

Chapter 2

Encoding Schemes and Number System

Encoding

Encoding is a mechanism of converting data into an equivalent cipher (secret code) using a specific code. We have different mechanisms for coding.

2.1.1 ASCII – American Standard Code for Information Interchange

- Any key pressed on the keyboard must be converted into its equivalent ASCII.
- It uses **7 bits** to represent different characters, which are not sufficient to represent other scripted languages. ($2^7 = 128$)

ASCII Table

- A – 65 a – 97
- B – 66 b – 98
- C – 67 c – 99
- D – 68 d – 100

Example: Conversion of “DATA”

- Characters: D A T A
- ASCII Codes: 68 65 84 65
- Binary Form:
 - D → 1000100
 - A → 1000001
 - T → 1010100
 - A → 1000001

2.1.2 ISCII - Indian Script Code for Information Interchange

- Developed in **India during the mid-1980s** to facilitate the use of Indian languages on computers.

- A **common standard** for coding Indian scripts.
- Uses **8-bit code representation** for Indian languages.
- Can represent $2^8=256$ characters.
- Retains all **128 ASCII codes**.
- The remaining **128 codes** are used for additional Indian language character sets.
- Additional codes are assigned in the **upper region (160–255)** for the *aksharas* of the language.

2.1.3 UNICODE

- Many **encoding schemes** were developed for different languages.
- These schemes could **not communicate with each other**, since each represented characters differently.
- Text created using one encoding scheme was **not recognized** by another machine using a different scheme.
- To solve this, a **standard called Unicode** was developed.
- Unicode incorporates **all characters of every written language** in the world.
- Provides a **unique number for every character**, regardless of:
 - Device (server, desktop, mobile)
 - Operating system (Linux, Windows, iOS)
 - Software application (browsers, text editors, etc.)
- Commonly used Unicode encodings:
 - **UTF-8**
 - **UTF-16**
 - **UTF-32**
- Unicode is a **superset of ASCII**.
 - Values **0–128** have the same characters as ASCII.

Example: Unicode characters for **Devanagari script** are represented in a table (each cell contains a character with its equivalent hexadecimal value).

ॐ	ॐ	ॐ	ॐ	ॐ	अ	आ	इ	ई	उ	ऊ	ऋ	ॠ	ऐ	ॐ	ए
0900	0901	0902	0903	0904	0905	0906	0907	0908	0909	090A	090B	090C	090D	090E	090F
ऐ	औ	औ	औ	औ	क	ख	ग	घ	ङ	च	छ	ज	झ	ञ	ट
0910	0911	0912	0913	0914	0915	0916	0917	0918	0919	091A	091B	091C	091D	091E	091F
ठ	ड	ढ	ण	त	थ	द	ध	न	न	प	फ	ब	भ	म	य
0920	0921	0922	0923	0924	0925	0926	0927	0928	0929	092A	092B	092C	092D	092E	092F
र	र	ल	ळ	ळ	व	श	ष	स	ह	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ
0930	0931	0932	0933	0934	0935	0936	0937	0938	0939	093A	093B	093C	093D	093E	093F
ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ
0940	0941	0942	0943	0944	0945	0946	0947	0948	0949	094A	094B	094C	094D	094E	094F
ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ
0950	0951	0952	0953	0954	0955	0956	0957	0958	0959	095A	095B	095C	095D	095E	095F
ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ
0960	0961	0962	0963	0964	0965	0966	0967	0968	0969	096A	096B	096C	096D	096E	096F
ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ	ॠ
0970	0971	0972	0973	0974	0975	0976	0977	0978	0979	097A	097B	097C	097D	097E	097F

2.2 Number System

• Keyboard Encoding

- Each key (character, symbol, function key, etc.) is internally mapped to an **ASCII code**.
- This encoded value is further converted into its **binary representation** so the computer can understand it.
- Example: Character “A” → Decimal code (65) → Binary code (1000001).

• Definition

- A **number system** is a method to represent (write) numbers.
- Each number system has a set of **unique characters/literals**.
- Base (Radix)**: The total number of digits present in any number system.

Examples:

- Decimal system** → Radix = 10 (digits 0–9)
- Binary system** → Radix = 2 (digits 0, 1)
- Octal system** → Radix = 8 (digits 0–7)
- Hexadecimal system** → Radix = 16 (digits 0–9 and A–F)

Positional Number System

- Value of each symbol (digit/alphabet) depends on its **position** in the number.
- Numbers may also have a **fractional part** (like 123.45).
- Integer part**:

- Rightmost symbol has position **0**.
- Position value increases by **+1** moving left.
- **Fractional part:**
 - First symbol after decimal has position **-1**.
 - Position value decreases by **-1** moving right.
- Each symbol's **positional value** is computed using:

$$\text{Positional Value} = (\text{Base})^{\text{Position}}$$

Example 1: (123.45)₁₀

Digit	1	2	3	.	4	5
Position Number	2	1	0		-1	-2
Positional Value	$(10)^2$	$(10)^1$	$(10)^0$		$(10)^{-1}$	$(10)^{-2}$

Add the product of positional value and corresponding digit to get decimal number.

$$1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0 + 4 \times 10^{-1} + 5 \times 10^{-2} = (123.45)_{10}$$

2.2.1 Decimal Number System

- The decimal number system is used in **day-to-day life**.
- Known as the **base-10 system** since it uses **10 digits (0,1,2,3,4,5,6,7,8,9)**.

Example 2: (237.25)₁₀

Digit	2	3	7	.	2	5
Position Number	2	1	0	.	-1	-2
Position Value	$(10)^2$	$(10)^1$	$(10)^0$	.	$(10)^{-1}$	$(10)^{-2}$

Calculation: $2 \times (10)^2 + 3 \times (10)^1 + 7 \times (10)^0 + 2 \times (10)^{-1} + 5 \times (10)^{-2} = 237.25$

2.2.2 Binary Number System

- Computers use this system to read or convert data.
- Uses only **2 digits (0, 1)** to represent any number.

Example: $(1011)_2$

Table 1: Binary value for (0–9) digits of decimal number system

Decimal	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001

2.2.3 Octal Number System

- The sequence of 0's and 1's is too long to remember and understand. Hence, the **octal number system** was developed. Uses **8 digits (0,1,2,3,4,5,6,7)** Called the **base-8 number system**.

Octal Digit	Decimal Value	3 -bit Binary Number
0	0	000
1	1	001
2	2	010
3	3	011
4	4	100
5	5	101
6	6	110
7	7	111

Table 2. Decimal and binary equivalent of octal numbers 0–7

Example: $(237.05)_8$

2.2.4 Hexadecimal Number System

- Easier to represent a sequence of 0's and 1's. Consists of **16 unique symbols**: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F Called the **base-16 number system**.
- Example: **FEED.26**₍₁₆₎

Hexadecimal Symbol	Decimal Value	(8421)4-Bit Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
A	10	1010
B	11	1011
C	12	1100
D	13	1101
E	14	1110
F	15	1111

Table 3: Decimal and binary equivalent of hexadecimal numbers 0–9, A–F

2.2.5 Applications of Hexadecimal Number System

- Used to simplify long binary numbers (16-bit, 32-bit).
- Commonly used for **webpage colours**.
 - Colours are made up of three primary components: **Red, Green, Blue (RGB)**.
 - Each component uses **8 bits**, so total = **24 bits** ($\approx$ 16 million colours).
- Remembering 24-bit binary codes is difficult → Hexadecimal is used for compact representation.

Colour Name	Decimal	Binary	Hexadecimal
Black	(0,0,0)	(00000000,00000000,00000000)	(00,00,00)
White	(255,255,255)	(11111111,11111111,11111111)	(FF,FF,FF)
Yellow	(255,255,0)	(11111111,11111111,00000000)	(FF,FF,00)
Grey	(128,128,128)	(10000000,10000000,10000000)	(80, 80, 80)

Table 4: Colour codes in decimal, binary and hexadecimal numbers

2.3 Conversion between Number Systems

2.3.1 Conversion from Decimal to other Number Systems

1. **Divide** the given decimal number by the **base value (b)** of the target number system.
 - Binary → base 2
 - Octal → base 8
 - Hexadecimal → base 16
2. **Note the remainder** after division.
3. **Repeat the process:**
 - Keep dividing the quotient by the base value.
 - Record the remainder each time.
 - Continue until the quotient becomes **zero**.
4. **Write the remainders in reverse order** (bottom to top).
 - This gives the equivalent number in the target system.

(A) Decimal to Binary Conversion

Example: Convert $(65)_{10}$ to Binary

Step 1: Divide the decimal number by 2.

2	65
2	32
2	16
2	8
2	4
2	2
2	1
2	0

Remainders

Step 2: Write its remainder.

Step 3: Keep on dividing the quotient by the base value 2 and note the remainder till the quotient is zero.

Step 4: Collect the remainders from bottom to top to get the binary equivalent.

$$(65)_{10} = (1000001)_2$$

Example 2: $(97)_{10} = (?)_2$

2	97	→ 1
2	48	→ 0
2	24	→ 0
2	12	→ 0
2	6	→ 0
2	3	→ 1
2	1	→ 1

$$(97)_{10} = (1100001)_2$$

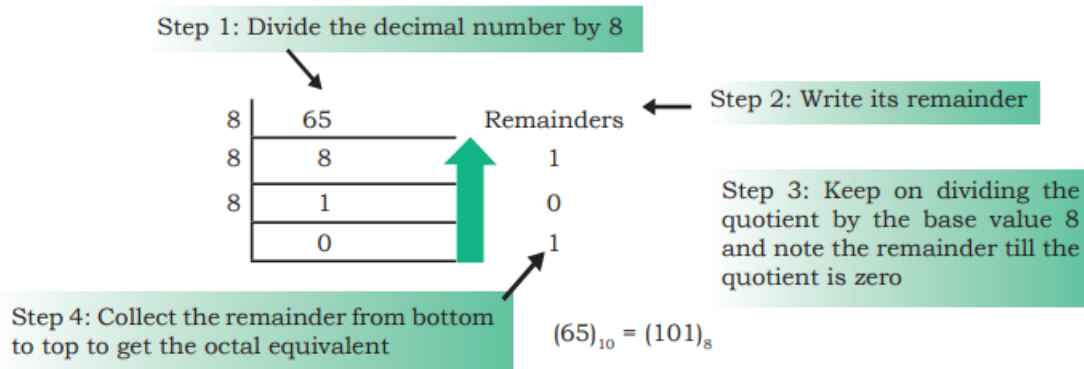
Example 3: $(122)_{10} = (?)_2$

2	122	
2	61	0
2	30	1
2	15	0
2	7	1
2	3	1
2	1	1
2	0	1

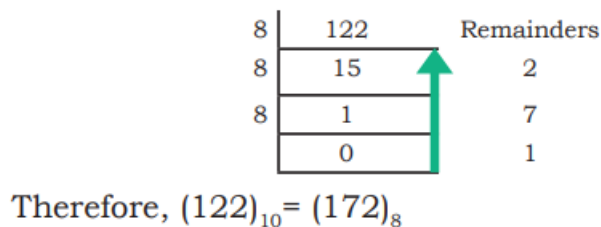
Therefore, $(122)_{10} = (1111010)_2$

(B) Decimal to Octal Conversion

Example 1: $(65)_{10} = (?)_8$

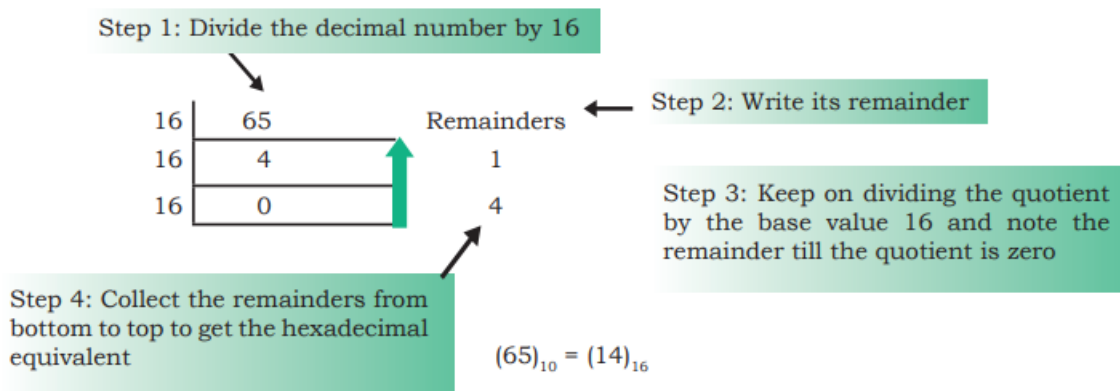


Example 2. Convert $(122)_{10}$ to octal number.

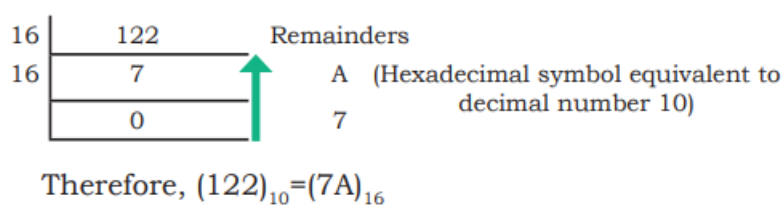


(C) Decimal to Hexadecimal Conversion

Example 1: $(65)_{10} = (?)_{16}$



Example 2. Convert $(122)_{10}$ to hexadecimal number.



2.3.2 Conversion from other Number Systems to Decimal Number System

Step 1: Write the position number for each alphanumeric symbol in the given number

Step 2: Get positional value for each symbol by raising its position number to the base value b symbol in the given number

Step 3: Multiply each digit with the respective positional value to get a decimal value

Step 4: Add all these decimal values to get the equivalent decimal number

A. Binary Number to Decimal Number

Example 1. Convert $(1101)_2$ into decimal number.

Digit	1	1	0	1
Position Number	3	2	1	0
Position Value	2^3	2^2	2^1	2^0

Calculation: $=1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$

$$= 8 + 4 + 0 + 1$$

$$= (13)_{10}$$

Example 2: $(1001111)_2 = (?)_{10}$

Digit	1	0	0	1	1	1	1
Position No	6	5	4	3	2	1	0
Position Value	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Calculation: $=1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$

$$= 64 + 0 + 0 + 8 + 4 + 2 + 1$$

$$= (79)_{10}$$

(B) Octal Number to Decimal Number

Example 1. Convert $(257)_8$ into decimal number.

Digit	2	5	7
Position Number	2	1	0
Position Value	8^2	8^1	8^0

Calculation:

$$= 2 \times 82 + 5 \times 81 + 7 \times 80$$

$$= 128 + 40 + 7$$

$$= (175)_{10}$$

Example 2: $(23456)_8 = (?)_{10}$

Digit	2	3	4	5	6
Position Number	4	3	2	1	0
Position Value	8^4	8^3	8^2	8^1	8^0

Calculation:

$$2 \times 84 + 3 \times 83 + 4 \times 82 + 5 \times 81 + 6 \times 80$$

$$= 8192 + 1536 + 256 + 40 + 6$$

$$= (10030)_{10}$$

Example 3: $(1372)_8 = (?)_{10}$

Digit	1	3	7	2
Position Number	3	2	1	0
Position Value	8^3	8^2	8^1	8^0

Calculation:

$$1 \times 83 + 3 \times 82 + 7 \times 81 + 2 \times 80$$

$$= 512 + 192 + 56 + 2$$

$$= (762)_{10}$$

(C) Hexadecimal Number to Decimal Number

Example 1: $(3A5)_{16} = (?)_{10}$

Digit	3	A	5
Position Number	2	1	0
Position Value	16^2	16^1	16^0

Calculation:

$$3 \times 16^2 + 10 \times 16^1 + 5 \times 16^0$$

$$= 768 + 160 + 5$$

$$= (933)_{10}$$

Example 2: $(FEED)_{16} = (?)_{10}$

Digit	F	E	E	D
Position Number	3	2	1	0
Position Value	16^3	16^2	16^1	16^0

Calculation:

$$15 \times 16^3 + 14 \times 16^2 + 14 \times 16^1 + 13 \times 16^0$$

$$= 61440 + 3584 + 224 + 13$$

$$= (65261)_{10}$$

Example 3: $(BEAD)_{16} = (?)_{10}$

Digit	B	E	A	D
Position Number	3	2	1	0
Position Value	16^3	16^2	16^1	16^0

Calculation:

$$11 \times 16^3 + 14 \times 16^2 + 10 \times 16^1 + 13 \times 16^0$$

$$= 45056 + 3584 + 160 + 13$$

$$= (48813)_{10}$$

2.3.3 Conversion from Binary Number to Octal/ Hexadecimal Number and Vice-Versa

(A) Binary Number to Octal Number

Example 1. Convert $(10101100)_2$ to octal number.

Make group of 3-bits of the given
binary number (right to left) 010 101 100
Write octal number for
each 3-bit group 2 5 4
Therefore, $(10101100)_2 = (254)_8$

Example 2: $(1101101)_2 = (?)_8$

- Group binary digits in sets of 3.
- $1101101 \rightarrow 001 \ 101 \ 101$
- Convert each group:
 - $001 = 1$
 - $101 = 5$
 - $101 = 5$
- Result: **$(155)_8$**

Example 3: $(11001001)_2 = (?)_8$

- Group binary digits in sets of 3.
- $11001001 \rightarrow 011 \ 001 \ 001$
- Convert each group:
 - $011 = 3$
 - $001 = 1$
 - $001 = 1$
- Result: **$(311)_8$**

(B) Octal Number to Binary Number

Example 1. Convert $(705)_8$ to binary number.

Octal digits	7	0	5
Write 3-bits binary value for each digit	111	000	101

Therefore, $(705)_8 = (111000101)_2$

Example 2: $(137255)_8 = (?)_2$

- Convert each octal digit into 3-bit binary:

$1 \rightarrow 001$

$3 \rightarrow 011$

$7 \rightarrow 111$

$2 \rightarrow 010$

$5 \rightarrow 101$

$5 \rightarrow 101$

- Result: **$(0010111101010101)_2$**

(C) Binary Number to Hexadecimal Number

Example 1: $(010110101100)_2 = (?)_{16}$

- Group binary digits in sets of 4 (from right).
- $010110101100 \rightarrow 0001\ 1010\ 1100$
- Convert each group:

$0001 = 1$

$1010 = A$

$1100 = C$

- Result: **$(1AC)_{16}$**

Example 2: $(1101011010)_2 = (?)_{16}$

- Group binary digits in sets of 4.
- $1101011010 \rightarrow 0110\ 1101$
- Convert each group:

$$0110 = 6$$

$$1101 = D$$

- Result: **(6D)₁₆**

Example 3: $(0010111101010101)_2 = (?)_{16}$

- Group binary digits in sets of 4.
- $0010111101010101 \rightarrow 0000\ 1011\ 1110\ 1010\ 1101$
- Convert each group:

$$0000 = 0$$

$$1011 = B$$

$$1110 = E$$

$$1010 = A$$

$$1101 = D$$

- Result: **(0BEAD)₁₆**

(D) Hexadecimal Number to Binary Number

Example 1. Convert $(23D)_{16}$ to binary number

Hexadecimal digits	2	3	D
Write 4-bit binary value for each digit	0010	0011	1101
Therefore, $(23D)_{16} = (001000111101)_2$			

Example 2: $(FADE)_{16} = (?)_2$

$$F (15) \rightarrow 1111$$

$$A (10) \rightarrow 1010$$

$$D (13) \rightarrow 1101$$

$$E (14) \rightarrow 1110$$

- Result: **(1111101011011110)₂**

Example 3: $(A492)_{16} = (?)_2$

$$A (10) \rightarrow 1010$$

$$4 \rightarrow 0100$$

$$9 \rightarrow 1001$$

$$2 \rightarrow 0010$$

- Result: **(1010010010010010)₂**

2.3.4 Conversion of a Number with Fractional Part

(A) Decimal Number with Fractional Part to another Number System

Example 1. Convert $(0.25)_{10}$ to binary.

$0.25 \times 2 = 0.50$	Integer part
$0.50 \times 2 = 1.00$	↓ 0
	↓ 1

$$(0.25)_{10} = \mathbf{(0.01)_2}$$

Example 2: $(0.675)_{10} = (?)_2$

$0.675 \times 2 = 1.350$	Integer part
$0.350 \times 2 = 0.700$	1
$0.700 \times 2 = 1.400$	0
$0.400 \times 2 = 0.800$	1
$0.800 \times 2 = 1.600$	0
$0.600 \times 2 = 1.200$	1
$0.200 \times 2 = 0.400$	1
	↓ 0

$$(0.675)_{10} = \mathbf{(0.1010110)_2}$$

Example 3: $(0.792)_{10} = (?)_2$

$$0.792 \times 2 = 1.584 \quad \rightarrow 1$$

$$0.584 \times 2 = 1.168 \quad \rightarrow 1$$

$$0.168 \times 2 = 0.336 \quad \rightarrow 0$$

$$0.336 \times 2 = 0.672 \quad \rightarrow 0$$

$$0.672 \times 2 = 1.344 \quad \rightarrow 1$$

$$0.344 \times 2 = 0.688 \quad \rightarrow 0$$

$$0.688 \times 2 = 1.376 \quad \rightarrow 1$$

$$0.376 \times 2 = 0.752 \quad \rightarrow 0$$

- Result: **$(0.110101010)_2$**

Decimal Fraction to Octal Conversion

Example 1. Convert $(0.675)_{10}$ to octal.

	Integer part
$0.675 \times 8 = 5.400$	5
$0.400 \times 8 = 3.200$	3
$0.200 \times 8 = 1.600$	1
$0.600 \times 8 = 4.800$	4
$0.800 \times 8 = 6.400$	6

$$(0.675)_{10} = \mathbf{(0.53146)_8}$$

Decimal to Hexadecimal Number System

Example 1. Convert $(0.675)_{10}$ to hexadecimal form

	Integer part
$0.675 \times 16 = 10.800$	↓ A (Hexadecimal symbol for 10)
$0.800 \times 16 = 12.800$	↓ C (Hexadecimal symbol for 12)

$$(0.675)_{10} = \mathbf{(0.AC)_{16}}$$

Example 2: $(83.796)_{10} = (?)_{16}$

- Integer part:
 - $83 \div 16 = 5$ remainder 3 $\rightarrow$ **53**
- Fractional part:

$$0.796 \times 16 = 12.736 \rightarrow 12 = \mathbf{C}$$

$$0.736 \times 16 = 11.776 \rightarrow 11 = \mathbf{B}$$

$$0.776 \times 16 = 12.416 \rightarrow 12 = \mathbf{C}$$

$$0.416 \times 16 = 6.656 \rightarrow \mathbf{6}$$

$$0.656 \times 16 = 10.496 \rightarrow 10 = A$$

$$0.496 \times 16 = 7.936 \rightarrow 7$$

$$0.936 \times 16 = 14.976 \rightarrow 14 = E$$

$$0.976 \times 16 = 15.616 \rightarrow 15 = F$$

- Result: $(53.CBCA7EEF)_{16}$

(B) Non-decimal Number with Fractional Part to Decimal Number System

Example 1. Convert $(100101.101)_2$ into decimal.

Digit	1	0	0	1	0	1	.	1	0	1								
Fractional Value	2^5	2^4	2^3	2^2	2^1	2^0		2^{-1}	2^{-2}	2^{-3}								
Decimal Value	1×2^5	$+ 0 \times 2^4$	$+ 0 \times 2^3$	$+ 1 \times 2^2$	$+ 0 \times 2^1$	$+ 1 \times 2^0$	+	1×2^{-1}	$+ 0 \times 2^{-2}$	$+ 1 \times 2^{-3}$								
	=	32	+	0	+	0	+	4	+	0	+	1	+	0.5	+	0	+	0.125
		37										0.625						
		= 37										+ 0.625						

Therefore, $(100101.101)_2 = (37.625)_{10}$

Example 2. Convert $(605.12)_8$ into decimal number.

Octal Digits	6	0	5	.	1	2
Positional Value	8^2	8^1	8^0		8^{-1}	8^{-2}
Decimal number	6×8^2	$+ 0 \times 8^1$	$+ 5 \times 8^0$	+	1×8^{-1}	$+ 2 \times 8^{-2}$
=	6×8² 384	+ 0 × 8¹ + 0	+ 5 × 8⁰ + 5	+	1 × 8⁻¹ .125	+ 2 × 8⁻² + .03125
	389				0.15625	
=	389 +		0.156225			

Therefore, $(605.12)_8 = (389.15625)_{10}$

(C) Fractional Binary Number to Octal or Hexadecimal Number

Example 1. Convert $(10101100.01011)_2$ to octal number.

Make perfect group of 3 bits 010 101 100 . 010 110

Write octal symbol for each group 2 5 4 . 2 6

Therefore, $(10101100.01011)_2 = (254.26)_8$

Example 2. Convert $(10101100.010111)_2$ to hexadecimal number

Make perfect group of 4 bits 1010 1100 . 0101 1100

Write hexadecimal symbol

for each group A C . 5 C

Therefore, $(10101100.010111)_2 = (AC.5C)_{16}$