ~~XXXXXX~~

2's Comp = 01101

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Shortcut Method to Calculate 2's Compliment

16

$(1011011100)_2$

1's Comp $\rightarrow$ 0100100011

$+1$

2's Comp $\rightarrow$ 0100100100

$\leftarrow$

1011011100

0100100100

2's compliment

$(101011000)_2$

1's Comp $\rightarrow$ 010100111

$+1$

2's Comp $\rightarrow$ 010101000

$\leftarrow$

101011000

010101000

2's compliment

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Binary Subtraction using 1's Compliment

17

→ $A - B \Rightarrow A + (-B) = y$

↑ 1's Compliment

→ In Addition, If carry is 1 then add +1 with y and answere is +ve.

→ In Addition, If Carry is 0 then answere is −ve and answere is 1's compliment of y.

Ex. 1 $(1011)_2 - (0101)_2$

A = 1011

B = 0101 ⟶ (−B) = 1010 (1's compliment).

→ y = A + (−B)

```
  1
  1011
  1010
 ------
(1)0101
 └──→ 1
 ------
```

Ans = (0110)

$\boxed{\begin{array}{l} 1.\ (1110)_2 - (0110)_2 \\ 2.\ (0111)_2 - (1001)_2 \end{array}}$

HW

Ex-2 $(0110)_2 - (1010)_2$

A = 0110

B = 1010 ⟶ (−B) = 0101 (1's Compliment)

→ y = A + (−B)

```
      1
      0110
      0101
     ------
[C=0] 1011
```

Ans = (−ve) = −0100

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Binary Subtraction using 2's Compliment

(18)

→ $A - B \rightarrow y = A + (-B)$

↑ 2's Compliment of B

→ In Addition, If carry is 1 then answer is +ve and answer is y.

→ In Addition, If carry is 0 then answer is (-ve) and answer is 2's compliment of y.

Ex. 1 $(1001)_2 - (0101)_2$

A = 1001

B = 010$\boxed{1}$ ⟶ −B = 1011 (2's compliment)

→ y = A + (−B)

$$\begin{array}{r} {\scriptstyle 1\ \ 1\,1\ } \\ 1001 \\ 1011 \\ \hline 1\,0100 \end{array}$$

Carry = 1, Ans = +ve = +y = $\boxed{0100}$

Ex. 2 $(0110)_2 - (1010)_2$

A = 0110

B = 10$\boxed{10}$ ⟶ −B = 0110 (2's compliment)

→ y = A + (−B)

$$\begin{array}{r} {\scriptstyle 1\ 1\ \ \ } \\ 0\,1\,1\,0 \\ 0\,1\,1\,0 \\ \hline \boxed{C=0}\ 1\,\boxed{1\,0\,0} \end{array}$$

Carry = 0, Ans = −ve = −0100

1. $(1101)_2 - (0111)_2$
2. $(1000)_2 - (1010)_2$

HW

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Classification of Codes

Codes - It is group of Symbols, which is used to represent data.

1] **Weighted Codes** - each position has fixed Value.

e.x. Binary, 8421, 2421

a_3	a_2	a_1	a_0		b_3	b_2	b_1	b_0
↑	↑	↑	↑		↑	↑	↑	↑
8	4	2	1		2	4	2	1

2] **Non-weighted Codes** - Position does not have any fixed value.

e.x. XS-3, Gray

3] **Reflective Codes** - It is self Complimenting code.

- In that code 9 is compliment of 0
- 8 is " " 1
- 7 is " " 2
- 6 is " " 3
- 5 is " " 4

e.x. 2421, XS-3

Decimal		2421
0	→	0000
1	→	0001
2	→	0010
3	→	0011
4	→	0100
5	→	1011
6	→	1100
7	→	1101
8	→	1110
9	→	1111

4] **Sequential Codes**

- Next data will Increment by 1.

e.x. binary, XS-3, 8421

5] **Alphanumeric Codes**

e.x. ASCII

American Standard Code for Information Interchange.

6] **Error Detecting and Correcting Codes.**

e.x. Hamming code, Cyclic Code.

BCD Code, [Binary Coded Decimal Code].

- In this code, each decimal digits are represented by 4 bits binary code.
- In decimal, digits are ranging from 0 to 9, which we will represent in 4 bit binary by BCD code.

Decimal		BCD code.
0	→	0000
1	→	0001
2	→	0010
3	→	0011
4	→	0100
5	→	0101
6	→	0110
7	→	0111
8	→	1000
9	→	1001

BCD code for decimal digits.

- Conversion of BCD from decimal

1.] $(149)_{10} \rightarrow [0001\ 0100\ 1001]_{BCD}$

2] $(638)_{10} \rightarrow [0110\ 0011\ 1000]_{BCD}$

3] $(378)_{10} \rightarrow [0011\ 0111\ 1000]_{BCD}$

- Conversion of BCD to Decimal

1] $[0001\ 0100]_{BCD} \rightarrow (14)_{10}$

2] $[0010\ 0010\ 0101]_{BCD} \rightarrow (225)_{10}$

HW

- Represent following BCD into Decimal

1] 010011

2] 10110110110101

3] 1011010110

HW

Represent following decimal into BCD

1] $(37)_{10}$

2] $(271)_{10}$

3] $(141)_{10}$

- Comparision of binary and BCD code.

Decimal	Binary	BCD
$(15)_{10}$	$(1111)_2$	$[0001\ 0101]_{BCD}$
$(28)_{10}$	$(11100)_2$	$[0010\ 1000]_{BCD}$

- Here in BCD code, we need more bits for same information compared to binary. So, BCD is less efficient code compared to binary code.

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BCD Addition (21)

- If Nibble to Nibble carry is 1, then add 0110 to that Nibble.
- If Addition of Nibble with Nibble is greater than 9, then add 0110 to that Nibble.

1) $(8)_{10} + (7)_{10} = (15)_{10}$

$$\begin{array}{rr} & 1000 \\ + & 0111 \\ \hline & 1111 \ (15) \\ & 0110 \\ \hline 0001 & 0101 \\ 1 & 5 \end{array}$$

2) $(9)_{10} + (8)_{10} = (17)_{10}$

$$\begin{array}{rr} & 1001 \\ & 1000 \\ \hline 1 & 0001 \\ & 0110 \\ \hline 0001 & 0111 \\ 1 & 7 \end{array}$$

3) $(89)_{10} + (79)_{10}$

$$\begin{array}{rrr} & 1000 & 1001 \\ & 0111 & 1001 \\ \hline 0001 & 0000 & 0010 \\ 0000 & 0110 & 0110 \\ \hline 0001 & 0110 & 1000 \\ 1 & 6 & 8 \end{array}$$

4) $(279)_{10} + (781)_{10} = (1060)_{10}$

$$\begin{array}{rrrr} & 0010 & 0111 & 1001 \\ & 0111 & 1000 & 0001 \\ \hline & 1001 & 1111 \ (15) & 1010 \ (10) \\ & 0000 & 0110 & 0110 \\ \hline & 1010 \ (10) & 0110 \ (6) & 0000 \ (0) \\ & 0110 & 0000 & 0000 \\ \hline 0001 & 0000 & 0110 & 0000 \\ 1 & 0 & 6 & 0 \end{array}$$

- In second time addition, we don't need to consider Nibble to Nibble carry rule for add 0110.

HW
1) $(189)_{10} + (265)_{10}$
2) $(742)_{10} + (688)_{10}$

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BCD to Binary Conversion 20

$\rightarrow (\quad)_{10} \rightarrow$

BCD number is given by

1) $\underbrace{0010}_{2}\ \underbrace{1001}_{9}\ \underbrace{0010}_{2}$

$\rightarrow (292)_{10}$

$\rightarrow (100100100)_2$

		R	
2	292		
2	146	0	LSB
2	73	0	
2	36	1	
2	18	0	
2	9	0	
2	4	1	
2	2	0	
MSB	1	0	

2) $\underbrace{0101}_{5}\ \underbrace{1000}_{8}\ \underbrace{1001}_{9}$

$\rightarrow (589)_{10}$

$\rightarrow (1001\ 001101)_2$

		R	
2	589		
2	294	1	LSB
2	147	0	
2	73	1	
2	36	1	
2	18	0	
2	9	0	
2	4	1	
2	2	0	
MSB	1	0	

HW

1) $(1010110)_{BCD} \longrightarrow (\ldots)_2$

2) $(101101001)_{BCD} \longrightarrow (\_\_)_2$

Binary to BCD Conversion (23)

$\rightarrow (\quad)_{10} \rightarrow$

- Binary numbers are given by

1] $(110011001)_2 \longrightarrow (\quad)_{BCD}$.

$$\begin{array}{ccccccccc} \uparrow&\uparrow&\uparrow&\uparrow&\uparrow&\uparrow&\uparrow&\uparrow&\uparrow \\ 8&7&6&5&4&3&2&1&0 \end{array}$$

$$= 1\times2^8 + 1\times2^7 + \underline{0\times2^6} + \underline{0\times2^5} + 1\times2^4 + 1\times2^3 + \underline{0\times2^2} + \underline{0\times2^1} + 1\times2^0$$

$$= (409)_{10}$$

$$= [0100 \ \ 0000 \ \ 1001]_{BCD}$$

2] $(11011101100.0101)_2 \longrightarrow (\quad)_{BCD}$

10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4

$$= 1\times2^{10} + 1\times2^9 + 1\times2^7 + 1\times2^6 + 1\times2^5 + 1\times2^3 + 1\times2^2 + 1\times2^{-2} + 1\times2^{-4}$$

$$= (1772.3125)_{10}$$

$$= [0001 \ 0111 \ 0111 \ 0010.\ 0011 \ 0001 \ 0010 \ 0101]_{BCD}$$

HW

1] $(1101101)_2 \longrightarrow (\quad)_{BCD}$

2] $(101010110)_2 \longrightarrow (\quad)_{BCD}$

3] $(762.6)_8 \longrightarrow (\quad)_{BCD}$.

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2421 BCD Code

- It is BCD (Binary Coded Decimal) Code.
- Some times it is reffered as 2*-4-2-1 code.

Decimal digits		2*-4-2-1 (X)		2-4-2-1
0	→	0 0 0 0	→	0 0 0 0
1	→	0 0 0 1	→	0 0 0 1
2	→	0 0 1 0	→	0 0 1 0
3	→	0 0 1 1	→	0 0 1 1
4	→	0 1 0 0	→	0 1 0 0
5	→	0 1 0 1	→	1 0 1 1
6	→	0 1 1 0	→	1 1 0 0
7	→	0 1 1 1	→	1 1 0 1
8	→	1 1 1 0	→	1 1 1 0
9	→	1 1 1 1	→	1 1 1 1

→ Self complimenting property means,

9 is compliment of 0
8 is " " 1
7 is " " 2
6 is " " 3
5 is " " 4

→ 7421, 5421, 3321, $84\bar{2}\bar{1}$ & $74\bar{2}\bar{1}$

→ HW

1.) Convert $(145)_{10}$ to 2421 Code.
2) $(0100\ 0100\ 1110)_{2421}$ to $(\_)_{10}$

Excess-3 Code 25

Decimal Number → 8421 BCD Code $\xrightarrow[0011]{Add}$ Excess-3

$\boxed{4}$ → 0100 → 0100 + 0011 = $(0111)_{Excess\text{-}3}$.

Decimal Numbers	8421 BCD	XS-3 (Add 0011)
0	0000	0011
1	0001	0100
2	0010	0101
3	0011	0110
4	0100	0111
5	0101	1000
6	0110	1001
7	0111	1010
8	1000	1011
9	1001	1100

- Excess-3 is Only unweighted Code which follows Self complimenting property.

- Based on bits, there is no well define weighted. so It is unweighted code.

- Conversion of decimal number in XS-3 code

$(36)_{10}$ → $\boxed{\text{8421 BCD}}$ 0011 0110 $\boxed{\xrightarrow[0011]{Add}}$

```
  0011 0110
+ 0011 0011
-----------
 (0110 1001)
```

$(395)_{10}$ → 8421 BCD (0011 1001 0101) $\xrightarrow[0011]{Add}$

```
  0011 1001 0101
+ 0011 0011 0011
----------------
 (0110 1100 1000)
```

HW.
1) $(27)_{10}$
2) $(462)_{10}$
3) $(1101011)_2$

← Convert into XS-3

Excess 3 Addition 26

Step-1 Convert given numbers into Excess 3.

Step-2 Add given Excess 3 numbers.

Step-3 watch Nibble to Nibble Carry.

Carry = 1 → Add 0011 with Nibble

Carry = 0 → sub 0011 with Nibble.

1.) $(3)_{10} + (6)_{10}$

$(3)_{10} \xrightarrow[8421]{} 0011 \xrightarrow[0011]{Add} 0110$

$(6)_{10} \xrightarrow{BCD} 0110 \longrightarrow 1001$

0

1111

− 0011

$(1100)_{Ex-3}$

2) $(38)_{10} + (28)_{10}$

$(38)_{10} \xrightarrow[8421]{} 0011\ 1000 \xrightarrow[0011]{Add} 0110\ 1011$

0011 0011

$(28)_{10} \xrightarrow{BCD} 0010\ 1000 \longrightarrow 0101\ 1011$

0011 0011

0 111 11

1100 0110

− 0011 + 0011

✓ $(1001\ 1001)_{Ex-3}$

$(38)_{10}$

$(28)_{10}$

$(66)_{10}$

$(99)_{EX-3}$

Identification of Self complimenting code. 27

→ If code satisfy given condition,

"9 is compliment of 0,
8 is compliment of 1,
7 is compliment of 2,
6 is compliment of 3,
5 is compliment of 4."

then given code is self complimenting code.

→ If given code is $(w_3 - w_2 - w_1 - w_0)$,

$w_3 + w_2 + w_1 + w_0 = 9$, then given code is self complimenting code.

→ 7421 ⟶ $7+4+2+1 = 14 \neq 9$ ✗

→ 5921 ⟶ $5+9+2+1 = 17 \neq 9$ ✗

→ 3321 ⟶ $3+3+2+1 = 9 = 9$ ✓

→ $84\bar{2}\bar{1}$ ⟶ $8+4-2-1 = 9 = 9$ ✓

→ $74\bar{2}\bar{1}$ ⟶ $7+4-2-1 = 8 \neq 9$ ✗

ASCII code

28

→ It is American standard code for Information Interchange.

→ It is 7 bits code.

→ total 127 different characters are represented by ASCII code.

→ It starts from 0 to 126.

35 → #

36 → $

37 → %

38 → &

⋮

48-57 → 0 to 9

⋮

65-90 → (A - Z)

⋮

97 -122 → (a - z)

⋮

126 → ~

— Remember

64 32 16 8 4 2 1

$\underbrace{1001101}_{77}\ \underbrace{1000111}_{71}\ \underbrace{1100111}_{103}$ (mGg)

77 → m, 71 → G, 103 → g

Bc4

$\underbrace{1000010}_{66}\ \underbrace{1100011}_{99}\ \underbrace{0110100}_{52}$

Convert into ASCII

HW 1.) 1001111 1001111 1101111 chars.

2.) ASCII Series is " B b 4 8 ", give binary data of it.

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Gray Code 29

- Code is name after Frank Gray.
- It is unweighted code. [No positonal weight].
- It is also reffered as reflected binary code.
- It is unit dist.^{n} code.
- It is Cyclic code.

1 bit gray code	2 bit gray code	3 bit gray code	4 bit gray code	4 bit Binary code
b_0	b_1 b_0	b_2 b_1 b_0	b_3 b_2 b_1 b_0	b_3 b_2 b_1 b_0
0	0 0	0 0 0	0 0 0 0	0 0 0 0
1	0 1	0 0 1	0 0 0 1	0 0 0 1
	1 1	0 1 1	0 0 1 1	0 0 1 0
	1 0	0 1 0	0 0 1 0	0 0 1 1
		1 1 0	0 1 1 0	0 1 0 0
		1 1 1	0 1 1 1	0 1 0 1
		1 0 1	0 1 0 1	0 1 1 0
		1 0 0	0 1 0 0	0 1 1 1
			1 1 0 0	1 0 0 0
			1 1 0 1	1 0 0 1
			1 1 1 1	1 0 1 0
			1 1 1 0	1 0 1 1
			1 0 1 0	1 1 0 0
			1 0 1 1	1 1 0 1
			1 0 0 1	1 1 1 0
			1 0 0 0	1 1 1 1

- Switching time for Gray code is less than any other code.

Appliations of gray code

- K-map function reduction
- Error detection
- Digital comm.^{n} [Cable TV]

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Binary to Gray Code Conversion

Step-1 - Take MSB as it is.

Step-2 - XOR MSB with next bit.

Step-3 - Repeat step-2.

$b_3 \quad b_2 \quad b_1 \quad b_0$

$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$

$g_3 \quad g_2 \quad g_1 \quad g_0$

$g_3 = b_3$

$g_2 = b_3 \oplus b_2$

$g_1 = b_2 \oplus b_1$

$g_0 = b_1 \oplus b_0$

Ex-1 Convert $(1001100)_2$ to Gray

1 0 0 1 1 0 0

$\downarrow$

(1 1 0 1 0 1 0) ← gray code

Ex-2 Convert $(0100110101)_2$ to Gray code

0 1 0 0 1 1 0 1 0 1

$\downarrow$

(0 1 1 0 1 0 1 1 1 1) ← gray code

HW
1) $(1011010)_2$ to gray code
2) $(346)_8$ to gray code

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Gray to Binary Conversion 3)

Step-1 Take MSB as it is.

Step-2 XOR MSB to next bit of Gray Code.

Step 3 Repeat step-2.

$g_3 \quad g_2 \quad g_1 \quad g_0$

$B_3 \quad B_2 \quad B_1 \quad B_0$

~~g_3 = MSB~~ $B_3 = g_3$

$B_2 = B_3 \oplus g_2 = g_3 \oplus g_2$

$B_1 = B_2 \oplus g_1 = g_3 \oplus g_2 \oplus g_1$

$B_0 = B_1 \oplus g_0 = g_3 \oplus g_2 \oplus g_1 \oplus g_0$

Ex.1 Convert 01101011 gray Code into Binary Code.

0 1 1 0 1 0 1 1

$(0\ 1\ 0\ 0\ 1\ 1\ 0\ 1)_2$ ← Binary Code

Ex.2 Convert 10110110 Gray Code into Binary code.

1 0 1 1 0 1 1 0

$(1\ 1\ 0\ 1\ 1\ 0\ 1\ 1)_2$ ← Binary Code.

HW

1.) 101101011 gray code → $(\ )_2$

2) 10101010 gray Code → $(\ )_8$.

Identification of base or radix of given number

- Identify base or radix for given number **32**

1] $52/4 = 12$

$\Rightarrow [5\times b^1 + 2\times b^0] = [1\times b^1 + 2\times b^0][4\times b^0]$

$\Rightarrow (5b+2) = (b+2)4$

$\Rightarrow 5b+2 = 4b+8$

$\Rightarrow \boxed{b=6}$

2] $24 + 17 = 40$

$\Rightarrow [2\times b^1 + 4\times b^0] + [1\times b^1 + 7\times b^0] = [4\times b^1 + 0\times b^0]$

$\Rightarrow 2b+4+b+7 = 4b$

$\Rightarrow \boxed{b=11}$

3] $\sqrt{22} = 6$

$\Rightarrow \sqrt{2\times b^1 + 2\times b^0} = 6\times b^0$

$\Rightarrow \sqrt{2b+2} = 6$

$\Rightarrow 2b+2 = 36$

$\Rightarrow 2b = 34$

$\Rightarrow \boxed{b=17}$

HW - you search for some questions.

4] $\sqrt{144} = 12$

$\Rightarrow \sqrt{1\times b^2 + 4\times b^1 + 4\times b^0} = 1\times b^1 + 2\times b^0$

$\Rightarrow \sqrt{b^2+4b+12} = b+2$

$\Rightarrow \sqrt{(b+2)^2} = 12$

$\Rightarrow b+2 = 12$

$\Rightarrow \boxed{b=10}$

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Total Bits Required to represent a number

1) How many bits req^{ed} to represent 12 digit Octal number.

$\Rightarrow 2^n \geq b^x$

$\Rightarrow 2^n \geq 8^{12}$

$\Rightarrow \log 2^n \geq \log 8^{12}$

$\Rightarrow n \log 2 \geq 12 \log 8$

$\Rightarrow n \geq 12\left(\frac{\log 8}{\log 2}\right)$

$\Rightarrow \boxed{n \geq 36}$

2) How many bits req^{ed} to represent 8 digit Hexadecimal number

$\Rightarrow 2^n \geq 16^x$

$\Rightarrow 2^n \geq 16^8$

$\Rightarrow \log 2^n \geq \log 16^8$

$\Rightarrow n \log 2 \geq 8 \log 16$

$\Rightarrow n \geq 8\left(\frac{\log 16}{\log 2}\right)$

$\Rightarrow n \geq 32$

3) How many bits req^{ed} to represent 15 digit decimal number

$\Rightarrow 2^n \geq b^x$

$\Rightarrow 2^n \geq 10^{15}$

$\Rightarrow \log 2^n \geq \log 10^{15}$

$\Rightarrow n \log 2 \geq 15 \log 10$

$\Rightarrow n \geq 15\left[\frac{\log 10}{\log 2}\right]$

$\Rightarrow n \geq 49.82 \Rightarrow \boxed{n \approx 50}$

HW How many bits req^{ed} to represent

1) 10 digit decimal
2) 11 digit base 5
3) $(129)_{12}$

4) How many bits req^{ed} to represent $(2679)_{10}$ number.

$\Rightarrow 2^n \geq (2679)$

$\Rightarrow \log 2^n \geq \log 2679$

$\Rightarrow n \log 2 \geq \log 2679$

$\Rightarrow n \geq \frac{\log 2679}{\log 2}$

$\Rightarrow n \geq 11.38 \Rightarrow \boxed{n \approx 12}$

Minimal Decimal Equivalent (34)

1] Find minimal decimal Equivalent of $(D17)_x$.

- Base = max. digit + 1
  $= 13 + 1$
  $= 14$
- Minimal decimal Equivalent
  $= 13\times14^2 + 1\times14^1 + 7\times14^0$
  $= (2569)_{10}$

→ Base = 16

→ Equivalent
$= 13\times16^2 + 1\times16 + 7\times16^0$
$= \boxed{3351}$

2] Find Minimal decimal Equivalent of $(731)_x$.

- Base = Max digit + 1
  $= 7+1$
  $= 8$
- Minimal decimal Equivalent
  $= 7\times8^2 + 3\times8^1 + 1\times8^0$
  $= (473)_{10}$

3] Find minimal decimal Equivalent of $(3241)_x$

- Base = Max. digit + 1
  $= 4+1$
  $= 5$
- Minimal decimal Equivalent
  $= 3\times5^3 + 2\times5^2 + 4\times5^1 + 1\times5^0$
  $= (446)_{10}$

HW Find minimal decimal Equivalent

1] $(3162)_x$

2] $(156)_x$

3] $(11)_x$

Hamming Code Basics 35

→ It is given by RW Hamming.

→ It is used to detect and correct error.

→ In Hamming code, we send data along with parity bits or Redandent bits.

→ It is represented by (n, k) code.

n → total bits, k → message bits.

→ Parity bits $p = n - k$

→ To Identity parity bits, It should satisfy given cond.ⁿ

$$\Rightarrow 2^p \geq p + k + 1$$

→ So for $k = 4$ message bits.

$$\Rightarrow 2^p \geq p + 4 + 1$$

$$\Rightarrow 2^p \geq p + 5$$

For $p = 1$	For $p = 2$	For $p = 3$
$2^1 \geq 6$	$2^2 \geq 7$	$2^3 = 8$
×	×	✓

$\Rightarrow p = 3$ for $k = 4$ bits.

$\Rightarrow n = 3 + 4 = 7$ bits.

→ This is (7, 4) code.

7	6	5	4	3	2	1
D_7	D_6	D_5	P_4	D_3	P_2	P_1

$P_1 = 2^0 = 1$

$P_2 = 2^1 = 2$

$P_4 = 2^2 = 4$

→ P_1 → $D_3\ D_5\ D_7$ (XOR)

→ P_2 → $D_3\ D_6\ D_7$ (XOR)

→ P_4 → $D_5\ D_6\ D_7$ (XOR).

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Generation of Hamming Code 36

- 5 bit data 01101 is given. Represent given data in Hamming code.

→ $K = 5$ bits.

→ Identify parity bits.

$$\Rightarrow 2^P \geq P + K + 1$$

$$\Rightarrow 2^P \geq P + 6$$

For $P=1$	For $P=2$	For $P=3$	For $\boxed{P=4}$
$2^1 \geq 7$	$2^2 \geq 8$	$2^3 \geq 9$	$2^4 \geq 10$
×	×	×	✓

→ So for $P=4$, $K=5$, $n=9$

→ This is (9, 5) hamming code.

9	8	7	6	5	4	3	2	1
0 D_9	P_8	1 D_7	1 D_6	0 D_5	P_4	1 D_3	P_2	P_1

→ Position of Parity bits.

$P_1 = 2^0 = 1$

$P_2 = 2^1 = 2$

$P_4 = 2^2 = 4$

$P_8 = 2^3 = 8$

→ Value of Parity bits.

$P_1 \rightarrow D_3\ D_5\ D_7\ D_9$

$P_2 \rightarrow D_3\ D_6\ D_7$

$P_4 \rightarrow D_5\ D_6\ D_7$

$P_8 \rightarrow D_9$

→ $P_1 = 1 \oplus 0 \oplus 1 \oplus 0 = 0$

→ $P_2 = 1 \oplus 1 \oplus 1 = 1$

→ $P_4 = 0 \oplus 1 \oplus 1 = 0$

→ $P_8 = D_9 = 0$

Code

$\boxed{001100110}$

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* IF Received Hamming Code is 1110101 with even Parity then detect and correct error.

7	6	5	4	3	2	1
D_7	D_6	D_5	P_4	D_3	P_2	P_1
1	1	1	0	1	0	1

$P_1 = 2^0 = 1$

$P_2 = 2^1 = 2$

$P_4 = 2^2 = 4$

$$\left.\begin{aligned} P_1 &= D_3 \oplus D_5 \oplus D_7 \\ 1 &= 1 \oplus 1 \oplus 1 \end{aligned}\right] \text{— } P_1 = 0 \ \checkmark$$

$$\left.\begin{aligned} P_2 &= D_3 \oplus D_6 \oplus D_7 \\ 0 &= 1 \oplus 1 \oplus 1 \end{aligned}\right] \text{— } P_2 = 1 \ \times$$

$$\left.\begin{aligned} P_4 &= D_7 \oplus D_6 \oplus D_5 \\ 0 &= 1 \oplus 1 \oplus 1 \end{aligned}\right] \text{— } P_4 = 1 \ \times$$

$P_4 P_2 P_1 = 110 = \underline{\underline{6}}^{th}$ bit error

E =

0	1	0	0	0	0	0

R =

1	1	1	0	1	0	1

→ Corrected data = $R \oplus E$

=

1	0	1	0	1	0	1

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IEEE 754 floating point double precision 64 bit Formate

(38)

<u>Step-1</u> Convert given number in binary.

<u>Step 2</u> Represent given binary number into Scientific notation.

<u>Step3</u> IEEE 754 double precision 64 bit Formate.

X	xxxx xxxx xxx	xxxx xxxx xx
1 bit sign	11 bits exponents.	52 bits Mantissa

+ve → 0
−ve → 1

$$= \text{exponents bias} + \text{power}.$$
$$= (2^{k-1} - 1) + \text{power}.$$
$$= (2^{11-1} - 1) + 15 = 1038$$

$[A0F9.0EB]_{16}$

<u>Step-1</u> Convert given number into binary

$[1010\ 0000\ 1111\ 1001.0000\ 1110\ 1011]_2$

<u>Step-2</u> write Scientific Notation.

$[1.010\ 0000\ 1111\ 1001\ 0000\ 1110\ 1011]_2 \times 2^{15}$

<u>Step-3</u> IEEE 754 double precision 64 bit Formate

0	1 0000 00 1110	010 0000 1111 1001 0000 1110 1011 000...
↑ Sign	↑ 11 bits exponents.	↑ 52 bits Mantissa

$[FAFA.01]_{16}$ ⟶ IEEE 754 64 bit double precision format.

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$[3066.25]_{10}$

2	3066	0
2	1533	1
2	766	0
2	383	1
2	191	1
2	95	1
2	47	1
2	23	1
2	11	1
2	5	1
2	2	0
	1	1

$3066 = 101111111010$

$0.25 \times 2 = 0.5 \rightarrow 0$

$0.5 \times 2 = 1.0 \rightarrow 1$

$0.25 = 0.01$

$[3066.25]_{10} = [101111111010.01]_2$

$= 1.01111111101001 \times 2^{11}$

$\underline{0}$ $\underline{1000\cancel{0}0\cancel{0}0}$ $\underline{0111\ 1111\ 0100\ 1000\ 0000\ 000}$

Sign   8 bits Exponents   23 bits Mantissa

$(236.75)_{10} \longrightarrow$ 754 IEEE 32 bits

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