

Multiplication in Number System 4

$$\begin{array}{r}
 222 \\
 \times 455 \\
 \hline
 4312 \\
 2145 *
 \end{array}$$

$$(25762)_8$$

Result = Carry X Base + Remainder.

$$\begin{array}{ll}
 42 = 5 \times 8 + 2 & 21 = 2 \times 8 + 5 \\
 41 = 5 \times 8 + 1 & 20 = 2 \times 8 + 4 \\
 35 = 4 \times 8 + 3 & 17 = 2 \times 8 + 1
 \end{array}$$

HW

$$(327)_8 \times (65)_8 = (?)_8$$

Result = Carry X Base + Remainder

$$\begin{array}{r}
 10110 \\
 \times 110 \\
 \hline
 00000 \\
 10110 *
 \end{array}$$

$$10110 \times 110$$

$$2 = 1 \times 2 + 0$$

HW

$$(110110)_2 \times (1101)_2 = (?)_2$$

$$\hookrightarrow (10000100)_2$$

Decimal to Binary Conversion 5

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

Division Multiplication

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

$$\begin{aligned} 0.25 \times 2 &= 0.5 \\ 0.5 \times 2 &= 1.0 \\ 0.0 & \end{aligned}$$

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

0 MSB
1 LSB

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

$$(612.4)_{10} \longrightarrow (\underline{\quad})_2 = (1001100100.010\ldots)_2$$

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

$$\begin{aligned} 0.4 \times 2 &= 0.8 \\ 0.8 \times 2 &= 1.6 \\ 0.6 \times 2 &= 1.2 \\ 0.2 \times 2 &= 0.4 \end{aligned}$$

0 MSB
1
1
0
; ;
LSB

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

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

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

Decimal to Octal Conversion 6

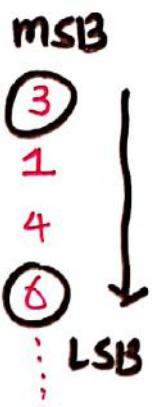
$$(3952.4)_{10} \rightarrow (\dots)_8 = (7560.3146\dots)_8$$

8	3952	R
8	494	○
8	61	6
8	7	5
		msb

$$\begin{aligned} 0.4 \times 8 &= 3.2 \\ 0.2 \times 8 &= 1.6 \\ 0.6 \times 8 &= 4.8 \\ 0.8 \times 8 &= 6.4 \end{aligned}$$

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

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



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

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

$$0.25 \times 8 = 2.0 \quad 2$$

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

$$(1629.3)_{10} \rightarrow (\dots)_8$$

Hence

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

Decimal to Hexadecimal Conversion

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

0, 1, 2, 3, 4, 5, 6, 7, 8, 9
 A, B, C, D, E, F
 ↓ ↓ ↓ ↓ ↓ ↓
 10 11 12 13 14 15

16 19628	R
16 1226	C
16 76	A
16 4	C
MSB	

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

$$\begin{array}{r}
 0.2 \times 16 = 3.2 \quad 3 \\
 0.2 \times 16 = 3.2 \quad 3 \\
 \vdots \\
 (0.2)_{10} = (0.33\dots)_6
 \end{array}$$

$$\begin{array}{r}
 (19628.2)_{10} = \\
 (4AC.33\dots)_{16}
 \end{array}$$

$$(76293.125)_{10} \rightarrow (\underline{\quad ? \quad})_{16} = (12A05.2)_{16}$$

16 76293	R
16 4768	5
16 298	O
16 18	A
MSB	2

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

$$\begin{array}{r}
 0.125 \times 16 = 2.0 \quad 2 \\
 \times \\
 (0.125)_{10} = (0.2)_{16}
 \end{array}$$

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

HW.

Number System to Decimal Conversion

$$(3ACB.AB)_{16} \rightarrow (\underline{\hspace{2cm}})_{10} \quad \textcircled{8}$$

$\begin{matrix} 3 & A & C & B & . & A & B \\ 3 & 2 & 1 & 0 & -1 & -2 \end{matrix}$

- 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
 ↓ ↓ ↓ ↓ ↓ ↓
 10 11 12 13 14 15

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

$$= (15051.66797)_{10} \quad \boxed{(ABCD.1F)_{16} \rightarrow (\underline{\hspace{2cm}})_{10}}$$

$$(3765.65)_8 \rightarrow (\underline{\hspace{2cm}})_{10}$$

$\begin{matrix} 3 & 7 & 6 & 5 & . & 6 & 5 \\ 3 & 2 & 1 & 0 & -1 & -2 \end{matrix}$

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

$$= (2037.828125)_{10} \quad \boxed{(4561.35)_8 \rightarrow (\underline{\hspace{2cm}})_{10}}$$

$$(11011.1011)_2 \rightarrow (\underline{\hspace{2cm}})_{10}$$

$\begin{matrix} 1 & 1 & 0 & 1 & 1 & . & 1 & 0 & 1 & 1 \\ 4 & 3 & 2 & 1 & 0 & -1 & -2 & -3 & -4 \end{matrix}$

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

$$= (27.6875)_{10} \quad \boxed{(1101011.1101)_2 \rightarrow (\underline{\hspace{2cm}})_{10}} \quad \text{Hω}$$

Hexadecimal to Binary to Octal Conversion &

$$(5ACD.BB)_{16} \rightarrow (\dots)_2 \rightarrow (\dots)_8$$

Visavarma
①

$$= [\begin{array}{cccc} 0101 & 1010 & 1100 & 1101 \end{array}]_2 \cdot \begin{array}{c} (xxxx) \\ 8421 \end{array}$$

$$= [55315.566]_8$$

$$\boxed{(3ABC.AC)_{16} \rightarrow (\dots)_2 \rightarrow (\dots)_8}$$

Hω

$$[\begin{array}{ccccc} 0011 & 0111 & 1011 & 011 \end{array}]_2 \cdot [\begin{array}{ccccc} 1011 & 0101 & 00 \end{array}]_2 \rightarrow (\dots)_8 \rightarrow (\dots)_{16}$$

$$= (1573.55)_8$$

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

$$\boxed{(10110101)01.1011101)_2 \rightarrow (\dots)_{16} \rightarrow (\dots)_8}$$

Hω.

$$(3716.563)_8 \rightarrow (\dots)_2 \rightarrow (\dots)_{16}$$

$$= (011111001110) \cdot [\begin{array}{ccccc} 101110 & 011000 \end{array}]_2$$

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

$$\boxed{(6576.562)_8 \rightarrow (\dots)_2 \rightarrow (\dots)_{16}}$$

Hω.

X Number System to Y Number System Conversion

$$\rightarrow (327.)_8 \rightarrow (\dots)_5 \quad (10)$$

\downarrow \uparrow
 $(\dots)_{10}$

$$= 3 \times 8^2 + 2 \times 8^1 + 7 \times 8^0$$
$$= (215)_{10}$$

5	215
5	43
5	8
1	

\uparrow LSB
 $(1330)_5$

$$\rightarrow (12332.)_4 \rightarrow (\dots)_3$$

\downarrow \uparrow
 $(\dots)_{10}$

$$= 1 \times 4^4 + 2 \times 4^3 + 3 \times 4^2 + 3 \times 4^1 + 2 \times 4^0$$
$$= (446)_{10}$$

3	446
3	148
3	49
3	16
3	5
1	

\uparrow LSB
 $(121112)_3$

$$(5621)_7 \rightarrow (\dots)_9$$

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

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

$$-(110101)_2$$

$$(001010)_2 \leftarrow 1's \text{ Compliment}$$

+1

$$\underline{(001011)_2} \leftarrow 2's \text{ Compliment}$$

$$(1011010)_2$$

$$(0100101)_2 \leftarrow 1's \text{ Compliment}$$

+1

$$\underline{(0100110)_2} \leftarrow 2's \text{ Compliment}$$

HW
 $(011010100)_2$

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

$$(67123)_8$$

$$\begin{array}{r} 77777 \\ - 67123 \\ \hline \end{array}$$

$$-(67123)$$

$$\underline{(10654)_8} \rightarrow 7's \text{ Compliment}$$

+1

$$\underline{(10655)_8} \rightarrow 8's \text{ Compliment}$$

HW
 $(235400)_8$

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

$$(169700)_{10}$$

$$\begin{array}{r} 999999 \\ - 169700 \\ \hline \end{array}$$

$$-(169700)$$

$$\underline{(830299)_{10}} \rightarrow 9's \text{ Compliment}$$

+1

$$\underline{(830300)_{10}} \rightarrow 10's \text{ Compliment}$$

HW
 $(235618)_{10}$

- 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
↓ ↓ ↓ ↓ ↓ ↓
10 11 12 13 14 15

$$\begin{array}{r} 15 15 15 15 15 \\ - 2 B C D E \\ \hline \end{array}$$

$$\underline{(D4321)_{16}} \rightarrow 15's \text{ Compliment}$$

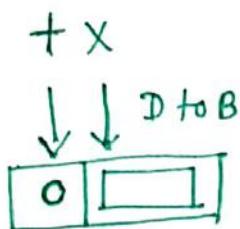
+1

$$\underline{(D4322)_{16}} \rightarrow 16's \text{ Compliment}$$

HW
 $(7D1600)_{16}$

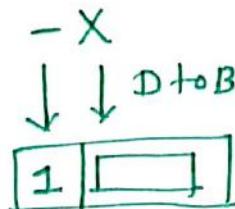
Signed Representation (12)

Simple



$$\text{e.g. } +5 \rightarrow 0101$$

1's Compliment



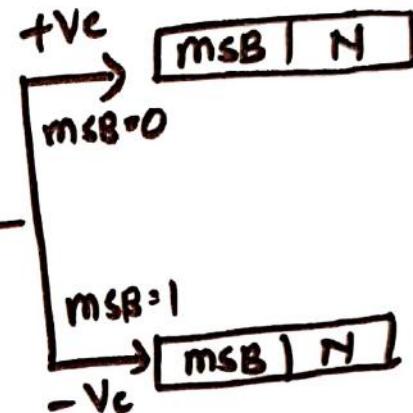
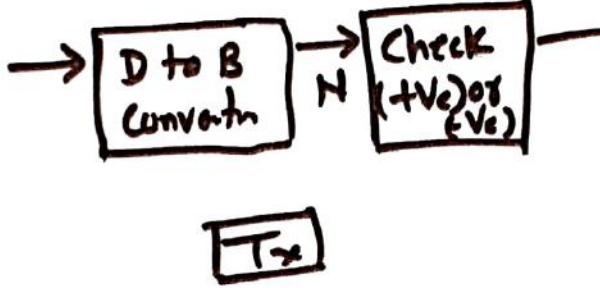
$$\text{e.g. } -6 \rightarrow 1110$$

2's Compliment

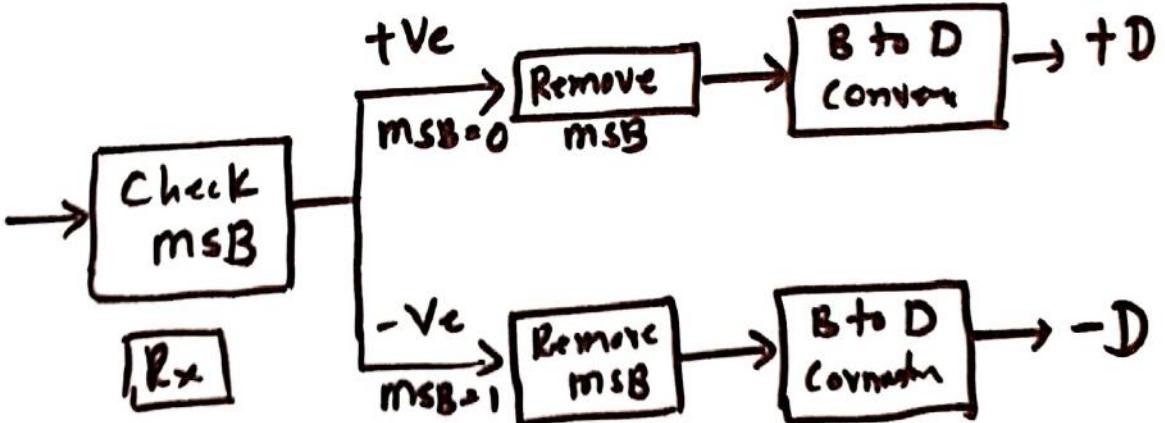
(+Ve)

Decimal Data

(-Ve)



Simple Signed Number



→ For n = 3

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

$$+Ve \quad (2^{n-1} - 1)$$

$$-Ve \quad (2^{n-1} - 1)$$

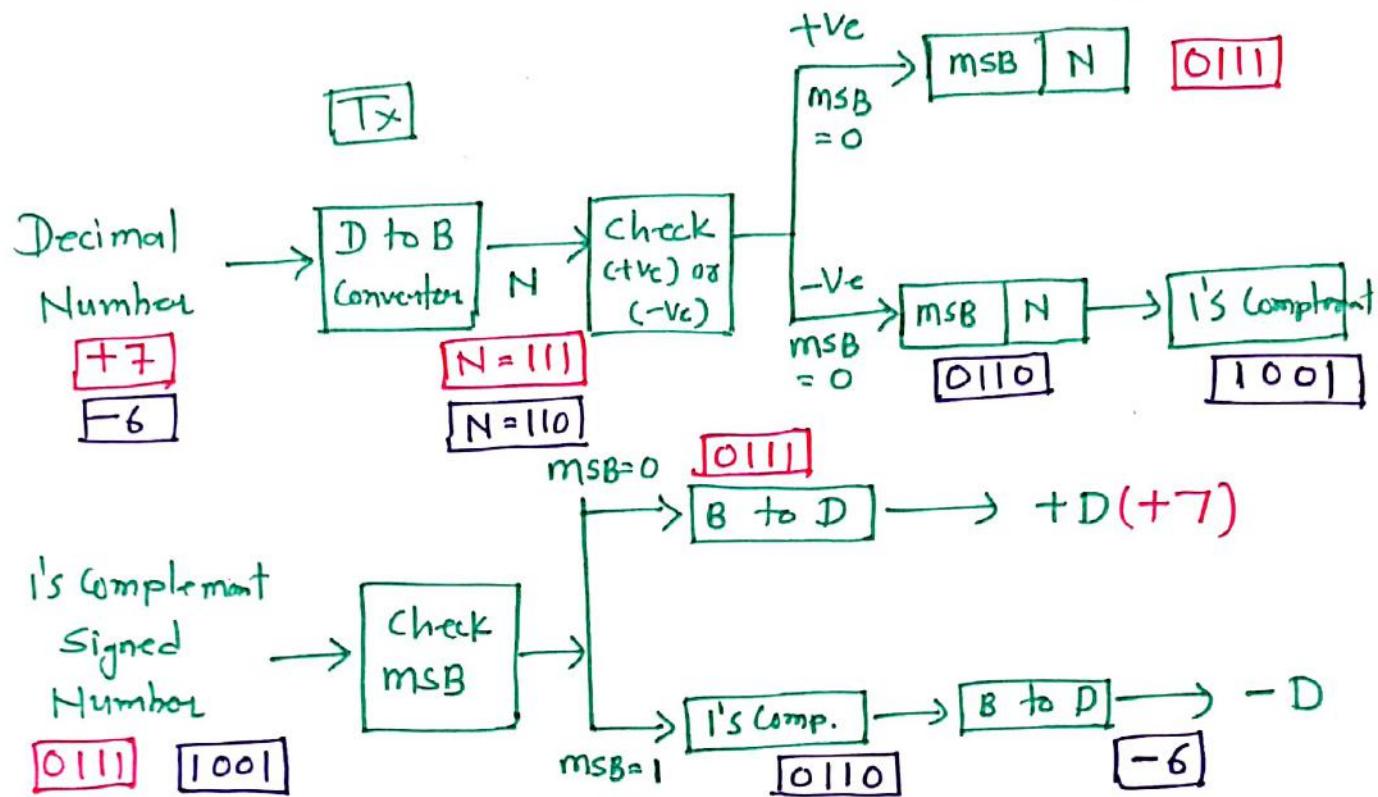
→ Range of number

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

→ total Numbers

$$\begin{aligned} &= (2^{n-1} - 1) + (2^{n-1} - 1) + 1 \\ &= 2^n - 1 \end{aligned}$$

1's Complement Signed Representation (B)



→ If n bits are given

0	0	0	0	+Ve 0
1	0	0	1	
2	0	1	0	
3	0	1	1	
-3	1	0	0	
-2	1	0	1	
-1	1	1	0	
x	1	1	1	-Ve 0

→ total Numbers
 $= (2^{n-1} - 1) + (2^{n-1} - 1) + 1$
 $= 2 \cdot 2^{n-1} - 1$
 $= 2^n - 1$

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

2's Complement Signed Representation (h)

(+6)

(+Vc)

Decimal
Numbers

(-Vc)

-7

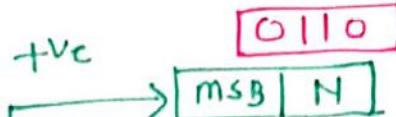
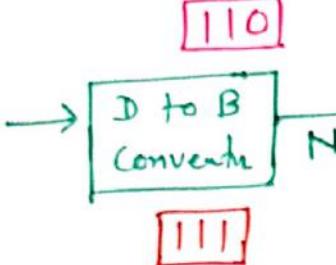
0110

2's Complement
Signed
Number

1001

11000

1000



Tx

1's Comp.

1001 2's Comp.

B to D → +D +6

0110 → 1's Complement

$$\begin{array}{r} 0110 \\ +1 \\ \hline 0111 \end{array}$$

msb = 0

msb = 1

00111 → 1's Complement

$$\begin{array}{r} 00111 \\ +1 \\ \hline 01000 \end{array}$$

0111 → 1's Complement

$$\begin{array}{r} 0111 \\ +1 \\ \hline 1000 \end{array}$$

→ -8

→ -8

→ for 1's complement

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

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

$$+Vc \text{ Numbers} = 2^{n-1} - 1$$

$$-Vc \text{ Numbers} = 2^{n-1} - 1$$

for 2's Complement

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

$$= 2^n$$

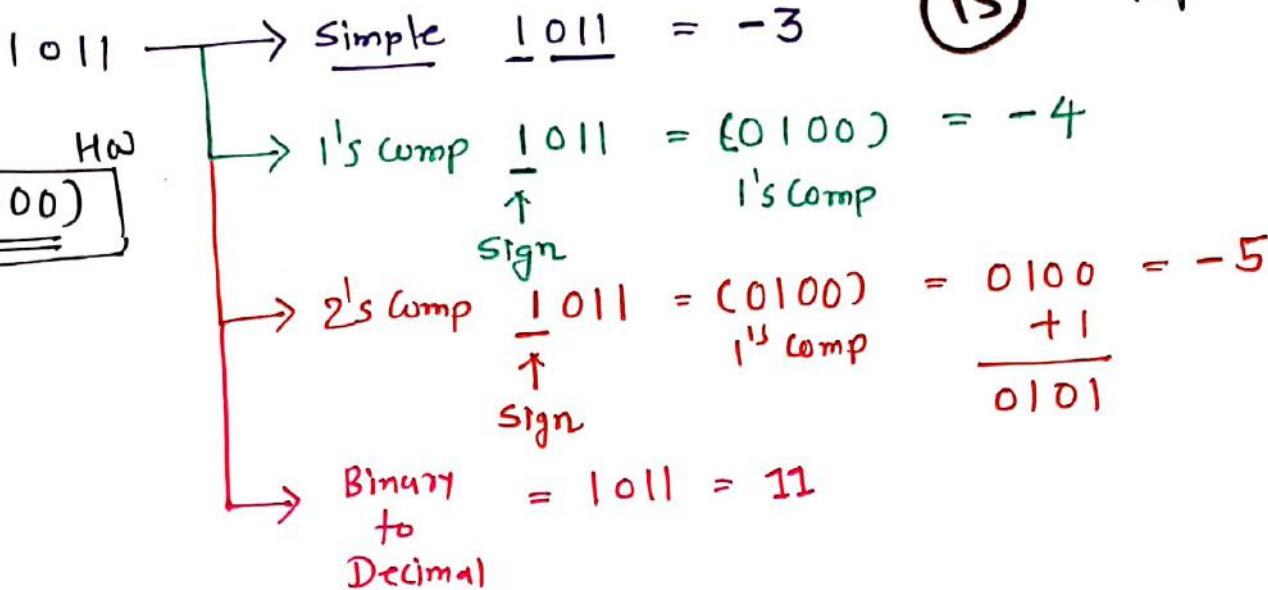
$$= 2^{n-1} - 1$$

✓

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

$\frac{1}{\text{As } n}$ 100 1000 10000 100000 <hr style="border-top: 1px solid black;"/> X
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Examples on Simple, 1's Complement and 2's Complement Signed Representation



	1's	2's	Simple
100	-3	-4	-0
1100	-3	-4	-4
11100	-3	-4	-12
111100	-3	-4	-28
<u>① 11111111 010</u>	<u>-5</u> ↑ 1's Comp Sign	<u>-6</u> ↑ 2's Comp Sign	

→ A & B are given in 2's complement, A = 0110 & B = 1001. Find A+B and A-B in Simple, 1's comp. & 2's comp sign.

$$A = \underline{0110} = +6$$

$$B = \underline{1001} = (0110) = (0111) = -7$$

↑
1's Comp ↑
2's Comp.

A = 1100
 B = 1001
 HW
 ②

$$\rightarrow A+B = 6-7 = -1$$

$$\text{Simple} = (11)$$

$$1's \text{ comp} = 01 = (10)$$

$$2's \text{ comp} = 01 = (10) = (11)$$

↑
1's Comp ↑
2's Comp

$$\rightarrow A-B = 6-(-7) = 13$$

$$\text{Simple} = 01101$$

$$1's \text{ comp} = 01101$$

$$2's \text{ comp} = 01101$$

Shortcut method to calculate 2's Compliment

$$(1011011100)_2$$
$$\begin{array}{r} \text{1's Comp} \rightarrow 0100100011 \\ +1 \\ \hline \text{2's Comp} \rightarrow 0100100100 \end{array}$$

$$\begin{array}{r} 1011011100 \\ \swarrow \\ 0100100100 \\ \hline \text{2's compliment} \end{array}$$

$$(101011000)_2$$
$$\begin{array}{r} \text{1's Comp} \rightarrow 0101001111 \\ +1 \\ \hline \text{2's Comp} \rightarrow 010101000 \end{array}$$

$$\begin{array}{r} 101011000 \\ \swarrow \\ 010101000 \\ \hline \text{2's compliment} \end{array}$$

Binary Subtraction using 1's Compliment

(17)

$$\rightarrow A - B \Rightarrow A + (-B) = \gamma$$

\uparrow
1's compliment

\rightarrow In Addition, If carry is 1 then add +1 with γ and answer is +ve.

\rightarrow In Addition, If carry is 0 then answer is -ve and answer is 1's compliment of γ .

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

$$A = 1011$$

$$B = 0101 \rightarrow (-B) = 1010 \text{ (1's compliment).}$$

$$\rightarrow \gamma = A + (-B)$$

$$\begin{array}{r} 1 \\ 1011 \\ 1010 \\ \hline \textcircled{1} 0101 \\ \swarrow 1 \end{array}$$

$$\text{Ans} = (0110)$$

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

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

$$A = 0110$$

$$B = 1010 \rightarrow (-B) = 0101 \text{ (1's compliment)}$$

$$\rightarrow \gamma = A + (-B)$$

$$\begin{array}{r} | \\ 0110 \\ 0101 \\ \hline \boxed{C=0} \ 1011 \end{array}$$

$$\text{Ans} = (\text{-ve}) = -1000$$

Binary Subtraction using 2's Compliment

$$\rightarrow A - B \rightarrow Y = A + (-B)$$

↑

2's Compliment of B

(16)

→ 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 $(1001)_2 - (0101)_2$

$$A = 1001$$

$$B = 010\boxed{1} \rightarrow -B = 1011 \quad (2's \text{ compliment})$$

$$\rightarrow Y = A + (-B)$$

$$\begin{array}{r} & | & | \\ & 1 & 1 \\ 1 & 0 & 0 & 1 \\ \hline & 1 & 0 & 1 & 1 \\ \hline & 0 & 1 & 0 & 0 \end{array}$$

$$\underline{\text{Carry} = 1}, \quad \text{Ans} = +ve = +Y = \boxed{0100}$$

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

$$A = 0110$$

$$B = 10\boxed{1}0 \rightarrow -B = 0110 \quad (2's \text{ compliment})$$

$$\rightarrow Y = A + (-B)$$

$$\begin{array}{r} & | & | \\ & 0 & 1 \\ 0 & 1 & 1 & 0 \\ \hline & 0 & 1 & 1 & 0 \\ \hline & \boxed{C=0} & 1 & \boxed{1} & 0 & 0 \end{array}$$

$$\underline{\text{Carry} = 0}, \quad \text{Ans} = -ve = -0100$$

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

Hw

Classification of Codes

(19)

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

$$\begin{array}{cccc} q_3 & q_2 & q_1 & q_0 \\ \uparrow & \uparrow & \uparrow & \uparrow \\ 8 & 4 & 2 & 1 \end{array} \quad \begin{array}{cccc} b_3 & b_2 & b_1 & b_0 \\ \uparrow & \uparrow & \uparrow & \uparrow \\ 2 & 4 & 2 & 1 \end{array}$$

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

e.x. XS-3, Gray

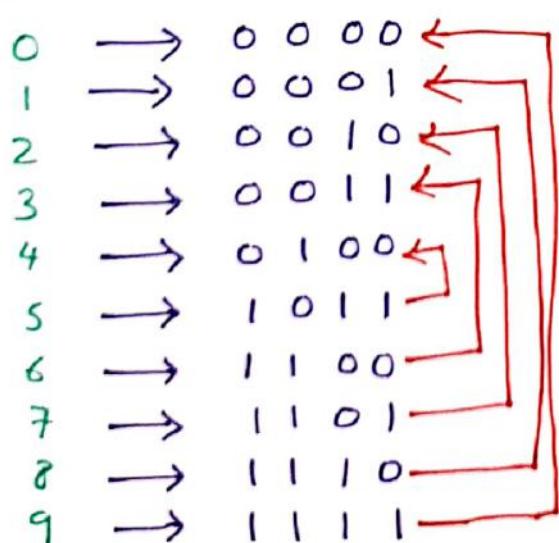
3] Reflective Codes - It is self Complimenting code.

- In that code 9 is Complement of 0

e.x. 2421, XS-3

8	is	"	"	1
7	is	"	"	2
6	is	"	"	3
5	is	"	"	4

Decimal 2 4 2 1



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, Golay code.

BCD Code, [Binary Coded Decimal Code]. (20)

- In this code, each decimal digits are represented by 4 bits binary code.
- In decimal, digits are varying 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

$$\begin{array}{l} 1] (149)_{10} \rightarrow [0001 \ 0100 \ 1001]_{BCD} \\ 2] (638)_{10} \rightarrow [0110 \ 0011 \ 1000]_{BCD} \\ 3] (378)_{10} \rightarrow [0011 \ 0111 \ 1000]_{BCD} \end{array}$$

HW
Represent following BCD into Decimal
 1] 010011
 2] 101101101010
 3] 1011010110

Conversion of BCD to Decimal

$$\begin{array}{l} 1] \underline{\underline{001}} \underline{\underline{0100}} \rightarrow (14)_{10} \\ 2] \underline{\underline{0010}} \underline{\underline{0010}} \underline{\underline{0101}} \rightarrow (225)_{10} \end{array}$$

HW
Represent following decimal into BCD
 1] (37)₁₀
 2] (271)₁₀
 3] (141)₁₀

Comparison 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.

B C D Addition (2)

- 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.

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

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

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

$$\begin{array}{r} 1001 \\ + 1000 \\ \hline 1000 \\ 0110 \\ \hline 0001 \quad 0111 \\ \hline 1 \quad 7 \end{array}$$

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

$$\begin{array}{r} 1111 \leftarrow 1 \\ 1000 \quad 1001 \\ 0111 \quad 1001 \\ \hline 0001 \quad 0000 \quad 0010 \\ 0000 \quad 0110 \quad 0110 \\ \hline 0001 \quad 0110 \quad 1000 \\ \hline 1 \quad 6 \quad 8 \end{array}$$

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

$$\begin{array}{r} 11 \leftarrow 1 \\ 0010 \quad 0111 \quad 1001 \\ 0111 \quad 1000 \quad 0001 \\ \hline 1001 \quad 1111 \text{ (15)} \quad 1010 \text{ (10)} \\ 0000 \quad 0110 \quad 0110 \\ \hline 1010 \text{ (10)} \quad 0110 \text{ (6)} \quad 0000 \text{ (0)} \\ 0110 \quad 0000 \quad 0000 \\ \hline 0001 \quad 0000 \quad 0000 \\ \hline 1 \quad 0 \end{array}$$

- 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) $(742)_{10} + (688)_{10}$

BCD to Binary Conversion

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

(2)

BCD number is given by

1) $\frac{0010}{2} \frac{1001}{9} \frac{0010}{2}$

$\rightarrow (292)_{10}$

$\rightarrow (100100100)_2$

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

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

$\rightarrow (589)_{10}$

$\rightarrow (1001001101)_2$

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

Hω

1) $(1010110)_{BCD} \rightarrow (_)_2$

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

Binary to BCD Conversion

(23)

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

- Binary numbers are given by

$$\text{1) } (110011001)_2 \rightarrow ()_{BCD},$$

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

$$\begin{aligned} &= 1 \times 2^8 + 1 \times 2^7 + \underline{0 \times 2^6} + \underline{0 \times 2^5} + 1 \times 2^4 + 1 \times 2^3 + \underline{0 \times 2^2} + \underline{0 \times 2^1} + 1 \times 2^0 \\ &= (409)_{10} \end{aligned}$$

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

$$\text{2) } (11011101100.0101)_2 \rightarrow ()_{BCD}$$

$\begin{matrix} \uparrow & \uparrow \\ 10 & 9 & 8 & 7 & 6 & 5 & 4 & 3 & 2 & 1 & 0 \\ -1 & -2 & -3 & -4 \end{matrix}$

$$\begin{aligned} &= 1 \times 2^{10} + 1 \times 2^9 + 1 \times 2^7 + 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^{-2} + 1 \times 2^{-4} \\ &= (1772.3125)_{10} \end{aligned}$$

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

Hw $\text{1) } (1101101)_2 \rightarrow ()_{BCD}$ $\text{2) } (101010110)_2 \rightarrow ()_{BCD}$ $\text{3) } (762.6)_8 \rightarrow ()_{BCD}$

2421 BCD Code

- It is BCD (Binary Coded Decimal) code.
- Sometimes it is referred as $2^* - 4 - 2 - 1$ code.

Decimal digits $\begin{array}{c} 2^* - 4 - 2 - 1 \\ \hline X \end{array}$ $2^* - 4 - 2 - 1$

0	\rightarrow	0 0 0 0	\rightarrow	0 0 0 0	\leftarrow
1	\rightarrow	0 0 0 1	\rightarrow	0 0 0 1	\leftarrow
2	\rightarrow	0 0 1 0	\rightarrow	0 0 1 0	\leftarrow
3	\rightarrow	0 0 1 1	\rightarrow	0 0 1 1	\leftarrow
4	\rightarrow	0 1 0 0	\rightarrow	0 1 0 0	\leftarrow
5	\rightarrow	0 1 0 1	\rightarrow	1 0 1 1	
6	\rightarrow	0 1 1 0	\rightarrow	1 1 0 0	
7	\rightarrow	0 1 1 1	\rightarrow	1 1 0 1	
8	\rightarrow	1 1 1 0	\rightarrow	1 1 1 0	
9	\rightarrow	1 1 1 1	\rightarrow	1 1 1 1	

→ Self Complementing property means,

9 is complement of 0

8 is " " 1

7 is " " 2

6 is " " 3

5 is " " 4

→ 7421, 5421, 3321, 8421 & 7421

→ HW

1] Convert $(145)_{10}$ to 2421 code.

2] $(0100 \ 0100 \ 1110)_{2421}$ to $(_)_{10}$

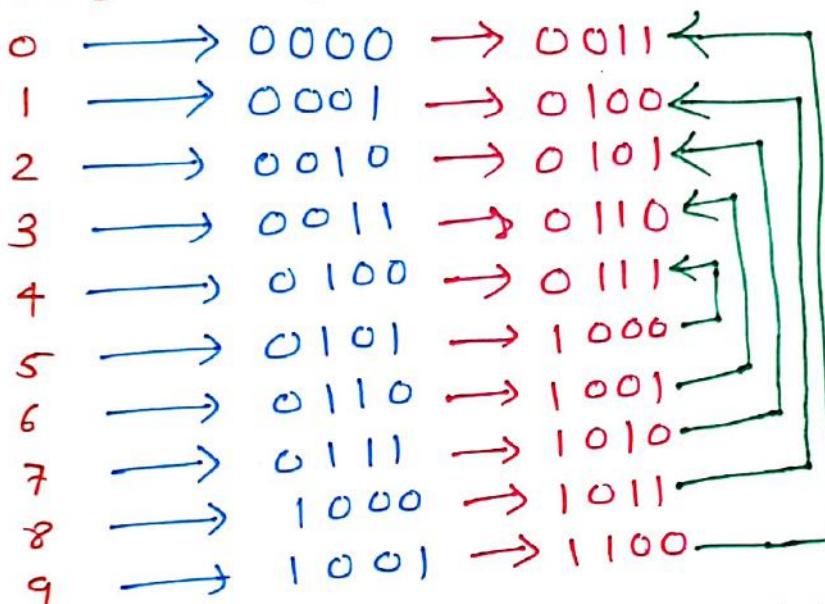
Excess-3 code 25

Decimal Number \rightarrow BCD Code $\xrightarrow{\text{Add}} 0111$ Excess-3

\downarrow

4 \rightarrow 0100 \rightarrow $\begin{array}{r} 0100 \\ 0011 \\ \hline (0111) \end{array}$ Excess-3

Decimal 8421 XS-3
Numbers BCD (Add 0011)



- Excess-3 is only unweighted code which follows self-complementing property.

→ Based on bits, there is no well define weighted. So it is unweighted code.

- Conversion of decimal numbers in XS-3 code

The diagram illustrates the conversion of the decimal number 36₁₀ to BCD and its addition to the decimal number 14₁₀. The BCD representation of 36 is shown as 0011 0110. This is added to 0011 0110 (labeled 'Add') to produce the sum 0110 1001.

$$(395)_{10} \xrightarrow{\text{8421 BCD}} (0011\ 1001\ 0101)_2$$

Add $\begin{array}{r} 001 \\ 001 \\ 001 \\ \hline 0010\ 1100\ 1000 \end{array}$

H.W.

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

← Convert into XS-3

Excess 3 Addition

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.

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

$$\begin{array}{rcl} (3)_{10} & \xrightarrow{8421} & 0011 \\ (6)_{10} & \xrightarrow{BCD} & 0110 \end{array} \quad \begin{array}{r} \text{Add} \\ 0011 \end{array} \quad \begin{array}{r} 0110 \\ \hline 1111 \\ - 0011 \\ \hline (1100)_{\text{Ex-3}} \end{array}$$

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

$$\begin{array}{rcl} (38)_{10} & \xrightarrow{8421} & 0011 \ 1000 \\ (28)_{10} & \xrightarrow{BCD} & 0010 \ 1000 \\ (38)_{10} \\ (28)_{10} \\ \hline (66)_{10} \end{array} \quad \begin{array}{r} \text{Add} \\ 0011 \end{array} \quad \begin{array}{r} 1110 \\ \hline 0110 \ 1011 \\ - 0011 + 0011 \\ \hline \checkmark (1001 \ 1001)_{\text{Ex-3}} \end{array}$$

Identification of Self Complementing Code. 27

→ If code satisfy given condition,

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

then given code is self complementing 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 complementing code.

$$\rightarrow 7421 \rightarrow 7+4+2+1 = 14 \neq 9 \quad \times$$

$$\rightarrow 5921 \rightarrow 5+9+2+1 = 17 \neq 9 \quad \times$$

$$\rightarrow 3321 \rightarrow 3+3+2+1 = 9 = 9 \quad \checkmark$$

$$\rightarrow 84\bar{2}\bar{1} \rightarrow 8+4-2-1 = 9 = 9 \quad \checkmark$$

$$\rightarrow 74\bar{2}\bar{1} \rightarrow 7+4-2-1 = 8 \neq 9 \quad \times'$$

ASCII Code

Q

- 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 → ~

043216 8421
1001101, 1000111, 1100111, (mkg)
77 71 103
m g ↓
g

Remember

Bc4

1000010, 1100011, 0110100,
66 99 52

HQ

Convert into ASCII
1] 10011110011111101111 char.
2] ASCII series is "B b 48", give
binary data of it.

Gray Code

- Code is name after Frank Gray.
- It is unweighted code. [No positional weight].
- It is also referred as reflected binary code.
- It is unit dist.^u 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
.....	0 1 1	0 0 1 1	0 0 1 0
1	1 1	0 1 1	0 0 1 0	0 0 1 1
0	1 0	0 1 0	0 1 1 0	0 1 0 1
.....	1 1 0	0 1 1 1	0 1 1 0
1	1 0	1 1 1	0 1 0 1	0 1 1 1
0	0 1	1 0 1	0 1 0 0	1 0 0 0
.....	1 0 0	1 1 0 0	1 0 0 1
1	0 0	1 1 0 1	1 0 1 0
0	1 1 1 0	1 0 1 1
.....	1 1 1 1	1 1 0 0
1	1 0 1 0	1 1 0 1
0	1 0 1 1	1 1 1 0
.....	0 0 0 1	1 1 1 1
0	0 0 0 0	0 0 0 0

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

Applications of Gray Code

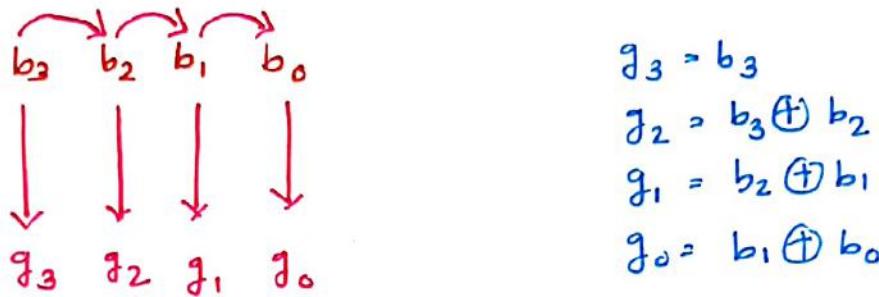
- K-Map function reduction
- Error detection
- Digital comm.ⁿ [Cable TV]

Binary to Gray Code Conversion 30

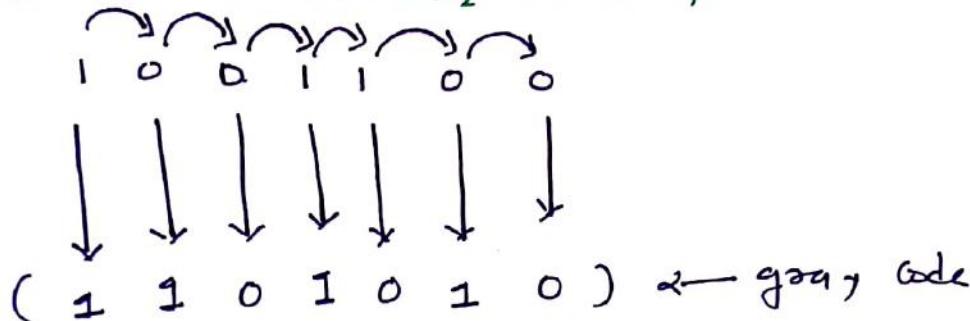
Step-1 - Take MSB as it is.

Step-2 - XOR MSB with next bit.

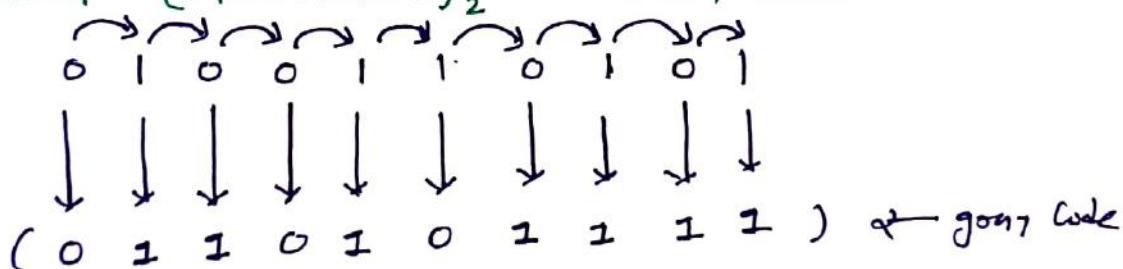
Step-3 - Repeat Step-2.



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



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



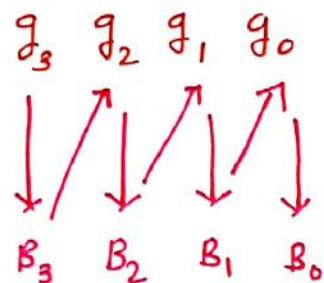
HW 1) $(1011010)_2$ to gray code
2) $(346)_8$ to gray code

Gray to Binary Conversion 3)

Step-1 Take msb as it is.

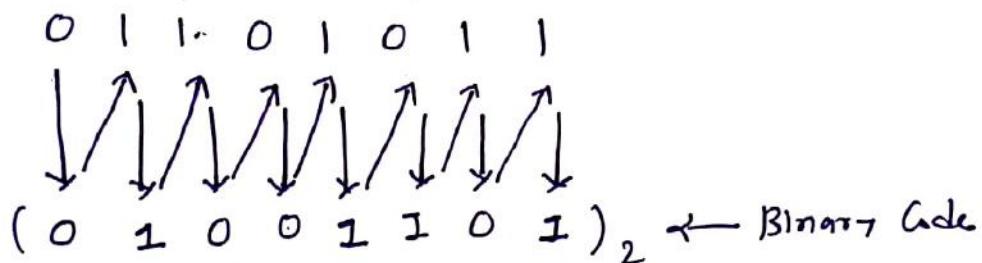
Step-2 XOR msb to next bit of Gray code.

Step-3 Repeat step-2.

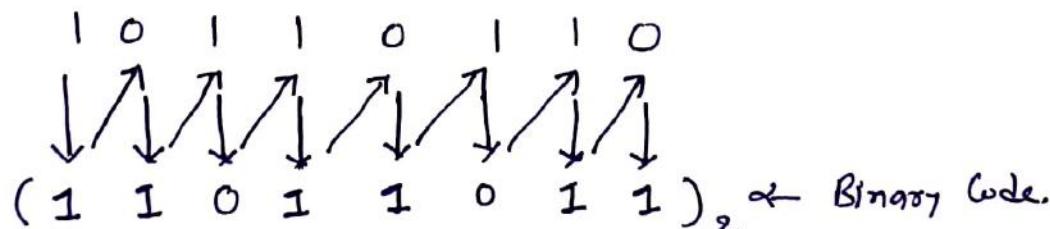


$$\begin{aligned}
 & g_3 \rightarrow B_3 \quad B_3 = g_3 \\
 & B_2 = B_3 \oplus g_2 = g_3 \oplus g_2 \\
 & B_1 = B_2 \oplus g_1 = g_3 \oplus g_2 \oplus g_1 \\
 & B_0 = B_1 \oplus g_0 = g_3 \oplus g_2 \oplus g_1 \oplus g_0
 \end{aligned}$$

Ex.1 Convert 01101011 gray code into binary code.



Ex.2 Convert 10110110 gray code into binary code.



Hw 1] 10110101 gray code $\rightarrow ()_2$

2] 10101010 gray code $\rightarrow ()_8$.

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] $\sqrt{144} = 12$

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

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

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

$$\Rightarrow b + 2 = 12$$

$$\Rightarrow \boxed{b = 10}$$

Total Bits Required to represent a number Q3

1) How many bits req'd 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'd to represent 8 digit Hexadecimal number

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

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

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

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

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

$$\Rightarrow n \geq 32$$

3) How many bits req'd 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'd to represent
1) 10 digit decimal
2) 11 digit base 5
3) $(129)_{12}$

4) How many bits req'd 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 35

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

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

\rightarrow Base = 16
 \rightarrow Equivalent
 $= 13 \times 16^2 + 1 \times 16 + 7 \times 16^0$
 $= \boxed{3351}$

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

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

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

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

To Find minimal decimal Equivalent

1) $(3162)_x$

2) $(56)_x$

3) $(11)_x$

Hamming Code Basics 35

- It is given by R.W. Hamming.
- It is used to detect and correct error.
- In Hamming Code, we send data along with parity bits or Redundant bits.
- It is represented by (n, k) code.
 - \downarrow total bits
 - \downarrow message bits.

$$\rightarrow \text{Parity bits } P = n - k$$

→ To identify 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 $P=1$

$$\frac{2^1 \geq 6}{X}$$

For $P=2$

$$\frac{2^2 \geq 7}{X}$$

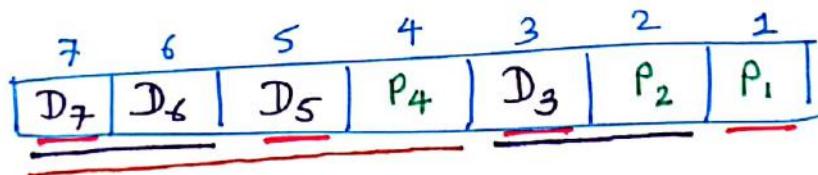
For $P=3$

$$\frac{2^3 = 8}{\checkmark}$$

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

$$\Rightarrow n = 3 + 4 = 7 \text{ bits.}$$

→ This is $(7, 4)$ code.



$$\begin{aligned} P_1 &= 2^0 = 1 \\ P_2 &= 2^1 = 2 \\ P_4 &= 2^2 = 4 \end{aligned}$$

$$\rightarrow P_1 \rightarrow D_3 D_5 D_7 (\text{XOR})$$

$$\rightarrow P_2 \rightarrow D_3 D_6 D_7 (\text{XOR})$$

$$\rightarrow P_4 \rightarrow D_5 D_6 D_7 (\text{XOR}).$$

Generation of Hamming Code 36

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

→ K = 5 bits.

→ Identify parity bits.

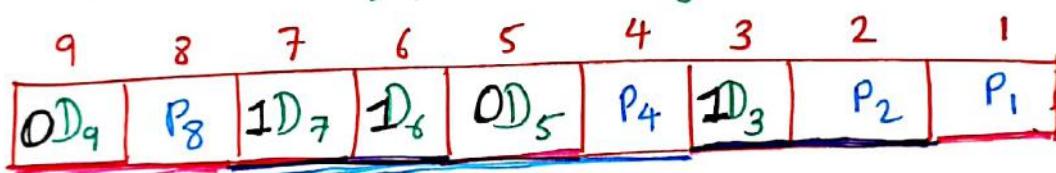
$$\Rightarrow 2^P \geq P + K + 1$$

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

For P=1	For P=2	For P=3	For P=4
$2^1 \geq 7$ X	$2^2 \geq 8$ X	$2^3 \geq 9$ X	$2^4 \geq 10$ ✓

→ So for P=4, K=5, n=9

→ This is (9,5) hamming code.



→ 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.

$$P_1 \rightarrow D_3 D_5 D_7 D_9$$

$$P_2 \rightarrow D_3 D_6 D_7$$

$$P_4 \rightarrow D_5 D_6 D_7$$

$$P_8 \rightarrow D_9$$

$$\rightarrow P_1 = 1 \oplus 0 \oplus 1 \oplus 0 = 0$$

$$\rightarrow P_2 = 1 \oplus 1 \oplus 1 = 1$$

$$\rightarrow P_4 = 0 \oplus 1 \oplus 1 = 0$$

$$\rightarrow P_8 = D_9 = 0$$

Wdt

001100110

Hamming Code Error detection & Error Correction

37

- * 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

$$P_1 = 2^0 = 1$$

$$P_2 = 2^1 = 2$$

$$P_4 = 2^2 = 4$$

$$P_1 = D_3 \oplus D_5 \oplus D_7 \quad P_1 = 0 \quad \checkmark$$

$$1 = 1 \oplus 1 \oplus 1 \quad P_1 = 0 \quad \checkmark$$

$$P_2 = D_3 \oplus D_6 \oplus D_7 \quad P_2 = 1 \quad \times$$

$$0 = 1 \oplus 1 \oplus 1 \quad P_2 = 1 \quad \times$$

$$P_4 = D_7 \oplus D_6 \oplus D_5 \quad P_4 = 1 \quad \times$$

$$0 = 1 \oplus 1 \oplus 1 \quad P_4 = 1 \quad \times$$

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

$$E = [0 | 1 | 0 | 0 | 0 | 0 | G]$$

$$R = [1 | 1 | 1 | 0 | 1 | 0 | 1 |]$$

$$\rightarrow \text{Corrected data} = R \oplus E$$

$$= [1 | 0 | 1 | 0 | 1 | 0 | 1 |]$$

IEEE 754 floating point double precision 64 bit Format

38

Step 1 Convert given number in binary.

Step 2 Represent given binary number into Scientific notation.

Step 3 IEEE 754 double precision 64 bit Format.

<u>X</u>	<u>xxxx xxxx xxx</u>	<u>xxxx xxxx ... xx</u>
1 bit sign	11 bits Exponents.	52 bits Mantissa
$\begin{aligned} +ve \rightarrow 0 &= \text{exponents bias} + \text{power.} \\ -ve \rightarrow 1 &= (2^{k-1} - 1) + \text{power.} \\ &= (2^{11-1} - 1) + 15 = 1038 \end{aligned}$		

$[AOF9.0EB]_{16}$

Step 1 Convert given number into binary

$[1010\ 0000\ 1111\ 1001.\ 0000\ 1110\ 1011]_2$

Step 2 Write Scientific Notation.

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

Step 3 IEEE 754 double precision 64 bit Format

<u>0</u>	<u>1 0000 00 0000 00</u>	<u>010 0000 1111 1001 0000 1110 1011</u>
↑ Sign	↑ 11 bits exponents.	$\overbrace{\hspace{10em}}$ ↑ 52 bits Mantissa

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

$[3066.25]_{10}$

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

$$3066 = 10111111010$$

$$\begin{aligned} 0.25 \times 2 &= 0.5 \rightarrow 0 \\ 0.5 \times 2 &= 1.0 \rightarrow 1 \end{aligned}$$

$$0.25 = 0.01$$

$$\begin{aligned} [3066.25]_{10} &= [1.01111110100101]_2 \\ &= 1.011111101001 \times 2^{11} \end{aligned}$$

0	1	1	1	1	1	1	1
↑	↑	↑	↑	↑	↑	↑	↑
Sign	8 bits	exponents					

0	100000000	0111111101001000000
\uparrow	\uparrow	\uparrow
Sign	8 bits	23 bits
		Mantissa

$(236.75)_{10} \rightarrow \underline{\text{754 IEEE 32 bit}}$