FRANKLIN'S LECTURES

LOGIC CIRCUIT DESIGN

MODULE 1

Part-1

PBECT304

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Syllabus

Introduction to digital circuits: Review of number systems representationconversions, Arithmetic of Binary number systems, Signed and unsigned numbers, BCD .
Boolean algebra: Theorems, sum of product and product of sum simplification, canonical forms- min term and max term, Simplification of Boolean expressions - Karnaugh map (upto 4 variables), Implementation of Boolean expressions using universal gates.

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Binary (2) Octal (8)
Decimal (10) Hex (16)

Practical Applications

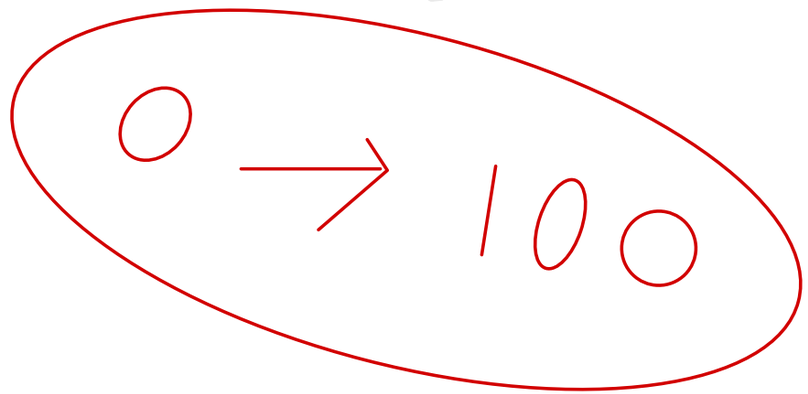
1. **Number Systems & Binary Arithmetic- Applications:**

- Microprocessors & Microcontrollers: Operate using binary data for instructions and memory addressing.
- Digital Communication: Data encoding/decoding in binary (e.g., ASCII, BCD) for transmission.
- Digital Instrumentation: Use of binary-coded outputs in measurement systems.
- Data Storage: Information stored in binary form in flash drives, RAM, and hard disks.

Practical Applications

2. Signed & Unsigned Numbers, BCD- Applications:

- Financial Systems: BCD (Binary-Coded Decimal) is preferred in digital calculators and billing machines to avoid round-off errors.
- Embedded Systems: Use signed/unsigned data for sensor readings, temperature measurements, etc.
- Digital Counters: Implementation of decade counters and BCD up/down counters.



Practical Applications

3. Boolean Algebra (Theorems, SOP, POS)- Applications:

- Logic Circuit Design: Used in designing combinational circuits like encoders, decoders, multiplexers.
- Optimization: Simplifying logic expressions helps reduce the number of gates in ICs, saving cost and power.
- Digital Troubleshooting: Boolean equations help in analyzing and fixing logic faults.

Practical Applications

4. Karnaugh Map (K-map) - Up to 4 Variables-Applications:

- Simplification Tool: Used by engineers to manually minimize logic functions before automation.
- Logic Gate Optimization: Reduces cost, area, and power consumption of circuits in VLSI and ASIC designs.

5. Implementation Using Universal Gates- Applications: NAND, NOR

- NAND/NOR Logic Circuits: Real-world circuits often use only NAND or NOR gates due to their availability and cost-effectiveness.
- FPGA/ASIC Implementation: Universal gate realization helps in building logic blocks in digital ICs.
- Digital Security Systems: Universal gate circuits are used in combinational locks and control logic.

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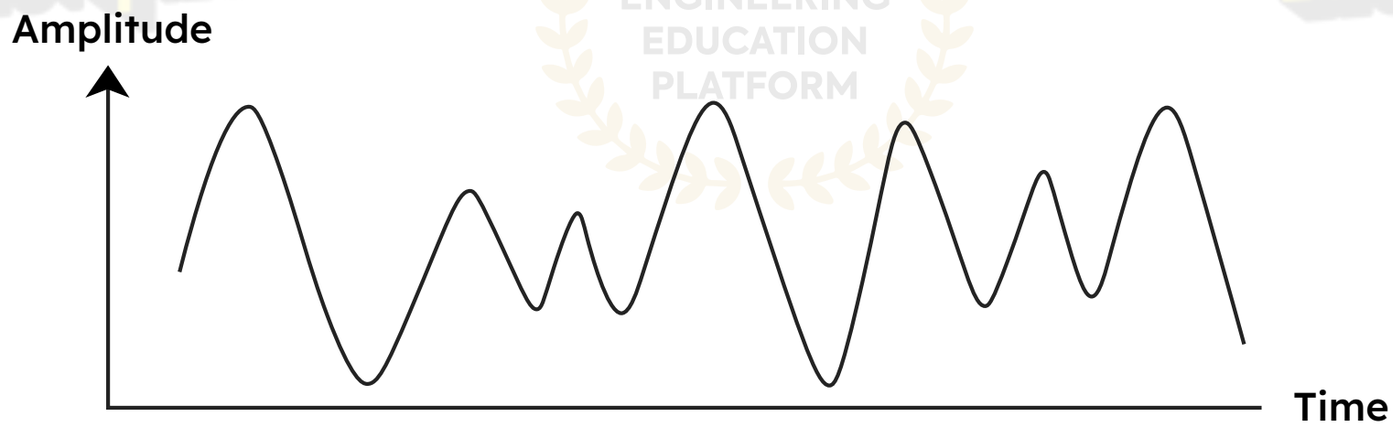
ANALOG ELECTRONICS

- Analog electronics deal with continuous signals that can vary smoothly over a range.
- They are ideal for natural data like sound, light, and temperature but are more prone to noise and distortion. Common analogue devices include radios, amplifiers, and old-style clocks.



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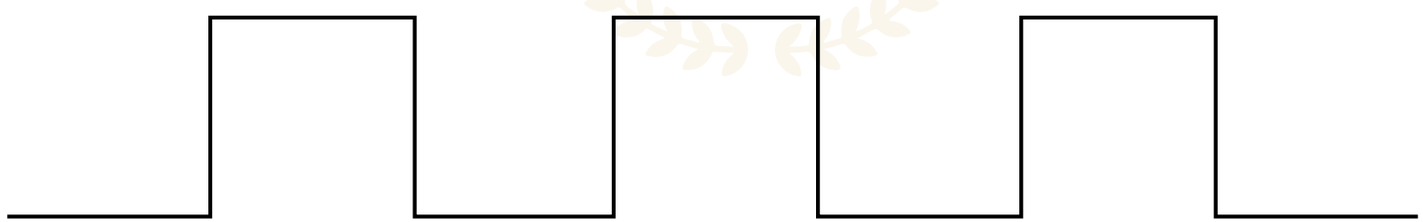
DIGITAL ELECTRONICS

- Digital electronics handle discrete signals, mainly using binary (0s and 1s).
- They offer higher accuracy, better noise resistance, and are easier to store and process. Examples include computers, smartphones, and digital watches.



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SL NO	PARAMETER	ANALOG ELECTRONICS	DIGITAL ELECTRONICS
1	Signal Type	Continuous signals (vary smoothly)	Discrete signals (0s and 1s)
2	Data Representation	Voltage, current, or frequency variations	Binary numbers (high = 1, low = 0)
3	Accuracy	High precision but prone to noise	Highly accurate (within defined levels)
4	Noise Sensitivity	Very sensitive to noise	Less sensitive to noise
5	Circuit Complexity	Simple for basic tasks, complex for precision	Complex for basic tasks, easier for precision
6	Examples	Amplifiers, radios, analog clocks	Computers, calculators, digital watches
7	Processing Speed	Slower for complex tasks	Faster due to discrete operations
8	Storage	Difficult (requires physical parameters)	Easy (binary data storage)

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NUMBER SYSTEM

- A number system is a structured and organized method for representing, expressing, and manipulating numbers.
- It consists of a set of symbols and rules for combining those symbols to represent quantities.
- Each number system is based on a specific base (or radix), which indicates the number of unique digits used in the system.

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CLASSIFICATION OF NUMBER SYSTEM

1. Non-Positional Number System

- In this system, the position of a digit does not affect its value.
- Each symbol has a fixed value, and numbers are formed by simply adding the values of the symbols.

Examples:

- Roman Numerals (I, V, X, L, etc.)
- Ancient Egyptian Number System

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CLASSIFICATION OF NUMBER SYSTEM

2. Positional Number System

- In this system, the position of a digit determines its value.
- Each digit's value is based on its position and the base (radix) of the system.
- Commonly used in mathematics, electronics, and computers.

- Examples of Positional Number Systems:

Number System	Base	Digits Used
Decimal	10	0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Binary	2	0, 1
Octal	8	0 to 7
Hexadecimal	16	0-9, A, B, C, D, E, F

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1- DECIMAL NUMBER SYSTEM

- The Decimal Number System is the most commonly used number system in daily life.
- It is a positional number system where the Base is 10.
- It uses 10 digits:

Key Features:

- Base: 10 (hence "deci-" meaning ten)
- Digits: 10 unique symbols (0–9)
- Place Value:
  The value of each digit depends on its position and is multiplied by **Powers of 10.**

3×10^2 6×10^1 7×10^0

300 60 7

3 6 7

10^2 10^1 10^0

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1- DECIMAL NUMBER SYSTEM

$(352)_{10} \Rightarrow$

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

$300 + 50 + 2$

Example:

- $(352)_{10} = (3 \times 10^2) + (5 \times 10^1) + (2 \times 10^0)$
- $(352) = 300 + 50 + 2$

Advantages:

- Easy to understand and use for humans.
- Well-suited for general-purpose counting and arithmetic operations.

Applications:

- Used in everyday counting, banking, measurements, billing, etc.
- Foundation for most manual calculations.

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2 - BINARY NUMBER SYSTEM

- The Binary Number System is the most fundamental number system for digital electronics and computers.
- It is a positional number system where the base is 2.
- It uses only 2 digits: 0,1

Key Features:

- Base: 2
- Digits: 2 unique symbols (0 and 1)
- Place Value:
  The value of each digit depends on its position and is multiplied by powers of 2.

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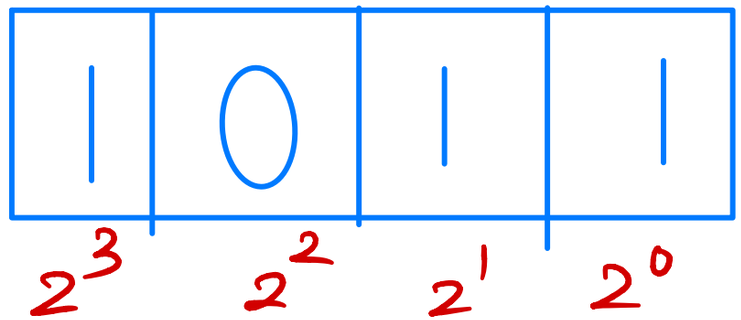
2 - BINARY NUMBER SYSTEM



Example:

$(1011)_2 = (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$

$(1011) = 8 + 0 + 2 + 1 = 11(Indecimal)$

$(1\times2^3)+(0\times2^2)+(1\times2^1)+(1\times2^0)$

$\Rightarrow 8+0+2+1$

Advantages:

- Simple to implement in electronic circuits (using ON and OFF states).
- High reliability and efficiency in digital systems.

Applications:

- Used in computers, mobile phones, calculators, and all digital electronic devices.
- Essential for data storage, processing, and transmission.

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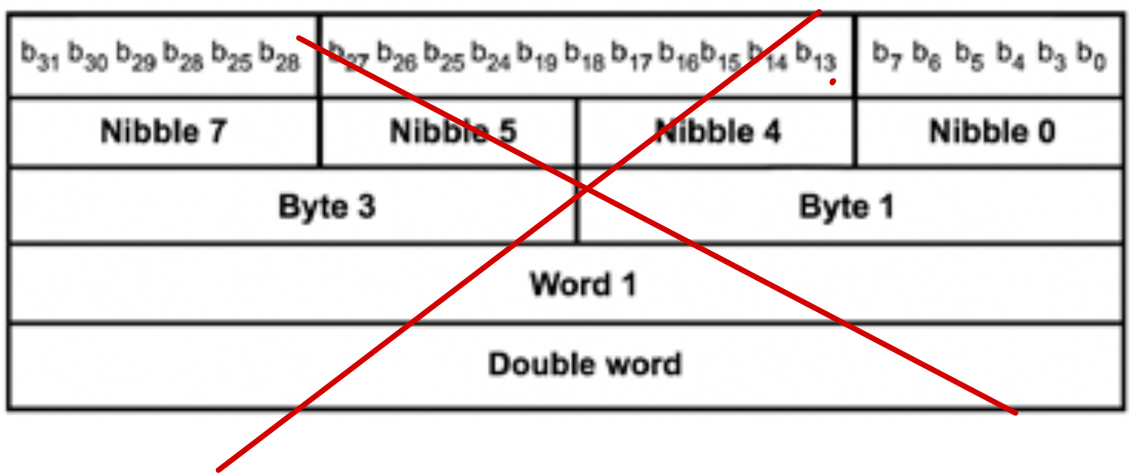
2 - BINARY NUMBER SYSTEM

Format of Binary Number :

- Four binary digits form a Nibble,
- Eight binary digits form a Byte,
- Sixteen binary digits form a Word
- Thirty-two binary digits form a Double-word.



b_3 b_2 b_1 b_0

1 0 1 0

Nibble.

b_7 b_6 b_5 b_4 b_3 b_2 b_1 b_0

Byte.

b_{15} b_{14} . . . . b_1 b_0

Word

3- OCTAL NUMBER SYSTEM

- The Octal Number System is a positional numbersystem used to simplify binary coding.
- It has a base of 8.
- It uses 8 digits: 0,1,2,3,4,5,6,7

Key Features:

- Base: 8
- Digits: 8 unique symbols (0 to 7)
- Place Value:
  The value of each digit depends on its position and is multiplied by powers of 8.

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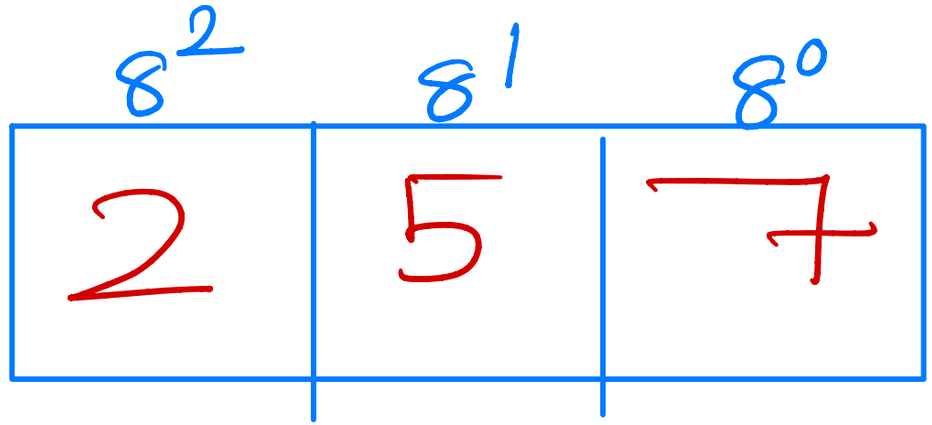
3- OCTAL NUMBER SYSTEM



$(2\times8^2)+(5\times8^1)$

$+(7\times8^0)$

Example:

$$(257)_8 = (2 \times 8^2) + (5 \times 8^1) + (7 \times 8^0)$$

$$(257) = 128 + 40 + 7 = 175(in Decimal)$$

Advantages:

- Easier to read and write than binary because it reduces long binary strings.
- Quick and convenient for compactly representing binary numbers (especially in computers).

Applications:

- Used in computer programming (especially in early computing systems).
- Applied in digital displays, memory addressing, and permission settings (like in Unix/Linux systems).

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4- HEXADECIMAL NUMBER SYSTEM

- The Hexadecimal Number System is widely used in digital and computer systems for compact representation of binary data.
- It has a base of 16.
- It uses 16 symbols:0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F (where A = 10, B = 11, C = 12, D = 13, E = 14, F = 15)

Key Features:

- Base: 16
- Digits: 0–9 and A–F
- Place Value:

Each digit's value depends on its position and is multiplied by powers of 16.

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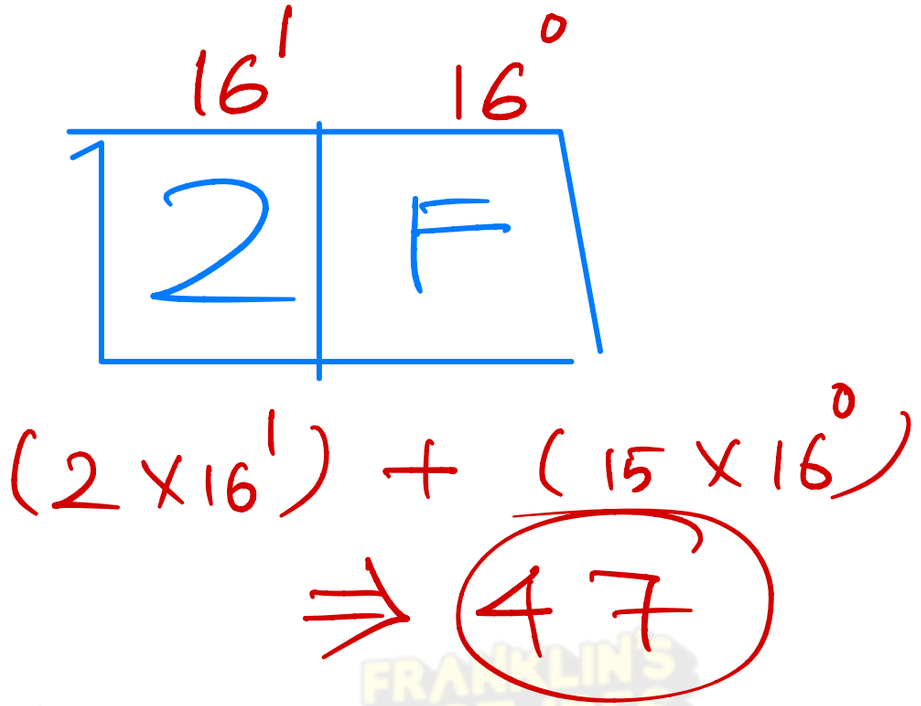
4- HEXADECIMAL NUMBER SYSTEM



Example:

$$(2F)_{16} = (2 \times 16^1) + (15 \times 16^0)$$

$$(2F)_{16} = 32 + 15 = 47(inDecimal)$$

Advantages:

- Very compact: 1 hexadecimal digit represents 4 binary digits (bits).
- Easier to read, understand, and write than long binary numbers.

Applications:

- Used extensively in programming, memory addressing, color codes (like HTML/CSS colors), and error checking.
- Essential in low-level computing and networking.

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RELATIONSHIP BETWEEN DIFFERENT NUMBERS

Decimal	Octal	Hexadecimal	Binary
0	0	0	0 0 0 0
1	1	1	0 0 0 1
2	2	2	0 0 1 0
3	3	3	0 0 1 1
4	4	4	0 1 0 0
5	5	5	0 1 0 1
6	6	6	0 1 1 0
7	7	7	0 1 1 1
8	10	8	1 0 0 0
9	11	9	1 0 0 1
10	12	A	1 0 1 0
11	13	B	1 0 1 1
12	14	C	1 1 0 0
13	15	D	1 1 0 1
14	16	E	1 1 1 0
15	17	F	1 1 1 1

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Decimal	Octal	HD	Binary
0	0	0	0 0 0 0
1	1	1	0 0 0 1
2	2	2	0 0 1 0
3	3	3	0 0 1 1
4	4	4	0 1 0 0
5	5	5	0 1 0 1
6	6	6	0 1 1 0
7	7	7	0 1 1 1
8	10	8	1 0 0 0
9	11	9	1 0 0 1
10	12	A	1 0 1 0
11	13	B	1 0 1 1
12	14	C	1 1 0 0
13	15	D	1 1 0 1
14	16	E	1 1 1 0
15	17	F	1 1 1 1

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COUNTING IN BASE r

Radix (Base) r	Characters in set
2 (Binary)	0, 1
3	0, 1, 2
4	0, 1, 2, 3
5	0, 1, 2, 3, 4
6	0, 1, 2, 3, 4, 5
7	0, 1, 2, 3, 4, 5, 6
8 (Octal)	0, 1, 2, 3, 4, 5, 6, 7
9	0, 1, 2, 3, 4, 5, 6, 7, 8
10 (Decimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9
:	
:	
16 (Hexadecimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

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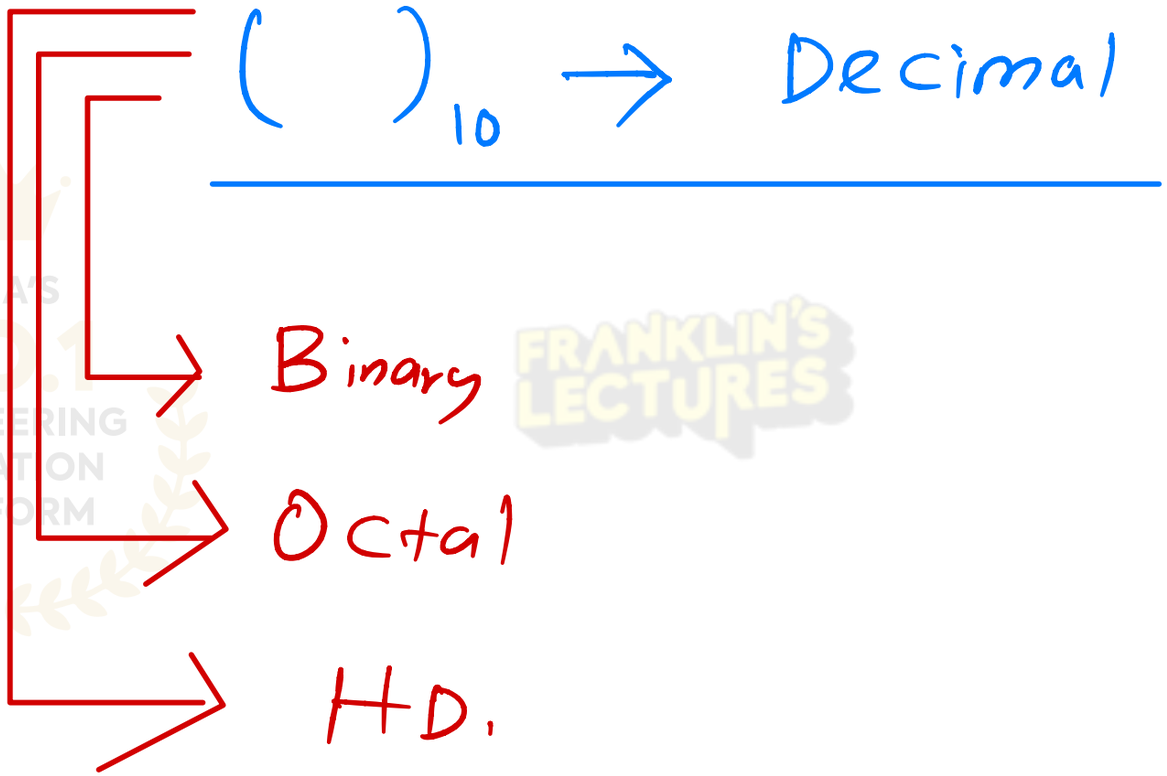
NUMBER SYSTEM CONVERSIONS

METHOD 1

SUCCESSIVE MULTIPLICATION AND DIVISION

$(D)_{10} \rightarrow (B)_2, (O)_8, (H)_{16}$



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1- DECIMAL TO BINARY CONVERSION

(a) Integer Part:

Divide by 2, record remainders (bottom to top).

(b) Fractional Part:

Multiply by 2, record the whole number, continue with the fractional part. (top to bottom).

Example:

Convert 12.125 decimal to Binary

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$(12.125)_{10} \rightarrow (\quad)_2$

Successive Division

2	12	0
2	6	0
2	3	1
	1	

(1100)

Successive Multiplication

$0.125 \times 2 = 0.25$ (0)

$0.25 \times 2 = 0.50$ (0)

$0.50 \times 2 = 1.00$ (1)

$(.001)$

$(1100.001)_2$

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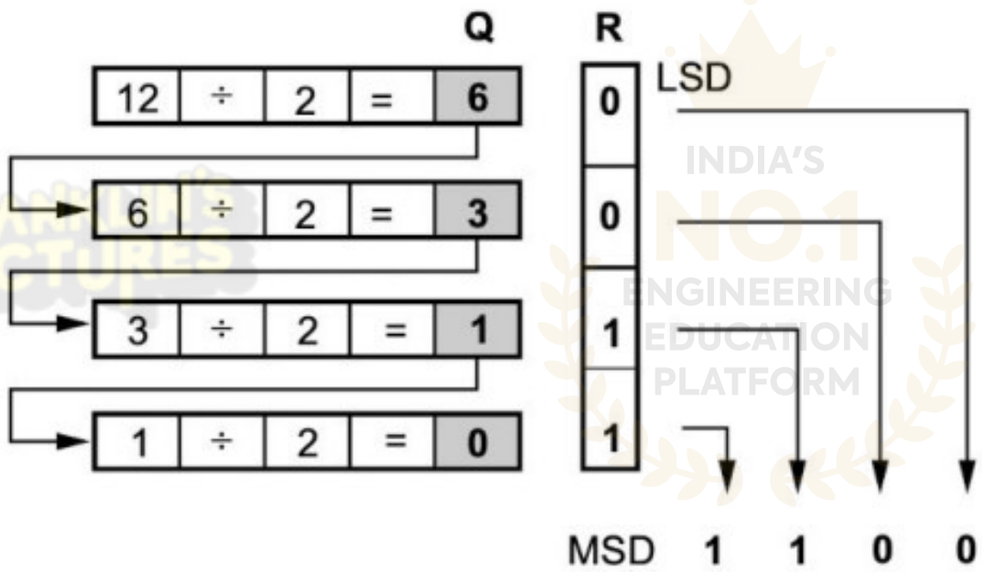
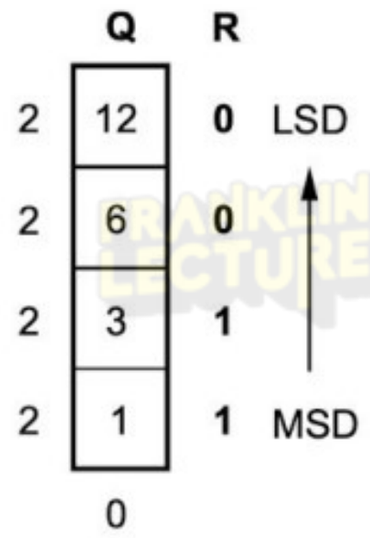
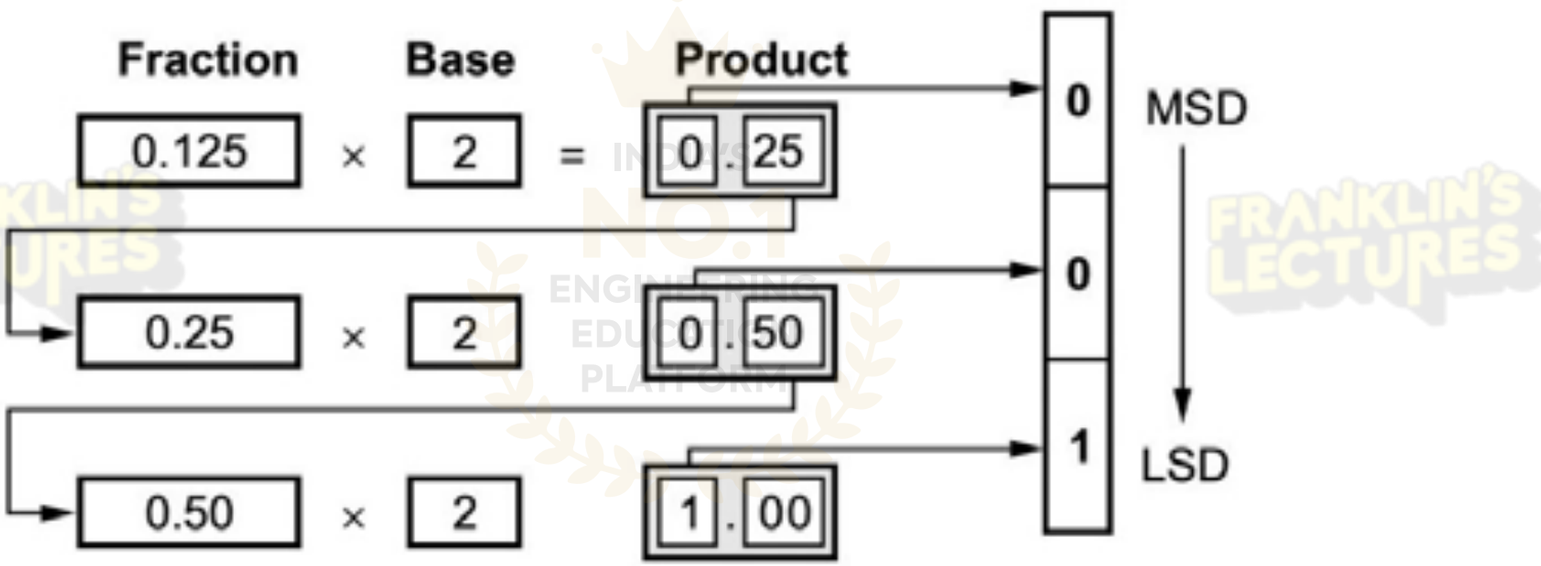
(a) Integer Part:



$(12)_{10} = (1\ 1\ 0\ 0)_2$



(a) Fractional Part:



$(0.125)_{10} = (0.001)_2$

$(12.125)_{10} = (1100.001)_2$

2. Decimal to Octal Conversion

(a) Integer Part:

Divide by 8, record remainders (bottom to top).

(b) Fractional Part:

Multiply by 8, record the whole number, continue with the fractional part. (top to bottom).

Example:

Convert 658.825 decimal to Octal

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$(658.825)_{10} \rightarrow (\quad)_8$

Successive Division (1222)

8	658	2
8	82	2
8	10	2
	1	

Successive Multiplication

$0.825 \times 8 = 6.6$

$0.6 \times 8 = 4.8$

$0.8 \times 8 = 6.4$

$(.646)$

1222.646

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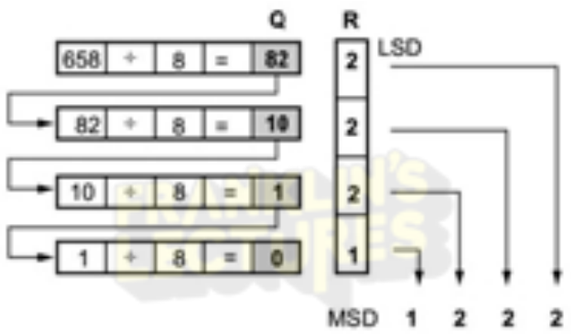
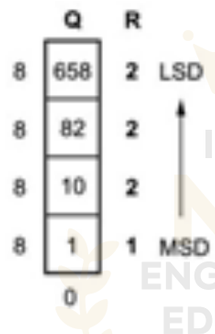
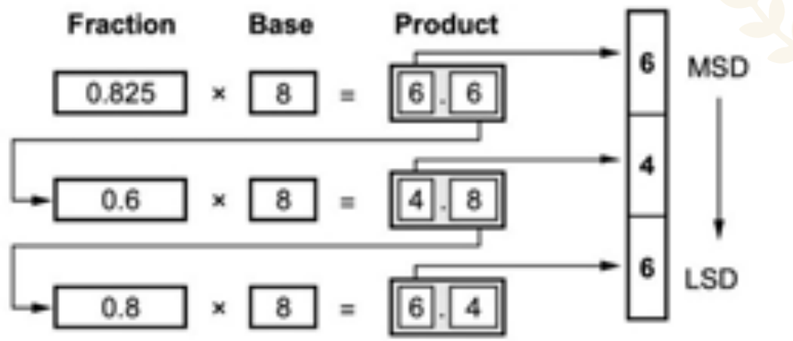
2- DECIMAL TO OCTAL CONVERSION







$(0.825)_{10} = (0.646)_8$ $\quad \therefore (658.825)_{10} = (1222.646)_8$

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3- DECIMAL TO HEXADECIMAL CONVERSION

(a) Integer Part:

Divide by 16, record remainders (bottom to top).

(b) Fractional Part:

Multiply by 16, record the whole number, continue with the fractional part. (top to bottom).

Example:

Convert 5386.345 decimal to HD

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$(5386.345)_{10} \rightarrow (\quad)_{16}$

Successive Division

16	5386	(10)	A
16	336	(0)	
16	21	(5)	
	1	(1)	

Successive Multiplication

$0.345 \times 16 = (5).52$

$0.52 \times 16 = (8).32$

$0.32 \times 16 = (5).12$

$(150A.585)_{16}$ //

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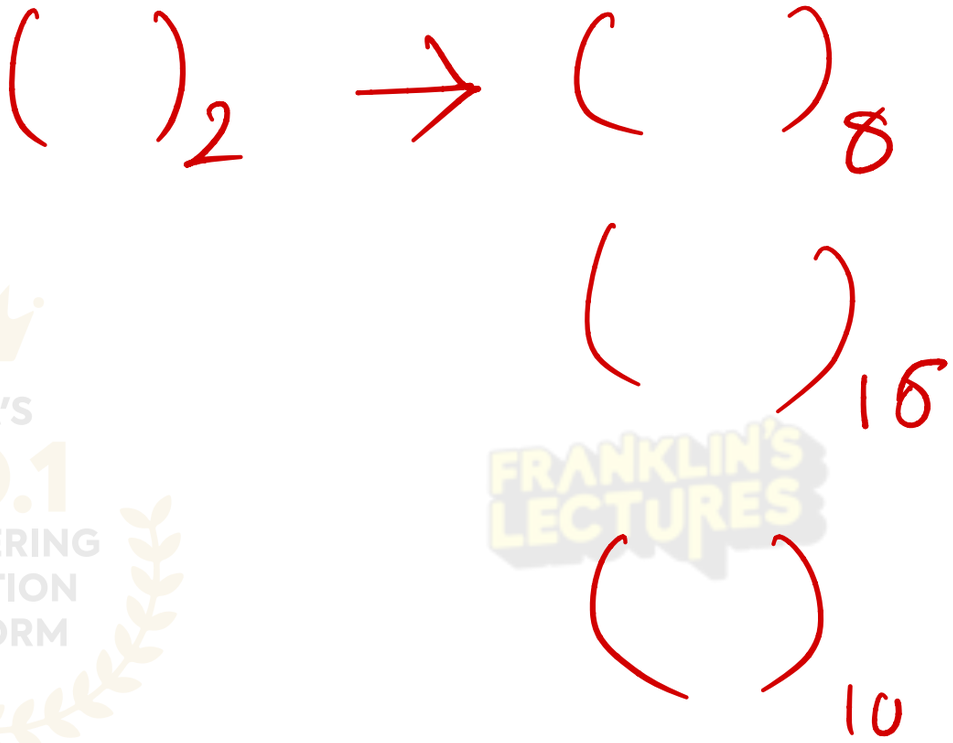
METHOD 2

POSITIONAL WEIGHT PRODUCT AND SUM

$(B)_2, (O)_8, (H)_{16} \rightarrow (D)_{10}$



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4,5,6- BINARY, OCTAL, HD TO DECIMAL CONVERSION

(a) Integer Part:

Multiply each bit by 2^n and sum.

(b) Fractional Part:

Multiply each bit by 2^{-n} and sum

Example:

Convert 101.101 Binary to Decimal

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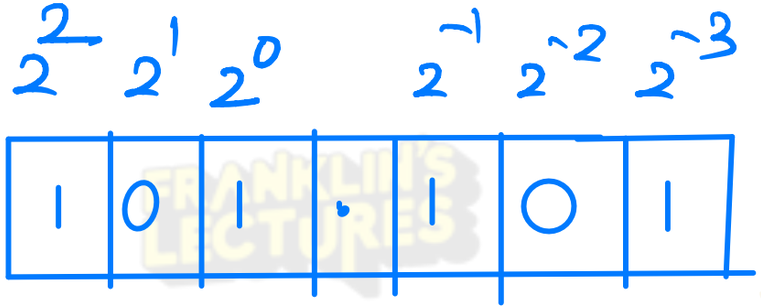
Example:

Convert 101.101 Binary to Decimal



$(1 \times 2^2) + (0 \times 2^1)$
$+ (1 \times 2^0) + (1 \times 2^{-1})$
$+ (1 \times 2^{-2}) + (1 \times 2^{-3})$

HD	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

$4 + 1 + \frac{1}{2^1} + \frac{1}{2^2}$
$+ \frac{1}{23}$

$5 + 0.5 + 0.25 + 0.125$

$\Rightarrow 5.625$

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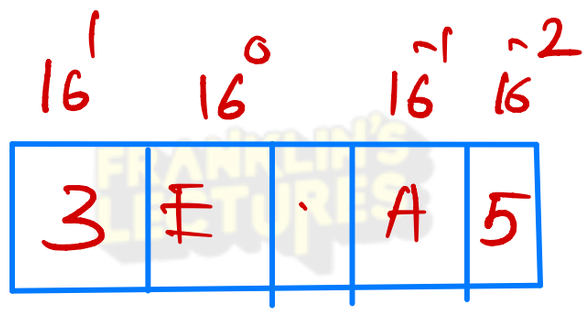
Example:

Convert 3E.A5 Hexadecimal to Decimal



$(3 \times 16^{1}) + (14 \times 16^{0}) + (10 \times 16^{-1}) + (5 \times 16^{-2})$

HD	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

$48 + 14 + 0.625 + 0.01953$

62.64453_{10}

Convert $(747.36)_8 \Rightarrow (\ )_{10}$

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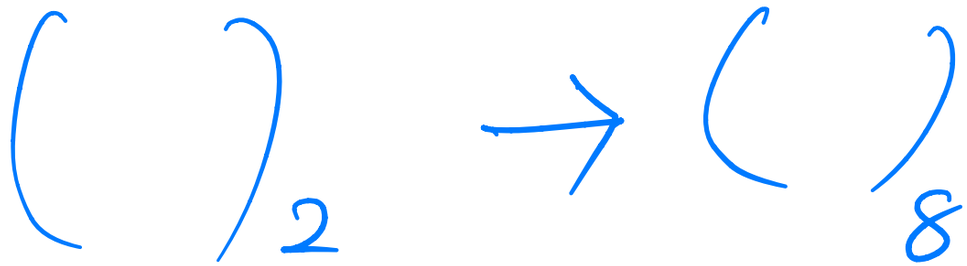

METHOD 3

GROUP OF BINARY DIGITS INTO 3 OR 4

$$(B)_2 \rightarrow (O)_8,\ (H)_{16}$$



$$(\quad)_2 \rightarrow (\quad)_8$$

$$(\quad)_{16}$$

$16 = 2^4$

$8 = 2^3$

7,8- BINARY TO OCTAL/ HD CONVERSION

STEPS

- Group binary digits in sets (3 for octal, 4 for hexadecimal).
- If needed, pad with zeros to complete groups.
- Integer and fraction parts are handled separately

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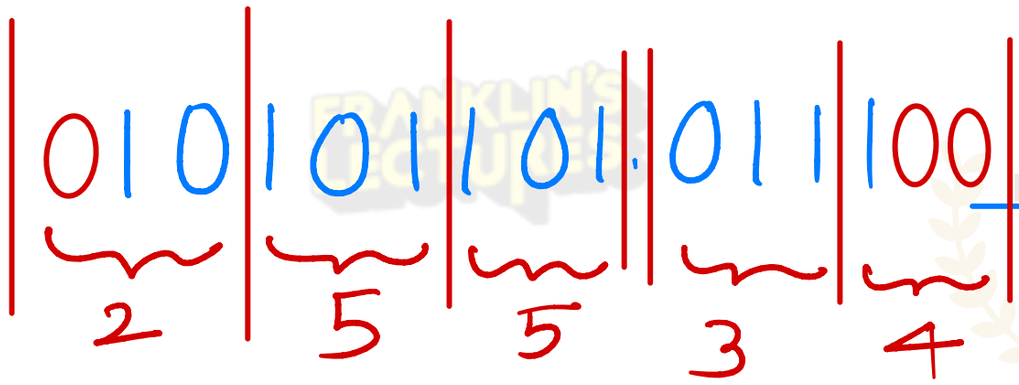
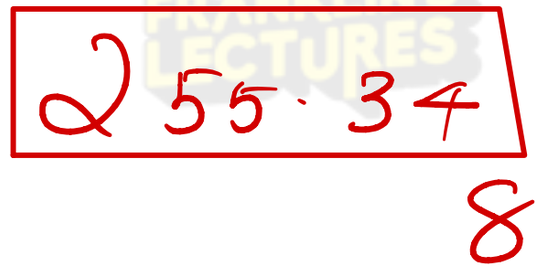
Example:

Convert 10101101.0111Binary to Octal

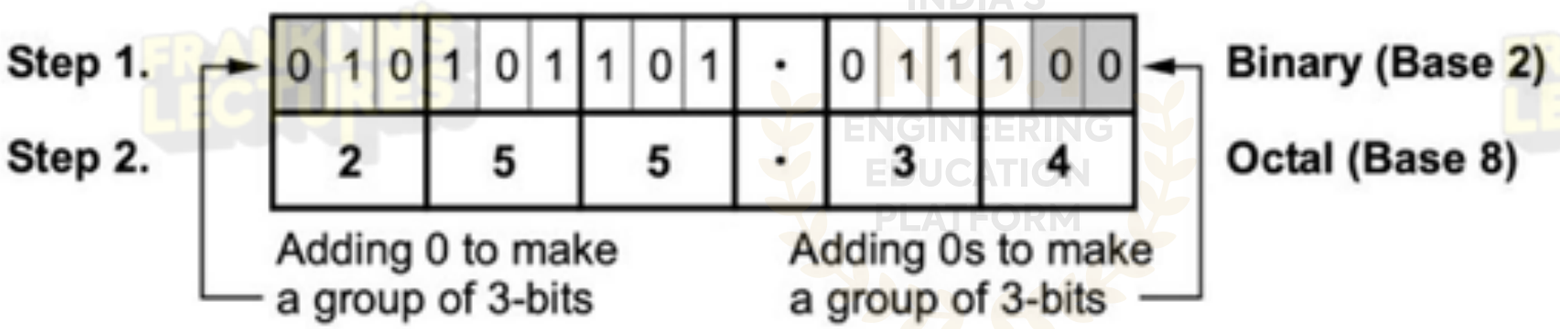
HD	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111



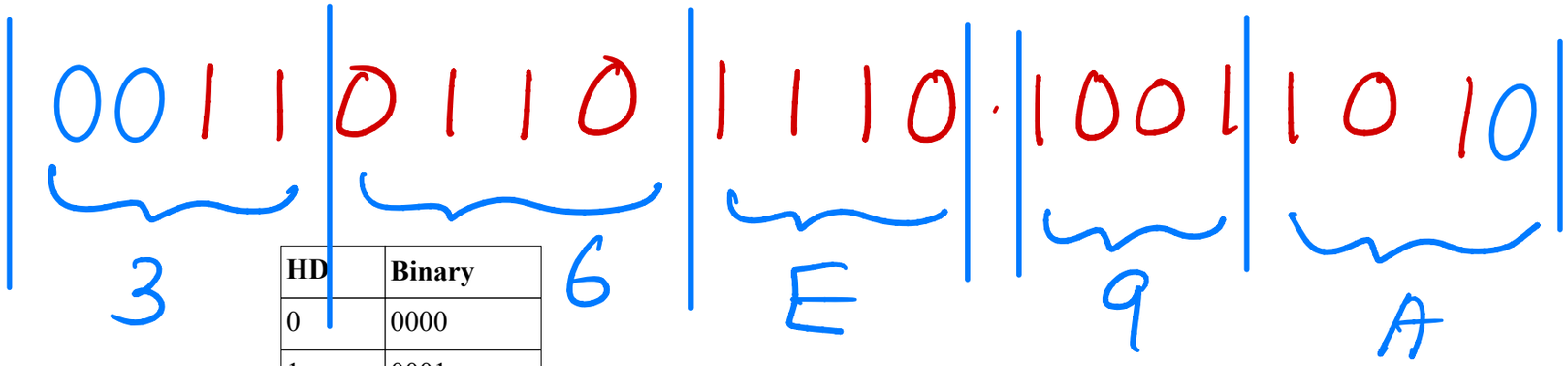


Example:

Convert 125.62 Octal to Binary



$$(10101101.0111)_2 = (255.34)_8$$



Example:

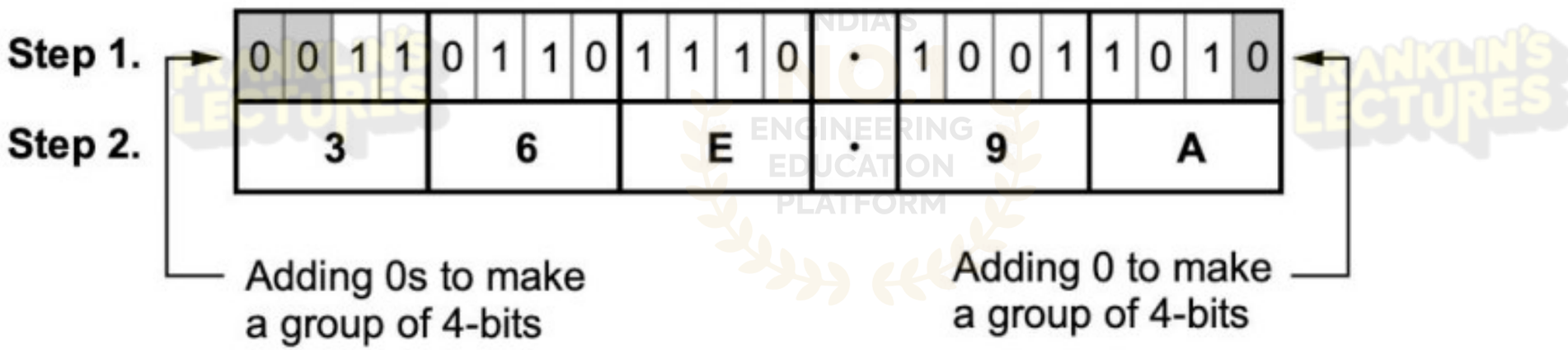
Convert 1101101110.1001101 Binary to Hexadecimal

HD	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

$36E.9A_{16}$

Example:

Convert 1101101110.1001101 Binary to Hexadecimal



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( )$_8$ → ( )$_2$

( )$_{16}$ → ( )$_2$

METHOD 4

REPLACE EACH DIGITS WITH 3 OR 4 BITS

$(O)_8 \; (H)_{16} \rightarrow (B)_2$

INDIA'S NO.1 ENGINEERING EDUCATION PLATFORM

9,10- OCTAL/ HD TO BINARY CONVERSION

STEPS

Octal to Binary:

Replace each octal digit with 3 bits.

Hexadecimal (HD) to Binary:

Replace each hexadecimal digit with 4 bits.

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FRANKLIN'S LECTURES

Example:

Convert 125.62 Octal to Binary

$(125.62)_8 \rightarrow (\quad)_2$

HD	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

001 010 101 . 110 010 $)_2$

Example:

Convert 125.62 Octal to Binary



Example:

Convert 8A9.B4 Hexadecimal to Binary

8A9.B4

1000 1010 1001 . 10110100

(1000 1010 1001 . 10110100)$_2$

HD	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Example:

Convert 8A9.B4 Hexadecimal to Binary

	8				A				9				·	B				4			
Step 1.	1	0	0	0	1	0	1	0	1	0	0	1	·	1	0	1	1	0	1	0	0
Step 2.	1	0	0	0	1	0	1	0	1	0	0	1	·	1	0	1	1	0	1		

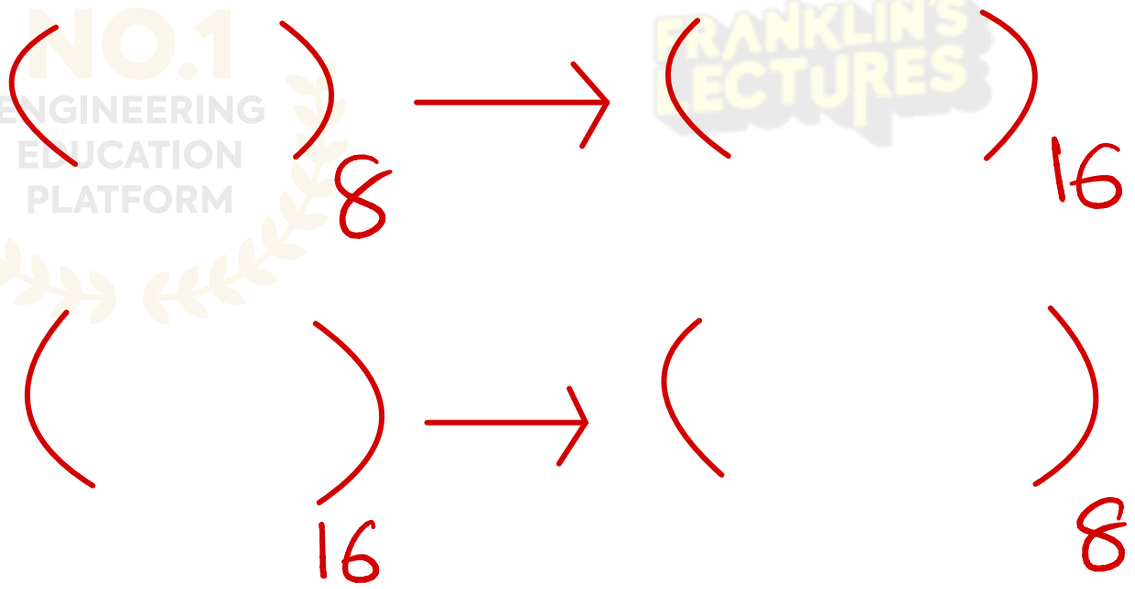
Trailing zeros

$$(8A9.B4)_{16} = (1000\ 1010\ 1001.101101)_2$$

METHOD 5

OCTAL / HD TO BINARY AND CONVERT BINARY TO HD/ OCTA

$$(O)_8 \rightarrow (H)_{16} \;\&\; (H)_{16} \rightarrow (O)_8$$



11. OCTAL TO HEXADECIMAL CONVERSION

STEPS

- Convert **Octal to Binary** (each octal digit → 3 bits).
- Group the binary digits into **sets of 4 bits** (starting from right for integer part).
- Convert each 4-bit group to **Hexadecimal.**

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FRANKLIN'S LECTURES

OCTAL TO HEXADECIMAL CONVERSION

$(615.25)_8 \rightarrow (\quad)_2 + (\quad)_{16}$

Example- Convert 615.25 Octal to Hexadecimal

$(615.25)_8 \rightarrow (110\,001\,101.010\,101)_2$

$(0001\,1000\,1101.0101\,0100)_2 \rightarrow (\quad)_{16}$

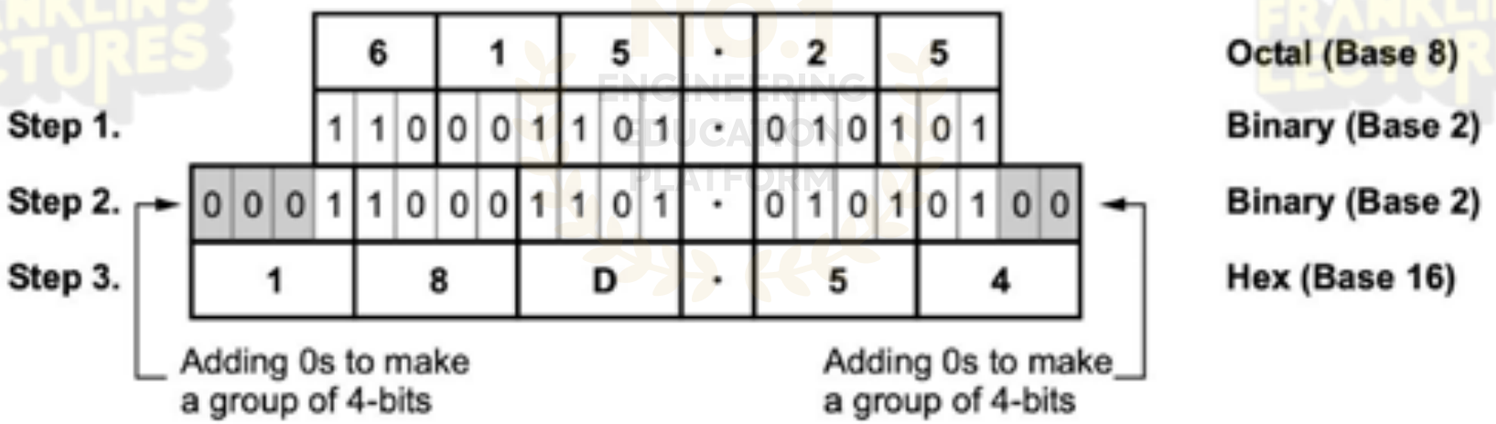
1 8 D . 5 4

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

INDIA'S NO.1 ENGINEERING EDUCATION PLATFORM

OCTAL TO HEXADECIMAL CONVERSION

Example- Convert 615.25 Octal to Hexadecimal



FRANKLIN'S LECTURES

HEXADECIMAL TO OCTAL CONVERSION

STEPS

- Convert **Hexadecimal to Binary** (each hex digit ⟶ 4 bits).
- Group the binary digits into **sets of 3 bits** (starting from right for integer part).
- Convert each 3-bit group to **Octal.**

NO.1 ENGINEERING EDUCATION PLATFORM

FRANKLIN'S LECTURES

$(\quad)_{16} \rightarrow (\quad)_2 \rightarrow (\quad)_8$

HEXADECIMAL TO OCTAL CONVERSION

Example- Convert BC66.AF Hexadecimal to Octal

$(136146.536)_8$

HD	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Binary

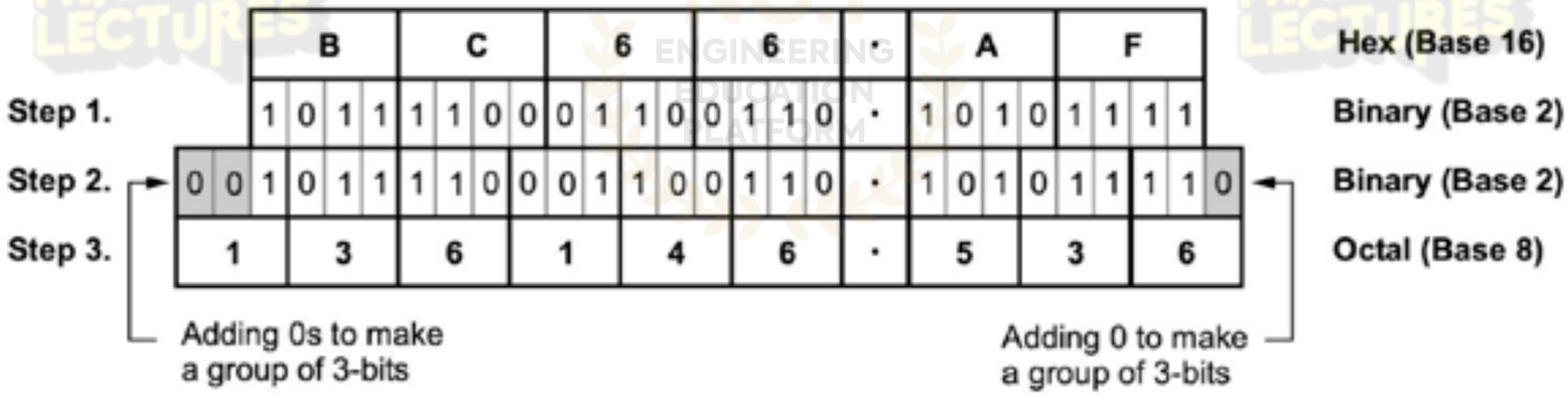
1011 1100 0110 0110 . 1010 1111

Octal

001	011	110	001	100	110	. 101	011	110
1	3	6	1	4	6	5	3	6

HEXADECIMAL TO OCTAL CONVERSION

Example- Convert BC66.AF Hexadecimal to Octal



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NUMBER SYSTEM SUMMARY

Conversion Type	Method
Decimal → Binary	Divide by 2 (record remainders)
Decimal → Octal	Divide by 8
Decimal → Hexadecimal	Divide by 16
Binary → Decimal	Multiply each bit by 2n2n and sum
Binary → Octal	Group 3 bits
Binary → Hexadecimal	Group 4 bits
Octal → Binary	Each octal digit → 3 bits
Hexadecimal → Binary	Each hex digit → 4 bits
Octal ↔ Hexadecimal	Use binary as an intermediate step

$(1A56.F3)_{16} \rightarrow (\ )_8, (\ )_{11}, (\ )_2$

$(374.401)_8 \rightarrow (\ )_{16}, (\ )_{10}$

$(10111110110.110101)_2 \rightarrow (\ )_{10}, (\ )_{16}$

$(149.37)_{10} \longrightarrow (\ )_8, (\ )_{16}$

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THANK YOU