Computer Organization and Architecture

Chapter One: Introduction

Hope Enterprise University College

Computer Organization Vs Computer architecture

WHAT IS COA?

- COA means Computer Organisation and Architecture.
- It is a combination of Computer Organisation and Computer Architecture.
- In COA, we discuss about the organisation of a computer and architecture of computer.

COMPUTER ORGANISATION

- Computer organisation deals with functions and design of various units of a digital system.
- CO is concerned with the way the h/w components operate and the way they are connected together to form a computer system.

COMPUTER ARCHITECTURE

- Computer Architecture deals with the specification of the instruction set and the h/w units that implement the instructions.
- It is concerned with the structure and behaviour of the computer as seen by the user.
- It includes the information formats, the instructions set and techniques for addressing the memory.

COMPARISON BETWEEN CO AND CA

COMPUTER ARCHITECTURE

- Computer Architecture is concerned with the way hardware components are connected together to form a computer system.
- It acts as the interface between hardware and software.
- Computer Architecture helps us to understand the functionalities of a system.

COMPUTER ORGANISATION

- Computer Organization is concerned with the structure and behavior of a computer system as seen by the user.
- It deals with the components of a connection in a system.
- Computer Organization tells us how exactly all the units in the system are arranged and interconnected.

COMPARISON BETWEEN CO AND CA

COMPUTER ARCHITECTURE

- While designing a computer system architecture is considered first.
- Computer Architecture deals with high-level design issues.
- Architecture involves Logic (Instruction sets, Addressing modes, Data types)

COMPUTER ORGANISATION

- An organization is done on the basis of architecture.
- Computer Organization deals with low-level design issues.
- Organization involves Physical Components (Circuit design, Adders, Signals, Peripherals)

WHAT IS SYSTEM?

- Asystem is a collection of elements or components that are organized for a common purpose.
- Asystem is a machine which have input, output and processing unit.
- Some systems also have memory unit as computer system.

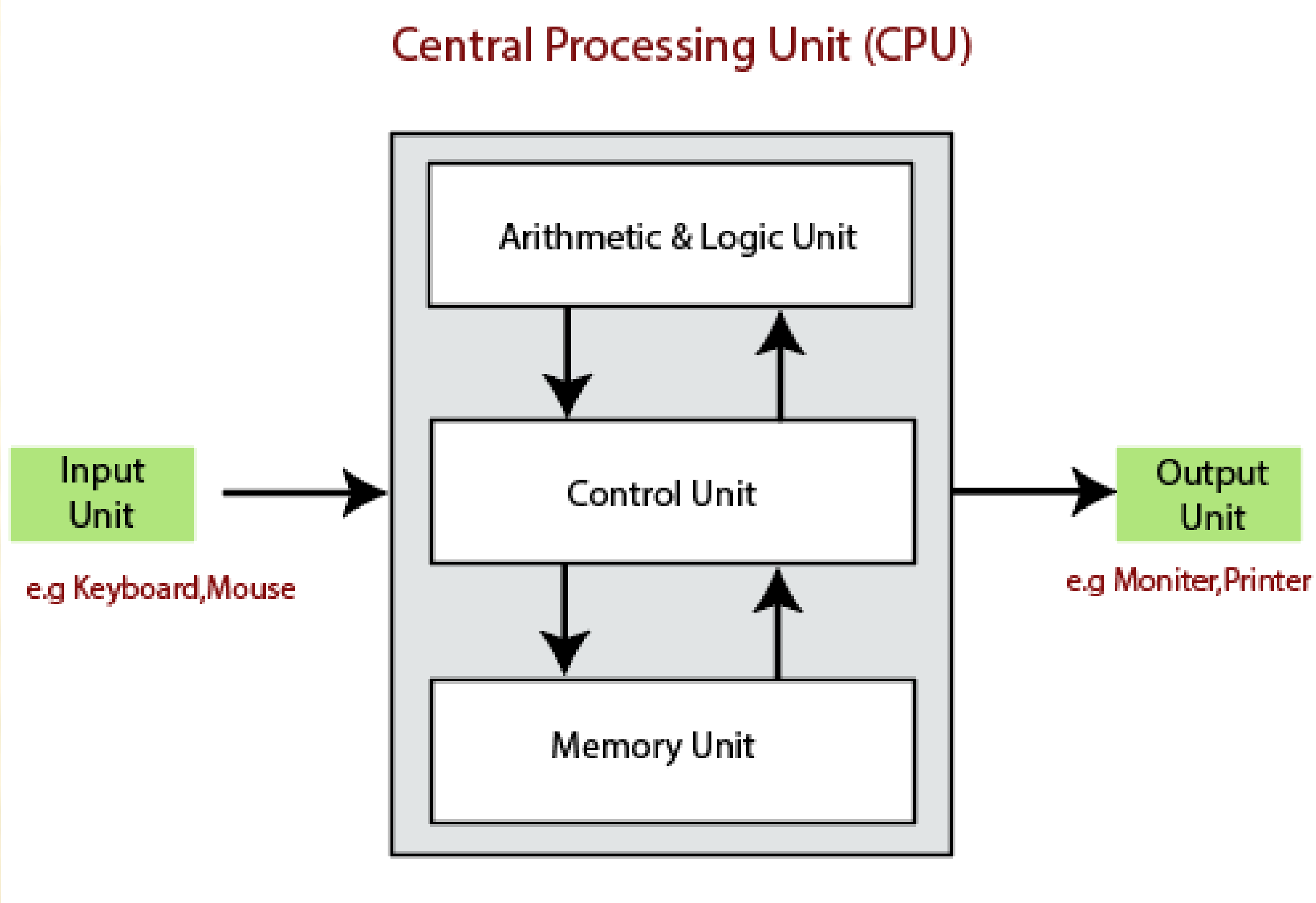
WHAT IS DIGITAL SYSTEM?

- Digital systems are designed to store, process, and communicate information in digital form.
- They are found in a wide range of applications, including process control, communication systems, digital instruments, and consumer products.
- The digital computer, more commonly called the computer, is an example of a typical digital system.

FUNCTIONAL UNITS OF DIGITAL SYSTEM

- Functional units of a computer system are parts of the CPU(Central Processing Unit) that performs the operations and calculations called for by the computer program.
- A computer consists of three main components namely, Input unit, Central Processing Unit and Output unit.

BLOCK DIAGRAM OF A COMPUTER



INPUT UNIT

- Input units are used by the computer to read the data. The most commonly used input devices are keyboards, mouse, joysticks, trackballs, microphones, etc.
- However, the most well-known input device is a keyboard. Whenever a key is pressed, the corresponding letter or digit is automatically translated into its corresponding binary code and transmitted over a cable to either the memory or the processor.

CENTRAL PROCESSING UNIT

- Central processing unit commonly known as CPU can be referred as an electronic circuitry within a computer that c out the instructions given by a computer program by perfo the basic arithmetic, logical, control and input/output (I/C operations specified by the instructions.

MEMORY UNIT

- The Memory unit can be referred to as the storage area in which programs are kept which are running and that contains data needed by the running programs.
- It enables a processor to access running execution applications and services that are temporarily stored in a specific memory location.

ARITHMETIC AND LOGICAL UNIT

- Most of all the arithmetic and logical operations of a computer are executed in the ALU (Arithmetic and Logical Unit) of the processor.
- It performs arithmetic operations like addition, subtraction, multiplication, division and also the logical operations like AND, OR, NOT operations.

CONTROL UNIT

- The control unit is a component of a computer's central processing unit that coordinates the operation of the processor.
- It tells the computer's memory, arithmetic/logic unit and input /output devices how to respond to a program's instructions.
- The control unit is also known as the nerve center of a computer system.

OUTPUT UNIT

- The primary function of the output unit is to send the processed results to the user.
- Output devices display information in a way that the user can understand.
- Output devices are pieces of equipment that are used to generate information or any other response processed by the computer.
- These devices display information that has been held or generated within a computer.

WHAT IS NUMBER SYSTEM

- Number systems are the technique to represent numbers in the computer system architecture.
- Every value that you are saving or getting into/from computer memory has a defined number system.

TYPES OF NUMBER SYSTEM

- Computer architecture supports following number systems:-
  - Binary number system
  - Octal number system
  - Decimal number system
  - Hexadecimal (hex) number system

1. BINARY NUMBER SYSTEM

- A Binary number system has only two digits that are 0 and 1.
- Every number (value) represents with 0 and 1 in this number system.
- The base of binary number system is 2, because it has only two digits.

2. OCTAL NUMBER SYSTEM

- Octal number system has only eight (8) digits from 0 to 7.
- Every number (value) represents with 0,1,2,3,4,5,6 and 7 in this number system.
- The base of octal number system is 8, because it has only 8 digits.

3. DECIMAL NUMBER SYSTEM

- Decimal number system has only ten (10) digits from 0 to 9.
- Every number (value) represents with 0,1,2,3,4,5,6, 7,8 and 9 in this number system.
- The base of decimal number system is 10, because it has only 10 digits.

4. HEXADECIMAL NUMBER SYSTEM

- AHexadecimal number system has sixteen (16) alphanumeric values from 0 to 9 and A to F.
- Every number (value) represents with 0,1,2,3,4,5,6, 7,8,9,A,B,C,D,E and F in this number system.
- The base of hexadecimal number system is 16, because it has 16 alphanumeric values.
- Here A is 10, B is 11, C is 12, D is 13, E is 14 and F is 15.

Number System Chart

Name	Base	Symbols	Example
Decimal	10	0,1,2,3,4,5,6,7,8,9	$(2795)_{10}$
Binary	2	0,1	111000010
Octal	8	0,1,2,3,4,5,6,7	$(1576)_8$
Hexadecimal	16	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F	3DB

HEXADECIMAL	DECIMAL	OCTAL	BINARY
0	0	0	0000
1	1	1	0001
2	2	2	0010
3	3	3	0011
4	4	4	0100
5	5	5	0101
6	6	6	0110
7	7	7	0111
8	8	10	1000
9	9	11	1001
A	10	12	1010
B	11	13	1011
C	12	14	1100
D	13	15	1101
E	14	16	1110
F	15	17	1111

NUMBER SYSTEM CONVERSION

- There are three types of conversion:
- Decimal Number System to Other Base
- [for example: Decimal Number System to Binary Number System]
- Other Base to Decimal Number System
- [for example: Binary Number System to Decimal Number System]
- Other Base to Other Base
- [for example: Binary Number System to Hexadecimal Number System]

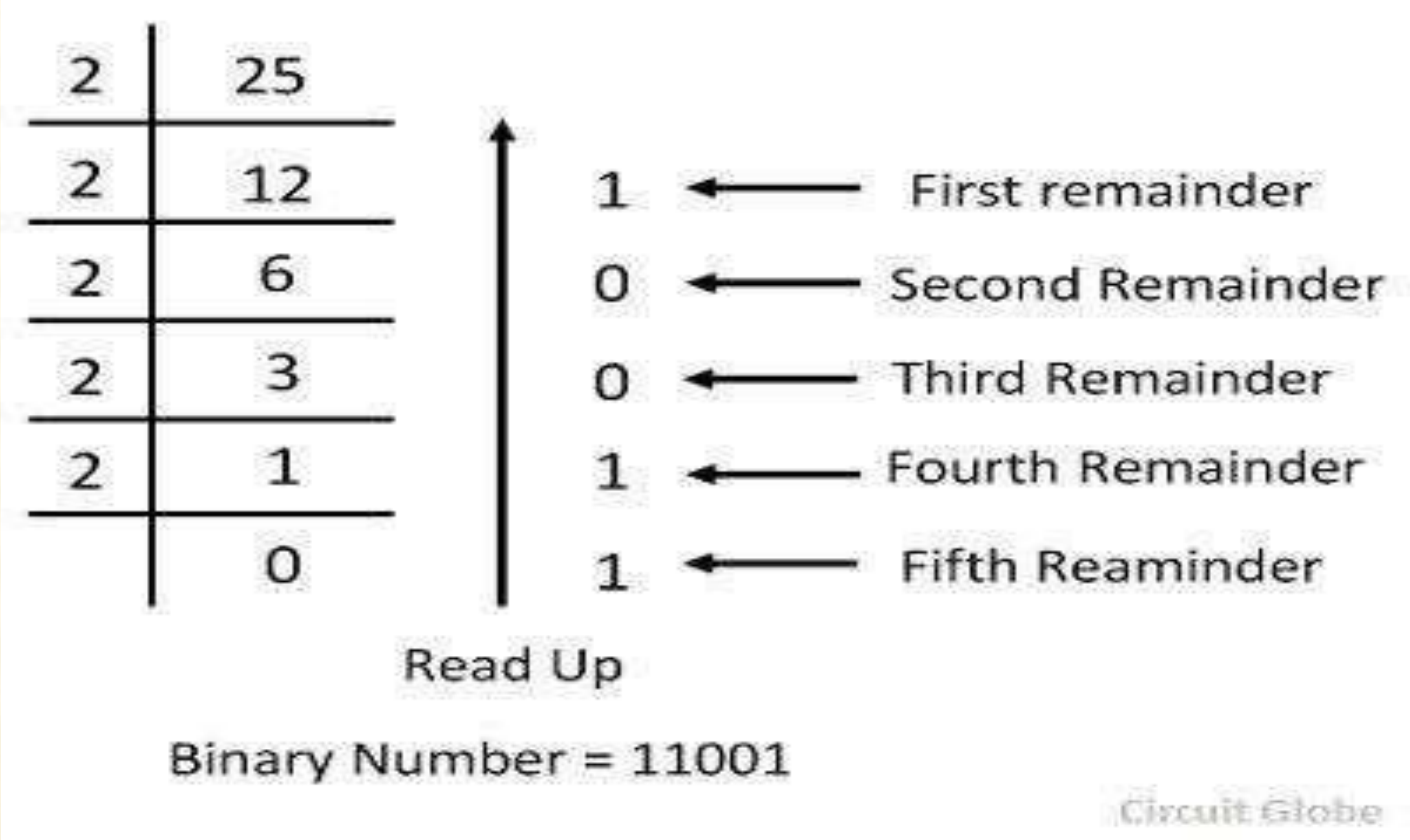
DECIMAL NUMBER SYSTEM TO OTHER BASE

- To convert from Decimal Number System to Any Other Base, you have to follow just two steps:

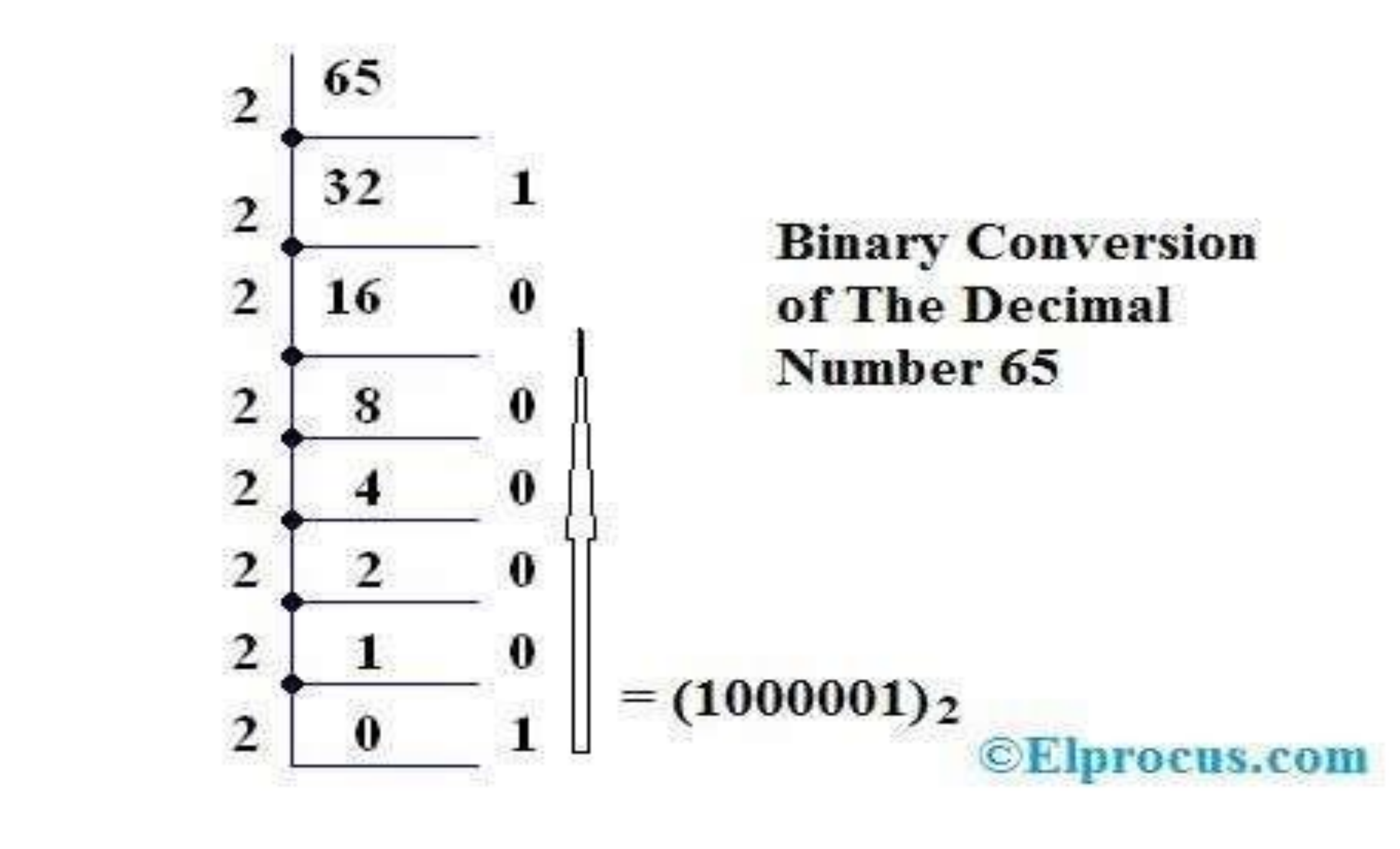
  A) Divide the Number by the base of target base system (in which you want to convert the number: Binary (2), octal (8) and Hexadecimal (16)).

  B) Write the remainder from bottom to top.

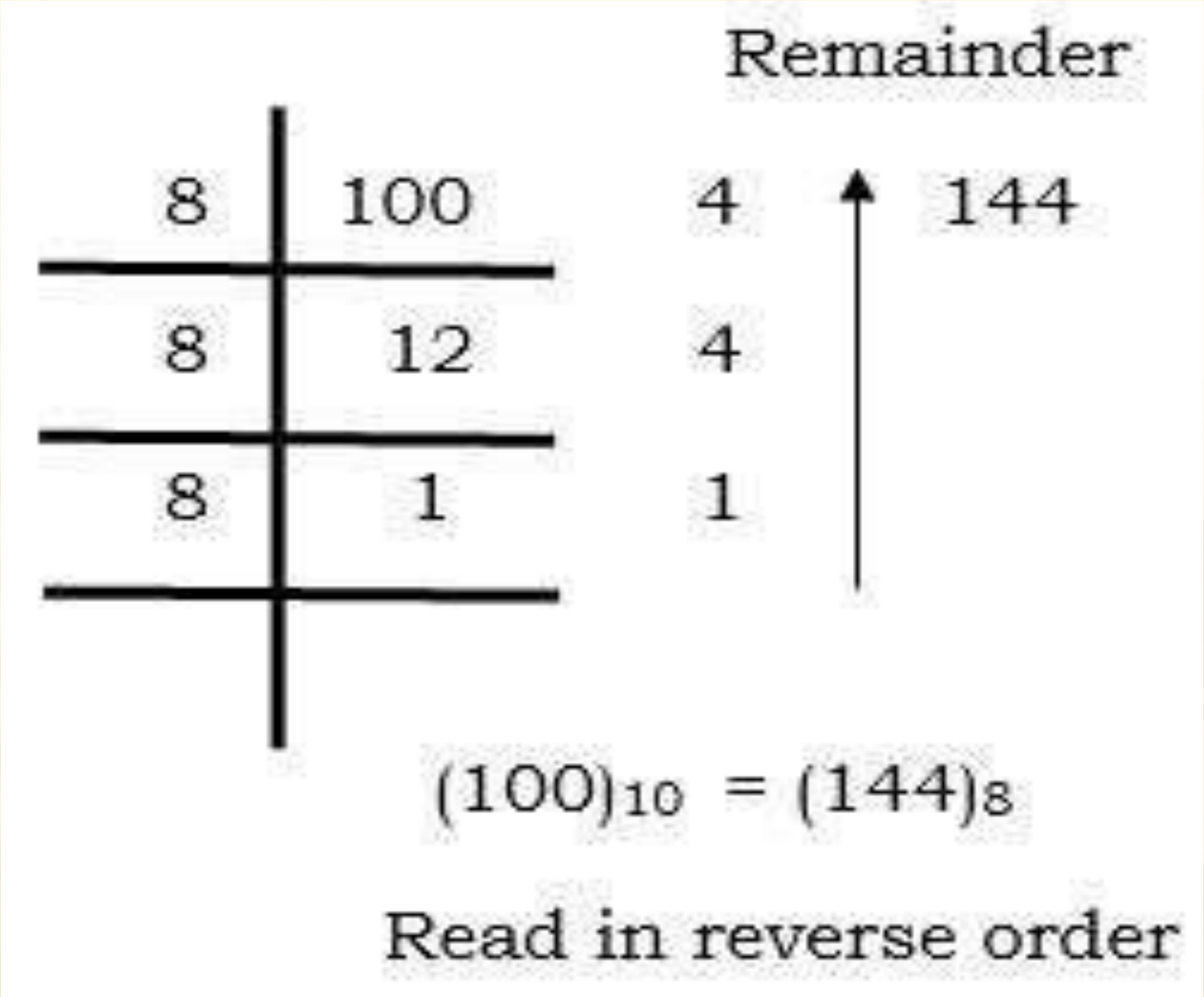
1. DECIMAL TO BINARY



One more example



2. DECIMAL TO OCTAL



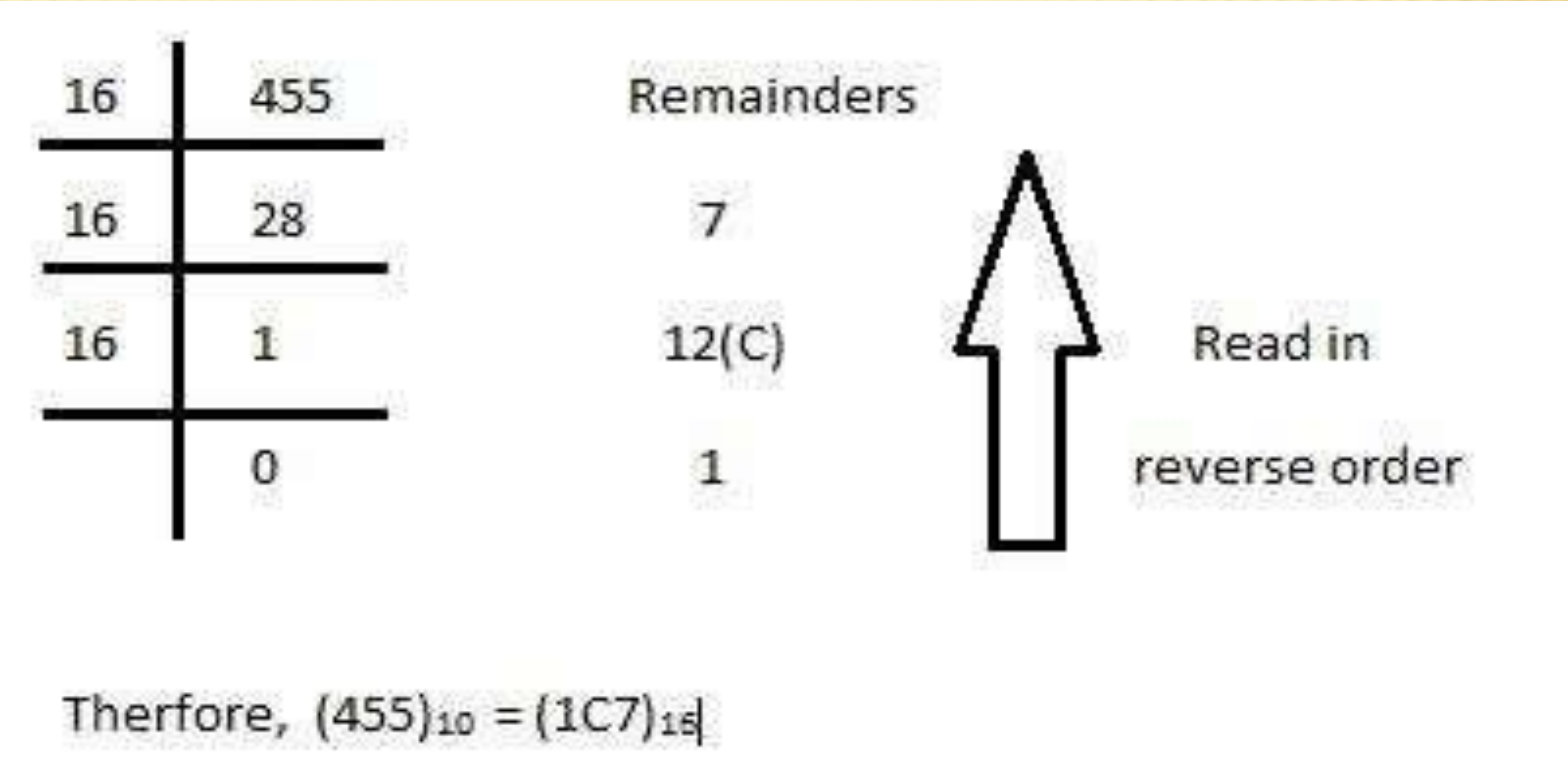
One more example

		Remainders
8	569	
8	71	1
8	8	7
8	1	0
	0	1

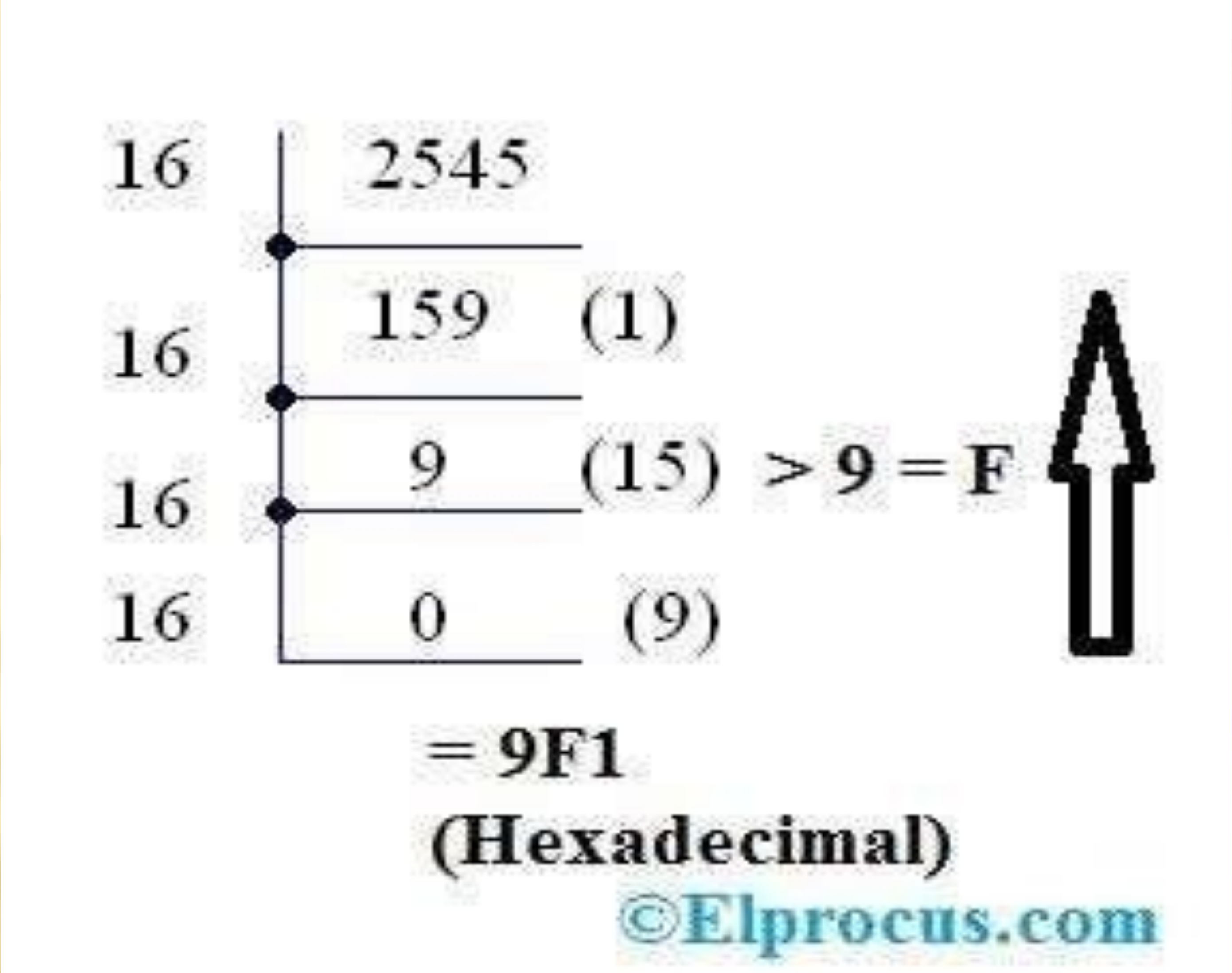
Read in reverse order

Therfore, $(569)_{10} = (1071)_8$

3. DECIMAL TO HEXADECIMAL



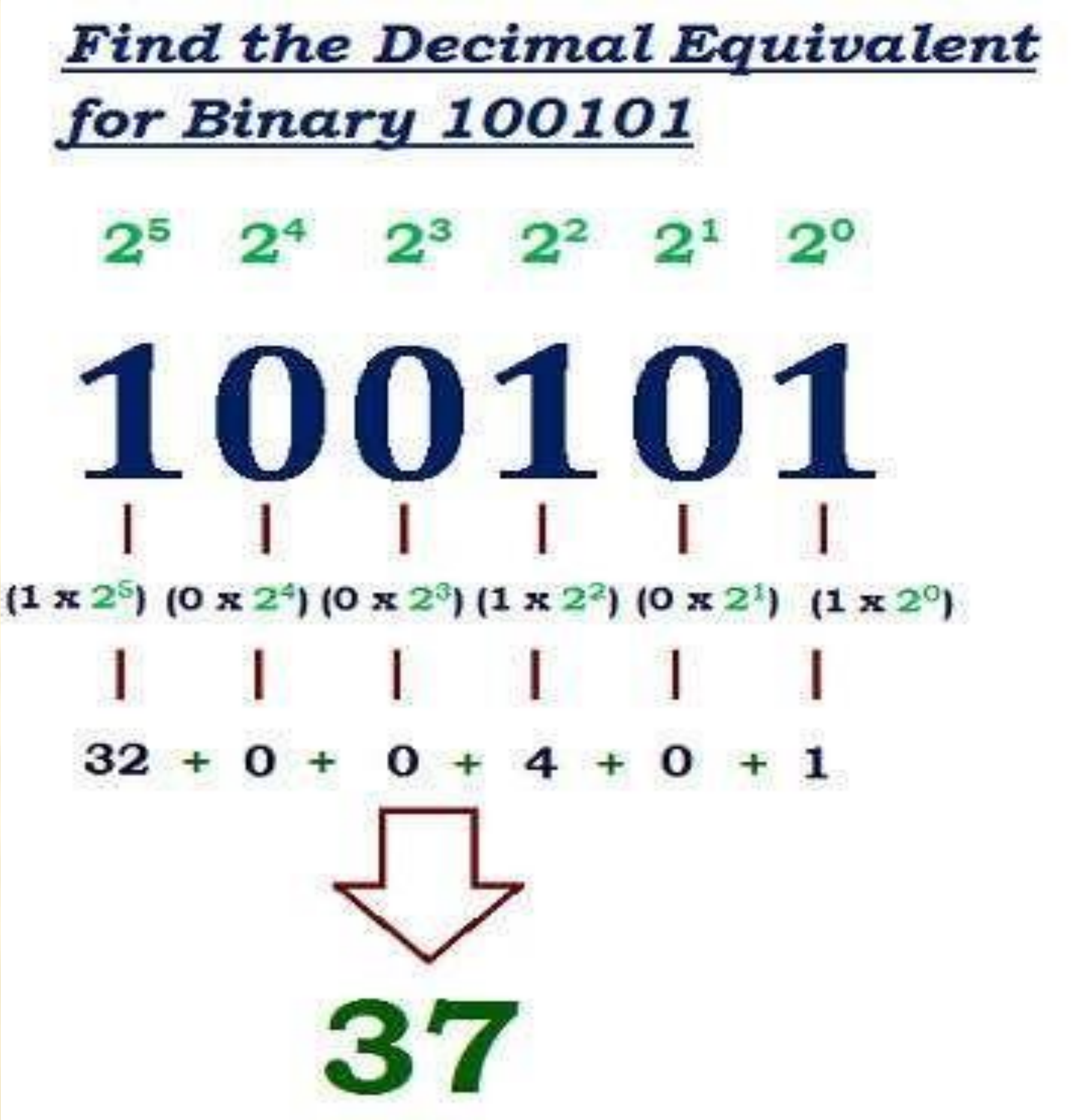
One more example



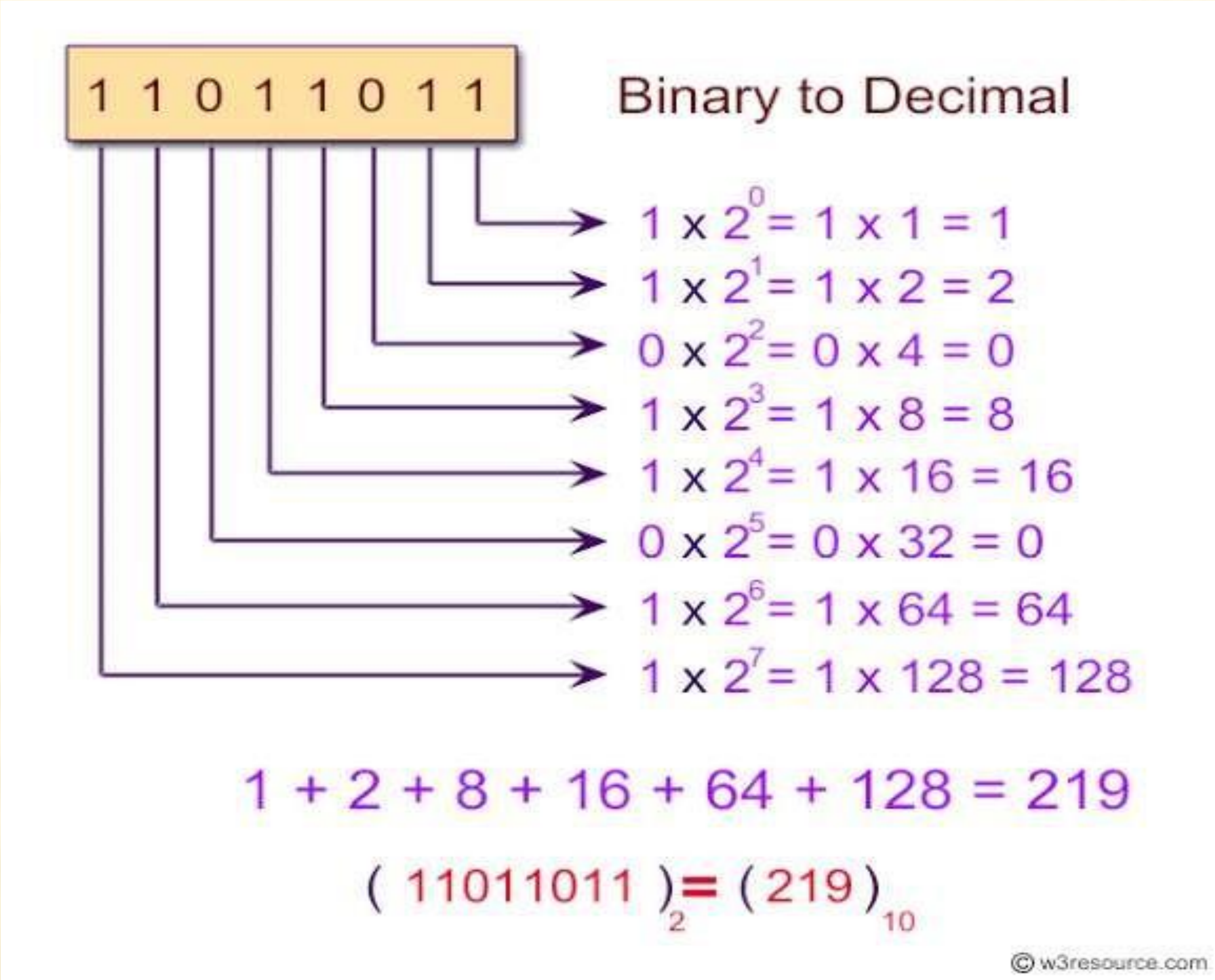
OTHER BASE SYSTEM TO DECIMAL NUMBER BASE

- To convert from Any Other Base System to Decimal Number System, you have to follow just three steps:
  - ✓ A)Determine the base value of source Number System that you want to convert and also determine the position of digits from first digit's position – 0, second digit's position – 1 and so on.
  - ✓ B) Multiply each digit with its corresponding multiplication of position value and Base of Source Number System's Base.
  - ✓ C) Add the resulted value in step-B.

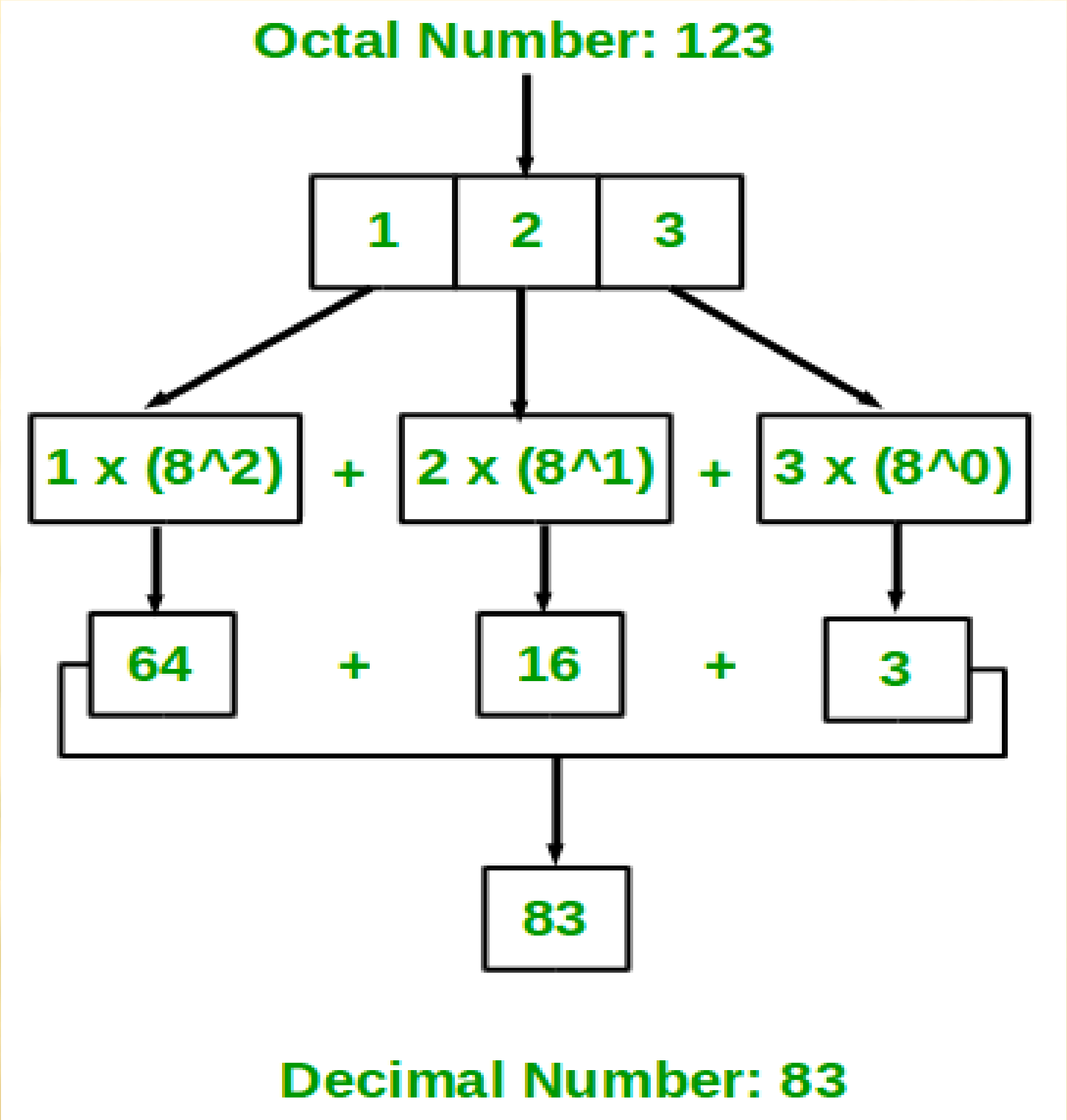
1. BINARY TODECIMAL



One more example



2. OCTAL TO DECIMAL



One more example

Octal Numbers to Decimal

3 2 1 0 ← power of 8

$$2754_8 = \begin{array}{lr} 2 \times 8^3 & 1024 \\ 7 \times 8^2 & 448 \\ 5 \times 8^1 & 40 \\ 4 \times 8^0 & 4 \\ \hline & 1516_{10} \end{array}$$

3. HEXADECIMAL TO DECIMAL

Hexadecimal to Decimal

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

Hexadecimal Value = 2A5

2 A 5

16^2 16^1 16^0

256 x 2 = 512   16 x 10 = 160   1 x 5 = 5

$$\underbrace{512 + 160 + 5}$$

677

$$(2A5)_{16} = (677)_{10}$$

One more example

Hexadecimal Numbers to Decimal

3 2 1 0 ← power of 16

$$A7F4_H = A \times 16^3 \rightarrow 10 \times 16^3$$

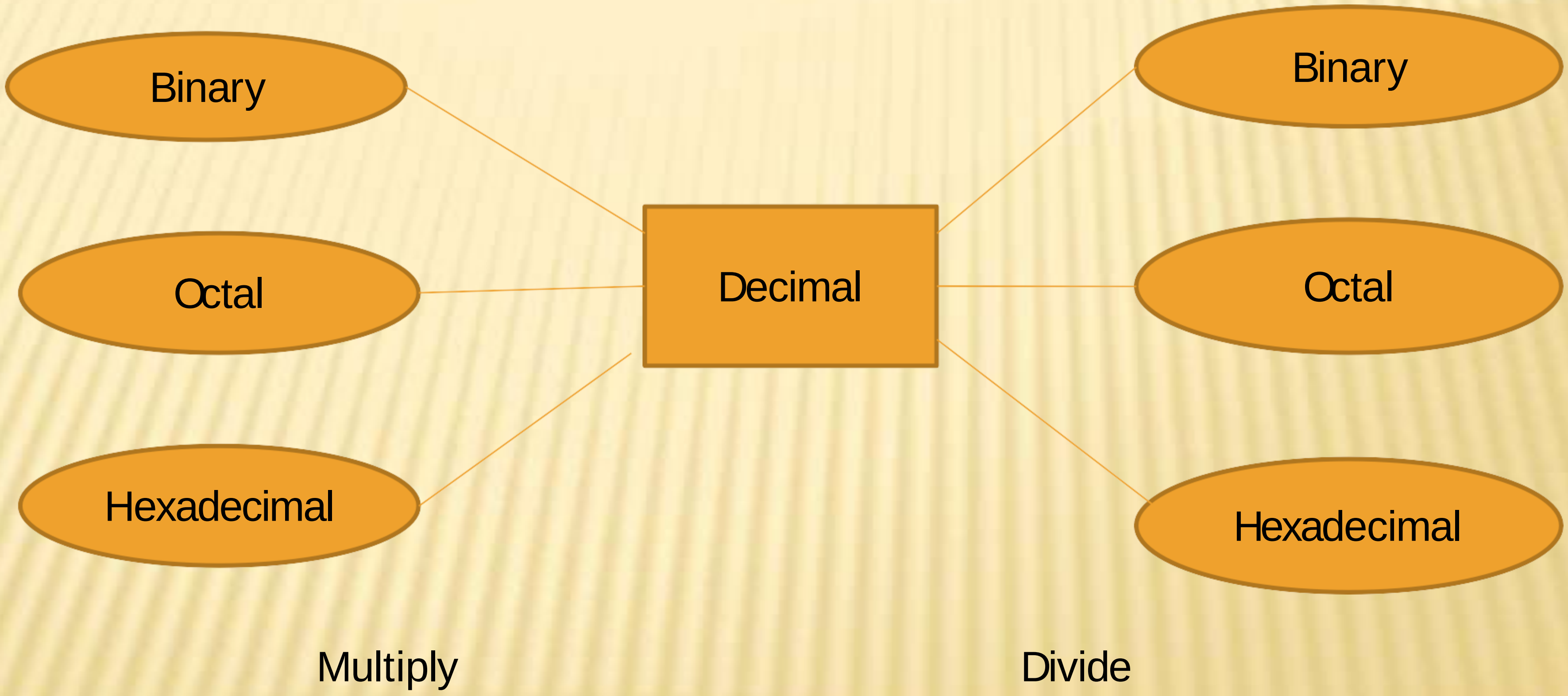
$$7 \times 16^2 \rightarrow 7 \times 16^2$$

$$F \times 16^1 \rightarrow 15 \times 16^1$$

$$4 \times 16^0 \rightarrow 4 \times 16^0$$

$$42{,}996_{10}$$

FORMULA TO LEARN



OTHER BASE TO OTHER BASE

- **Binary Number into Octal Number System**

To convert any binary value into its equivalent octal value, we have to follow these two steps:-

i. First convert the given binary Number into decimal Number.
ii. Now, convert this decimal Number into its equivalent octal Number.

BINARY TO OCTAL EXAMPLE

- Example − Convert binary number 10010110 into octal number.
- First convert this into decimal number

  $= (10010110)_2$

  $=1x2^7+0x2^6+0x2^5+1x2^4+0x2^3+1x2^2+1x2^1+0x2^0$

  $= 128+0+0+16+0+4+2+0$

  $= (150)_{10}$
- Then, convert it into octal number

$= (150)_{10}$

$$
= \begin{array}{r|l}
8 & 150 \\ \hline
8 & 18 \\ \hline
8 & 2 \\ \hline
 & 0
\end{array}
\qquad
\begin{array}{c}
\text{Remainder} \\
6 \\
2 \\
2
\end{array}
$$

$= (226)_8$ which is answer.

SHORT CUT METHOD (GROUPING METHOD)

- Since, there are only 8 digits (from 0 to 7) in octal number system, so we can represent any digit of octal number system using only 3 bits.
- So, if you make each group of 3 bit of binary input number, then replace each group of binary number from its equivalent octal digits.
- That will be octal number of given number number.

GROUPING METHOD

- So, these are following steps to convert abinary number into octal number:-
- Take binary number
- Divide the binary digits into groups of three starting from right.
- Convert each group of three binary digits to one octal digit.

EXAMPLE

- Convert binary number 1010111100 into octal number. Since there is no binary point here and no fractional part. So,

$$= (1010111100)_2$$

$$= (001 \quad 010 \quad 111 \quad 100)_2$$

$$= (1 \quad 2 \quad 7 \quad 4)_8$$

$$= (1274)_8$$

ANOTHER EXAMPLE

- Convert binary number 0110011 into octal number. So,

Examples: convert from binary to octal.

Answer: 111001101 111 001 101

7 1 5

$\therefore (111\ 001\ 101)_2 \equiv (715)_8$

OTHER BASE TO OTHER BASE

Binary to Hexadecimal Number System

To convert any binary value into its equivalent hexadecimal value, we have to follow these two steps:-

i. First convert the given binary Number into decimal Number.
ii. Now, convert this decimal Number into its equivalent hexadecimal Number.

BINARY TO HEXADECIMAL EXAMPLE

- Convert binary number 1101010 into hexadecimal number.
- First convert this into decimal number:

$$= (1101010)_2$$

$$= 1x2^6+1x2^5+0x2^4+1x2^3+0x2^2+1x2^1+0x2^0$$

$$= 64+32+0+8+0+2+0$$

$$= (106)_{10}$$

- Then, convert it into hexadecimal number $(106)_{10}$

$= (106)_{10}$

=	16	106	Remainders
	16	6	10
		0	6

$=(6\ 10)_{16}$ but we know that in hexadecimal 10=A

= So, Answer will be $(6A)_{16}$.

ANOTHER METHOD (GROUPING METHOD)

- These are following steps to convert a binary number into hexadecimal number:-
- Take binary number.
- Divide the binary digits into groups of four digits starting from right.
- Convert each group of four binary digits to one hexadecimal digit.

EXAMPLE-1

Convert binary number 1010101101001 into hexadecimal number.

$= (1010101101001)_2$

$= (1 \quad 0101 \quad 0110 \quad 1001)_2$

$= (0001 \quad 0101 \quad 0110 \quad 1001)_2$

$= (1 \; 5 \quad 6 \quad 9)_{16}$

$= (1569)_{16}$

EXAMPLE-2

Binary to Hexadecimal Conversion

Convert the binary number 1111110101110011_2 to its hexadecimal equivalent.

1. *Separate the digits into groups from right to left side; each group contains 4 bits of binary number.*

1111 1101 0111 0011

2. *Find the equivalent hexadecimal number for each group.*

1111 1101 0111 0011

F D 7 3

3. *Write the all groups hexadecimal numbers together, maintaining the group order provides the equivalent hex number for the given binary.*

FD73

Result

$1111110101110011_2 = FD73_{16}$

DECIMAL TO BASE N CONVERSION

- To convert from Decimal to a different number base such as base 3, base 4 or base 5, we just follow the same steps as followed for converting from Decimal to binary,octal and hexadecimal.
- Divide the decimal Number by the number base until quotient is zero.
- Collect the remainders in reverse order.

DECIMAL TO BASE 3 NUMBER CONVERSION

Convert $(123)_{10}$ into base 3 number:-

Divisor	Dividend	Remainders
3	123	
3	41	0
3	13	2
3	4	1
3	1	1
	0	1

Answer will be $(123)_{10} = (11120)_3$

DECIMAL TO BASE 4 NUMBER CONVERSION

- Convert $(123)_{10}$ into base 4 number:-

4	123	Reminders
4	30	3
4	7	2
4	1	3
4	0	1

- Answer will be $(123)_{10} = (1323)_4$

DECIMAL TO BASE 5 NUMBER CONVERSION

- Convert $(123)_{10}$ into base 5 number:-

		Remainders
5	123	
5	24	3
5	4	4
5	0	4

- Answer will be $(123)_{10} = (443)_5$

BASE 3 NUMBER TO DECIMAL CONVERSION

- Convert $(1121)_3$ into decimal number
- $=1x3^3 + 1x3^2 + 2x3^1 + 1x3^0$
- $=1x27 + 1x9 + 2x3 + 1x1$
- 27+9+6+1
- 43
- Answer will be $(1121)_3=(43)_3$
- In the same way, we can convert form base 4 and base 5 to decimal number system.

OCTAL TO BINARY CONVERSION

- In octal to binary conversion, there are same methods to be followed. In which, we follow two steps:-
  i. In first step, we convert the given octal number into its decimal number.
  ii. In second step, we convert decimal number to its binary equivalent.

OCTAL TO BINARY CONVERSION

- Convert $(456)_8$ into its binary equivalent.

i. First convert this into decimal number-

$=4x8^2+5x8^1+6x8^0$

$=4x64+5x8+6x1$

$=256+40+6$

$=(302)_{10}$

- (b) Now convert decimal into its binary equivalent:-

		Remainders
2	302	
2	151	0
2	75	1
2	37	1
2	18	1
2	9	0
2	4	1
2	2	0
2	1	0
2	0	1

Answer will be = $(100101110)_2$

ANOTHER METHOD (DISTRIBUTION METHOD)

- In this method, we convert each digit of given octal number into its individual binary equivalent in 3 bits.
- Then, combine them all into one.
- And now, we get our binary equivalent of any given octal number.

EXAMPLE-1

- Convert $(456)_8$ into its binary number.
- $= (4 \quad 5 \quad 6)_8$
- $=(100 \quad 101 \quad 110)_2$
- $=(100101110)_2$
- This is our final answer.

HEXADECIMAL TO BINARY CONVERSION

- In hexadecimal to binary conversion, there are same methods to be followed. In which, we follow two steps:-
- (a) In first step, we convert the given hexadecimal number into its decimal number.
- (b) In second step, we convert this decimal number into its binary equivalent.

- Convert $(A6)_{16}$ into its binary equivalent.
- (a) First convert this into decimal number-
- $=Ax16^1+6x16^0$
- $=10x16+6x1$
- $=160+6$
- $=(166)_{10}$

- (b) Now convert decimal into its binary equivalent:-

Divisor	Dividend	Remainders
2	166	
2	83	0
2	41	1
2	20	1
2	10	0
2	5	0
2	2	1
2	1	0
2	0	1

- Answer will be = $(10100110)_2$

ANOTHER METHOD (DISTRIBUTION METHOD)

- In this method, we convert each digit of given hexadecimal number into its individual binary equivalent in 4 bits.
- Then, combine them all into one.
- And now, we get our binary equivalent of any given hexadecimal number.

EXAMPLE

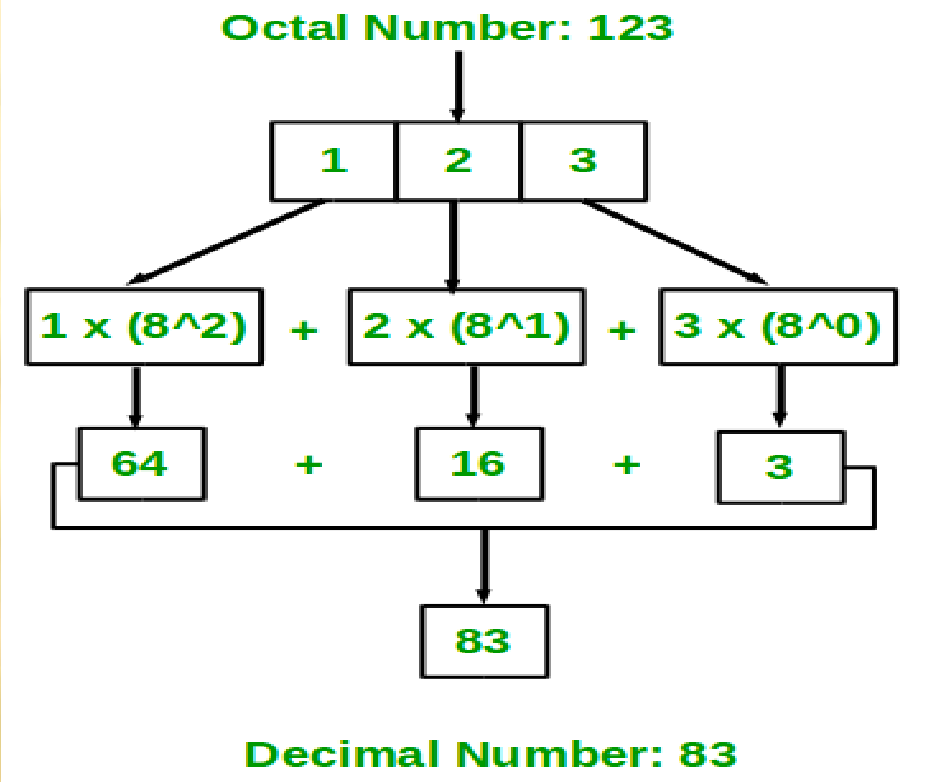
- Convert $(A6)_{16}$ into its equivalent.
- $=(10 \quad 6)_{16}$
- $=(1010 \quad 0110)_2$
- $=(10100110)_2$
- Our final answer is $=(10100110)_2$

OCTAL TO HEXADECIMAL CONVERSION

- Octal to Hexadecimal Conversion can be implemented in two various ways. In first ways there are two following steps:-
- (a) First convert the octal number into its decimal equivalent.
- (b) Then convert this intermediate decimal number into its hexadecimal equivalent.

OCTAL TO HEXADECIMAL EXAMPLE

- Convert $(123)_8$ into hexadecimal:-
- (a) First convert $(123)_8$ into decimal



- (b) Converted decimal number =$(83)_{10}$

Divisor	Dividend	Remainders
16	83	
16	5	3
16	0	5

- So, the final answer will be = $(53)_{16}$

ANOTHER METHOD

- In this method, there are again two steps:-
- (a) In first step, we convert the given octal number into its binary equivalent using distribution method.
- (b) In second step, we convert the binary value into its hexadecimal number using grouping method.

- Example- Convert $(123)_8$ into hexadecimal number.
- (a) $(123)_8$
- $(1 \quad 2 \quad 3)_8$
- $(001 \quad 010 \quad 011)_2$
- $(001010011)_2$

- $= (001010011)_2$
- Using grouping method-
- $(0000 \quad 0101 \quad 0011)_2$
- $(0 \quad 5 \quad 3)_{16}$
- Answer will be= $(53)_{16}$

HEXADECIMAL TO OCTAL CONVERSION

- Hexadecimal to Octal Conversion can be implemented in two various ways. In first ways there are two following steps:-
- (a) First convert the hexadecimal number into its decimal equivalent.
- (b) Then convert this intermediate decimal number into its octal equivalent.

EXAMPLE

- Convert $(A52)_{16}$ into Octal number.
- (a) First we convert this hexadecimal number into decimal number.
- $=A\times16^2+5\times16^1+2\times16^0$
- $=10\times256+5\times16+2\times1$
- $=2560+80+2$
- $=(2642)_{10}$

- (b) In second step, we convert intermediate decimal result $(2652)_{10}$ into its octal number.

8	2642	Remainders
8	330	2
8	41	2
8	5	1
8	0	5

- So, our answer will be $=(5122)_8$

ANOTHER METHOD

- In this method, there are again two steps:-
- (a) In first step, we convert the given hexadecimal number into its binary equivalent using distribution method.
- (b) In second step, we convert the binary value into its octal number using grouping method.

EXAMPLE

- Convert $(A52)_{16}$ into Octal number.
- (a) In first step we convert the hexadecimal number into binary number using distribution method.
- $= (A52)_{16}$
- $= (10 \quad 5 \quad 2)_{16}$
- $=(1010 \quad 0101 \quad 0010)_2$
- $=(101001010010)_2$

- (b) In second step, we follow the grouping method.
- As we know, octal value is made up of 3 binary digit, so we make group of three digits from right to left of intermediate binary value.
- $=(101001010010)_2$
- $=(101 \quad 001 \quad 010 \quad 010)_2$
- $=(\ 5 \quad 1 \quad 2 \quad 2)_8$
- $=(5122)_8$
- So, our final result is $=(5122)_8$

FRACTIONAL NUMBERS

- Fractional numbers are those number which contain a decimal(.) itself.
- It is divided into two parts: Integer part and Fractional part.
- For example:- number is 123.2120
- Integer part of this number will be 123 and fractional part will be .2120

BINARY TO DECIMAL FRACTIONAL CONVERSION

- To convert any binary fraction to Decimal fraction, the following rules are followed:-
- (a) Write the binary number.
- (b) Multiply each digit of given number with power of position.
- (c) Before the point, power will be in terms of positive number and after the point power will be in negative number.

EXAMPLE

- Convert $(1011.011)_2$ into decimal fractional value:
- $=(1x2^3+0x2^2+1x2^1+1x2^0)+(0x2^{-1}+1x2^{-2}+1x2^{-3})$
- $=(8+0+2+1)+(0+1/4+1/8)$
- $=(11)+(0.25+0.125)$
- $=(11.375)_{10}$
- This is your answer.

ONE MORE EXAMPLE

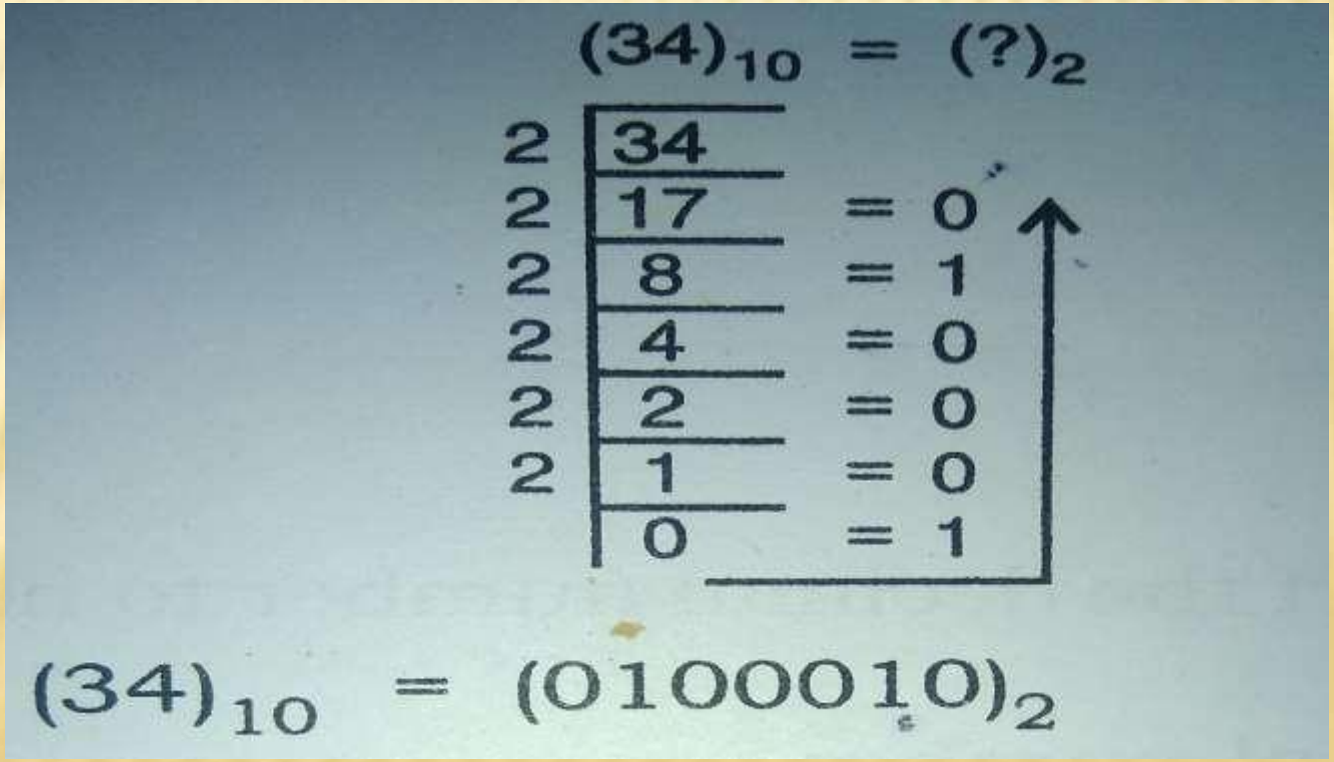
- Convert $(110.11)_2$ into decimal fractional value:
- $=(1x2^2+1x2^1+0x2^0)+(1x2^{-1}+1x2^{-2})$
- $=(4+2+0)+(1/2+1/4)$
- $=(6)+(0.50+0.25)$
- $=(6.75)_{10}$
- This is your answer.

DECIMAL TO BINARY FRACTIONAL CONVERSION

- To convert decimal fraction to binary fraction, following rules are followed:-
- (a) Write decimal number.
- (b) Integer part is divided by 2 and remainders are noted down from bottom to top.
- (c) The fractional part is multiplied by 2 until fractional part becomes same or approximately near to 0 then stop the process.
- (d) Merge the results of Integer and fractional value and you will get your final answer.

EXAMPLE

- Convert $(34.4)_{10}$ into binary number.
- First we convert (34) into its binary equivalent.



- Now, here we convert the fractional part.

$$(.4)_{10} = (?)_2$$

$$0.4 \times 2 = 0.8 = 0$$

$$0.8 \times 2 = 1.6 = 1$$

$$0.6 \times 2 = 1.2 = 1$$

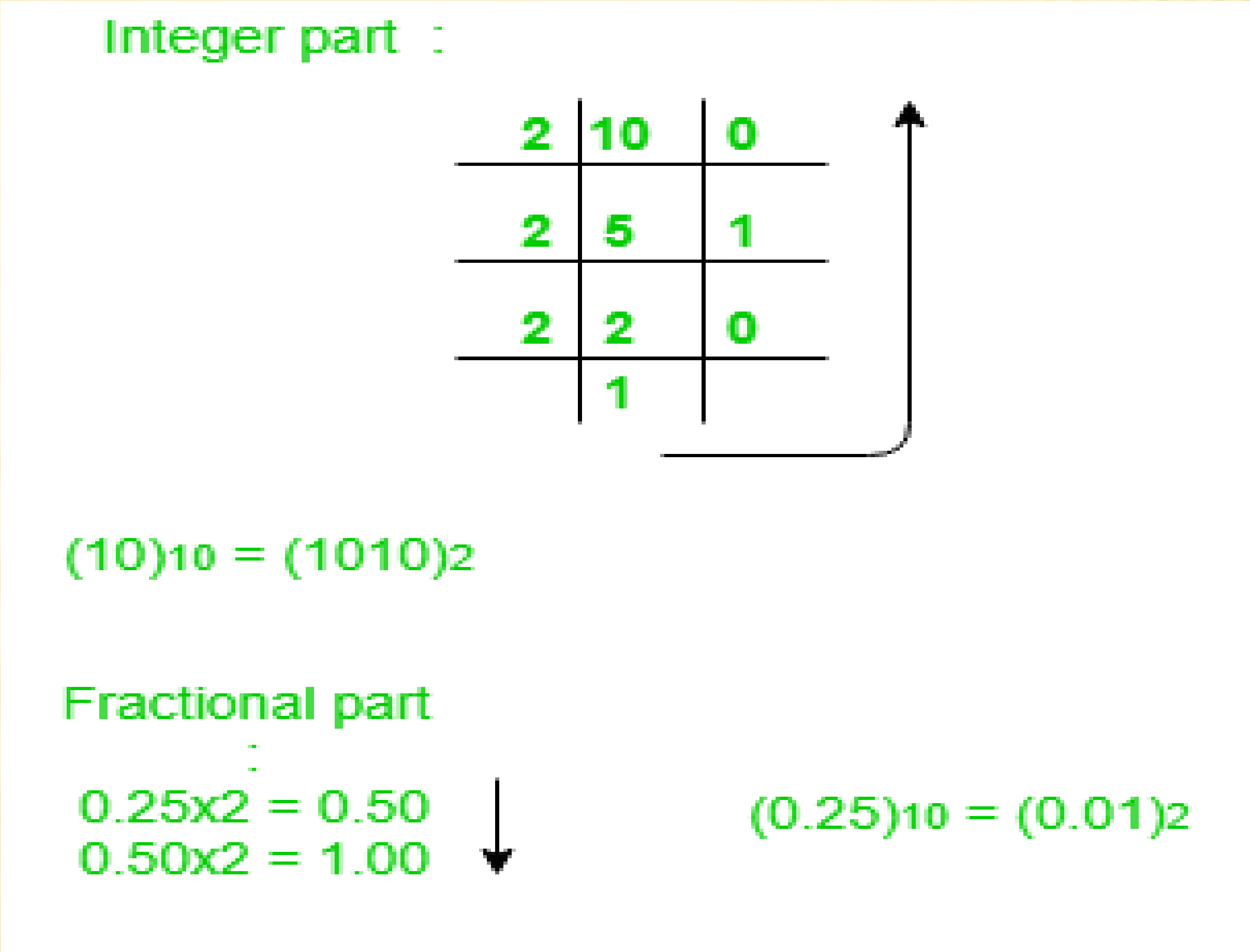
$$0.2 \times 2 = 0.4 = 0$$

$$(.4)_{10} = (.0110)_2$$

$$(34.4)_{10} = (?)_2 = (0100010.0110)_2.$$

ONE MORE EXAMPLE

Convert $(10.25)_{10}$ into binary number.



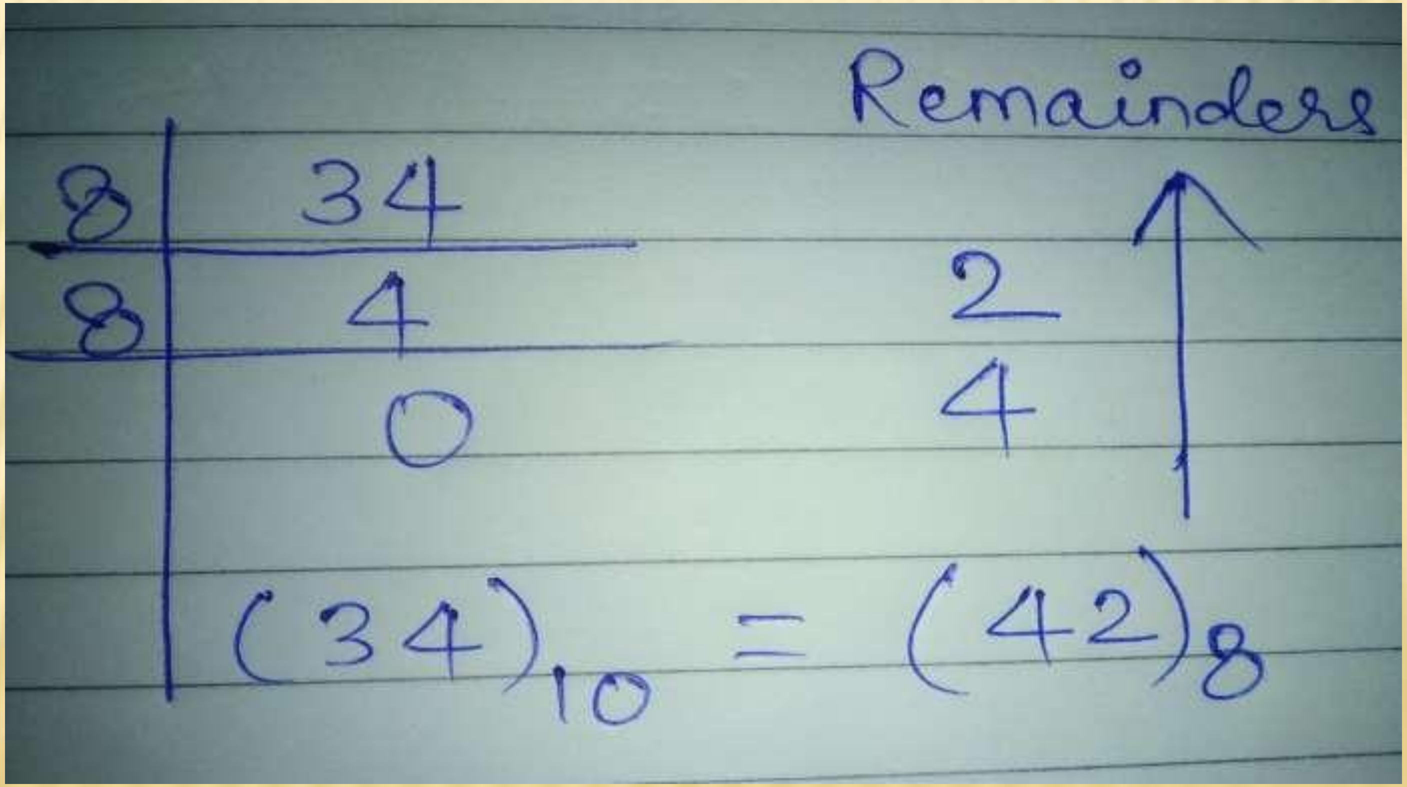
- Note: Keep multiplying the fractional part with 2 until decimal part 0.00 is obtained.
- $(0.25)_{10} = (0.01)_2$
- Answer: $(10.25)_{10} = (1010.01)_2$

DECIMAL TO OCTAL FRACTIONAL CONVERSION

- To convert decimal fraction to octal fraction, following rules are followed:-
- (a) Write decimal number.
- (b) Integer part is divided by 8 and remainders are noted down from bottom to top.
- (c) The fractional part is multiplied by 8 until fractional part becomes same or approximately near to 0 then stop the process.
- (d) Merge the results of Integer and fractional value and you will get your final answer.

EXAMPLE

- Convert $(34.4)_{10}$ into octal number.
- First we convert (34) into its octal number.



- Now, here we convert the fractional part.

Example: $(.4)_{10} = (?)_8$

$$0.4 \times 8 = 3.2 \Rightarrow 3$$
$$0.2 \times 8 = 1.6 \Rightarrow 1$$
$$0.6 \times 8 = 4.8 \Rightarrow 4$$
$$0.8 \times 8 = 6.4 \Rightarrow 6$$

i.e. $(.4)_{10} = (.3146)$

Example: $(34.4)_{10} = (?)_8$

$\Rightarrow (42.3146)_8$

OCTAL TO DECIMAL FRACTIONAL CONVERSION

- To convert any octal fraction to Decimal fraction, the following rules are followed:-
- (a) Write the octal number.
- (b) Multiply each digit of given number with power of position.
- (c) Before the point, power will be in terms of positive number and after the point power will be in negative number.

EXAMPLE

- Convert octal number $(7.12172)_8$ into decimal form.
- $= 7x8^0 + 1x8^{-1} + 2x8^{-2} + 1x8^{-3} + 7x8^{-4} + 2x8^{-5}$
- $= 7 + 0.125 + 0.03125 + 0.001953125 + 0.001708984375 + 0.00006103515624$
- $= 10.1599...$
- $= (10.16)_{10}$ (approx. value)

ONE MORE EXAMPLE

- Convert $(2\ 1\ .\ 2\ 1)_8 = (?)_{10}$
- $= (2\ 1\ .\ 2\ 1)_8$
- $= (2 \times 8^1 + 1 \times 8^0) + (2 \times 8^{-1} + 1 \times 8^{-2})$
- $= (2 \times 8 + 1 \times 1) + (2 \times (1 / 8) + 1 \times (1 / 64))$
- $= (16 + 1) + (0.25) + (0.015625)$
- $= 17 + 0.265625$
- $= 17.265625$
- Therefore $(2\ 1\ .\ 2\ 1)_8 = (1\ 7\ .\ 2\ 6\ 5\ 6\ 2\ 5)_{10}$

DECIMAL TO HEXADECIMAL FRACTIONAL CONVERSION

- To convert decimal fraction to Hexadecimal fraction, following rules are followed:-
- (a) Write decimal number.
- (b) Integer part is divided by 16 and remainders are noted down from bottom to top.
- (c) The fractional part is multiplied by 16 until fractional part becomes same or approximately near to 0 then stop the process.
- (d) Merge the results of Integer and fractional value and you will get your final answer.

EXAMPLE

$(374.37)_{10}$

16	374	
16	23	6
16	1	7
	0	1

$0.37 \times 16 = 5.92 = 0.92$ with Carry 5

$0.92 \times 16 = 14.72 = 0.72$ with Carry 14 (E)

$0.72 \times 16 = 11.52 = 0.52$ with Carry 11 (B)

$0.52 \times 16 = 8.32 = 0.32$ with Carry 8

$(176)_{16}$

Integer Part

$(0.5EB8)_{16}$

Fraction Part

$(374.37)_{10} = (176.5EB8)_{16}$

ONE MORE EXAMPLE

Decimal to hexadecimal

- The conversion method of decimal to hexadecimal is the same as that of decimal to binary except that the base taken is 16 instead of 2.
- For example, to convert 765.245_{10} to the hexadecimal equivalent, do the following:

Integer Part

16	765
16	47 - 13
16	2 - 15
	0 - 2

Fractional Part

$$\begin{array}{r} 0.245 \\ \times\ 16 \\ \hline 3.920 \\ \times\ 16 \\ \hline 14.720 \\ \times\ 16 \\ \hline 11.520 \end{array}$$

$765.245_{10} = 2FD.3EB_{16}$

HEXADECIMAL TO DECIMAL FRACTIONAL CONVERSION

- To convert any hexadecimal fraction to Decimal fraction, the following rules are followed:-
- (a) Write the hexadecimal number.
- (b) Multiply each digit of given number with power of position.
- (c) Before the point, power will be in terms of positive number and after the point power will be in negative number.

EXAMPLE

Hexadecimal fraction to decimal

Example

- Convert (1E.8C)16 to decimal

$16^1 \; 16^0 \; . \; 16^{-1} \; 16^{-2}$

1 E 8 C

$= (1 \times 16^1) + (14 \times 16^0) + (8 \times 16^{-1}) + (12 \times 16^{-2})$

$= 16+14+0.5+0.04688$

$= (30.54688)_{10}$

ONE MORE EXAMPLE

- Convert hexadecimal number $(1F.01B)_{16}$ into decimal number.
- Since value of Symbols: B and F are 11 and 15 respectively. Therefore equivalent decimal number is,
- $= (1 \quad 15 \quad . \quad 0 \quad 1 \quad 11)_{16}$
- $= (1x16^{1}+15x16^{0}+0x16^{-1}+1x16^{-2}+11x16^{-3})_{10}$
- $= (31.0065918)_{10}$ which is answer.

BINARY TO OCTAL FRACTIONAL CONVERSION

- Binary to octal fractional Conversion is very simple. We have to just follow these steps-
- (a) Take integer part and make grouping of 3 digits from right to left.
- (b) Take fractional part and make grouping of 3 digits from left to right.
- (c) Combine them with point.
- (d) Here is the answer.

EXAMPLE

- Convert binary number $(0110\ 011.1011)_2$ into octal number. Since there is binary point here and fractional part. So,
- $(0110\,011.1011)_2$
- $= (0\ 110\ 011\ .\ 101\ 1)_2$
- $= (110\ 011\ .\ 101\ 100)_2$
- $= (6\ 3\ .\ 5\ 4)_8$
- $= (63.54)_8$

OCTAL TO BINARY FRACTIONAL CONVERSION

- In octal to binary fractional Conversion, we follow these steps-
- (a) Write octal number.
- (b) Write the binary equivalent of each digit in 3 bits either they are integer digits or fractional digits.
- (c) Combine them with point.
- (d) Here is your answer.

EXAMPLE

- Convert$(541.63)_8$ into binary number.

$(541.63)_8$

5 = 101

4 = 100

1 = 001

6 = 110

3 = 011

Thus it can be written as

$(541.63)_8 = (101100001.110011)_2$

Octal to Binary Conversion

BINARY TO HEXADECIMAL FRACTIONAL CONVERSION

- Binary to Hexadecimal fractional Conversion is very simple. We have to just follow these steps-
- (a) Take integer part and make grouping of 4 digits from right to left.
- (b) Take fractional part and make grouping of 4 digits from left to right.
- (c) Combine them with point.
- (d) Here is the answer.

HEXADECIMAL TO BINARY FRACTIONAL CONVERSION

- In hexadecimal to binary fractional Conversion, we follow these steps-
- (a) Write hexadecimal number.
- (b) Write the binary equivalent of each digit in 4 bits either they are integer digits or fractional digits.
- (c) Combine them with point.
- (d) Here is your answer.

EXAMPLE FOR BOTH CONVERSIONS

Converting fractional numbers from from binary to hex and from hex to binary

- The same principle with integer numbers applies: Group four bits together, padding with zeros if necessary, but this time from *left to right*, and convert its 4-bit group to its corresponding Hexadecimal number and vice versa

- Examples:

$$(0.5A4C)_{16} = (0.0101101001001100)_2$$

$$(0.01001)_2 = (0.01001000)_2 = (0.48)_{16}$$

$$(3B.25)_{16} = (00111011.00100101)_2$$

$$(110.011)_2 = (0110.0110)_2 = (6.6)_{16}$$

OCTAL TO HEXADECIMAL FRACTIONAL CONVERSION

- In octal to hexadecimal fractional Conversion, we have to follow these two steps-
- (a) In this step, we first convert the given octal number into its equivalent fractional binary number.
- (b) In second step, we convert fractional binary number into its equivalent fractional Hexadecimal number.
- (c) Here is your answer.

EXAMPLE

- Convert (635.175)8 into Hexadecimal-

Example: Octal to Hexadecimal via Binary

1. Convert octal to binary
2. Use groups of four binary bits and express them as hexadecimal digits

- Example: Octal → Binary → Hexadecimal

$(6 \quad 3 \quad 5 \,.\, 1 \quad 7 \quad 5)_8$

110 011 101 . 001 111 101

Appended 0's

0001 1001 1101 . 0011 1110 1000

$= (1 \quad 9 \quad D \,.\, 3 \quad E \quad 8)_{16}$

- Represent Octal in binary
- Group into 4 bit groups for both the integer and fraction parts, **starting at the radix point**
- **Append** leading **0's** to the left of integer part and trailing 0's to the right of

HEXADECIMAL TO OCTAL FRACTIONAL CONVERSION

- In Hexadecimal to octal fractional Conversion, we have to follow these two steps-
- (a) In this step, we first convert the given Hexadecimal number into its equivalent fractional binary number.
- (b) In second step, we convert fractional binary number into its equivalent fractional octal number.
- (c) Here is your answer.

EXAMPLE

- Convert$(08B.FCD)_{16}$ to octal number.

First Conversion of Hexadecimal into Binary

0	8	B	.	F	C	D
↓	↓	↓		↓	↓	↓
0000	1000	1011		1111	1100	1101

$(08B.FCD)_{16} = (000010001011.111111001101)_2$

Again Conversion of Binary into Octal

000	010	001	011	.	111	111	001	101
0	2	1	3		7	7	1	5

$(000010001011.111111001101)_2 = (213.7715)_8$

So $(08B.FCD)_{16} = (213.7715)_8$

BINARY ARITHMETIC

- Addition, subtraction, multiplication and division are the four types of operation on which all the arithmetic operation depends of decimal number system.
- These are the pillars of binary arithmetic also.
- The first and perhaps the most important of them all is binary addition and it is the easiest of them all also.

BINARY ADDITION

- Binary number system uses only two digits 0 and 1 due to their addition is simple.
- There are four basic operations for binary addition, as mentioned .

Case	A	+	B	Sum	Carry
1	0	+	0	0	0
2	0	+	1	1	0
3	1	+	0	1	0
4	1	+	1	0	1

EXAMPLE-1

- Let us consider the addition of 11101 and 11011.

		1	1	1	1		← carry
		1	1	1	0	1	
(+)		1	1	0	1	1	
	1	1	1	0	0	0	

EXAMPLE-2

- Add 0011010 and 001100

$$
\begin{array}{r}
1\,1 \\
0\,0\,1\,1\,0\,1\,0 \\
+\,0\,0\,0\,1\,1\,0\,0 \\
\hline
0\,1\,0\,0\,1\,1\,0
\end{array}
$$

BINARY SUBTRACTION

- Subtraction and Borrow, these two words will be used very frequently for the binary subtraction.
- There are four rules of binary subtraction.

Case	A	-	B	Subtract	Borrow
1	0	-	0	0	0
2	1	-	0	1	0
3	1	-	1	0	0
4	0	-	1	0	1

EXAMPLE-1

- Consider the following example
- Subtract 1010 from 1100.

$$\begin{array}{cccccc} & & 0 & 10 & & \leftarrow \text{borrow} \\ & 1 & \cancel{1} & \cancel{0} & 0 & \\ (-) & 1 & 0 & 1 & 0 & \\ \hline & 0 & 0 & 1 & 0 & \\ \hline \end{array}$$

- The above subtraction is carried out through the following steps.
- 0 – 0 = 0
- For 0 – 1 = 1, taking borrow 1 and then 10 – 1 = 1
- For 1 – 0 , since 1 has already been given, it becomes 0 – 0 = 0
- 1 – 1 = 0
- Therefore the result is 0010.

EXAMPLE-2

- Subtract (101110) from (11100101)

$$
\begin{array}{r}
1\ 1\ 1\ 0\ 0\ 1\ 0\ 1 \\
-\quad 0\ 0\ 1\ 0\ 1\ 1\ 1\ 0 \\
\hline
1\ 0\ 1\ 1\ 0\ 1\ 1\ 1
\end{array}
$$

BINARY MULTIPLICATION

- Binary multiplication is similar to decimal multiplication.
- It is simpler than decimal multiplication because only 0s and 1s are involved.
- There are four rules of binary multiplication.

Case	A	x	B	Multiplication
1	0	x	0	0
2	0	x	1	0
3	1	x	0	0
4	1	x	1	1

EXAMPLE-1

- Multiply binary value 1001 by binary 101.

$$
\begin{array}{rr}
 & 1001 \\
 & \times\ 101 \\
\hline
 & 1001 \\
 & 0000 \\
+ & 1001 \\
\hline
 & 101101
\end{array}
$$

EXAMPLE-2

- Multiply binary value 1011 by binary 1101.

```
      1011
     x1101
  --------
      1011
     0000X
    1011XX
   1011XXX
  --------
  10001111
  --------
```

BINARY DIVISION

- The binary division is much easier than the decimal division when you remember the following division rules. The main rules of the binary division include:
- 1÷1 = 1
- 1÷0 = 0
- 0÷1 = Meaningless
- 0÷0 = Meaningless

EXAMPLE-1

- Solve the following binary calculation: 101101 ÷ 101

```
101) 101101 ( 1001
 (-) 101
     ------
        101
    (-) 101
     ------
          0
```

EXAMPLE-2

- Divide 11010 from 101

```
1 0 1)1 1 0 1 0(1 0 1 → quotient
      1 0 1
--------------------
      0 0 1 1 0
        1 0 1
--------------------
        0 0 1 → remainder
```

COMPLIMENTS

- Compliments are used in digital computers to simplify the subtraction and for logical manipulations.
- There are two categories of compliments:-

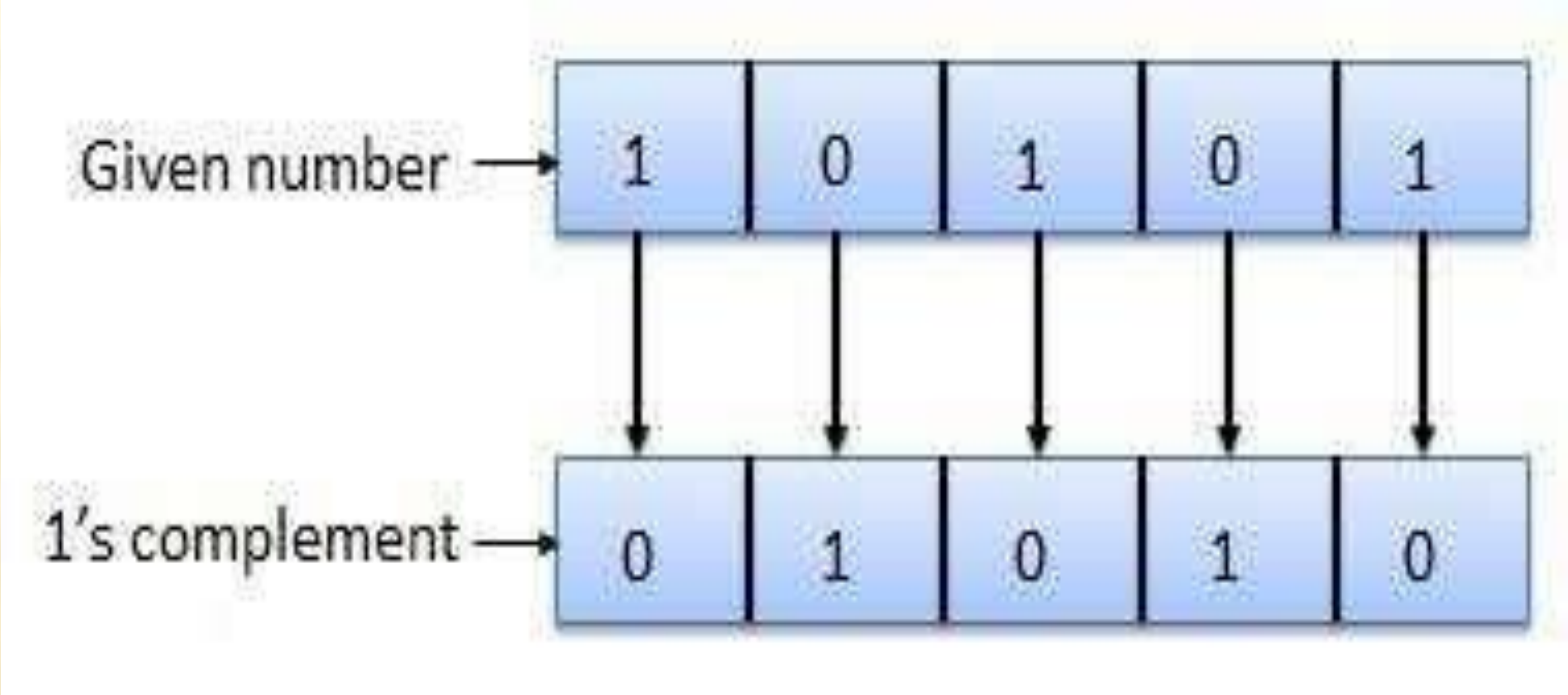
  (a) the radix (r's) compliment

  (b) the diminished radix (r-1)'s compliment
- When value of r is substituted, two types of compliments are received for binary and
- To be continued...

- two types of compliments are received for decimal numbers.
  - ✓ The two binary compliments are 2's compliments and 1's compliments.
  - ✓ And the two decimal compliments are 10's compliments and 9's compliments.

BINARY SYSTEM COMPLEMENTS

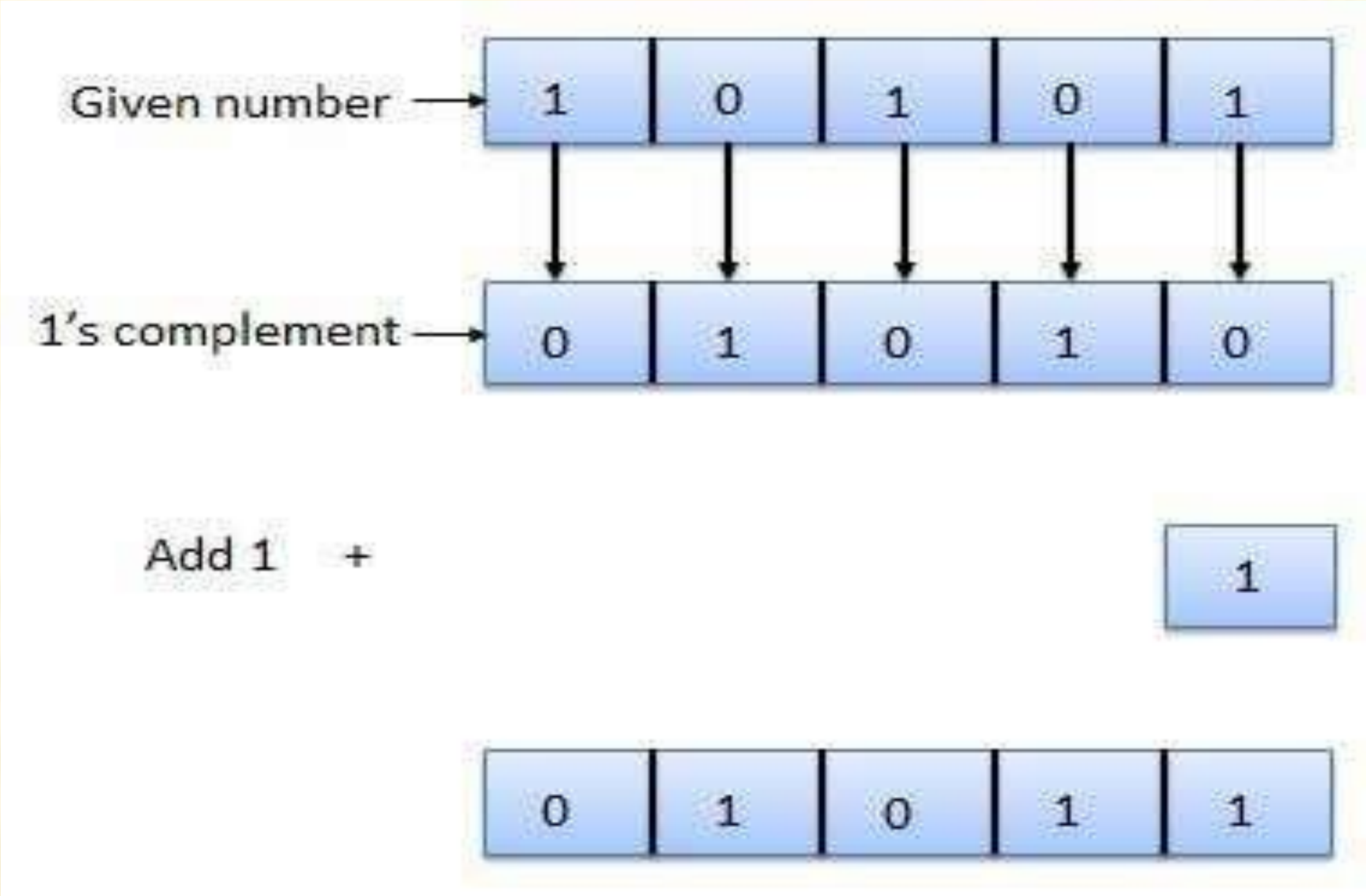
- **1's complement**
- The 1's complement of a number is found by changing all 1's to 0's and all 0's to 1's.
- Example of 1's Complement is as follows:-



BINARY SYSTEM COMPLIMENTS

- **2's complement**
- The 2's complement of binary number is obtained by adding 1 to the Least Significant Bit (LSB) of 1's complement of the number.
- 2's complement = 1's complement + 1

- To be continued.....


Given number
1 0 1 0 1
1's complement
0 1 0 1 0
Add 1 +
1
0 1 0 1 1

DECIMAL SYSTEM COMPLIMENTS

- 9's Compliments
- The 9's complement of a number is calculated by subtracting each digit of the number by 9.

2- Find the 9's complement of 546700 and 12389

The 9's complement of 546700 is 999999 - 546700= 453299

	9	9	9	9	9	9
-	5	4	6	7	0	0
	4	5	3	2	9	9

and the 9's complement of 12389 is
99999- 12389 = 87610.

		9	9	9	9	9
-		1	2	3	8	9
		8	7	6	1	0

DECIMAL SYSTEM COMPLIMENTS

- The 10's complement
- The 10's compliment of a number is calculated by subtracting each digit by 9 and then adding 1 to the result.
- Simply, by adding 1 to its 9's complement we can get its 10's complement value.

10 's complement of $(567)_{10}$ = 9's complement of $(567)_{10}$ + 1

9's complement of $(567)_{10}$ = 432 + 1

$$
\begin{array}{r}
4 \quad 3 \quad 2 \\
+ \quad 1 \\
\hline
\end{array}
$$

10 's complement of $(567)_{10}$ = 4 3 3

SUBTRACTION USING 9'S COMPLIMENT

- With the help of the 9's complement, the process of subtraction is done in a much easier way.
- For subtraction, we first have to find the 9's complement of the subtrahend and then we will add this complement value with the minuend.
- There are two possible cases when we subtract the numbers using 9's complement.

CASE 1: WHEN THE SUBTRAHEND IS SMALLER THAN THE MINUEND.

- For subtracting the smaller number from the larger number using 9's complement, we will find the 9's complement of the subtrahend, and then we will add this complement value with the minuend.
- By adding both these values, the result will come in the formation of carry.
- At last, we will add this carry to the result obtained previously.

EXAMPLE-1

When subtrahend is smaller than the minuend

General Subtraction

$$
\begin{array}{r}
841 \\
-\ 329 \\
\hline
512
\end{array}
$$

Subtraction using 9's Complement

$$
\begin{array}{rl}
841 & \\
+\ 670 & \leftarrow \text{(9's Complement of 329)} \\
\hline
1\,511 & \\
+1 & \\
\hline
512 &
\end{array}
$$

EXAMPLE-2

When smaller number is to be subtracted from larger one

Regular subtraction

```
 678
-234
----
 444
```

Subtraction using 9's complement

```
 678
+765 ←(9's complement of 234)
----
1443
  +1
----
 444
```

CASE 2: WHEN THE SUBTRAHEND IS GREATER THAN THE MINUEND.

- In this case, when we add the complement value and the minuend, the result will not come in the formation of carry.
- This indicates that the number is negative, and for finding the final result, we need to find the 9's complement of the result.

EXAMPLE-1

When subtrahend is greater than the minuend

General Subtraction

$$\begin{array}{r} 841 \\ -\ 983 \\ \hline -\ 142 \end{array}$$

Subtraction using 9's Complement

$$\begin{array}{r} 841 \\ +016 \\ \hline 857 \\ \downarrow \\ -142 \end{array}$$

+016 ← (9's Complement)

857 (No carry indicates -ve value)

−142 (9's Complement of result)

EXAMPLE-2

When larger number is to be subtracted from smaller one

Regular subtraction

```
  228
- 485
-----
- 257
```

Subtraction using 9's complement

```
 228
+514  ←(9's complement of 485)
----
 742  (No carry indicates –ve value)
  ↓
- 257 (9's complement of result)
```

10'S COMPLIMENT

- The 10's complement is also used to find the subtraction of the decimal numbers.
- The 10's complement of a number is calculated by subtracting each digit by 9 and then adding 1 to the result.
- Simply, by adding 1 to its 9's complement we can get its 10's complement value.

EXAMPLE

- The **10’s complement** is obtained by adding 1 to the 9’s complement:
  - Example: The 10’s complement of 546700 is
  - 999999 – 546700 = 453299 <u>+ 1</u> = 453300
  - **<u>Or</u>**, 1000000 – 546700 = 453300

SUBTRACTION USING 10'S COMPLIMENT

- For subtracting two numbers using 10's complement, we first have to find the 10's complement of the subtrahend and then we will add this complement value with the minuend.
- There are two possible cases when we subtract the numb using 10's complement.

CASE 1: WHEN THE SUBTRAHEND IS SMALLER THAN THE MINUEND.

- For subtracting subtraction using 10's complement, we will find the 10's complement of the subtrahend and then we will add this complement value with the minuend.
- By adding both these values, the result will come in the formation of carry.
- We ignore this carry and the remaining digits will be the answer.

EXAMPLE -1

When subtrahend is smaller than the minuend

General Subtraction

$$\begin{array}{r} 821 \\ -\ 413 \\ \hline 408 \end{array}$$

Subtraction using 10's Complement

$$\begin{array}{rl} 821 & \\ +\ 586 & \text{(10's Complement of 413)} \\ \hline 1\,408 & \text{(Ignore the carry)} \\ \hline 408 & \end{array}$$

EXAMPLE-2

When smaller number is to be subtracted from larger one

Regular subtraction

$$\begin{array}{r} 678 \\ -234 \\ \hline 444 \end{array}$$

Subtraction using 10's complement

$$\begin{array}{rl} 678 & \\ +766 & \leftarrow \text{(10's complement of 234)} \\ \hline 1444 & \leftarrow \text{(Ignore the carry)} \\ \hline 444 & \end{array}$$

CASE 2: WHEN THE SUBTRAHEND IS GREATER THAN THE MINUEND.

- In this case, when we add the complement value and the minuend, the result will not come in the formation of carry.
- This indicates that the number is negative and for finding the final result,
- we need to find the 10's complement of the result obtained by adding complement value of subtrahend and minuend.

EXAMPLE -1

When subtrahend is smaller than the minuend

General Subtraction

$$
\begin{array}{r}
325 \\
-\,641 \\
\hline
-\,{\color{red}316}
\end{array}
$$

Subtraction using 10's Complement

$$
\begin{array}{rl}
325 & \\
+\,359 & \leftarrow \text{(10's Complement of 641)} \\
\hline
684 & \leftarrow \text{(No carry indicate negative -ve value)} \\
\hline
\downarrow & \\
-\,{\color{red}316} & \leftarrow \text{(10's Complement of result)}
\end{array}
$$

EXAMPLE-2

When larger number is to be subtracted from smaller one

Regular subtraction

$$\begin{array}{r} 228 \\ -\ 485 \\ \hline -\ 257 \end{array}$$

Subtraction using 10's complement

$$\begin{array}{rl} 228 & \\ +515 & \leftarrow \text{(10's complement of 485)} \\ \hline 743 & \text{(No carry indicates –ve value)} \\ \downarrow & \\ -\ 257 & \text{(10's complement of result)} \end{array}$$

INTRODUCTION OF BITS, BYTES & MORE

- Bit:- The bit is a basic unit of information in computing and digital communications.
- The bit represents a logical state with one of two possible values commonly represented as either 1 or 0.
- But other representations such as true/false, yes/no, or o are common.

CONVERSION TABLE OF BITS/BYTES

- 1 Nibble = 4 bits

Term (Abbreviation)	Approximate Size
Byte (B)	8 bits
Kilobyte (KB)	1024 bytes / 10^3 bytes
Megabyte (MB)	1024 KB / 10^6 bytes
Gigabyte (GB)	1024 MB / 10^9 bytes
Terabyte (TB)	1024 GB / 10^{12} bytes
Petabyte (PB)	1024 TB / 10^{15} bytes
Exabyte (EB)	1024 PB / 10^{18} bytes
Zettabyte (ZB)	1024 EB / 10^{21} bytes
Yottabyte (YB)	1024 ZB / 10^{24} bytes