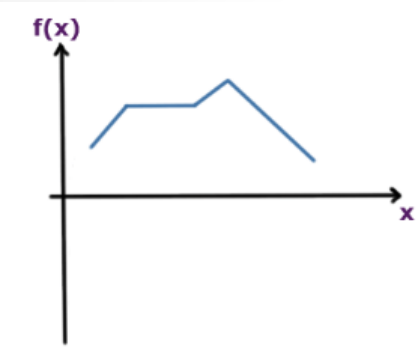
Signals

Signal : Signal is a function, that represents the variation of a physical quantity with respect to any parameter.



EXAMPLES :

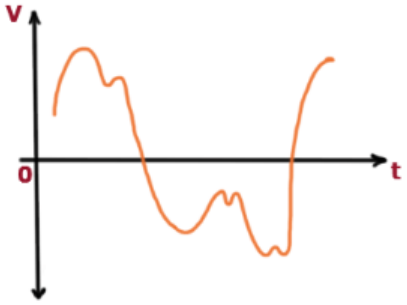
Motion: The motion of an object can be considered to be a signal.

Sound : sound is a vibration of a medium (such as air).

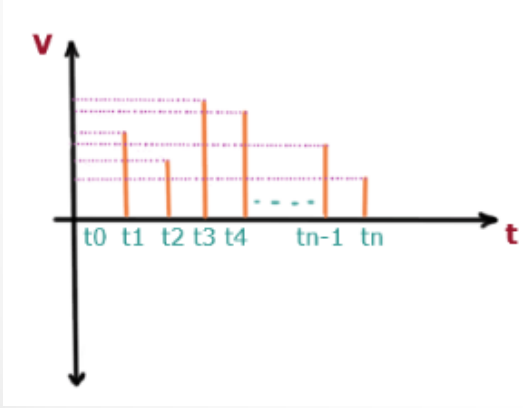
Image : A picture or image consists of a brightness or color signal.

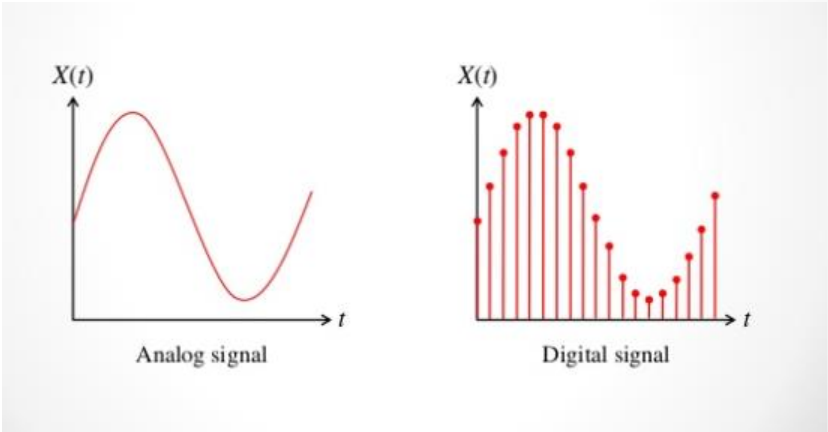
Video :A video signal is a sequence of images

•**Analog Signal:** Analog signal is a signal which can take any value within the given limit



•**Discrete Time Signal:** The signal which is defined for discrete intervals of time is called discrete time signal





Why Digital Electronics?

•All real life signals are analog in nature and at first sight, it seems use of analog is much better as compared to digital signal. But digital signals have various advantages over the analog signal like noise immunity. Digital signal is used in communication process to **minimize** the effect of **noise**

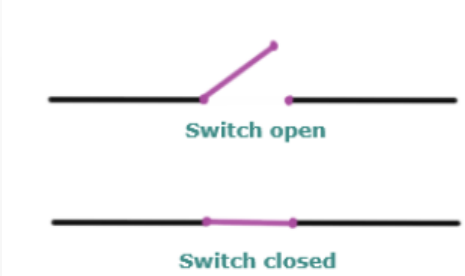
•Digital Signals **carry more** information per unit time as compared to analog signals
•**Quality** of digital signal is better over long distance transmission
•We can **encrypt** digital signals
•**Noise** removal is easy in digital signals

Important points:

•We use analog to digital converter to convert analog signal to digital signal
•Computer, calculator, digital watch, measuring instruments are some examples of digital system
•We use digital to analog converter to convert digital signal back to analog signal

•0V is represented by "0.
•5V is represented by "1.
•We can represent two levels by using one switch.

If switch is open it is OFF(0) and
if switch is closed it is ON(1) .



•If *n* is number of levels and *m* is number of switches, then

n=2 power m.

Chapter - I
Number System

Chapter I – Number System

- **Introduction to digital signal, Advantages of Digital System over analog systems**
  - ✓ Number Systems: Different types of number systems(Binary, Octal, Hexadecimal), conversion of number systems,
  - ✓ Binary arithmetic: Addition, Subtraction, Multiplication, Division.
  - ✓ Subtraction using 1's complement and 2's complement
- **Codes**
  - ✓ Codes -BCD, Gray Code, Excess-3, ASCII code
  - ✓ BCD addition, BCD subtraction using 9's and 10' complement
- **(Numericals based on above topic)**.

Chapter I – Number System

- **Introduction to digital signal, Advantages of Digital System over analog systems**

Number System

- ✓ A number system defines a set of values used to represent quantity.

Different Number Systems

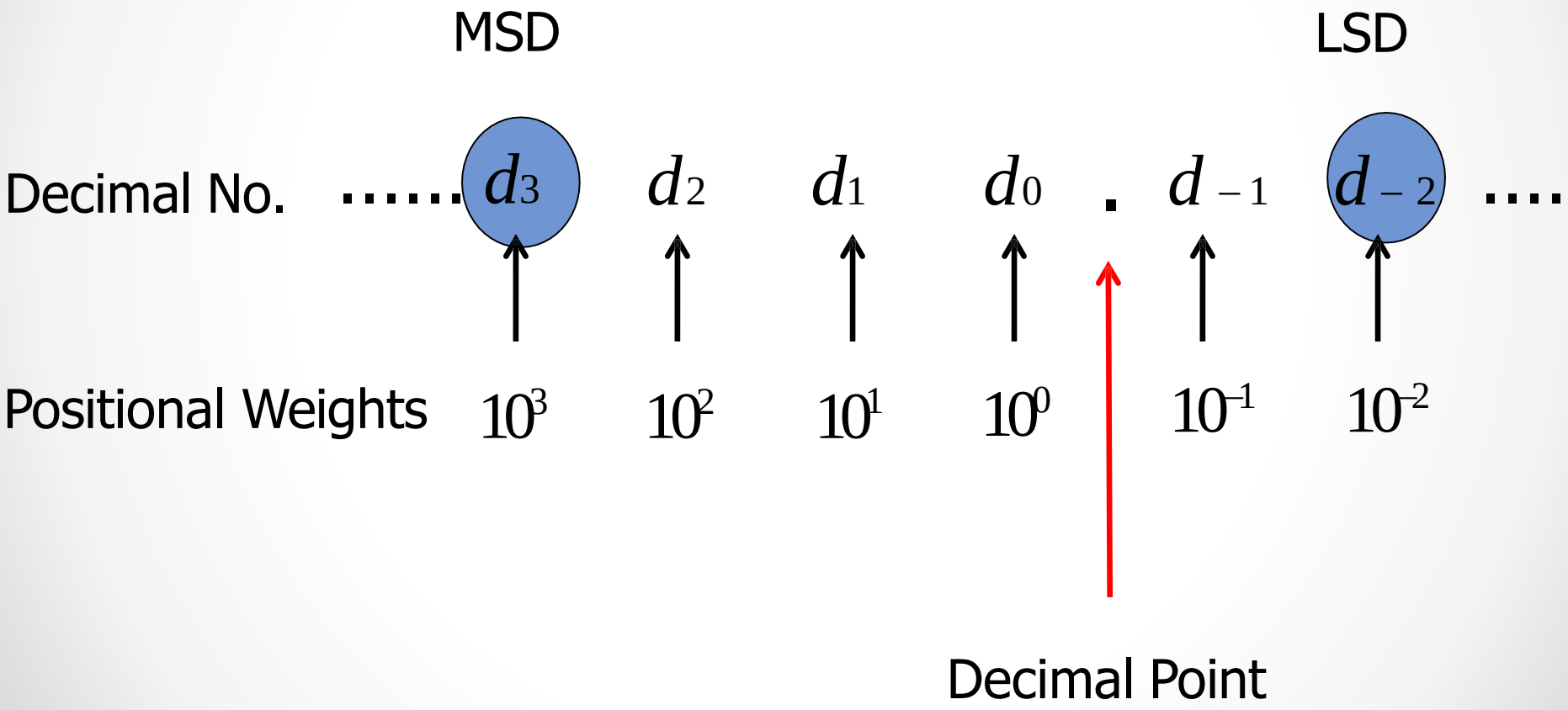
- ✓ Decimal Number System
  - Base 10
- ✓ Binary Number System
  - Base 2
- ✓ Octal Number System
  - Base 8
- ✓ Hexadecimal Number System
  - Base 16

Decimal Number System

- ✓ Decimal number system contains ten unique symbols 0,1,2,3,4,5,6,7,8 and 9
- ✓ Since counting in decimal involves ten symbols, we can say that its base or radix is ten.
- ✓ It is a positional weighted system

Decimal Number System

Structure:



Binary Number System

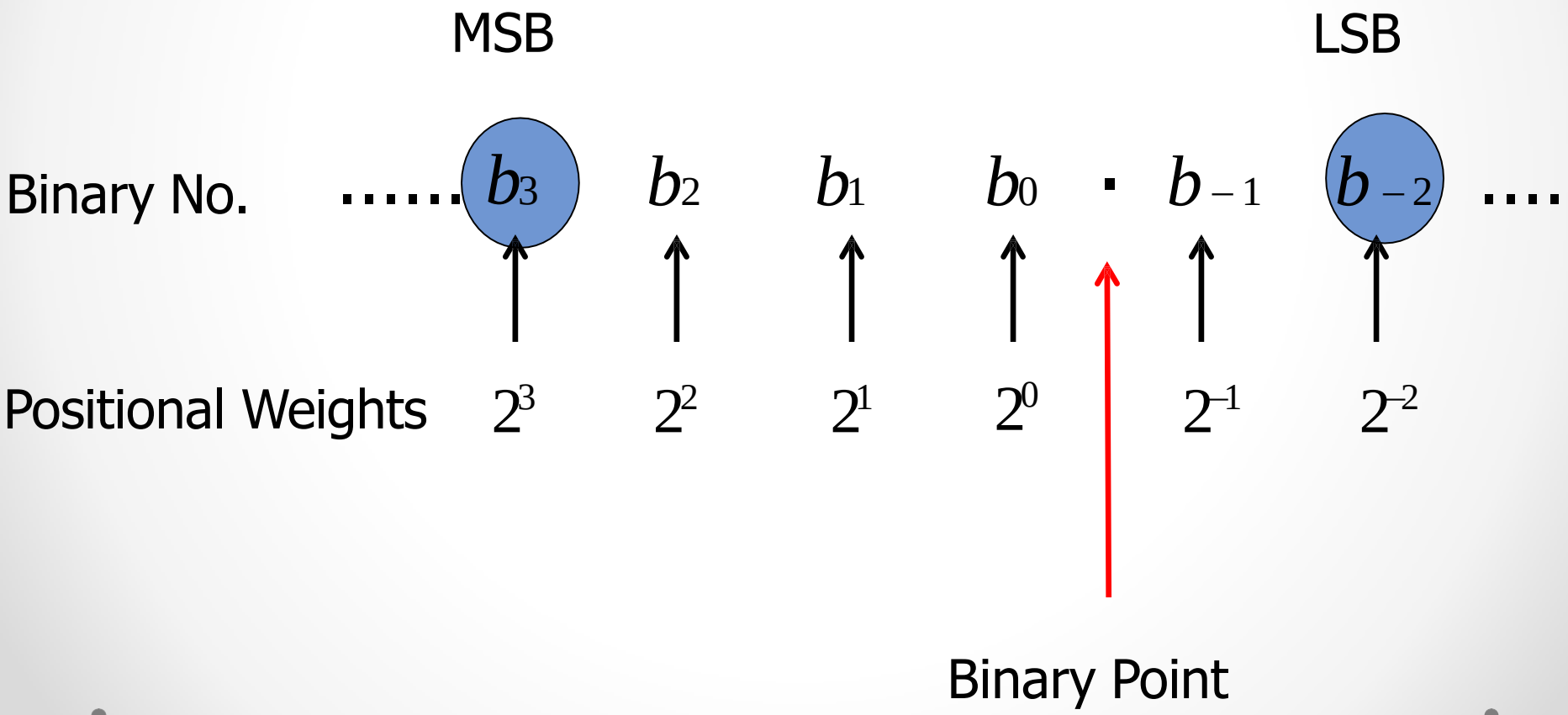
- ✓ Binary number system is a positional weighted system
- ✓ It contains two unique symbols 0 and 1
- ✓ Since counting in binary involves two symbols, we can say that its base or radix is two.

Binary Number System

- ✓ A binary digit is called a "Bit"
- ✓ A binary number consists of a sequence of bits, each of which is either a 0 or a 1.
- ✓ The binary point separates the integer and fraction parts

Binary Number System

Structure:



Binary Number System

Decimal No.	Binary No.
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111

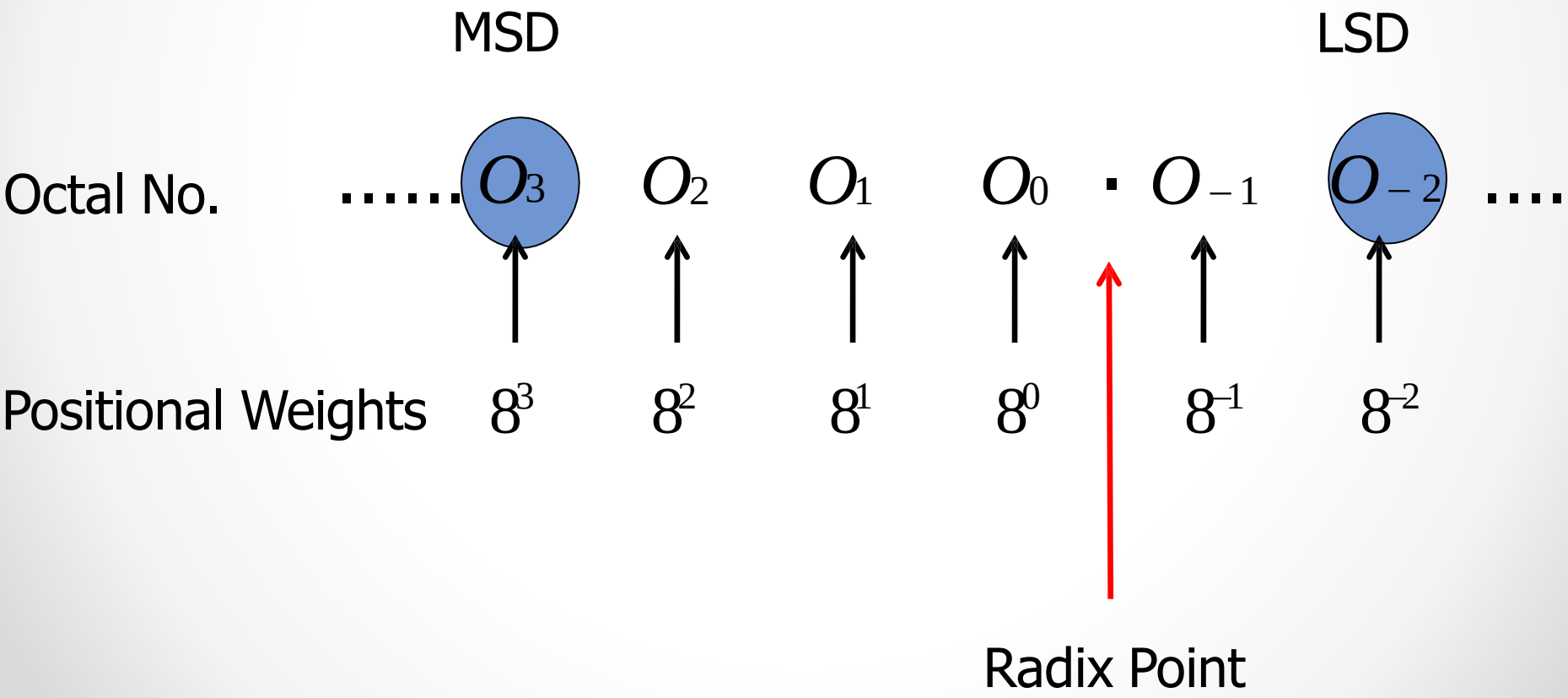
Decimal No.	Binary No.
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

Octal Number System

- ✓ Octal number system is a positional weighted system
- ✓ It contains eight unique symbols 0,1,2,3,4,5,6 and 7
- ✓ Since counting in octal involves eight symbols, we can say that its base or radix is eight.
- ✓ The largest value of a digit in the octal system will be 7.

Octal Number System

Structure:



Octal Number System

Decimal No.	Binary No.	Octal No.
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	10
9	1001	11
10	1010	12
11	1011	13
12	1100	14
13	1101	15

Hexadecimal Number System (HEX)

- ✓ Binary numbers are long. These numbers are fine for machines but are too lengthy to be handled by human beings. So there is a need to represent the binary numbers concisely.

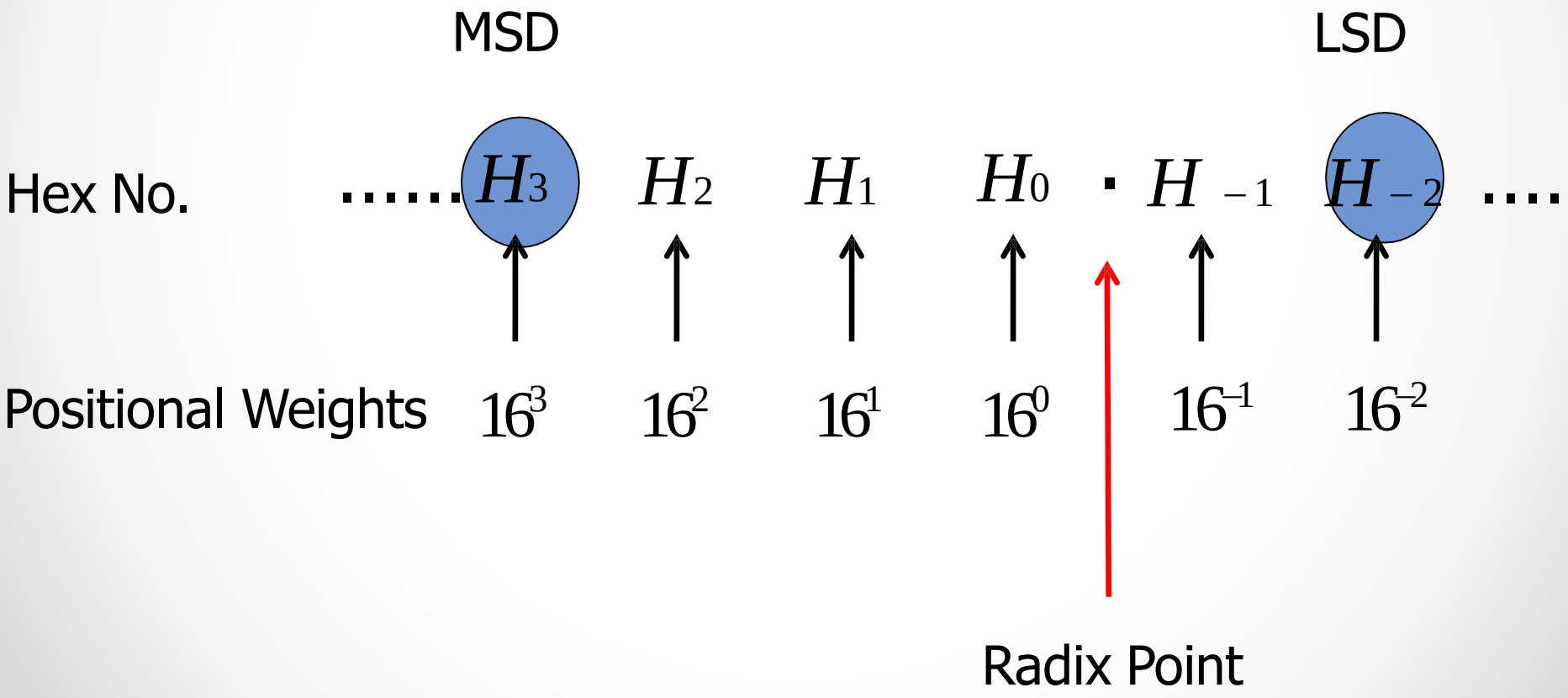
- ✓ One number system developed with this objective is the hexadecimal number system (or Hex)

Hexadecimal Number System (HEX)

- ✓ Hex number system is a positional weighted system
- ✓ It contains sixteen unique symbols 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E and F.
- ✓ Since counting in hex involves sixteen symbols, we can say that its base or radix is sixteen.

Hexadecimal Number System (HEX)

Structure:



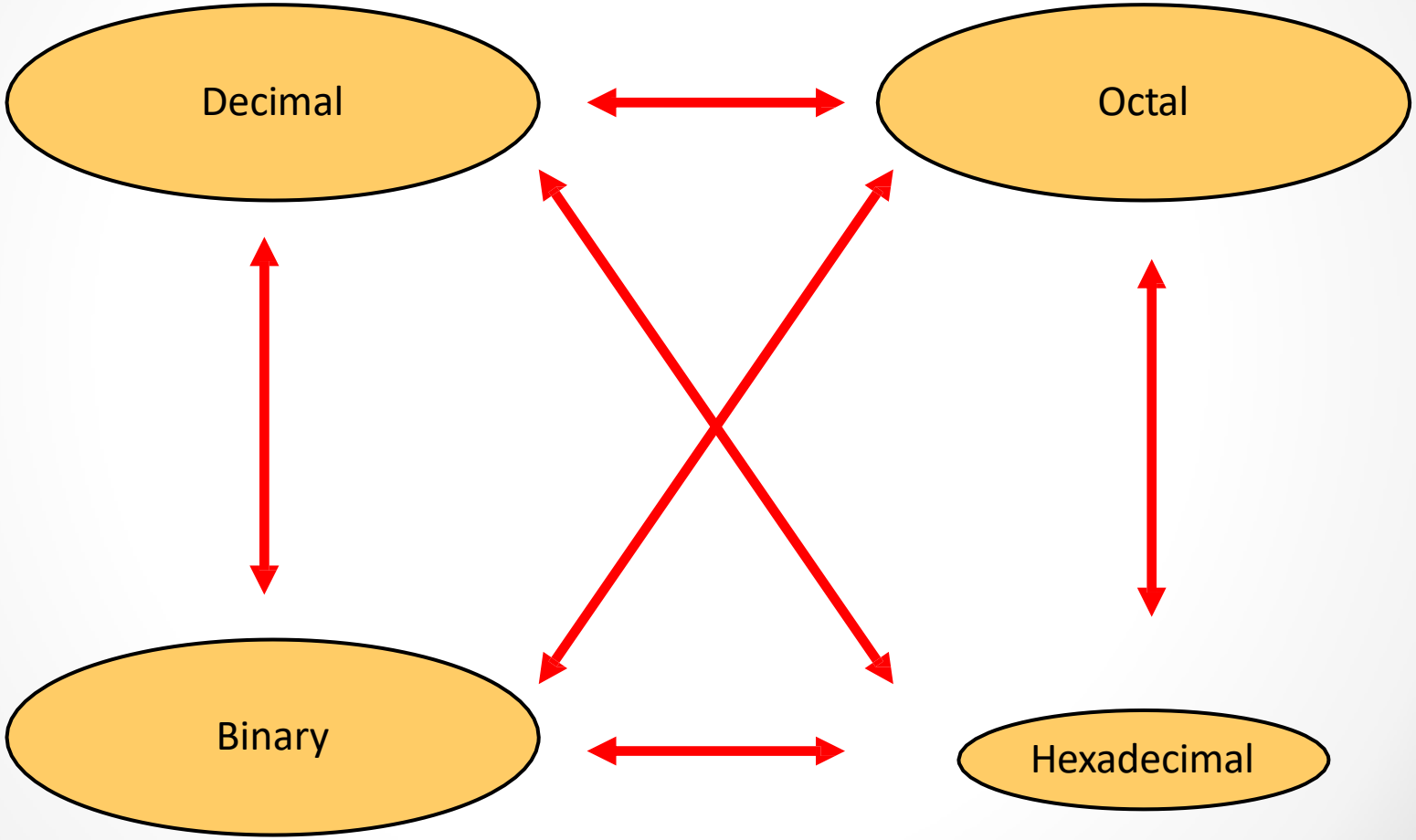
Hexadecimal Number System (HEX)

Decimal No.	Binary No.	Hex No.
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7

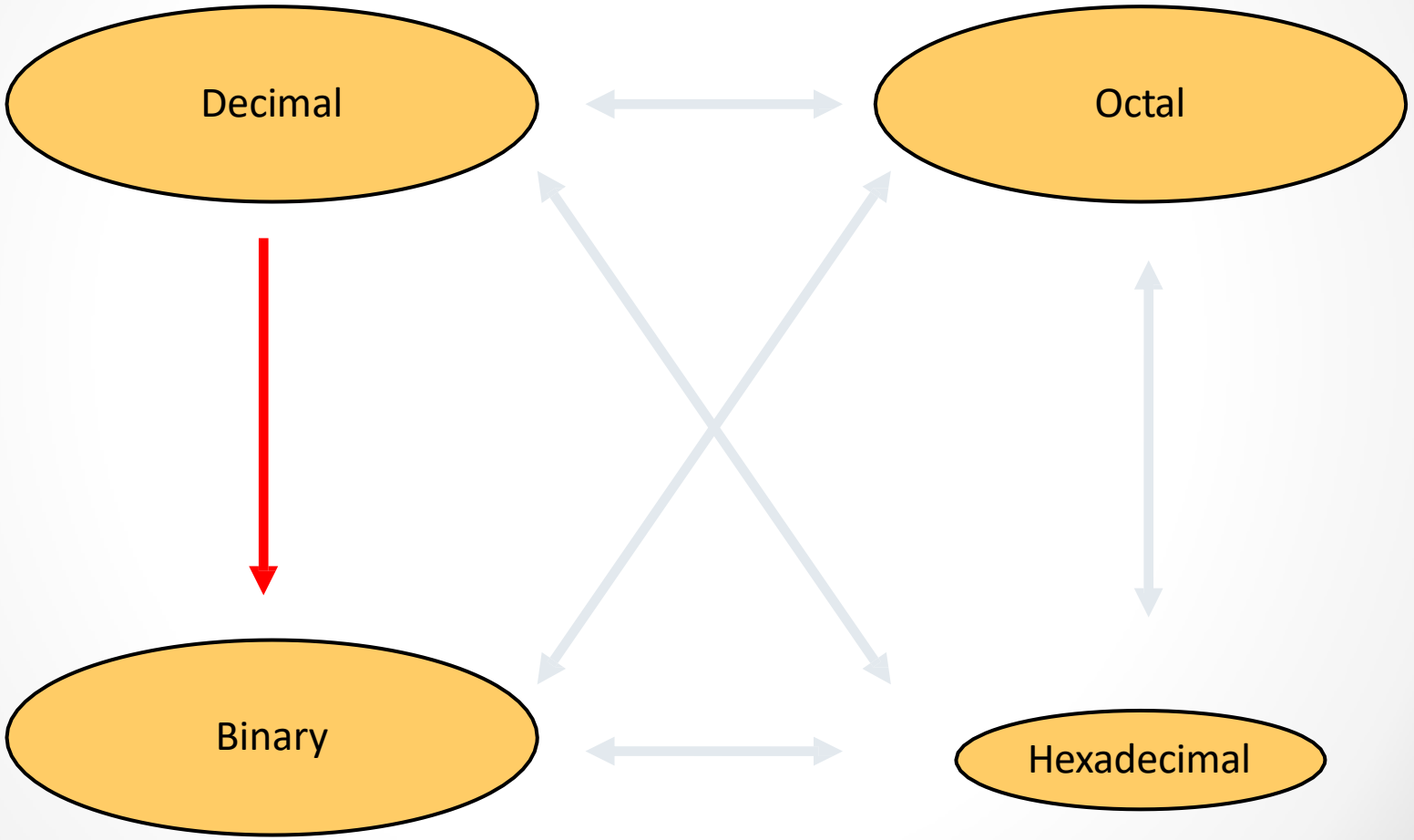
Decimal No.	Binary No.	Hex No.
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Conversion Among Bases

Possibilities



Conversion from Decimal Number to Binary Number



Conversion of Decimal number into Binary number (Integer Number)

Procedure:

1. Divide the decimal no by the base 2, noting the remainder.
2. Continue to divide the quotient by 2 until there is nothing left, keeping the track of the remainders from each step.
3. List the remainder values in reverse order to
   - d the number's binary equivalent

Example: Convert 105 decimal number in to it's equivalent binary number.

Example: Convert 105 decimal number in to it's equivalent binary number.

Example: Convert 105 decimal number in to it's equivalent binary number.

2	105	
2	52	1

Example: Convert 105 decimal number in to it's equivalent binary number.

2	105	
2	52	1
2	26	0

Example: Convert 105 decimal number in to it's equivalent binary number.

2	105	
2	52	1
2	26	0
2	13	0

Example: Convert 105 decimal number in to it's equivalent binary number.

2	105	
2	52	1
2	26	0
2	13	0
2	6	1

Example: Convert 105 decimal number in to it's equivalent binary number.

2	105	
2	52	1
2	26	0
2	13	0
2	6	1
2	3	0

Example: Convert 105 decimal number in to it's equivalent binary number.

2	105	
2	52	1
2	26	0
2	13	0
2	6	1
2	3	0
2	1	1

Example: Convert 105 decimal number in to it's equivalent binary number.

2	105	
2	52	1
2	26	0
2	13	0
2	6	1
2	3	0
2	1	1
	0	1

Example: Convert 105 decimal number in to it's equivalent binary number.

2	105	
2	52	1
2	26	0
2	13	0
2	6	1
2	3	0
2	1	1
	0	1

LSB

MSB

$$(105)_{10} = (1101001)_2$$

Conversion of Decimal number into Binary number (Fractional Number)

Procedure:

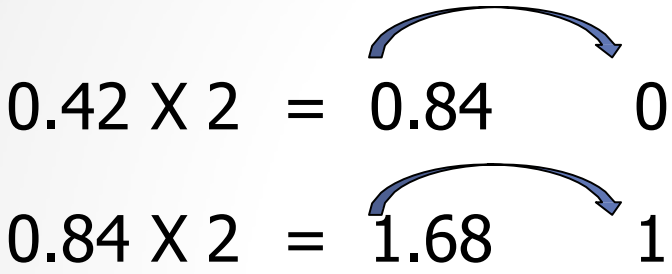
1. Multiply the given fractional number by base 2.
2. Record the carry generated in this multiplication as MSB.
3. Multiply only the fractional number of the product in step 2 by 2 and record the carry as the next bit to MSB.
4. Repeat the steps 2 and 3 up to 5 bits. The last carry will represent the LSB of equivalent binary number

Example: Convert 0.42 decimal number in to it's equivalent binary number.

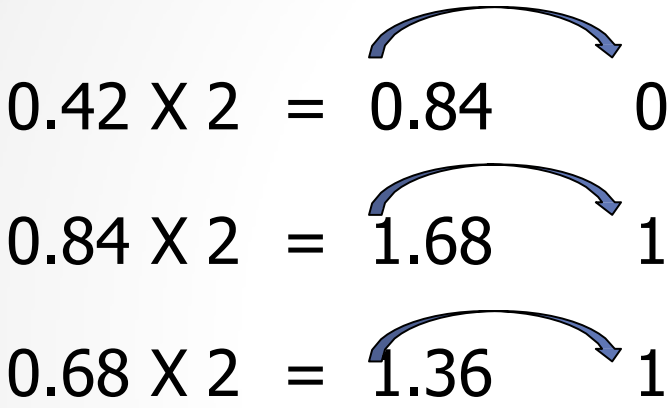
Example: Convert 0.42 decimal number in to it's equivalent binary number.

0.42 X 2 = 0.84 0

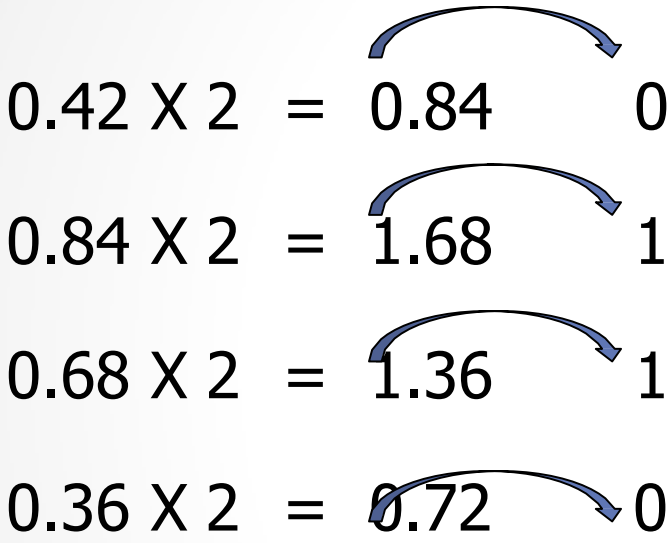
Example: Convert 0.42 decimal number in to it's equivalent binary number.



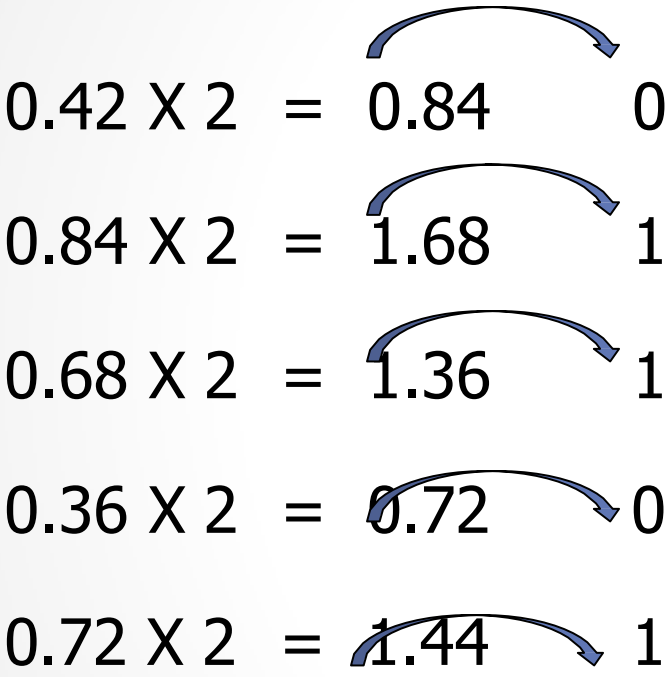
Example: Convert 0.42 decimal number in to it's equivalent binary number.



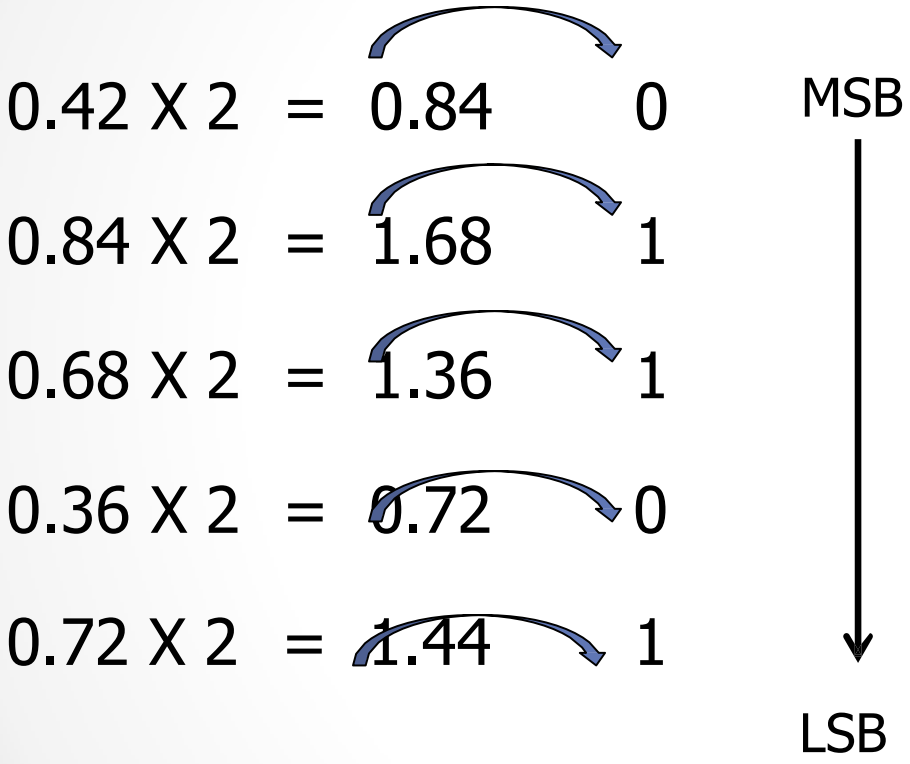
Example: Convert 0.42 decimal number in to it's equivalent binary number.



Example: Convert 0.42 decimal number in to it's equivalent binary number.



Example: Convert 0.42 decimal number in to it's equivalent binary number.



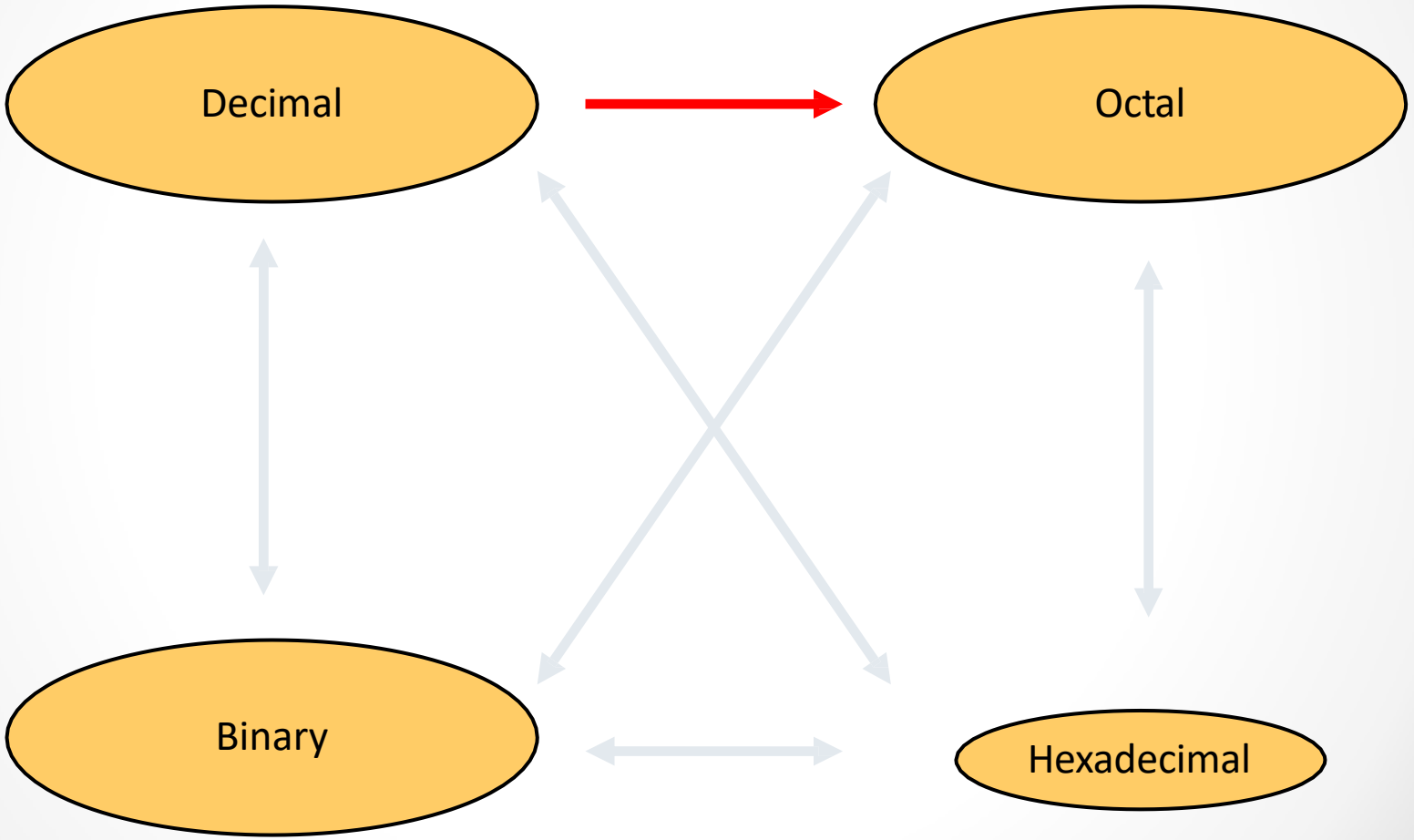
$$(0.42)_{10} = (0.01101)_2$$

Exercise

- Convert following Decimal Numbers in to its equivalent Binary Number:

1. $(1248.56)_{10} = (\ ?\ )_2$
2. $(8957.75)_{10} = (\ ?\ )_2$
3. $(420.6)_{10} = (\ ?\ )_2$
4. $(8476.47)_{10} = (\ ?\ )_2$

Conversion from Decimal Number to Octal Number



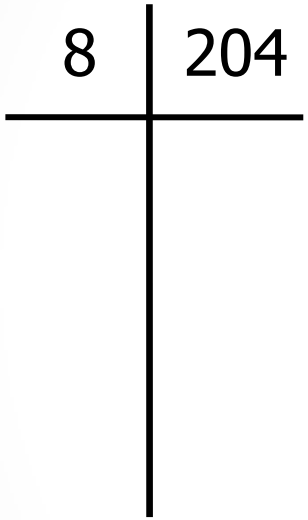
Conversion of Decimal Number into Octal Number (Integer Number)

Procedure:

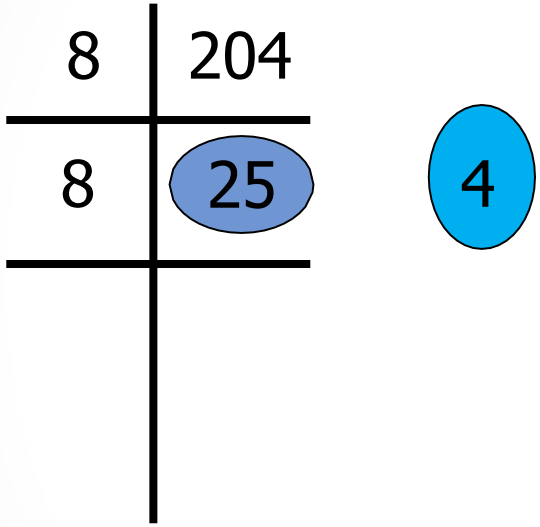
1. Divide the decimal no by the base 8, noting the remainder.
2. Continue to divide the quotient by 8 until there is nothing left, keeping the track of the remainders from each step.
3. List the remainder values in reverse order to find the number's octal equivalent

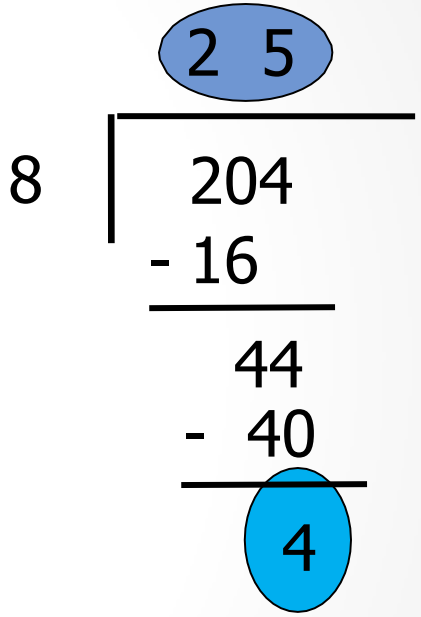
Example: Convert 204 decimal number in to it's equivalent octal number.

Example: Convert 204 decimal number in to it's equivalent octal number.

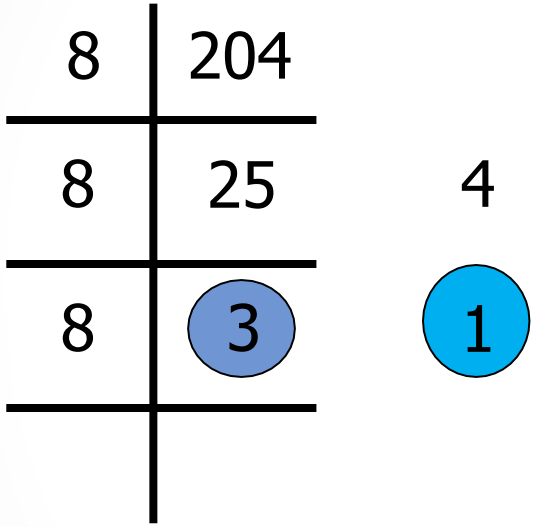


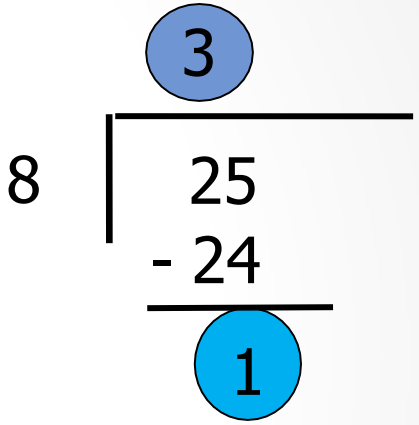
Example: Convert 204 decimal number in to it's equivalent octal number.





Example: Convert 204 decimal number in to it's equivalent octal number.





Example: Convert 204 decimal number in to it's equivalent octal number.

8	204	
8	25	4
8	3	1
	0	3

Example: Convert 204 decimal number in to it's equivalent octal number.

8 | 204		
8 | 25	4	LSB
8 | 3	1	↑
0	3	MSB

$$(204)_{10} = (314)_8$$

Conversion of Decimal Number into Octal Number (Fractional Number)

Procedure:

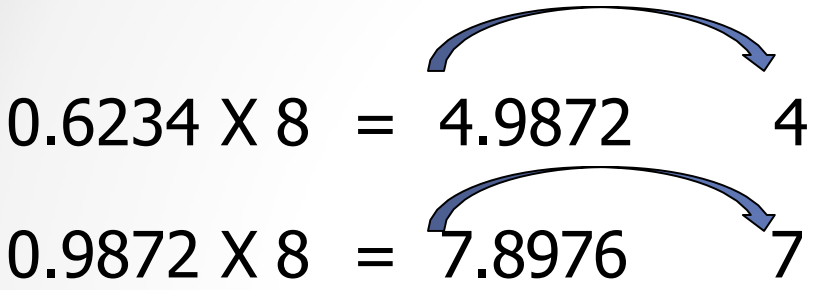
1. Multiply the given fractional number by base 8.
2. Record the carry generated in this multiplication as MSB.
3. Multiply only the fractional number of the product in step 2 by 8 and record the carry as the next bit to MSB.
4. Repeat the steps 2 and 3 up to 5 bits. The last carry will represent the LSB of equivalent octal number

Example: Convert 0.6234 decimal number in to it's equivalent Octal number.

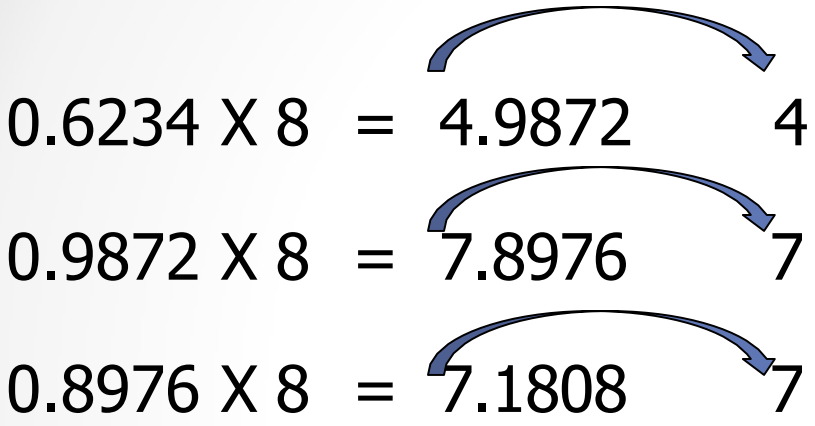
Example: Convert 0.6234 decimal number in to it's equivalent Octal number.

0.6234 X 8 = 4.9872 4

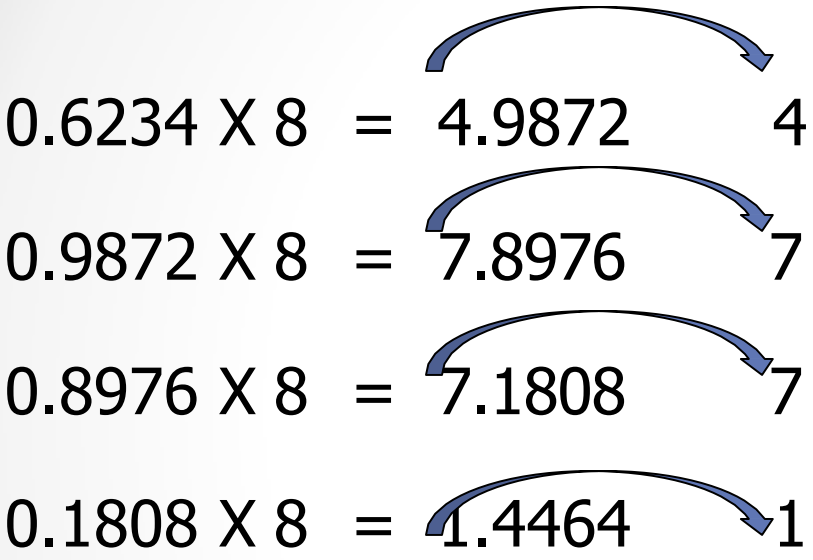
Example: Convert 0.6234 decimal number in to it's equivalent Octal number.



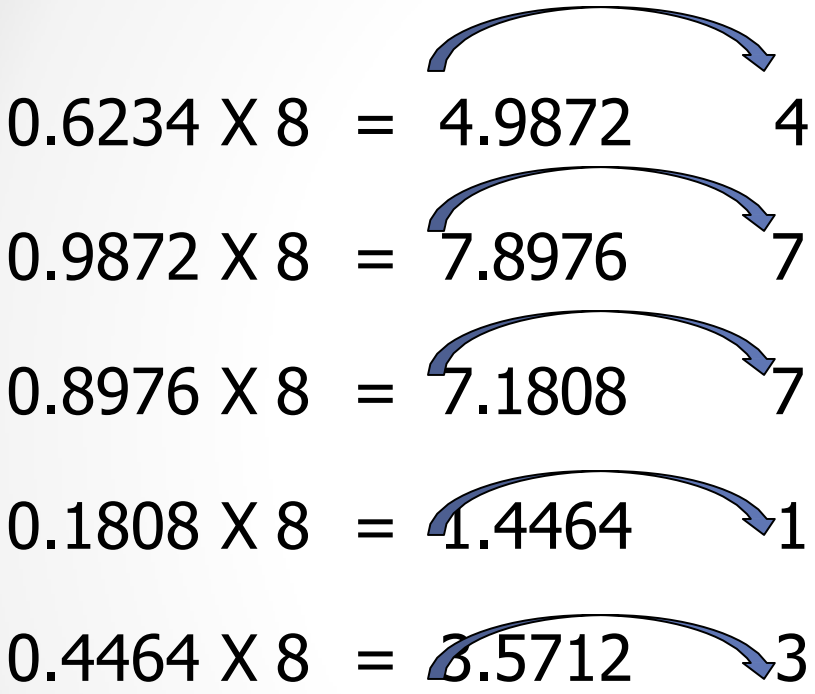
Example: Convert 0.6234 decimal number in to it's equivalent Octal number.



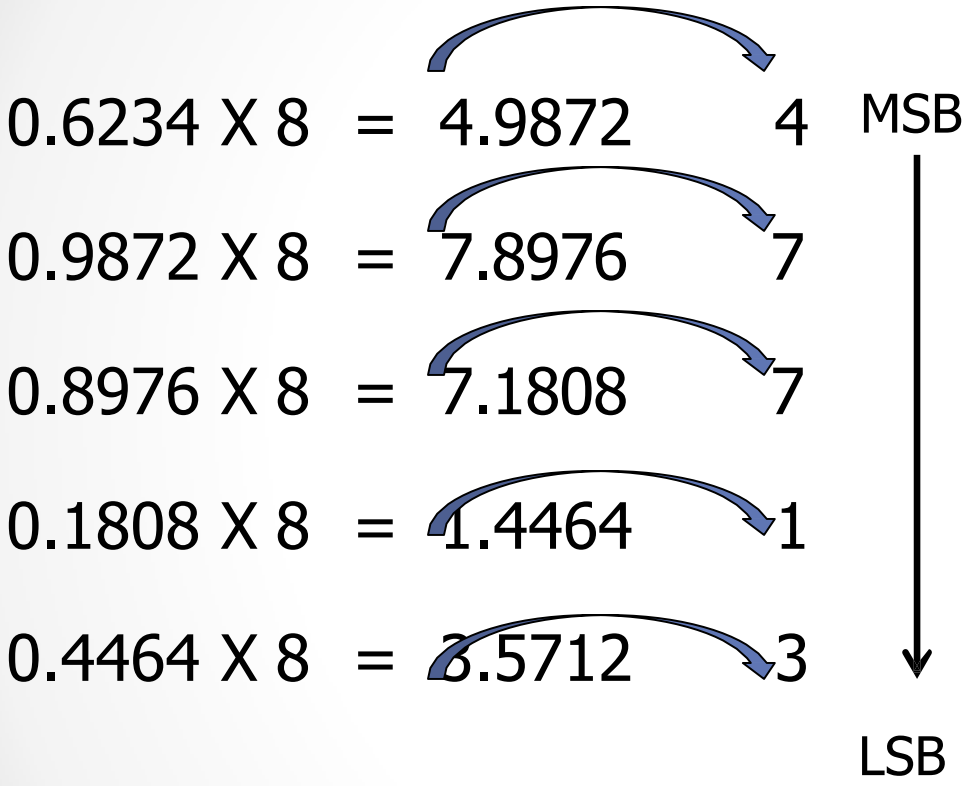
Example: Convert 0.6234 decimal number in to it's equivalent Octal number.



Example: Convert 0.6234 decimal number in to it's equivalent Octal number.



Example: Convert 0.6234 decimal number in to it's equivalent Octal number.



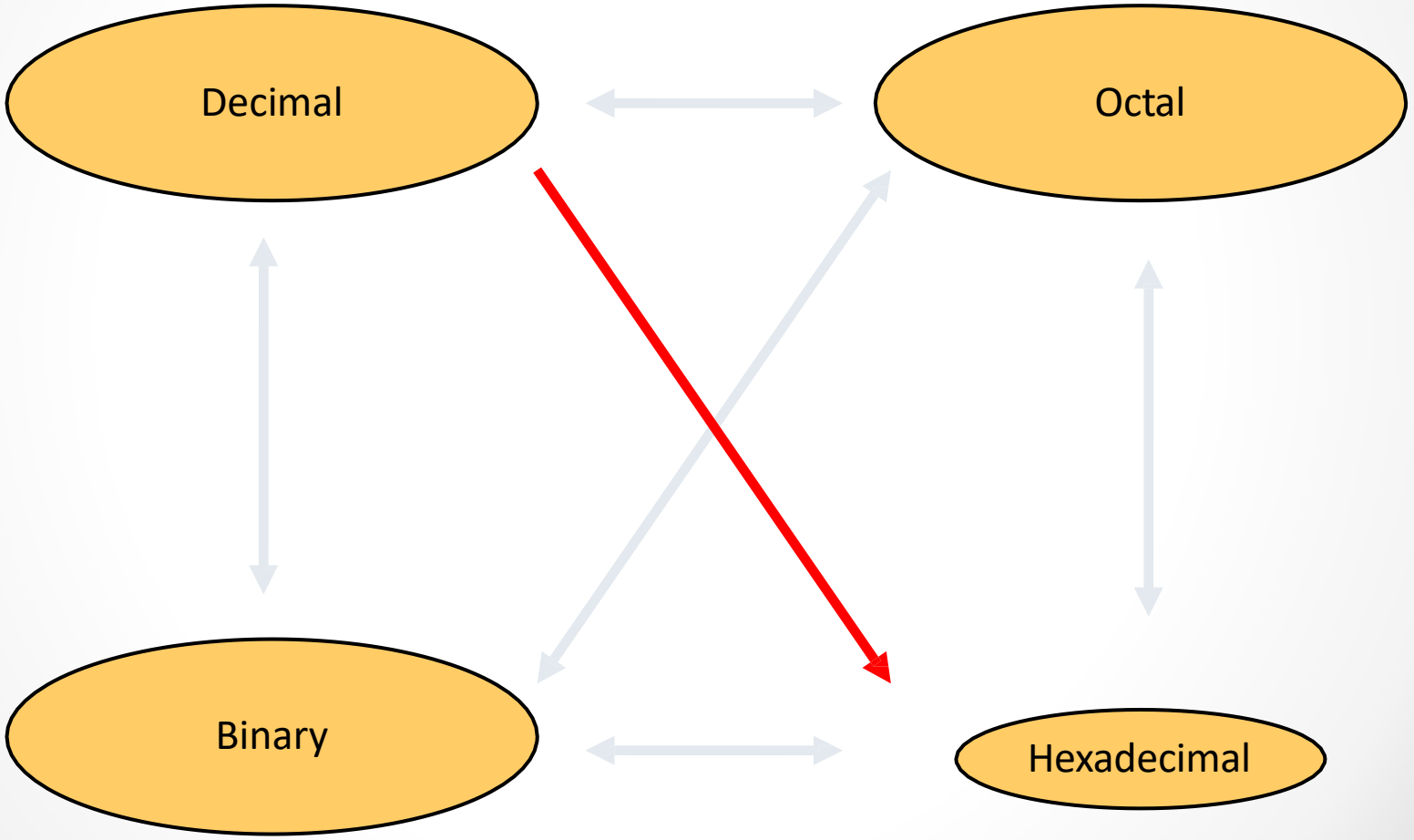
$$(0.6234)_{10} = (0.47713)_{8}$$

Exercise

- Convert following Decimal Numbers in to its equivalent Octal Number:

1. $(1248.56)_{10}$ = (2340.43656)$_8$
2. $(8957.75)_{10}$ = (21375.6)$_8$
3. $(420.6)_{10}$ = (644.463 1)$_8$
4. $(8476.47)_{10}$ = (20434.36)$_8$

Conversion from Decimal Number to Hex Number



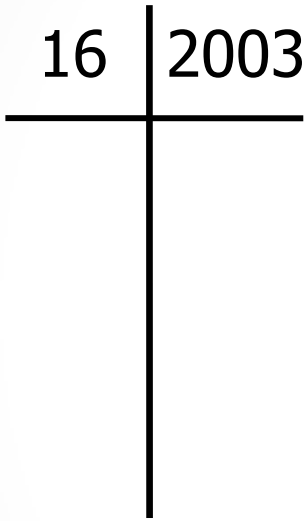
Conversion of Decimal Number into Hexadecimal Number (Integer Number)

Procedure:

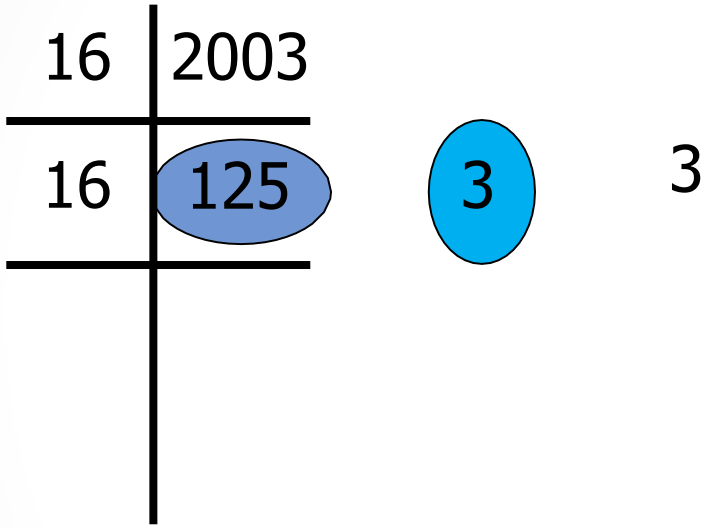
1. Divide the decimal no by the base 16, noting the remainder.
2. Continue to divide the quotient by 16 until there is nothing left, keeping the track of the remainders from each step.
3. List the remainder values in reverse order to find the number's hex equivalent

Example: Convert 2003 decimal number in to it's equivalent Hex number.

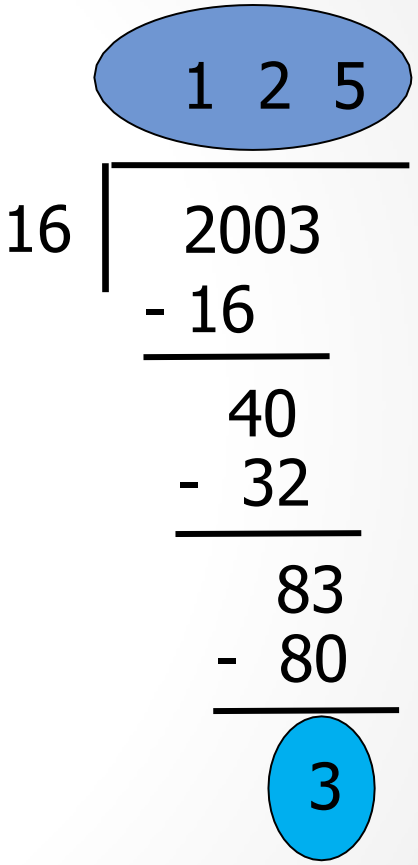
Example: Convert 2003 decimal number in to it's equivalent Hex number.



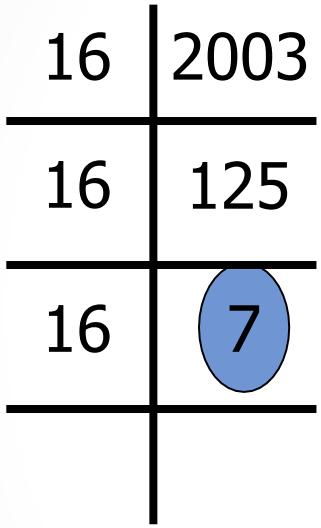
Example: Convert 2003 decimal number in to it's equivalent Hex number.

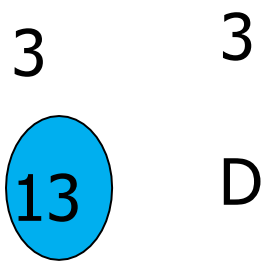


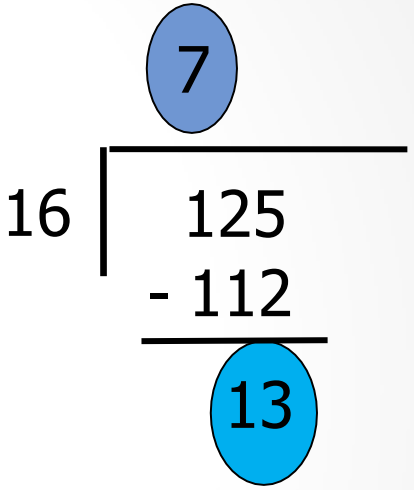
3



Example: Convert 2003 decimal number in to it's equivalent Hex number.







Example: Convert 2003 decimal number in to it's equivalent Hex number.

16	2003		
16	125	3	3
16	7	13	D
	0	7	7

Example: Convert 2003 decimal number in to it's equivalent Hex number.

16	2003		
16	125	3	3
16	7	13	D
	0	7	7

LSB

MSB

$$(2003)_{10} = (7D3)_{16}$$

Conversion of Decimal Number into Hexadecimal Number (Fractional Number)

Procedure:

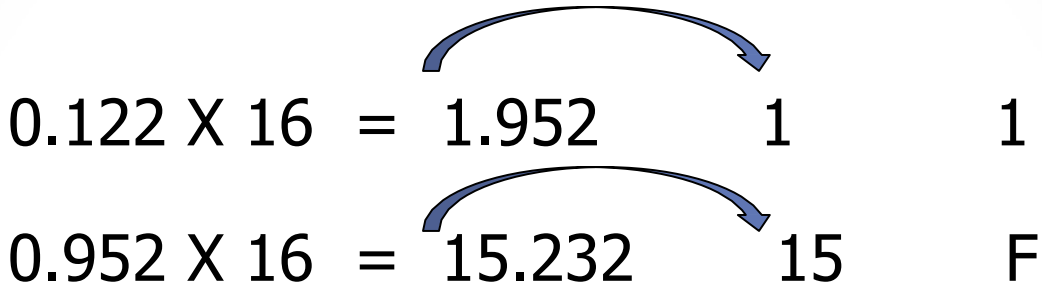
1. Multiply the given fractional number by base 16.
2. Record the carry generated in this multiplication as MSB.
3. Multiply only the fractional number of the product in step 2 by 16 and record the carry as the next bit to MSB.
4. Repeat the steps 2 and 3 up to 5 bits. The last carry will represent the LSB of equivalent hex number

Example: Convert 0.122 decimal number in to it's equivalent Hex number.

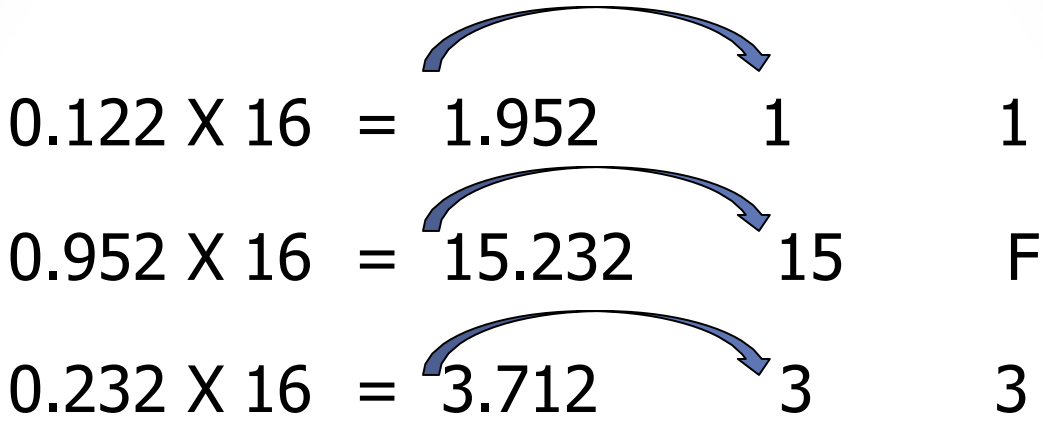
Example: Convert 0.122 decimal number in to it's equivalent Hex number.

0.122 X 16 = 1.952 1 1

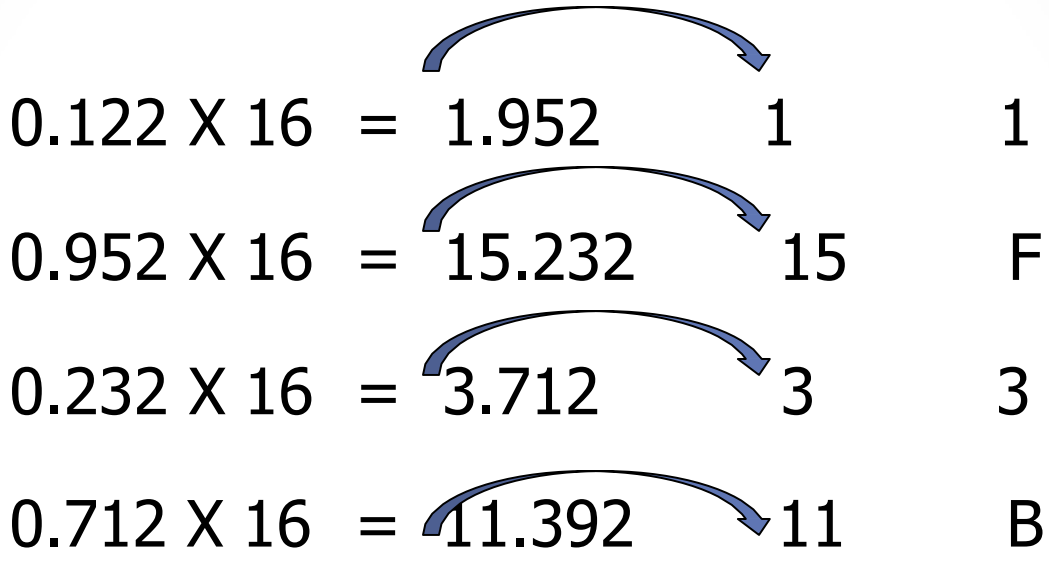
Example: Convert 0.122 decimal number in to it's equivalent Hex number.



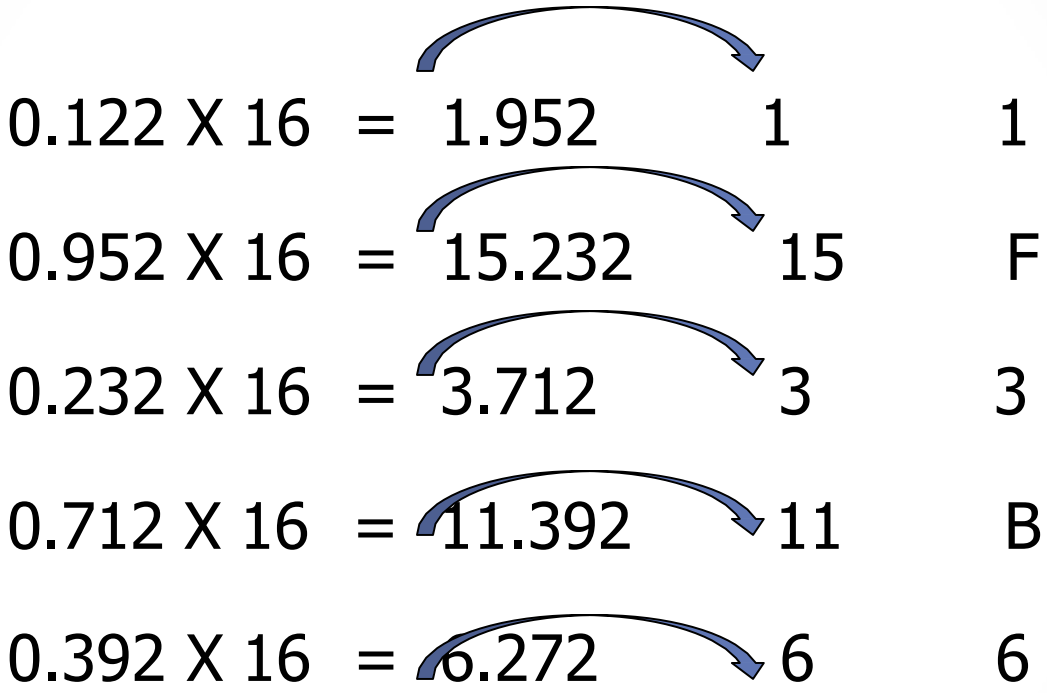
Example: Convert 0.122 decimal number in to it's equivalent Hex number.



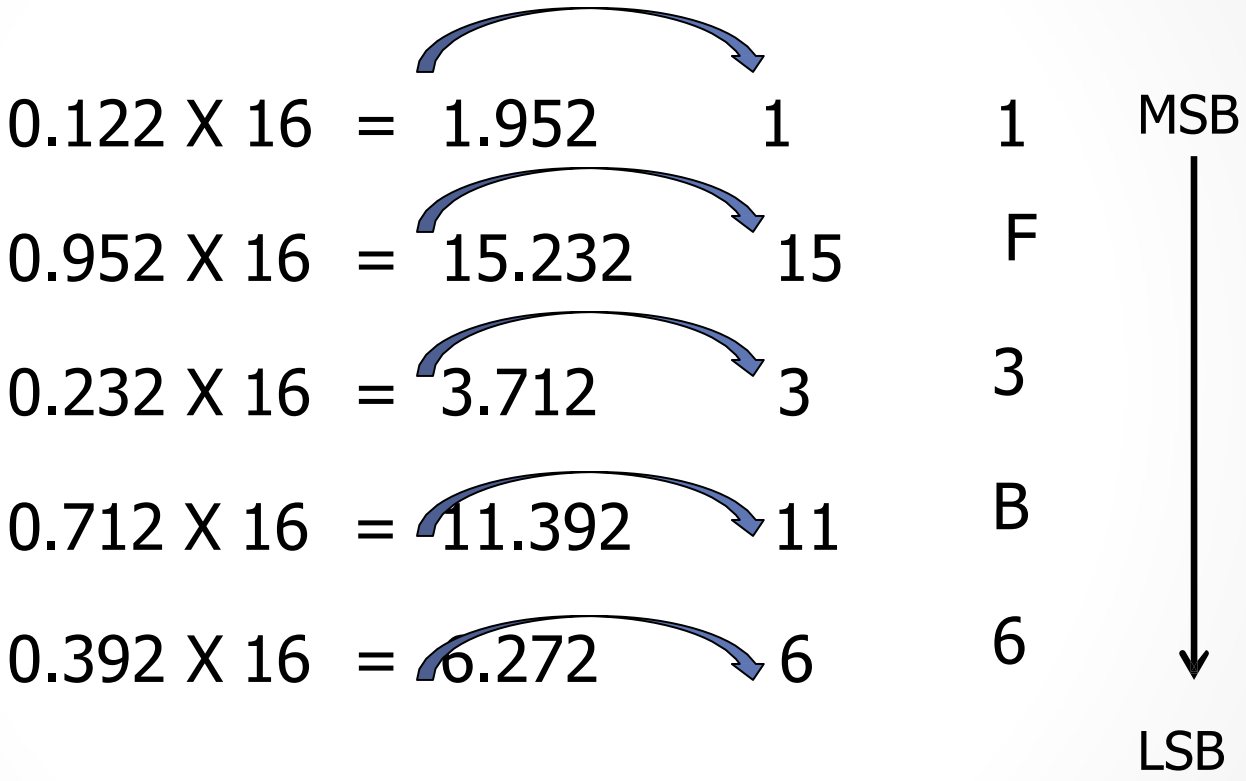
Example: Convert 0.122 decimal number in to it's equivalent Hex number.



Example: Convert 0.122 decimal number in to it's equivalent Hex number.



Example: Convert 0.122 decimal number in to it's equivalent Hex number.



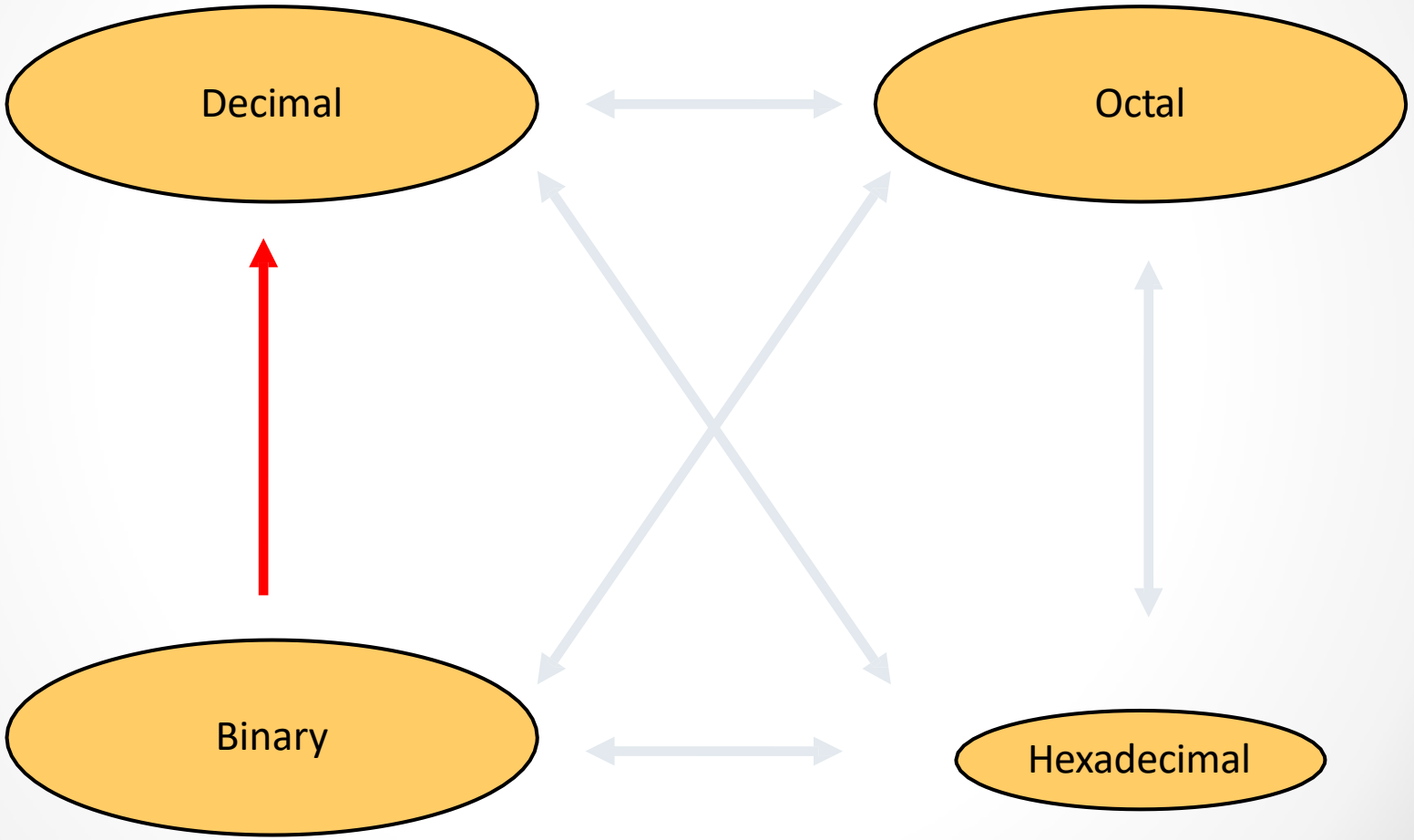
$$(0.122)_{10} = (0.1F3B6)_{16}$$

Exercise

- Convert following Decimal Numbers in to its equivalent Hex Number:

1. $(1248.56)_{10} = (\ ?\ )_{16}$
2. $(8957.75)_{10} = (\ ?\ )_{16}$
3. $(420.6)_{10} = (\ ?\ )_{16}$
4. $(8476.47)_{10} = (\ ?\ )_{16}$

Conversion from Binary Number to Decimal Number



Conversion of Binary Number into Decimal Number

Procedure:

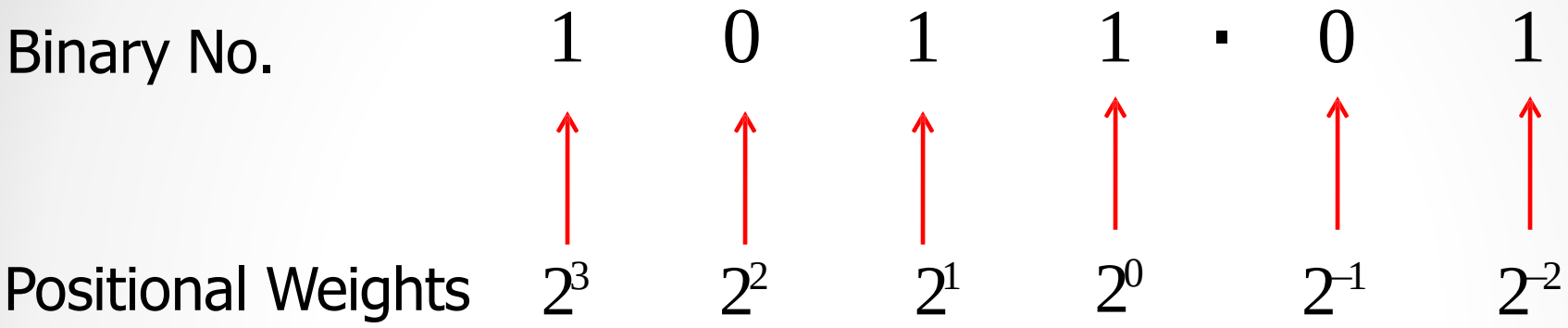
1. Write down the binary number.
2. Write down the weights for different positions.
3. Multiply each bit in the binary number with the corresponding weight to obtain product numbers to get the decimal numbers.
4. Add all the product numbers to get the decimal

Example: Convert 1011.01 binary number in to it's equivalent decimal number.

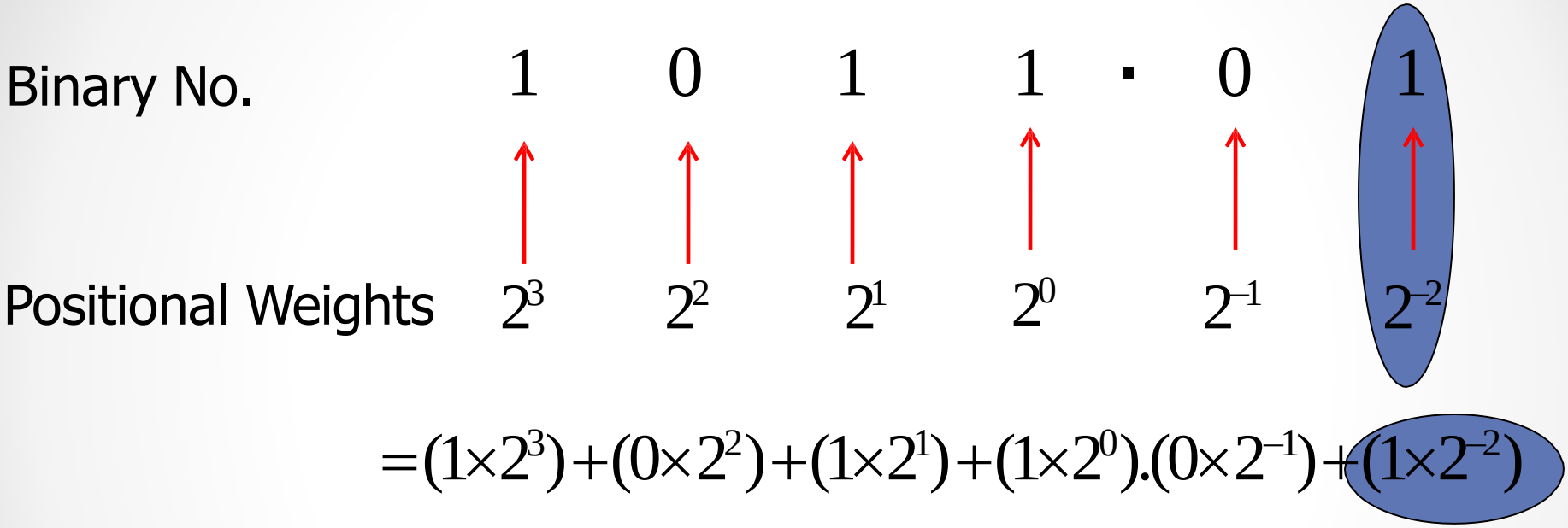
Example: Convert 1011.01 binary number in to it's equivalent decimal number.

Binary No.	1	0	1	1	·	0	1

Example: Convert 1011.01 binary number in to it's equivalent decimal number.

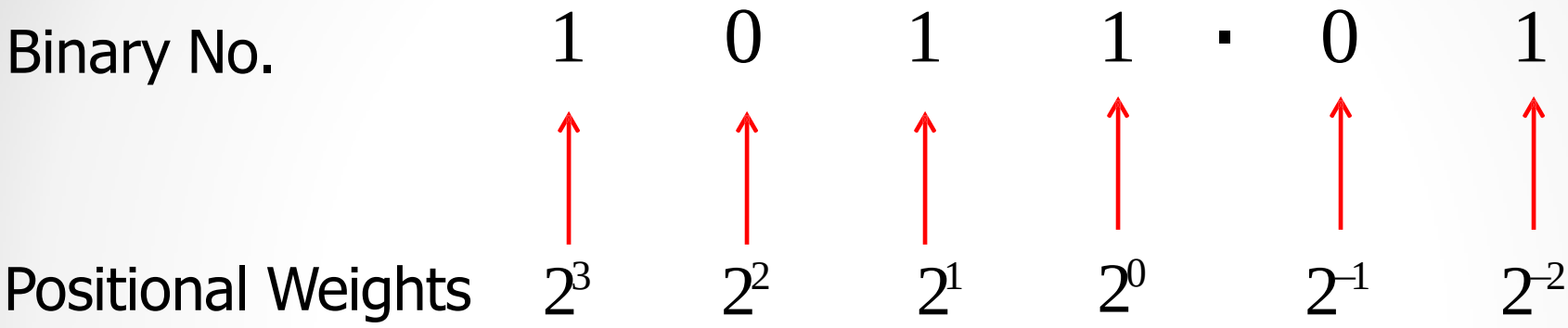


Example: Convert 1011.01 binary number in to it's equivalent decimal number.



$$=(1\times2^3)+(0\times2^2)+(1\times2^1)+(1\times2^0).(0\times2^{-1})+(1\times2^{-2})$$

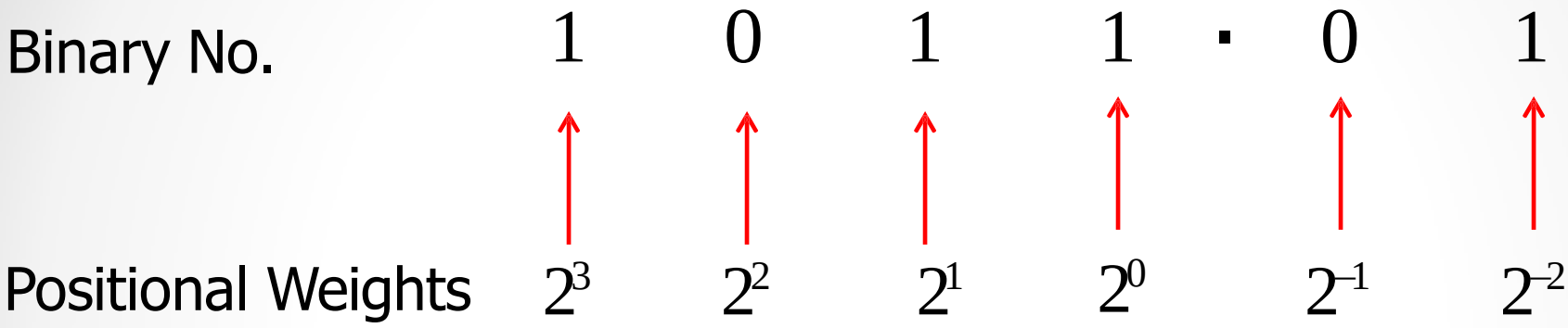
Example: Convert 1011.01 binary number in to it's equivalent decimal number.



$$=(1\times2^3)+(0\times2^2)+(1\times2^1)+(1\times2^0).(0\times2^{-1})+(1\times2^{-2})$$

$$= 8 + 0 + 2 + 1 . 0 + 0.25$$

Example: Convert 1011.01 binary number in to it's equivalent decimal number.

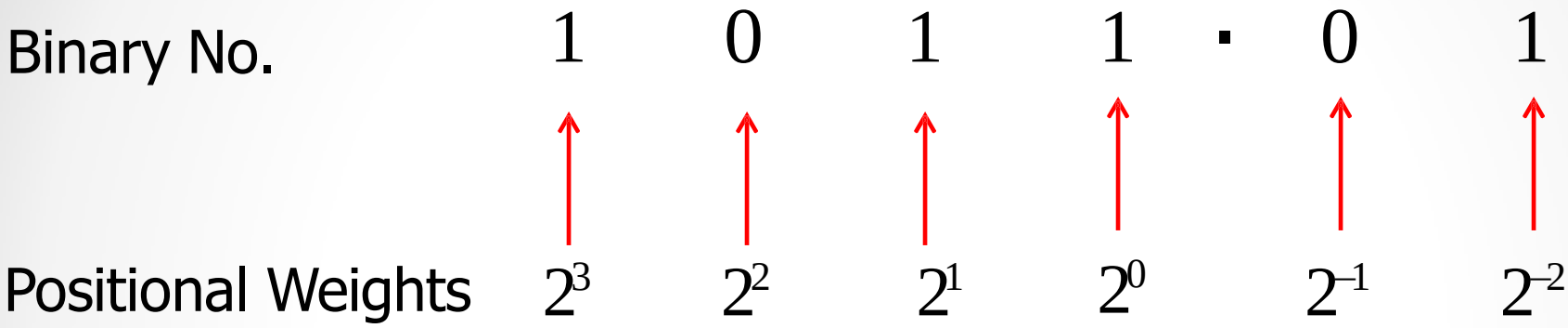


$$=(1\times2^3)+(0\times2^2)+(1\times2^1)+(1\times2^0).(0\times2^{-1})+(1\times2^{-2})$$

$$= 8 + 0 + 2 + 1 . 0 + 0.25$$

$$= 11.25$$

Example: Convert 1011.01 binary number in to it's equivalent decimal number.



$$=(1\times2^3)+(0\times2^2)+(1\times2^1)+(1\times2^0).(0\times2^{-1})+(1\times2^{-2})$$

$$= 8 + 0 + 2 + 1 . 0 + 0.25$$

$$= 11.25$$

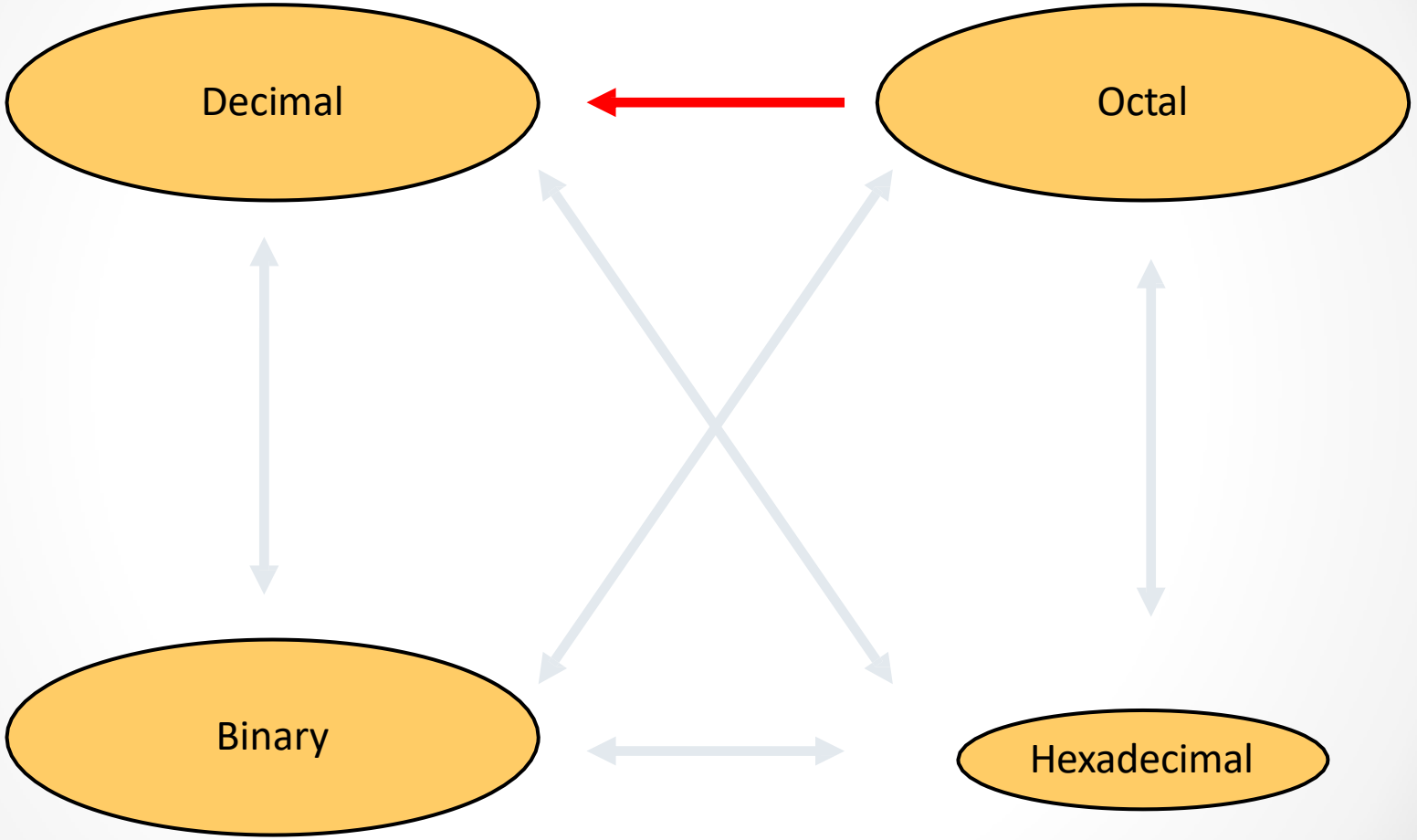
$(1011.01)_2 = (11.25)_{10}$

Exercise

- Convert following Binary Numbers in to its equivalent Decimal Number:

1. $(1101110.011)_2 = (\ ?\ )_{10}$
2. $(1101.11)_2 = (\ ?\ )_{10}$
3. $(10001.01)_2 = (\ ?\ )_{10}$

Conversion from Octal Number to Decimal Number



Conversion of Octal Number into Decimal Number

Procedure:

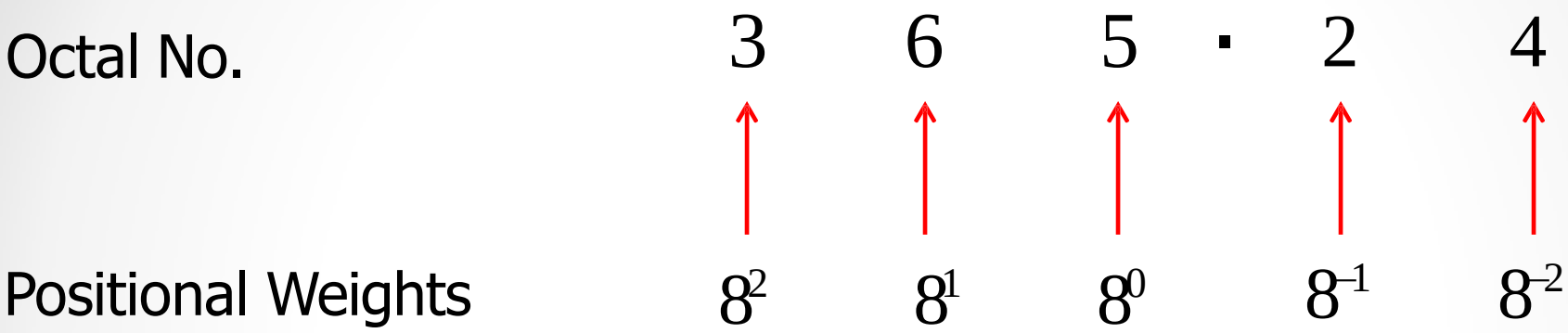
1. Write down the octal number.
2. Write down the weights for different positions.
3. Multiply each bit in the binary number with the corresponding weight to obtain product numbers to get the decimal numbers.
4. Add all the product numbers to get the decimal uivalent

Example: Convert 365.24 octal number in to it's equivalent decimal number.

Example: Convert 365.24 octal number in to it's equivalent decimal number.

Octal No.	3	6	5	·	2	4

Example: Convert 365.24 octal number in to it's equivalent decimal number.



Example: Convert 365.24 octal number in to it's equivalent decimal number.

Octal No. $3\ 6\ 5 \cdot 2\ 4$

Positional Weights $8^2\ 8^1\ 8^0\ 8^{-1}\ 8^{-2}$

$$=(3\times8^2)+(6\times8^1)+(5\times8^0).(2\times8^{-1})+(4\times8^{-2})$$

Example: Convert 365.24 octal number in to it's equivalent decimal number.

Octal No.	3	6	5	·	2	4
Positional Weights	8^2	8^1	8^0		8^{-1}	8^{-2}

$$=(3\times8^2)+(6\times8^1)+(5\times8^0).(2\times8^{-1})+(4\times8^{-2})$$

$$= 192 + 48 + 5 . 0.25 + 0.0625$$

Example: Convert 365.24 octal number in to it's equivalent decimal number.

Octal No. 3 6 5 . 2 4

Positional Weights 8^2 8^1 8^0 8^{-1} 8^{-2}

$$=(3\times8^2)+(6\times8^1)+(5\times8^0).(2\times8^{-1})+(4\times8^{-2})$$

$$= 192 + 48 + 5 . 0.25 + 0.0625$$

$$= 245.3125$$

Example: Convert 365.24 octal number in to it's equivalent decimal number.

Octal No.	3	6	5	.	2	4
Positional Weights	8^2	8^1	8^0		8^{-1}	8^{-2}

$$=(3\times8^2)+(6\times8^1)+(5\times8^0).(2\times8^{-1})+(4\times8^{-2})$$

$$= 192 + 48 + 5 . 0.25 + 0.0625$$

$$= 245.3125$$

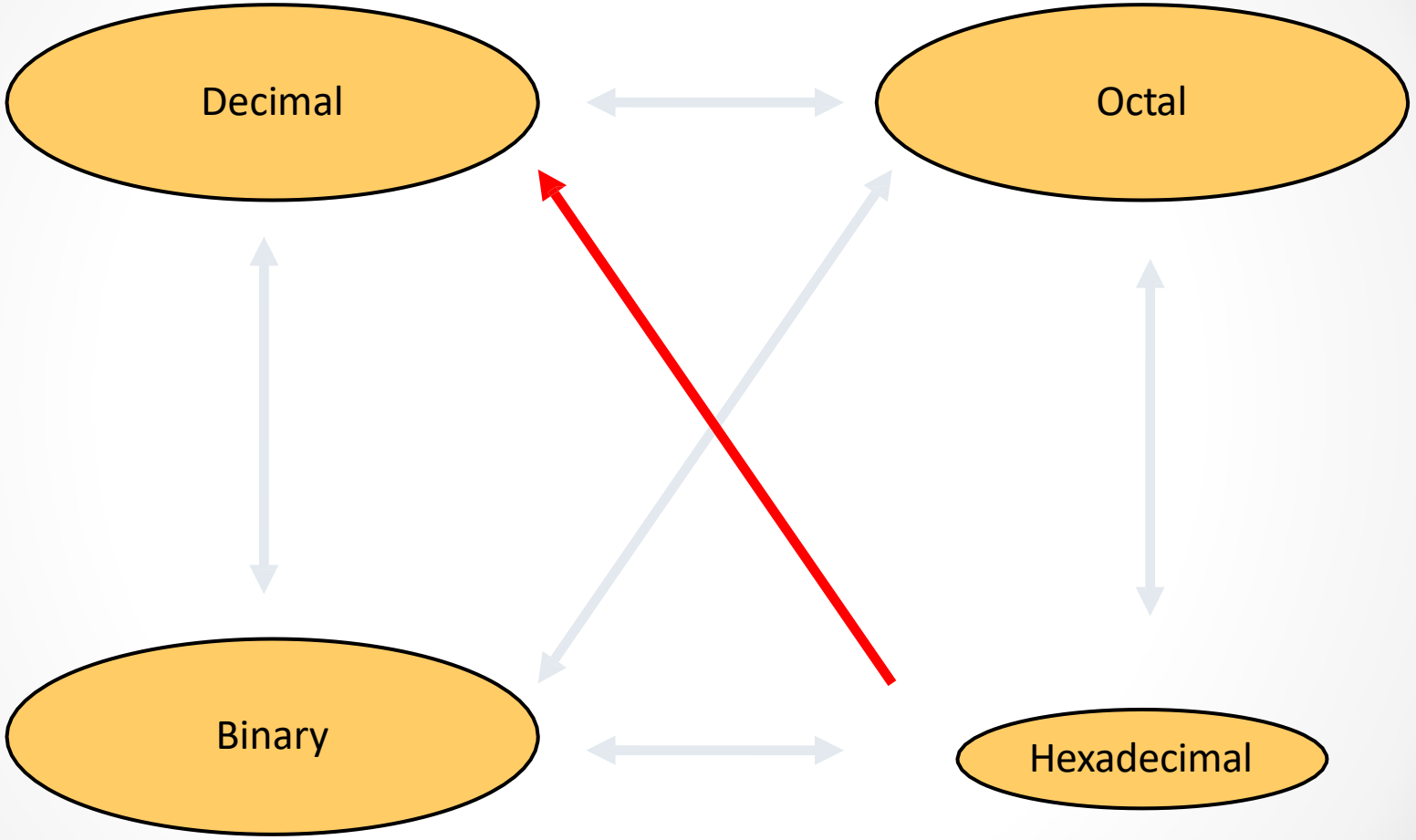
$$(365.24)_8 = (245.3125)_{10}$$

Exercise

- Convert following Octal Numbers in to its equivalent Decimal Number:

1. $(3006.05)_8 = (\ ?\ )_{10}$
2. $(273.56)_8 = (\ ?\ )_{10}$
3. $(6534.04)_8 = (\ ?\ )_{10}$

Conversion from Hex Number to Decimal Number



Conversion of Hexadecimal Number into Decimal Number

Procedure:

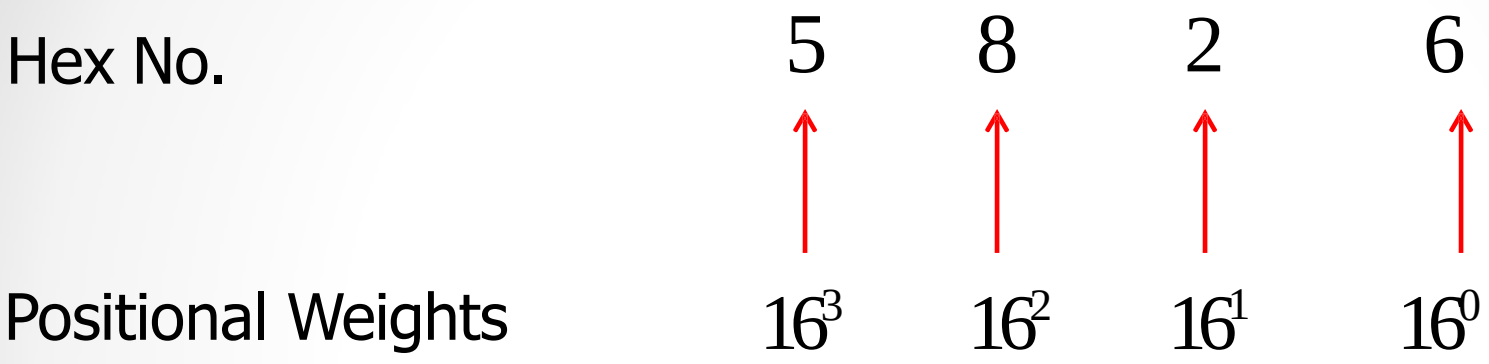
1. Write down the hex number.
2. Write down the weights for different positions.
3. Multiply each bit in the binary number with the correspondingweight to obtain product numbers to get the decimal numbers.
4. Add all the product numbers to get the decimal equivalent

Example: Convert 5826 hex number in to it's equivalent decimal number.

Example: Convert 5826 hex number in to it's equivalent decimal number.

Hex No.	5	8	2	6

Example: Convert 5826 hex number in to it's equivalent decimal number.



Example: Convert 5826 hex number in to it's equivalent decimal number.

Hex No. 5 8 2 6

Positional Weights 16^3 16^2 16^1 16^0

$$=(5\times16^3)+(8\times16^2)+(2\times16^1)+(6\times16^0)$$

Example: Convert 5826 hex number in to it's equivalent decimal number.

Hex No. 5 8 2 6

Positional Weights 16^3 16^2 16^1 16^0

$$=(5\times16^3)+(8\times16^2)+(2\times16^1)+(6\times16^0)$$

$$=20480 + 2048 + 32 + 6$$

Example: Convert 5826 hex number in to it's equivalent decimal number.

Hex No. 5 8 2 6

Positional Weights 16^3 16^2 16^1 16^0

$$=(5\times16^3)+(8\times16^2)+(2\times16^1)+(6\times16^0)$$

$$=20480 + 2048 + 32 + 6$$

$$= 22566$$

Example: Convert 5826 hex number in to it's equivalent decimal number.

Hex No.	5	8	2	6
Positional Weights	16^3	16^2	16^1	16^0

$$=(5\times16^3)+(8\times16^2)+(2\times16^1)+(6\times16^0)$$

$$=20480 + 2048 + 32 + 6$$

$$= 22566$$

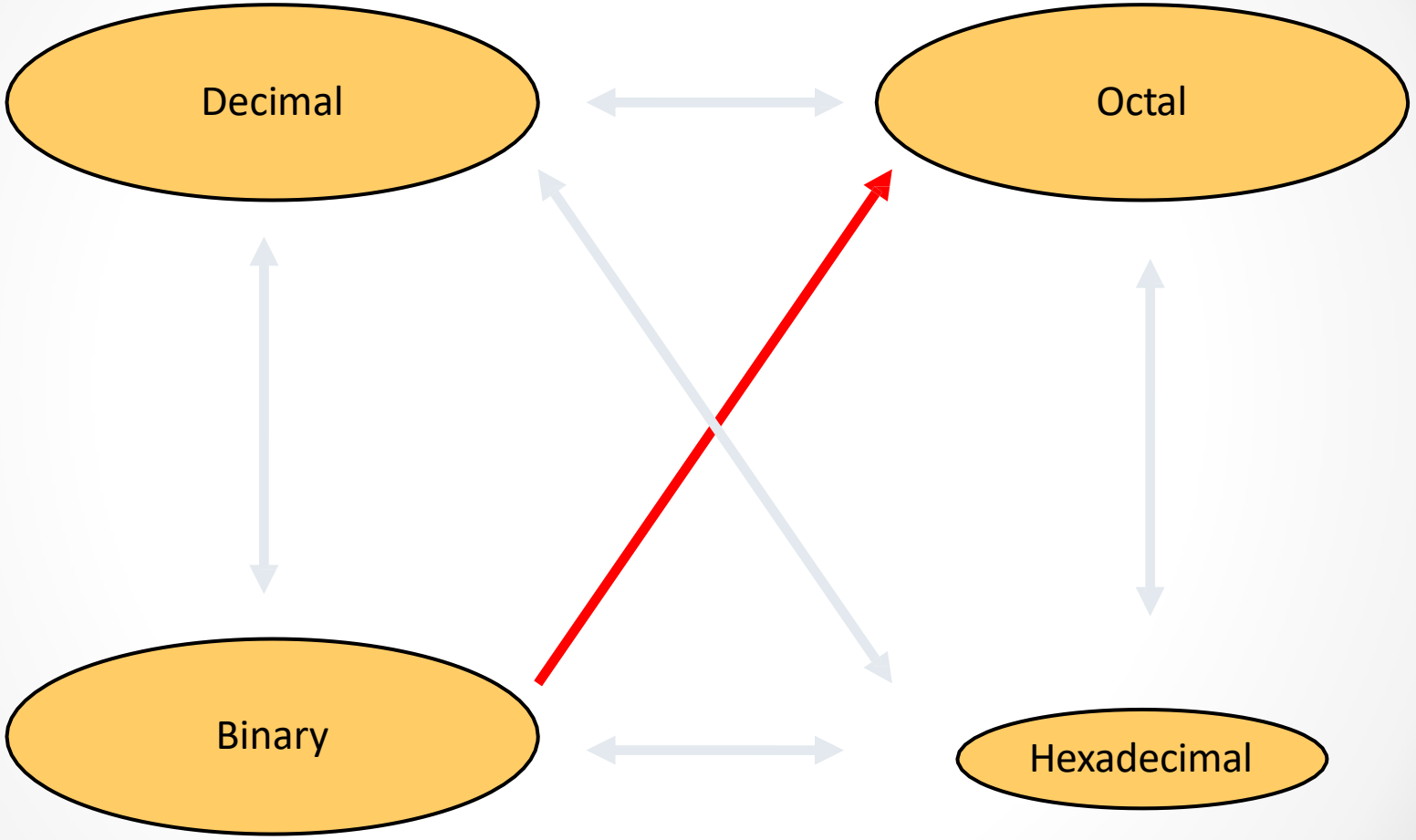
$$(5826)_{16} = (22566)_{10}$$

Exercise

- Convert following Hexadecimal Numbers in to its equivalent Decimal Number:

1. $(4056)_{16} = (\ ?\ )_{10}$
2. $(6B7)_{16} = (\ ?\ )_{10}$
3. $(8E47.AB)_{16} = (\ ?\ )_{10}$

Conversion from Binary Number to Octal Number



Conversion of Binary Number into Octal Number

Procedure:

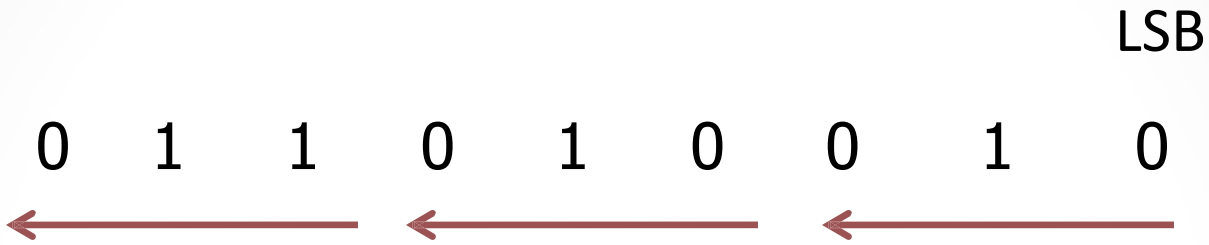
1. Group the binary bits into groups of 3 starting from LSB.
2. Convert each group into its equivalent decimal. As the number of bits in each group is restricted to 3, the decimal number will be same as octal number

Example: Convert 11010010 binary number in to it's equivalent octal number.

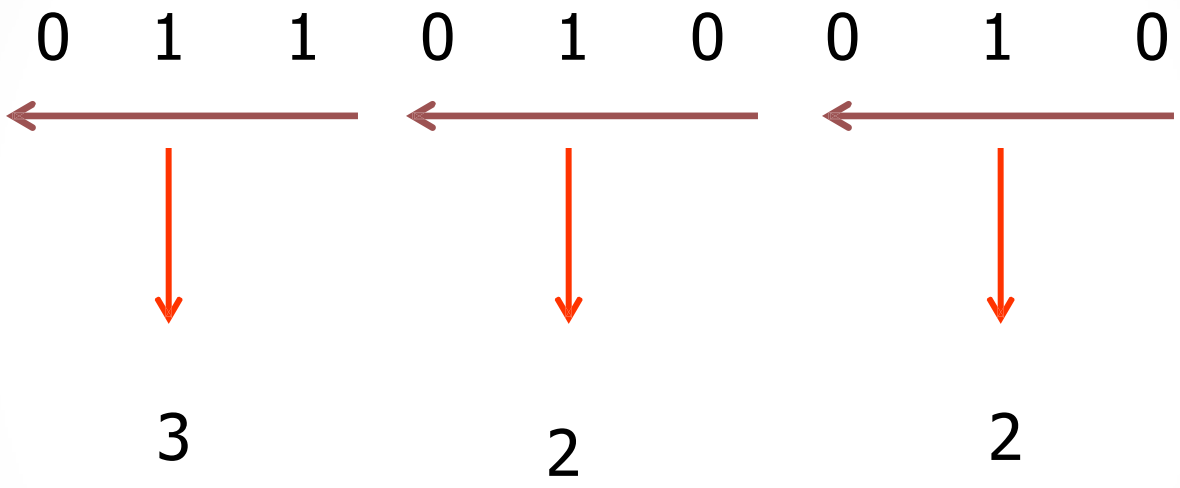
Example: Convert 11010010 binary number in to it's equivalent octal number.

0 1 1 0 1 0 0 1 0

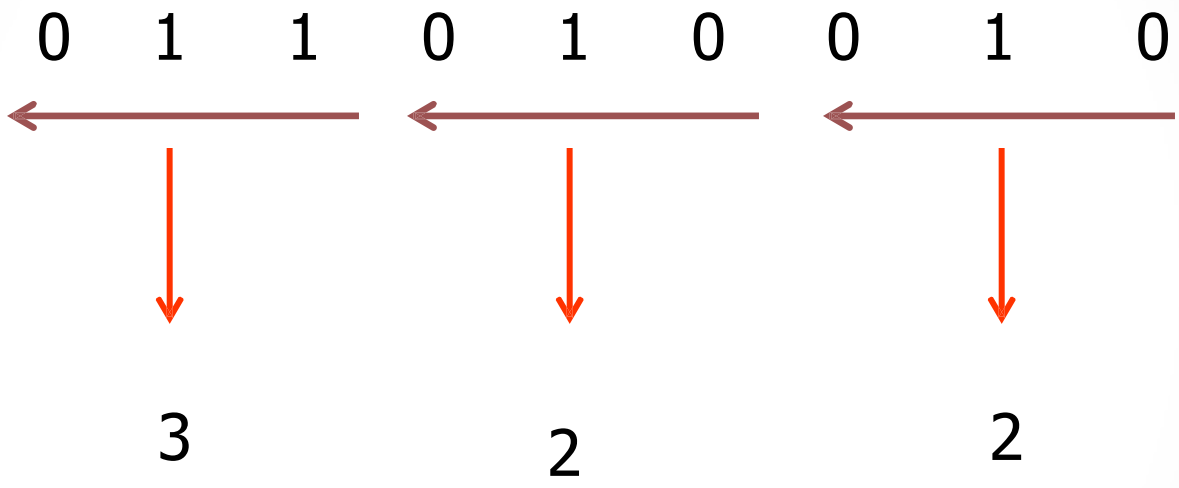
Example: Convert 11010010 binary number in to it's equivalent octal number.



Example: Convert 11010010 binary number in to it's equivalent octal number.



Example: Convert 11010010 binary number in to it's equivalent octal number.



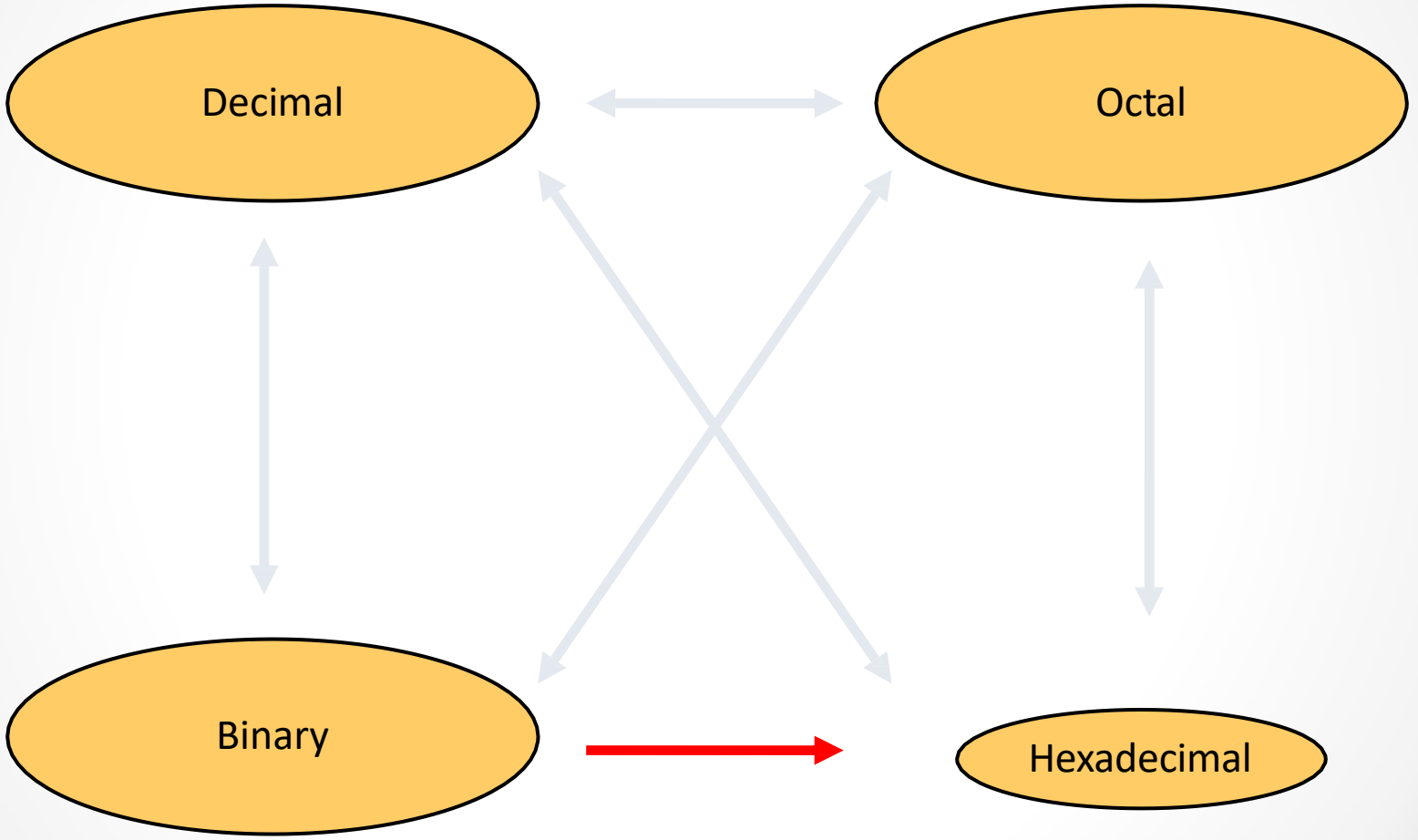
$$(11010010)_2 = (322)_8$$

Exercise

- Convert following Binary Numbers in to its equivalent Octal Number:

1. $(1101110.011)_2 = (\ ?\ )_8$
2. $(1101.11)_2 = (\ ?\ )_8$
3. $(10001.01)_2 = (\ ?\ )_8$

Conversion from Binary Number to Hexadecimal Number



Conversion of Binary Number to Hexadecimal Number

Procedure:

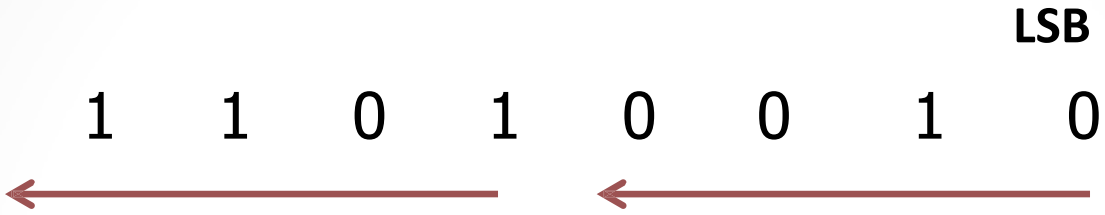
1. Group the binary bits into groups of 4 starting from LSB.
2. Convert each group into its equivalent decimal. As the number of bits in each group is restricted to 4, the decimal number will be same as hex number

Example: Convert 11010010 binary number in to it's equivalent hex number.

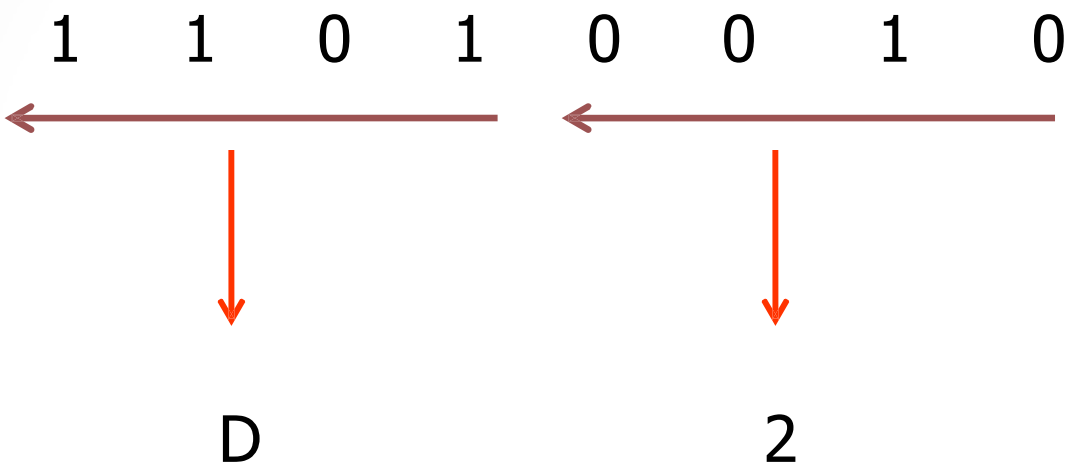
Example: Convert 11010010 binary number in to it's equivalent hex number.

							LSB
1	1	0	1	0	0	1	0

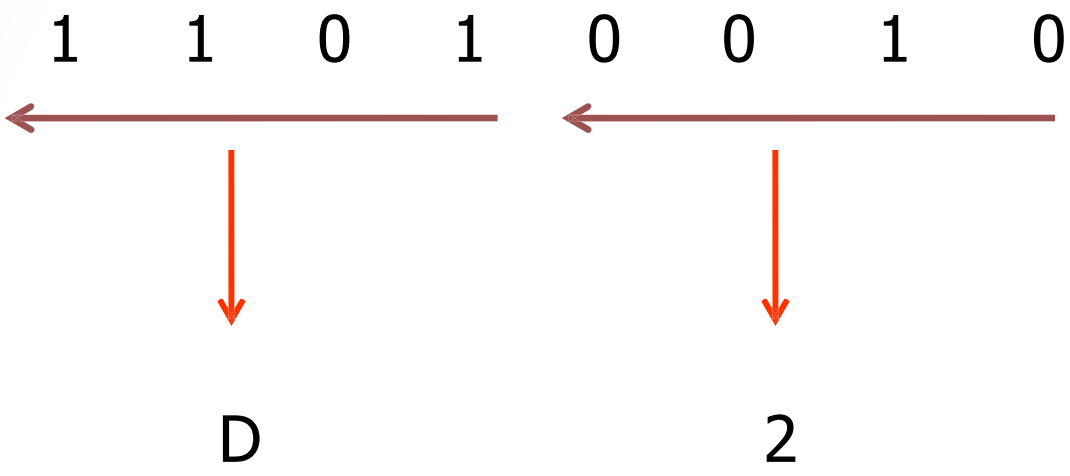
Example: Convert 11010010 binary number in to it's equivalent hex number.



Example: Convert 11010010 binary number in to it's equivalent hex number.



Example: Convert 11010010 binary number in to it's equivalent hex number.



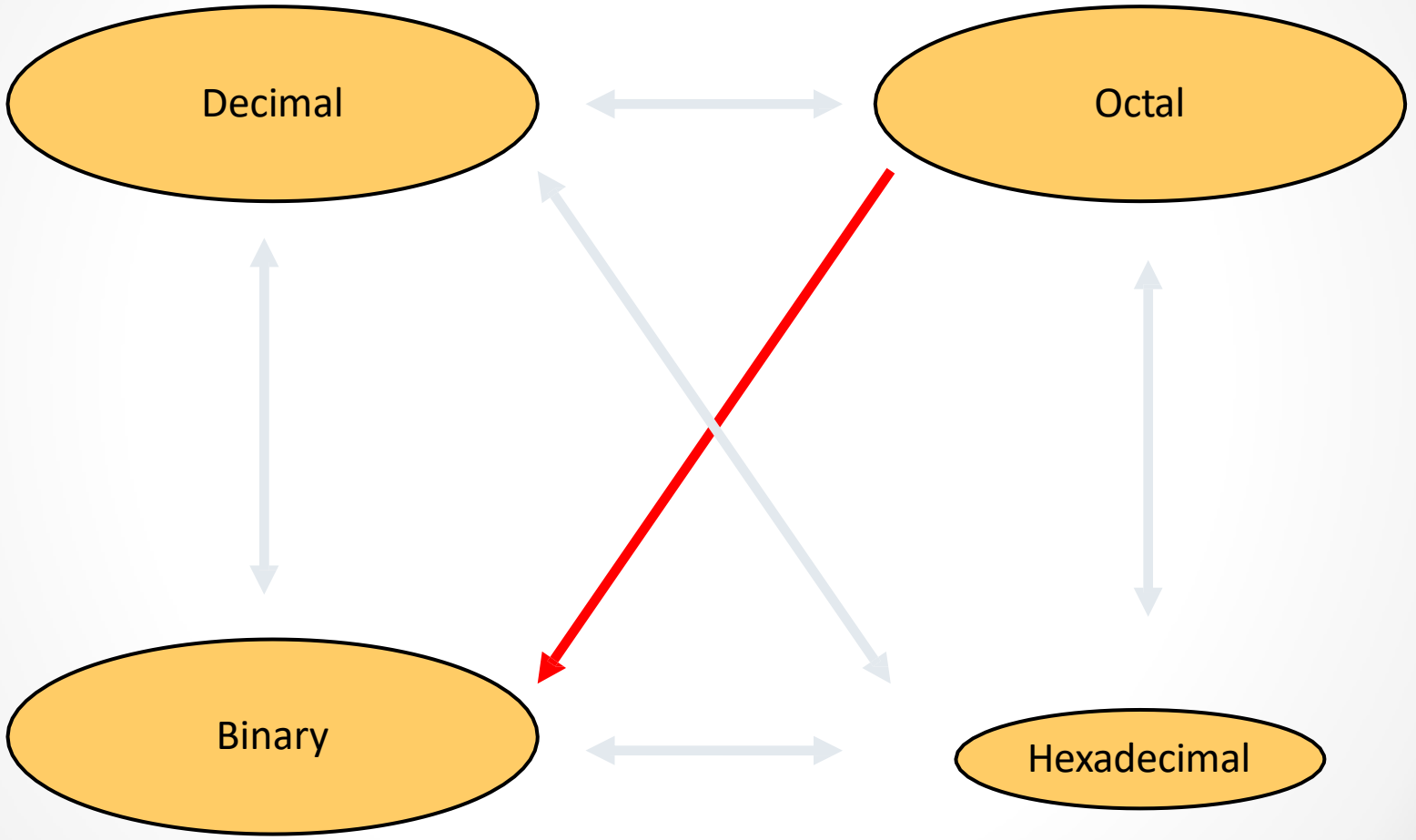
$$(11010010)_2 = (D2)_{16}$$

Exercise

- Convert following Binary Numbers in to its equivalent Hexadecimal Number:

1. $(1101110.011)_2 = (\ ?\ )_{16}$
2. $(1101.11)_2 = (\ ?\ )_{16}$
3. $(10001.01)_2 = (\ ?\ )_{16}$

Conversion from Octal Number to Binary Number



Conversion of Octal Number into Binary Number

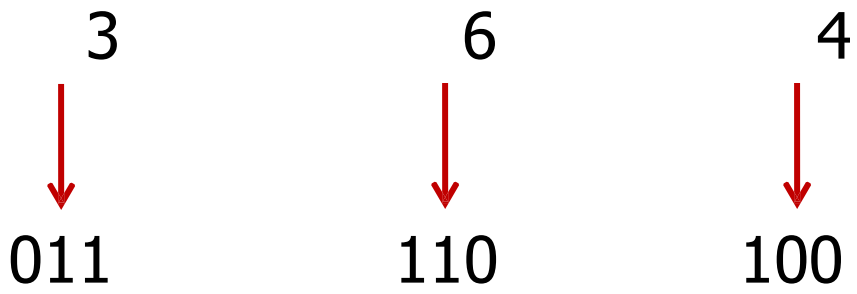
- ✓ To get the binary equivalent of the given octal number we have to convert each octal digit into its equivalent 3 bit binary number

Example: Convert 364 octal number in to it's equivalent binary number.

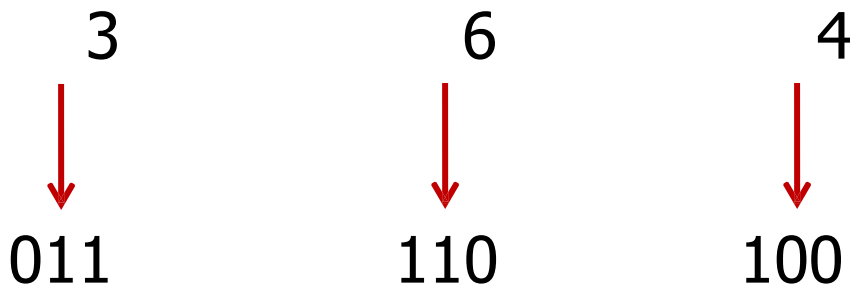
Example: Convert 364 octal number in to it's equivalent binary number.

3 6 4

Example: Convert 364 octal number in to it's equivalent binary number.

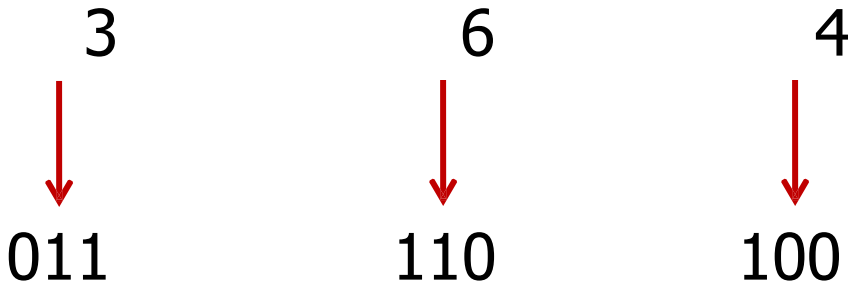


Example: Convert 364 octal number in to it's equivalent binary number.



$$(364)_8 = (011110100)_2$$

Example: Convert 364 octal number in to it's equivalent binary number.



$$(364)_8 = (011110100)_2$$

OR

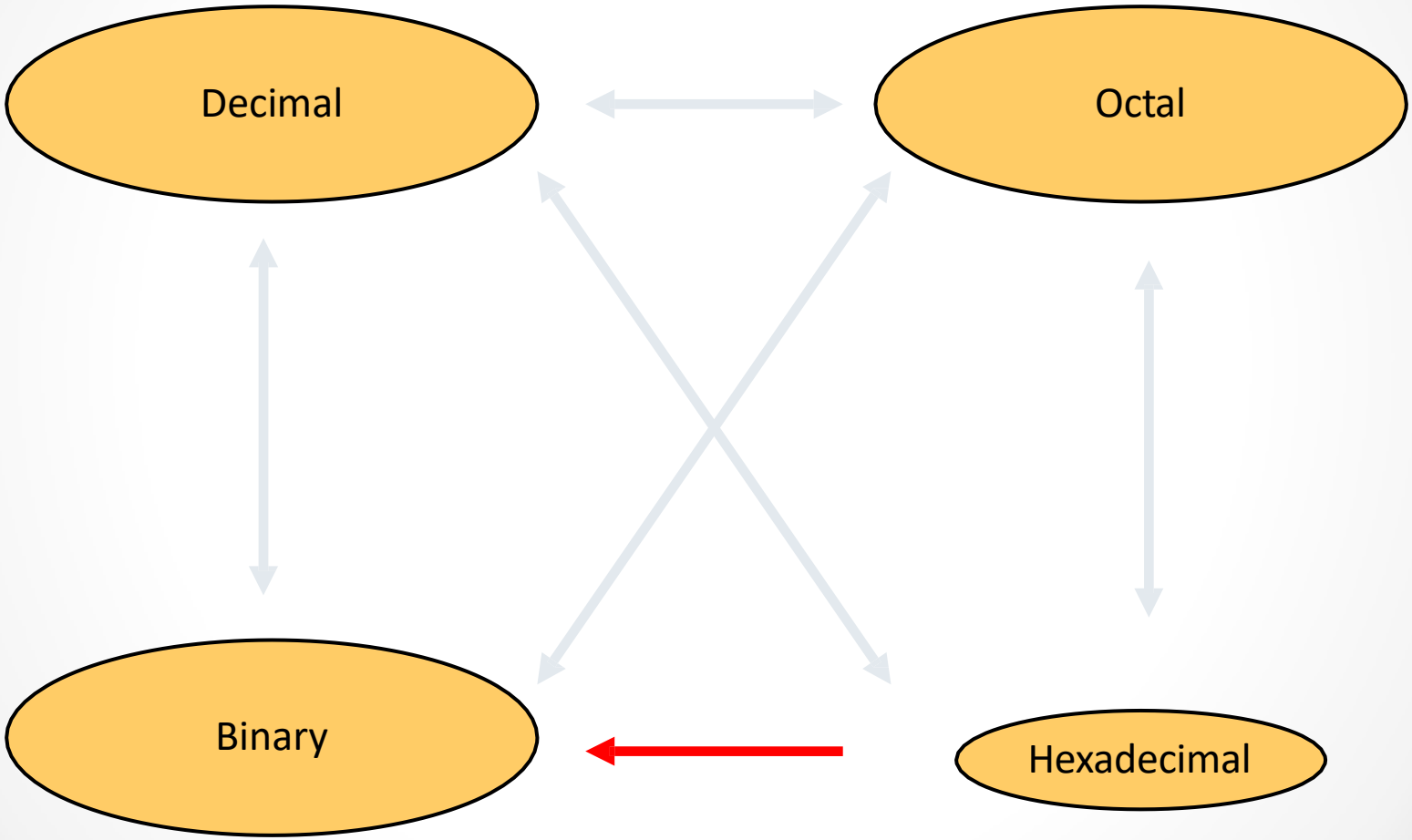
$$(364)_8 = (11110100)_2$$

Exercise

- Convert following Octal Numbers in to its equivalent Binary Number:

1. $(3006.05)_8 = (\ ?\ )_2$
2. $(273.56)_8 = (\ ?\ )_2$
3. $(6534.04)_8 = (\ ?\ )_2$

Conversion from Hex Number to Binary Number



Conversion of Hexadecimal Number into Binary Number

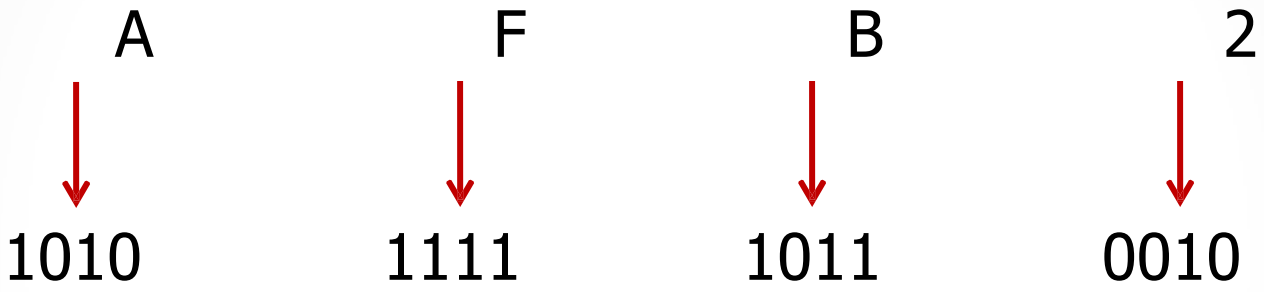
- ✓ To get the binary equivalent of the given hex number we have to convert each hex digit into its equivalent 4 bit binary number

Example: Convert AFB2 hex number in to it's equivalent binary number.

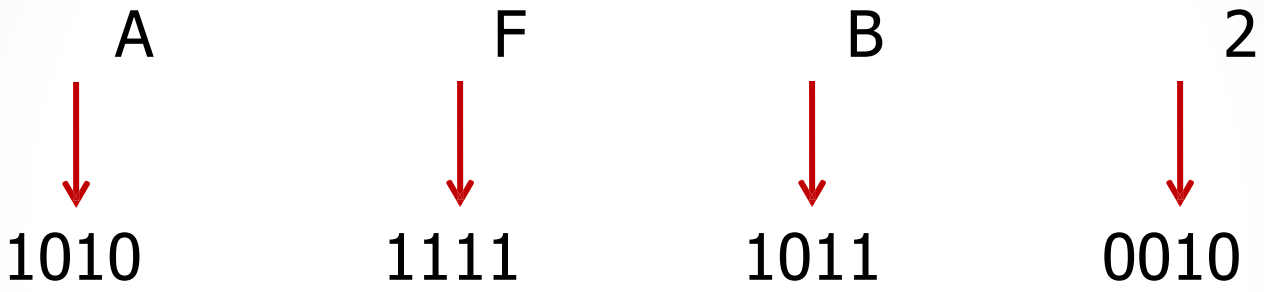
Example: Convert AFB2 hex number in to it's equivalent binary number.

A F B 2

Example: Convert AFB2 hex number in to it's equivalent binary number.



Example: Convert AFB2 hex number in to it's equivalent binary number.



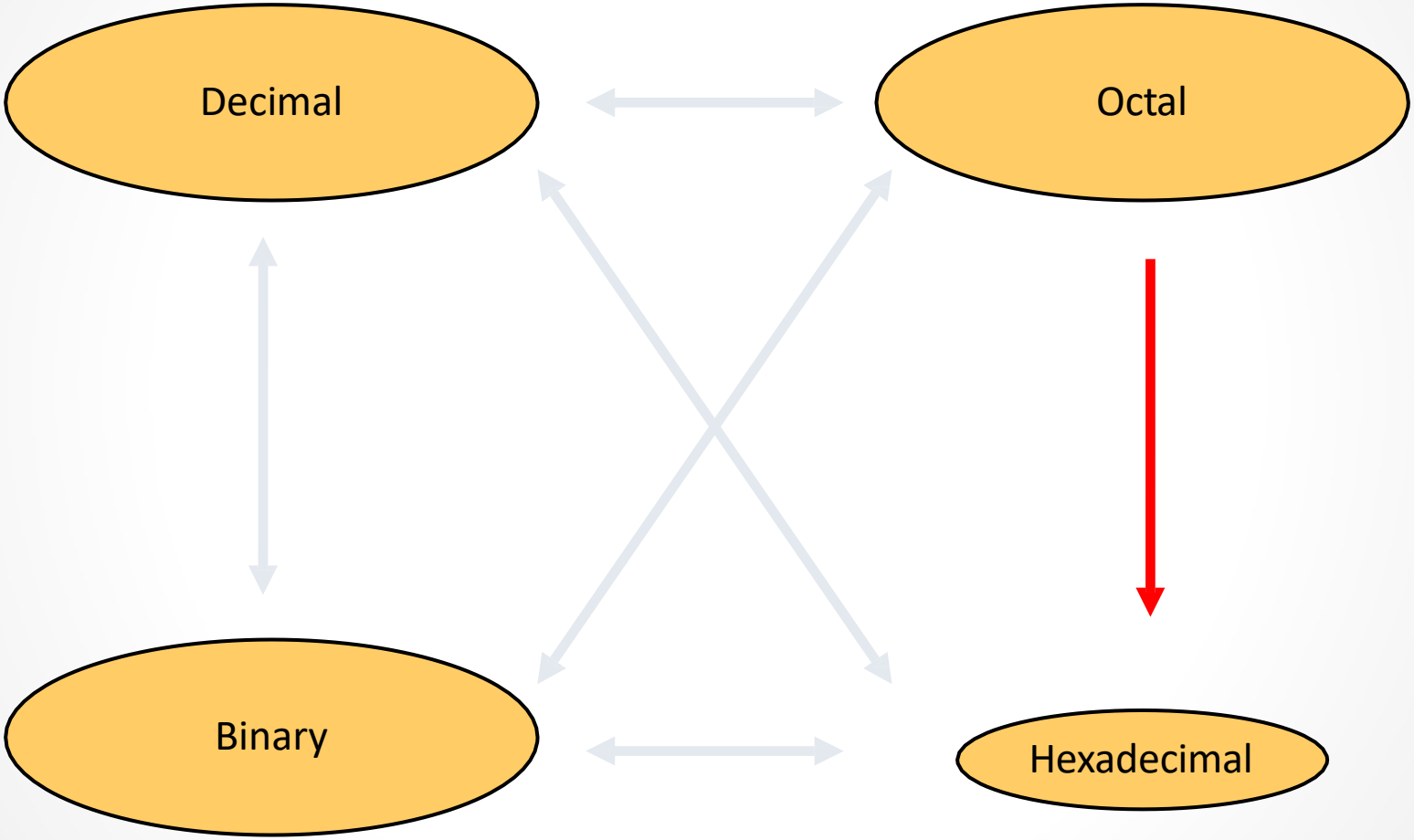
$$(AFB2)_{16} = (1010111110110010)_2$$

Exercise

- Convert following Hexadecimal Numbers in to its equivalent Binary Number:

1. $(4056)_{16} = (\ ?\ )_2$
2. $(6B7)_{16} = (\ ?\ )_2$
3. $(8E47.AB)_{16} = (\ ?\ )_2$

Conversion from Octal Number to Hex Number



Conversion of Octal Number into Hexadecimal Number

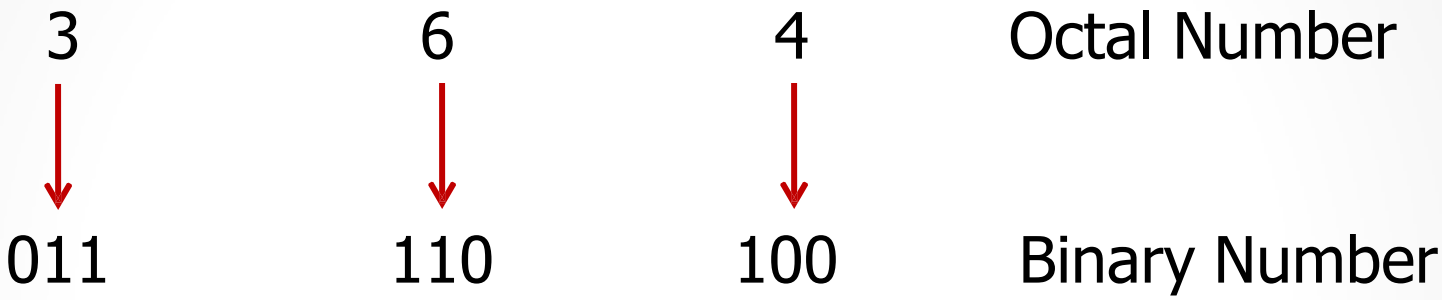
- ✓ To get hex equivalent number of given octal number, first we have to convert octal number into its 3 bit binary equivalent and then convert binary number into its hex equivalent.

Example: Convert 364 octal number in to it's equivalent hex number.

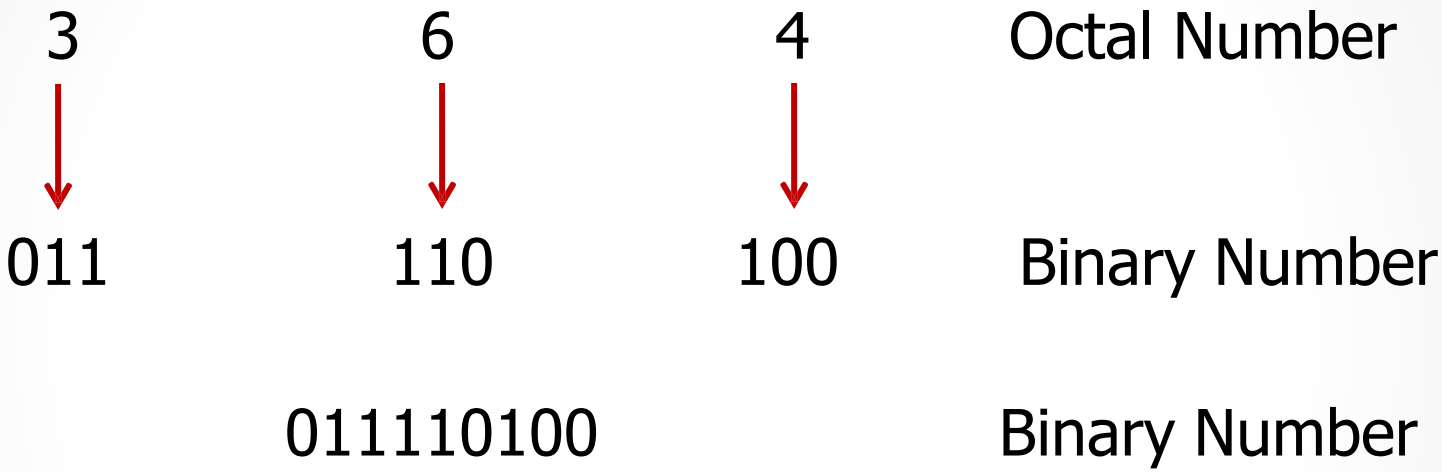
Example: Convert 364 octal number in to it's equivalent hex number.

3	6	4	Octal Number

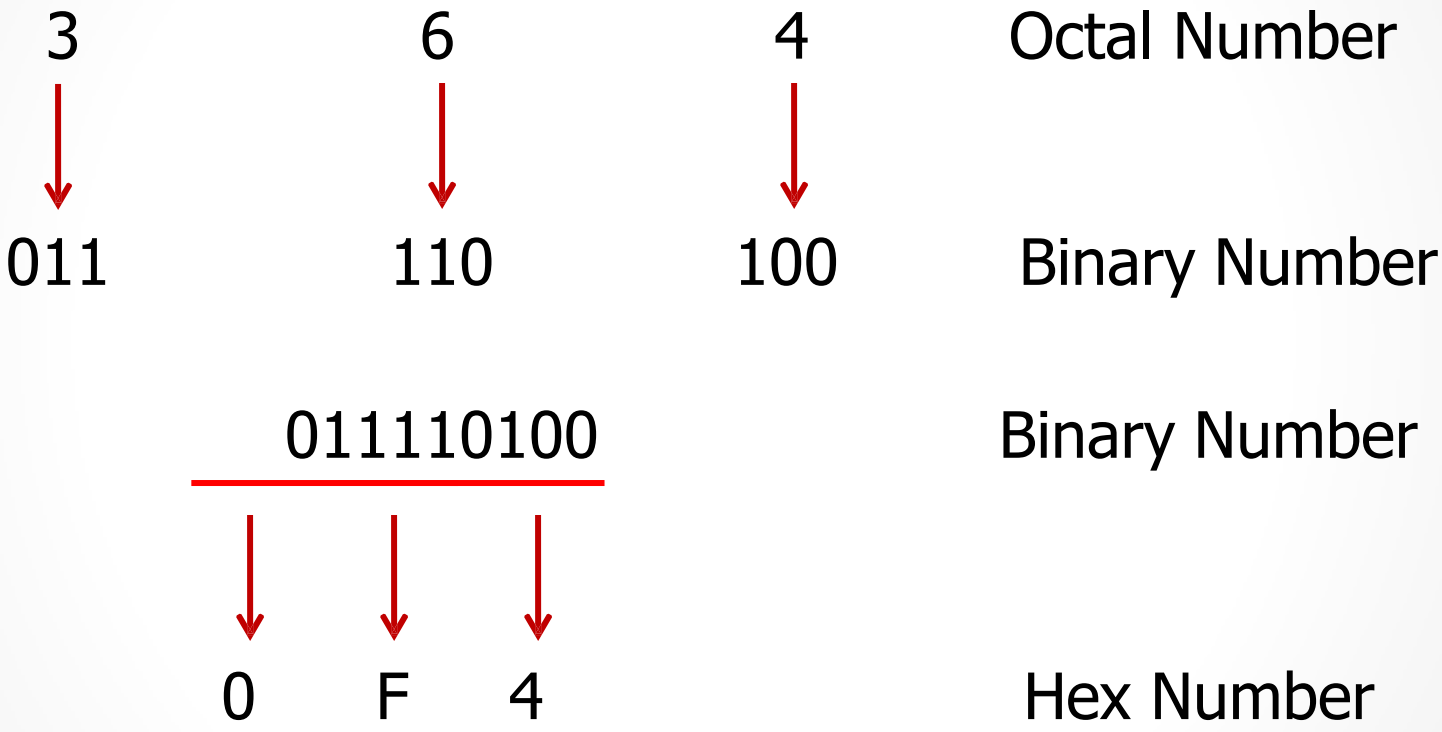
Example: Convert 364 octal number in to it's equivalent hex number.



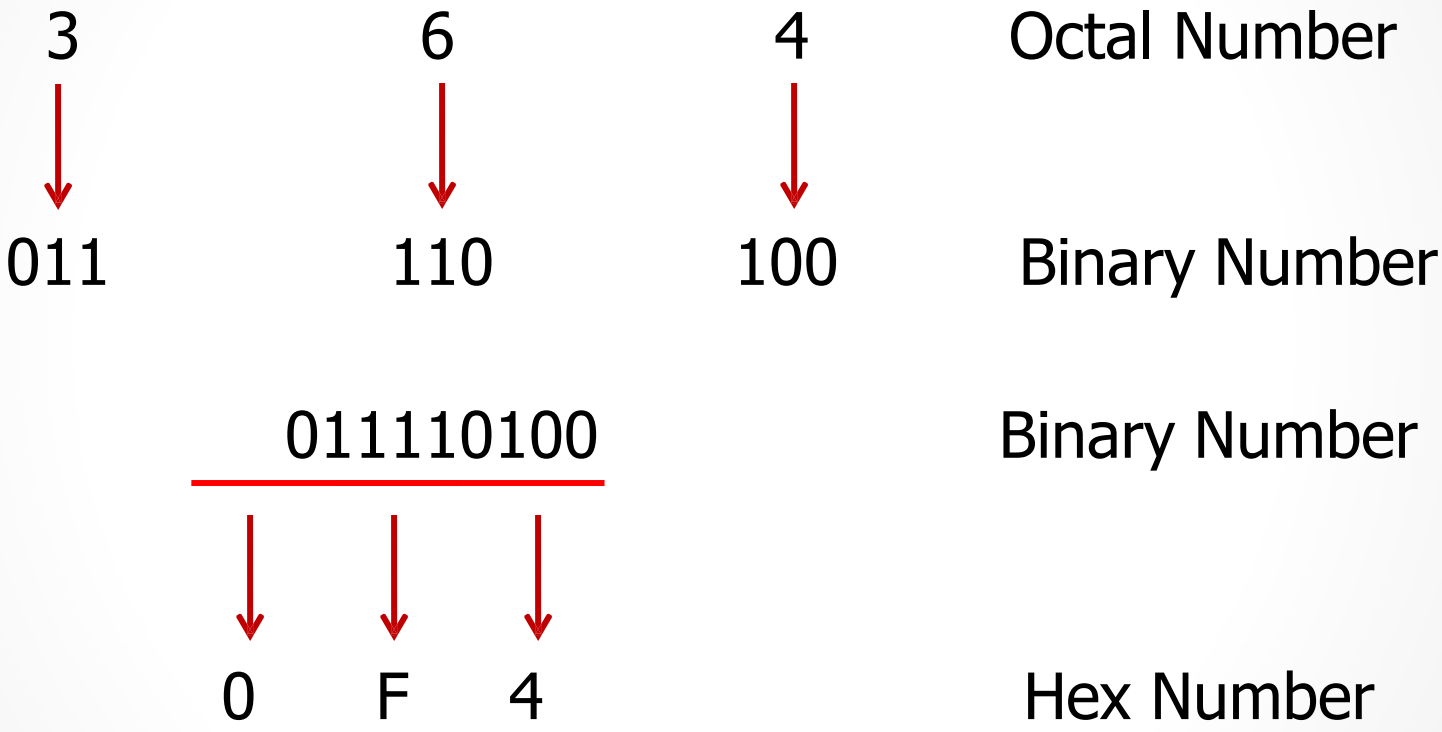
Example: Convert 364 octal number in to it's equivalent hex number.



Example: Convert 364 octal number in to it's equivalent hex number.



Example: Convert 364 octal number in to it's equivalent hex number.



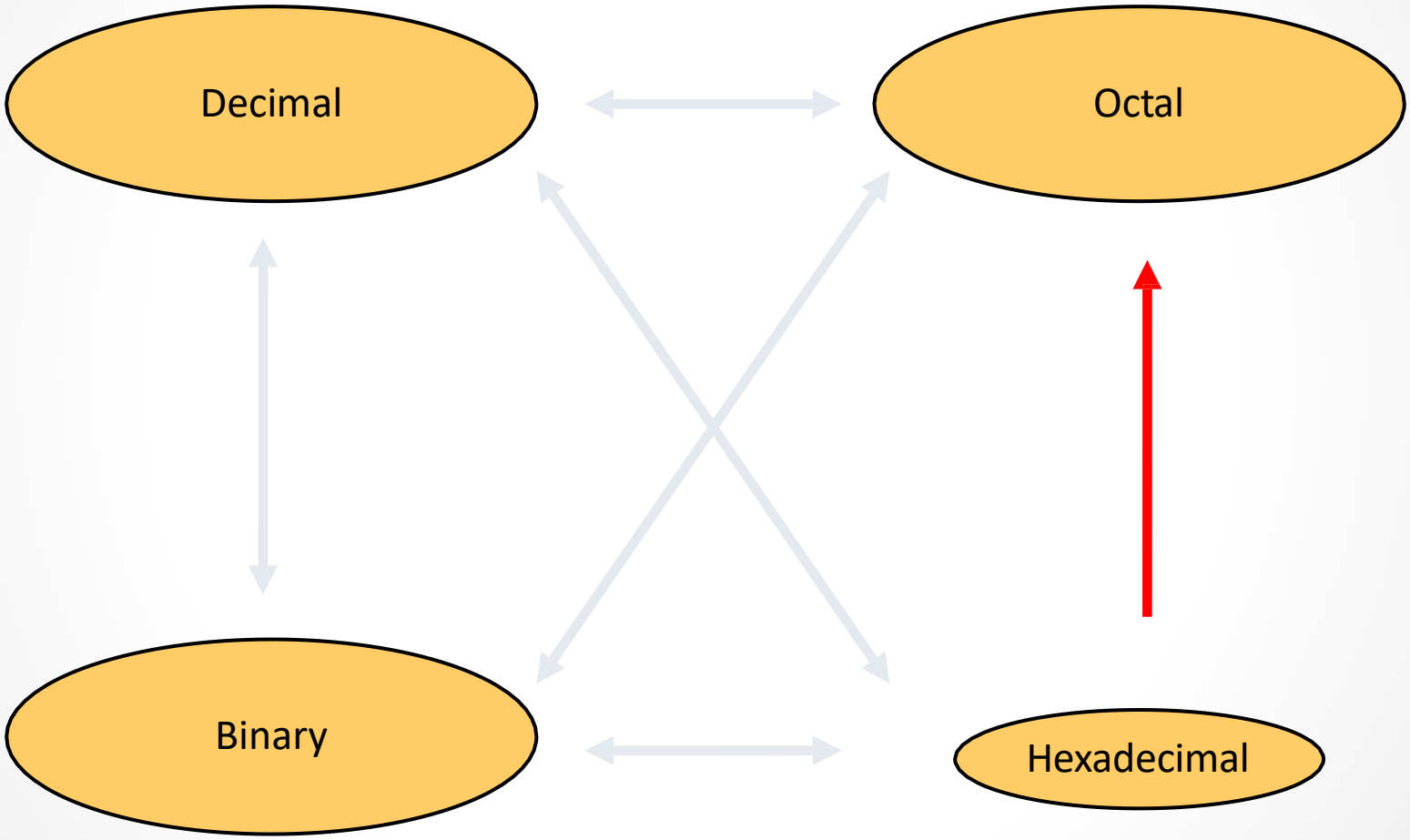
$$(364)_8 = (F4)_{16}$$

Exercise

- Convert following Octal Numbers in to its equivalent Hex Number:

1. $(3006.05)_8 = (\ ?\ )_{16}$
2. $(273.56)_8 = (\ ?\ )_{16}$
3. $(6534.04)_8 = (\ ?\ )_{16}$

Conversion from Hex Number to Octal Number



Conversion of Hexadecimal Number into Octal Number

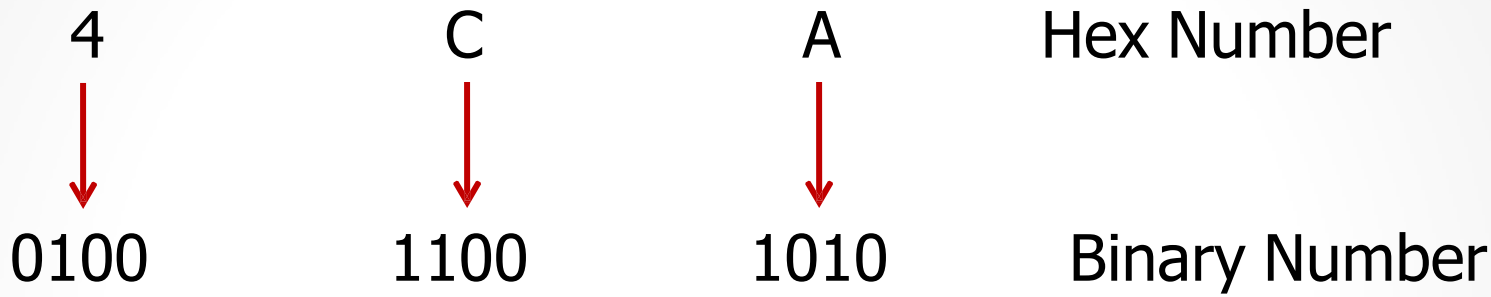
- ✓ To get octal equivalent number of given hex number, first we have to convert hex number into its 4 bit binary equivalent and then convert binary number into its octal equivalent.

Example: Convert 4CA hex number in to it's equivalent octal number.

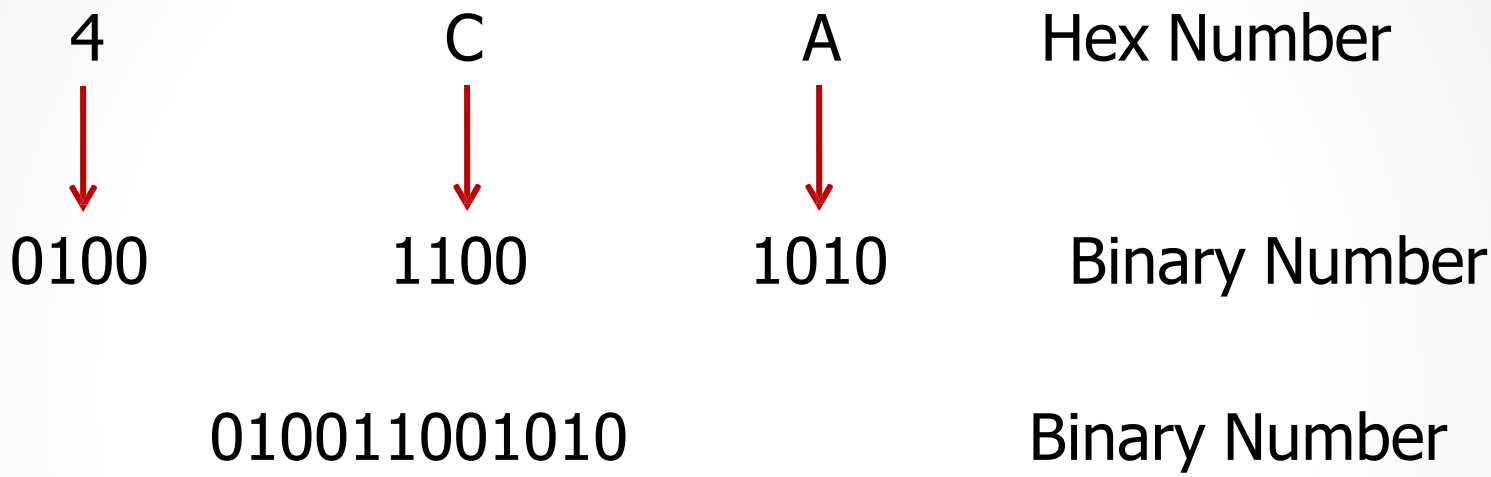
Example: Convert 4CA hex number in to it's equivalent octal number.

4	C	A	Hex Number

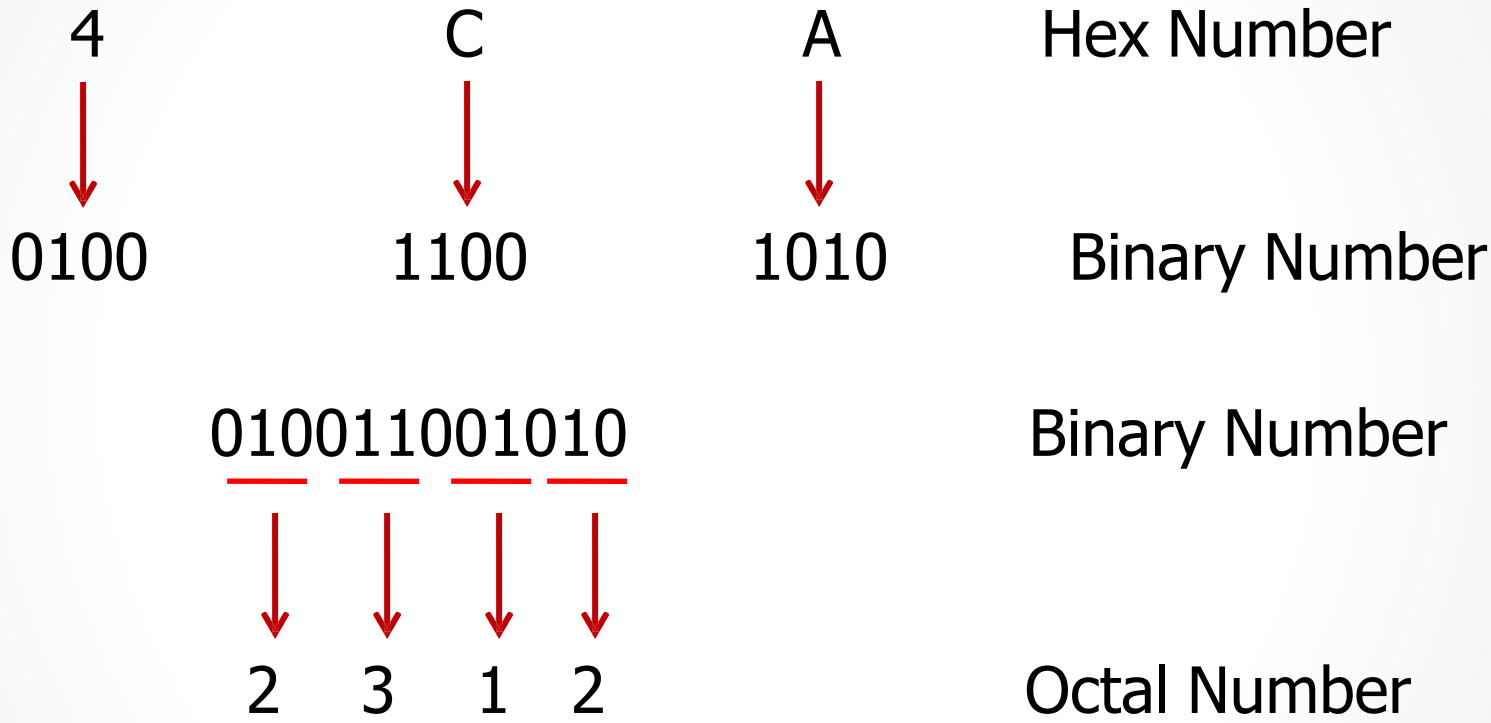
Example: Convert 4CA hex number in to it's equivalent octal number.



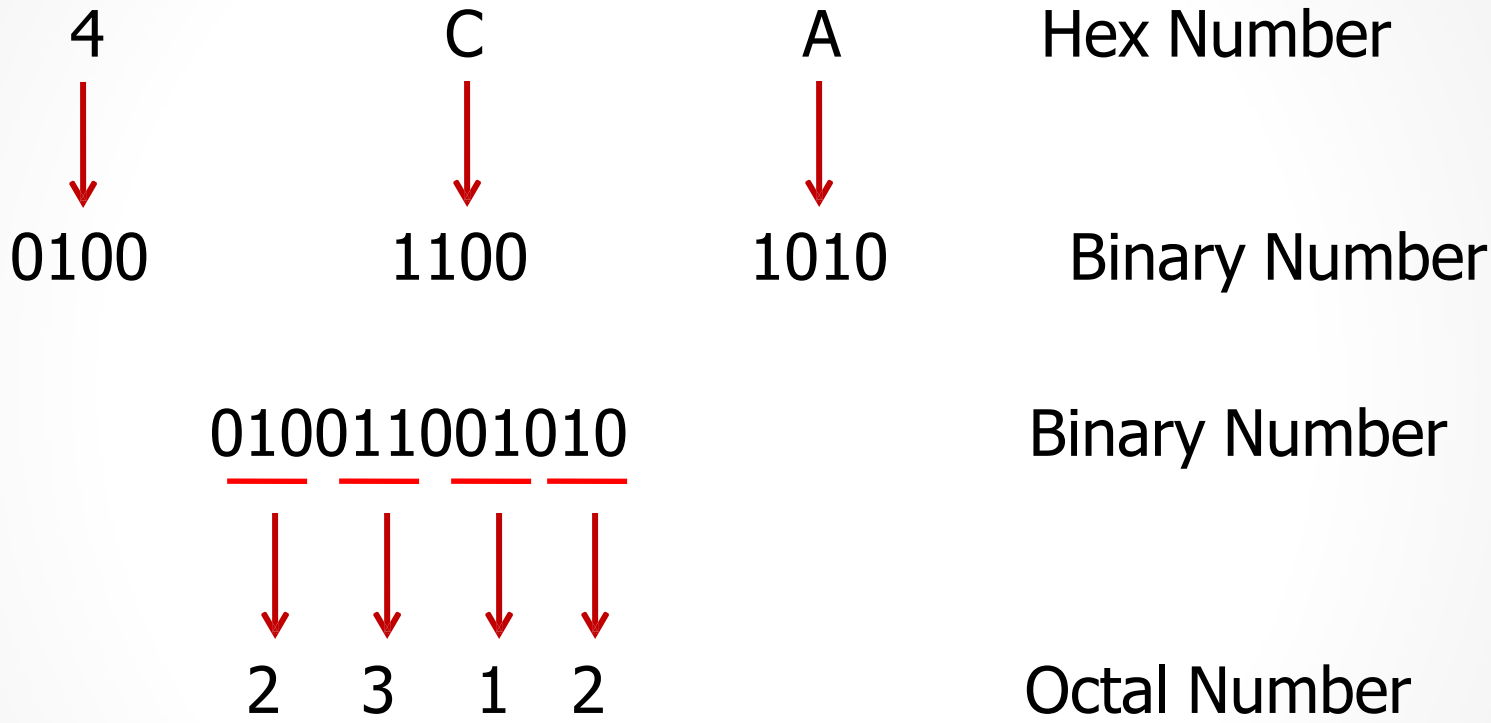
Example: Convert 4CA hex number in to it's equivalent octal number.



Example: Convert 4CA hex number in to it's equivalent octal number.



Example: Convert 4CA hex number in to it's equivalent octal number.



$$(4CA)_{16} = (2312)_8$$

Exercise

- Convert following Hexadecimal Numbers in to its equivalent Octal Number:

1. $(4056)_{16} = (\ ?\ )_{8}$
2. $(6B7)_{16} = (\ ?\ )_{8}$
3. $(8E47.AB)_{16} = (\ ?\ )_{8}$

Chapter I – Number System

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  - ✓ BCD addition, BCD subtraction using 9's and 10' complement
- **(Numericals based on above topic)**.

Binary Addition

- Following are the four most basic cases for binary addition

0	+	0	=	0
0	+	1	=	1
1	+	0	=	1
1	+	1	=	10 i.e. 0 with carry 1

Binary Addition

Example: Perform $(10111)_2 + (11001)_2$

Binary Addition

Example: Perform $(10111)_2 + (11001)_2$

$$
\begin{array}{cccccc}
 & & & 1 & & \\
 & 1 & 0 & 1 & 1 & 1 \\
+ & 1 & 1 & 0 & 0 & 1 \\
\hline
 & & & & & 0
\end{array}
$$

Binary Addition

Example: Perform $(10111)_2 + (11001)_2$

$$
\begin{array}{cccccc}
 & & & 1 & 1 & \\
 & 1 & 0 & 1 & 1 & 1 \\
+ & 1 & 1 & 0 & 0 & 1 \\
\hline
 & & & & 0 & 0
\end{array}
$$

Binary Addition

Example: Perform $(10111)_2 + (11001)_2$

$$
\begin{array}{cccccc}
 & & 1 & 1 & & \\
 & 1 & 0 & 1 & 1 & 1 \\
+ & 1 & 1 & 0 & 0 & 1 \\
\hline
 & & & 0 & 0 & 0
\end{array}
$$

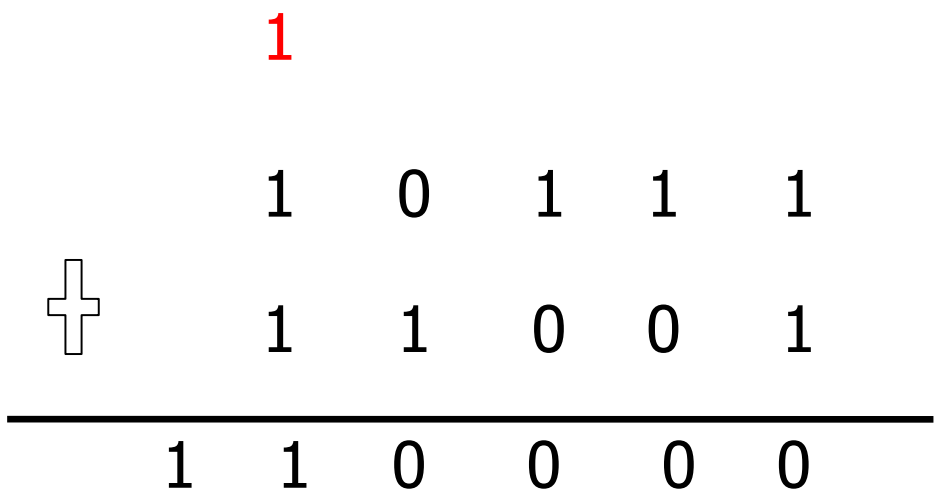
Binary Addition

Example: Perform $(10111)_2 + (11001)_2$

$$
\begin{array}{cccccc}
 & 1 & 1 & & & \\
 & 1 & 0 & 1 & 1 & 1 \\
+ & 1 & 1 & 0 & 0 & 1 \\
\hline
 & & 0 & 0 & 0 & 0
\end{array}
$$

Binary Addition

Example: Perform $(10111)_2 + (11001)_2$



Binary Addition

Example: Perform $(10111)_2 + (11001)_2$

$$
\begin{array}{cccccc}
 & 1 & 1 & 1 & 1 & \\
 & 1 & 0 & 1 & 1 & 1 \\
+ & 1 & 1 & 0 & 0 & 1 \\
\hline
1 & 1 & 0 & 0 & 0 & 0
\end{array}
$$

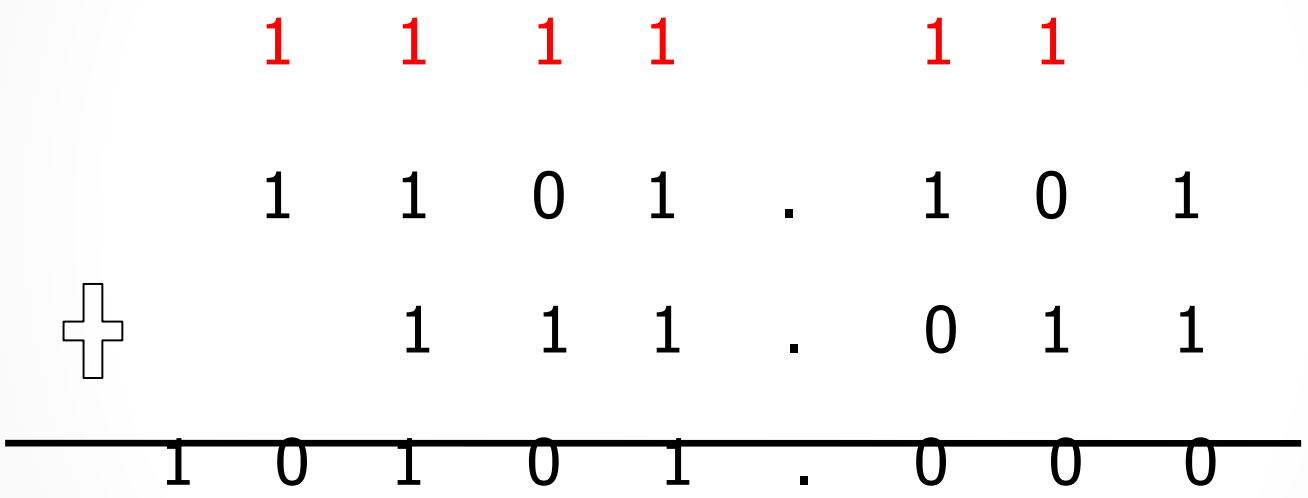
$$(10111)_2 + (11001)_2 = (110000)_2$$

Binary Addition

Example: Perform $(1101.101)_2 + (111.011)_2$

Binary Addition

Example: Perform $(1101.101)_2 + (111.011)_2$



$$(1101.101)_2 + (111.011)_2 = (10101.000)_2$$

Exercise

- Perform Binary Addition of following:

1. $(11011)_2+(1101)_2$ =101000
2. $(1011)_2+(1101)_2+(1001)_2+(1111)_2$ =110000
3. $(1010.11)_2+(1101.10)_2+(1001.11)_2+(1111.11)_2$ =110001.11
4. $(10111.101)_2+(110111.01)_2$ =101110.110

Binary Subtraction

- Following are the four most basic cases for binary subtraction

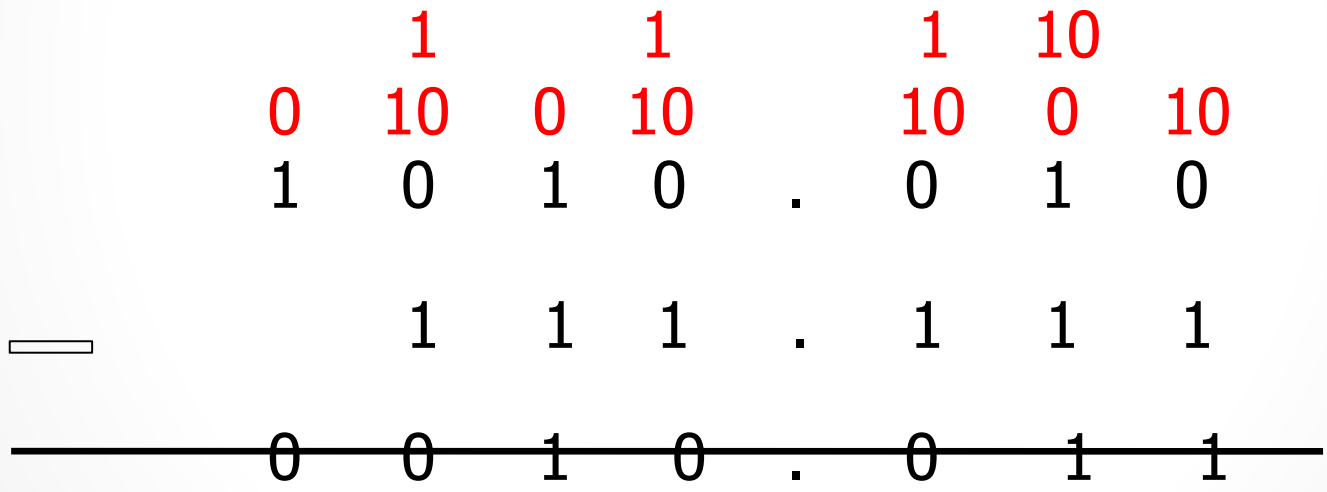
					Subtraction	Borrow
0	-	0	=	0		0
0	-	1	=	1		1
1	-	0	=	1		0
1	-	1	=	0		0

Binary Subtraction

Example: Perform $(1010.010)_2 - (111.111)_2$

Binary Subtraction

Example: Perform $(1010.010)_2 - (111.111)_2$



$$(1010.010)_2 + (111.111)_2 = (0010.011)_2$$

Exercise

- Perform Binary Subtraction of following:

1. $(1011)_2$- $(101)_2$
2. $(1100.10)_2$- $(111.01)_2$
3. $(10110)_2$- $(1011)_2$
4. $(10001.01)_2$- $(1111.11)_2$

Binary Multiplication

- Following are the four most basic cases for binary multiplication

0	X	0	=	0
0	X	1	=	0
1	X	0	=	0
1	X	1	=	1

Binary Multiplication

Example: Perform $(1001)_2 + (1000)_2$

Binary Multiplication

Example: Perform $(1001)_2 + (1000)_2$

$$
\begin{array}{cccccccc}
 & & & 1 & 0 & 0 & 1 & \\
 & & \times & 1 & 0 & 0 & 0 & \\
\hline
 & & & 0 & 0 & 0 & 0 & \\
 & & 0 & 0 & 0 & 0 & x & \\
+ & 0 & 0 & 0 & 0 & x & x & \\
1 & 0 & 0 & 1 & x & x & x & \\
\hline
1 & 0 & 0 & 1 & 0 & 0 & 0 &
\end{array}
$$

$$(1001)_2 + (1000)_2 = (1001000)_2$$

Exercise

- Perform Binary Multiplication of following:

1. $(1101)_2 \, X \, (101)_2$
2. $(1101.11)_2 \, X \, (101.1)_2$
3. $(11001)_2 \, X \, (10)_2$
4. $(10110)_2 \, X \, (10.1)_2$

Binary Division

Example: Perform $(110110)_2 / (101)_2$

Binary Division

Example: Perform $(110110)_2 / (101)_2$

```
          1  0  1  0
      ┌──────────────
101   │  1  1  0  1  1  0
        -1  0  1
      ──────────────
          0  0  1  1
            -0  0
          ──────────
             1  1  1
            -1  0  1
          ──────────
             0  1  0  0
               -0  0  0
             ──────────
                1  0  0
```

Exercise

- Perform Binary Division of following:

1. $(1010)_2$ by $(11)_2$
2. $(11110)_2$ by $(101)_2$
3. $(11011)_2$ by $(10.1)_2$
4. $(110111.1)_2$ by $(101)_2$

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1’s Complement

- The 1’s complement of a number is obtained by simply complementing each bit of the number that is by changing all 0’s to 1’s and all 1’s to 0’s.

- This system is called as 1’s complement because the number can be subtracted from 1 to obtain result

1’s Complement

Example: Obtain 1’s complement of the 1010

$$\begin{array}{rcccc} & 1 & 1 & 1 & 1 \\ - & 1 & 0 & 1 & 0 \\ \hline & 0 & 1 & 0 & 1 \end{array}$$

1’s complement of the 1010 is 0101

1’s Complement

Sr. No.	Binary Number	1’s Complement
1	1101 0101	0010 1010
2	1001	0110
3	1011 1111	0100 0000
4	1101 1010 0001	0010 0101 1110
5	1110 0111 0101	0001 1000 1010
6	1011 0100 1001	0100 1011 0110
7	1100 0011 0010	0011 1100 1101
8	0001 0010 1000	1110 1101 0111

Subtraction Using 1's Complement

- In 1's complement subtraction, add the 1's complement of subtrahend to the minuend.
- If there is carry out, bring the carry around and add it to LSB.
- Look at the sing bit (MSB), if this is 0, the result is positive and is in its true binary form.
- If the MSB is 1(whether there is a carry or no carry at all), the result is negative & is in its 1's complement form. So take 1's complement to obtain result.

Subtraction using 1's Complement

Example: Perform using 1' complement $(9)_{10} - (4)_{10}$

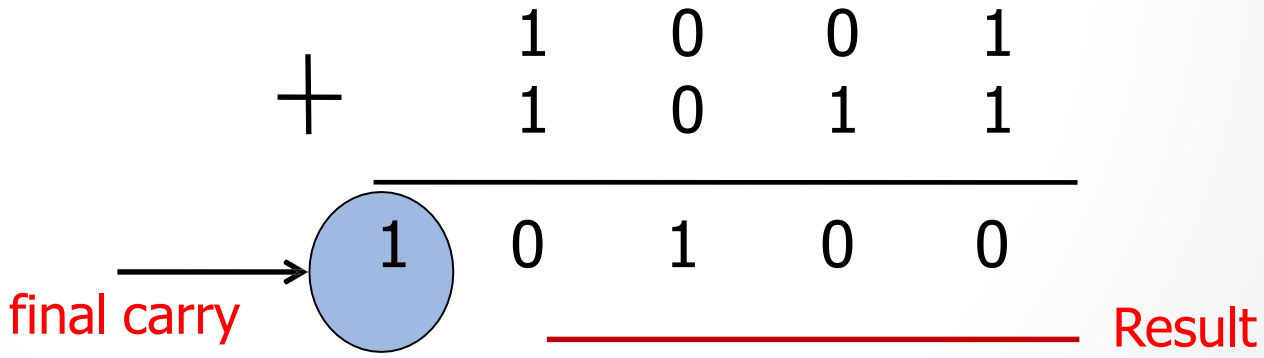
Subtraction using 1's Complement

Example: Perform using 1' complement $(9)_{10} - (4)_{10}$

Step 1: Take 1' complement of $(4)_{10} = (0100)_2$

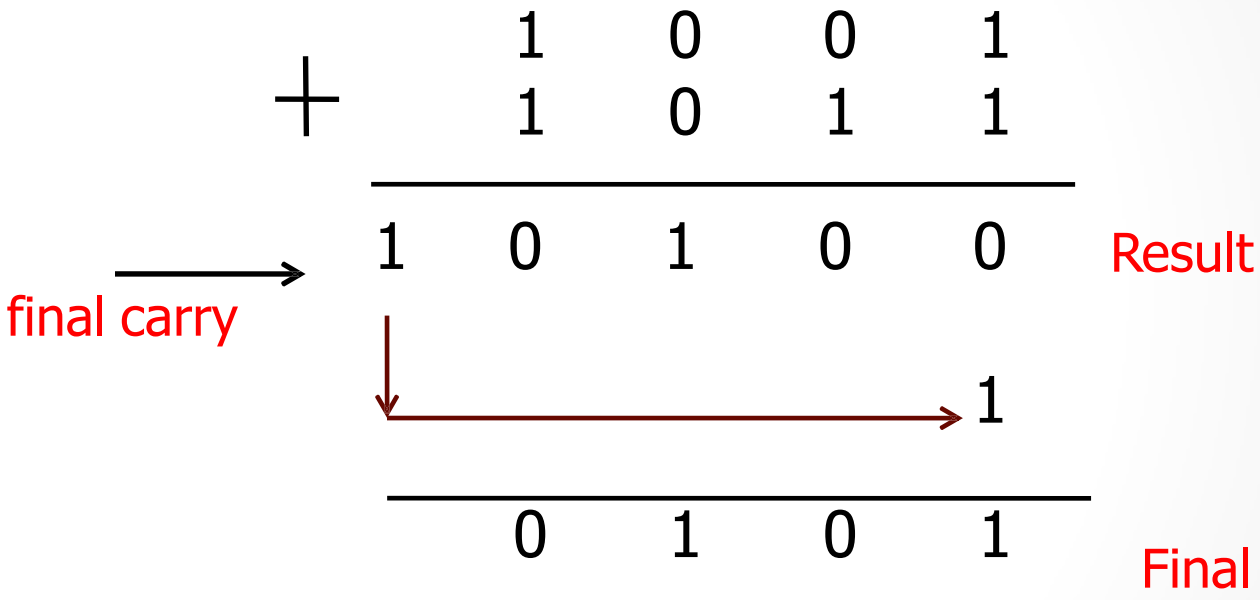
$= 1011$

Step 2: Add 9 with 1' complement of 4



Step 3:If carry is generated add final carry to the result

Example Continue



When the final carry is produced the answer is positive and is in its true binary form

Exercise

- Perform Binary Subtraction using 1's Complement method

1. $(52)_{10} - (17)_{10}$
2. $(46)_{10} - (84)_{10}$
3. $(63.75)_{10} - (17.5)_{10}$
4. $(73.5)_{10} - (112.75)_{10}$

2’s Complement

- ✓ The 2’s complement of a number is obtained by adding 1 to the 1’s complement of that number

2’s Complement

Example: Obtain 2’s complement of the 1010

2’s Complement

Example: Obtain 2’s complement of the 1010

```
        1   1   1   1
    -   1   0   1   0
  -------------------
        0   1   0   1      ---1’s complement
                    1
  -------------------
        0   1   1   0      ----2’s complement
```

2’s complement of the 1010 is 0110

2’s Complement

Sr. No.	Binary Number	1’s Complement	2’s Complement
1	1101 0101	0010 1010	0010 1011
2	1001	0110	0111
3	1011 1111	0100 0000	0100 0001
4	1101 1010 0001	0010 0101 1110	0010 0101 1111
5	1110 0111 0101	0001 1000 1010	0001 1000 1011

Subtraction Using 2's Complement

- In 2's complement subtraction, add the 2's complement of subtrahend to the minuend.
- If carry is generated then the result is positive and in its true form.
- If the carry is not produced, then the result is negative and in its 2's complement form.

*Carry is always to be discarded

Subtraction Using 2's Complement

Example: Perform using 2' complement $(9)_{10} - (4)_{10}$

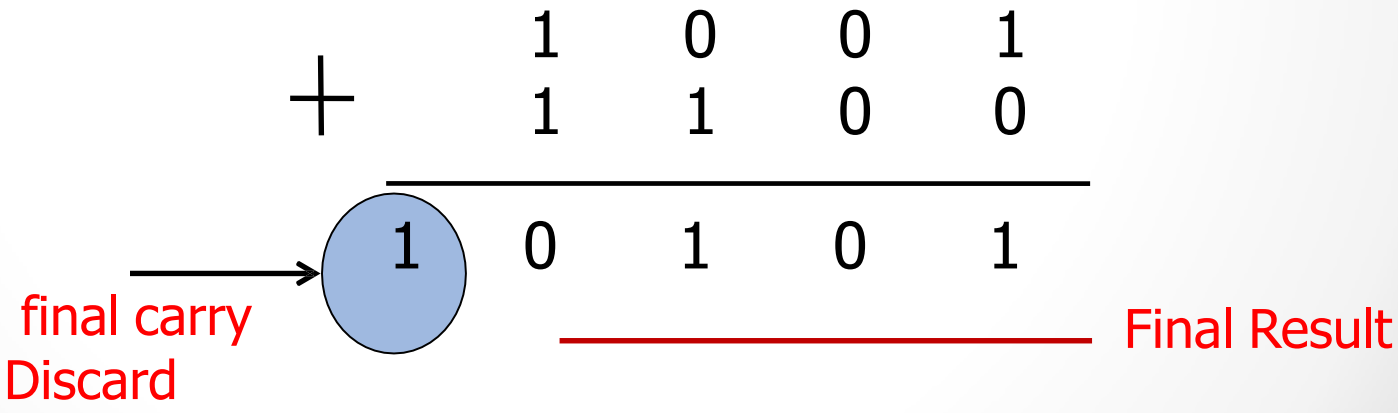
Subtraction Using 2's Complement

Example: Perform using 2' complement $(9)_{10} - (4)_{10}$

Step 1: Take 2' complement of $(4)_{10} = (0100)_2$

$$= 1011 + 1 = 1100$$

Step 2: Add 9 with 2' complement of 4



If Carry is generated, discard carry. The result is positive and its true binary form

Exercise

- Perform Binary Subtraction using 2's Complement method

    1. $(46)_{10} - (19)_{10}$
    2. $(27)_{10} - (75)_{10}$
    3. $(125.3)_{10} - (46.7)_{10}$
    4. $(36.75)_{10} - (89.5)_{10}$

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- **(Numericals based on above topic).**

BCD or 8421 Code

- The smallest BCD number is (0000) and the largest is (1001). The next number to 9 will be 10 which is expressed as (0001 0000) in BCD.

- There are six illegal combinations 1010, 1011, 1100, 1101, 1110 and 1111 in this code i.e. they are not part of the 8421 BCD code

Decimal to BCD Conversion

Sr. No.	Decimal Number	BCD Code
1	8	1000
2	47	0100 0111
3	345	0011 0100 0101
4	99	1001 1001
5	10	0001 0000

Exercise

- Convert following Decimal Numbers into BCD

1. $(286)_{10}$
2. $(807)_{10}$
3. $(429.5)_{10}$
4. $(158.7)_{10}$

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- **(Numericals based on above topic).**

BCD Addition

- The BCD addition is performed by individually adding the corresponding digits of the decimal number expressed in 4 bit binary groups starting from LSB.

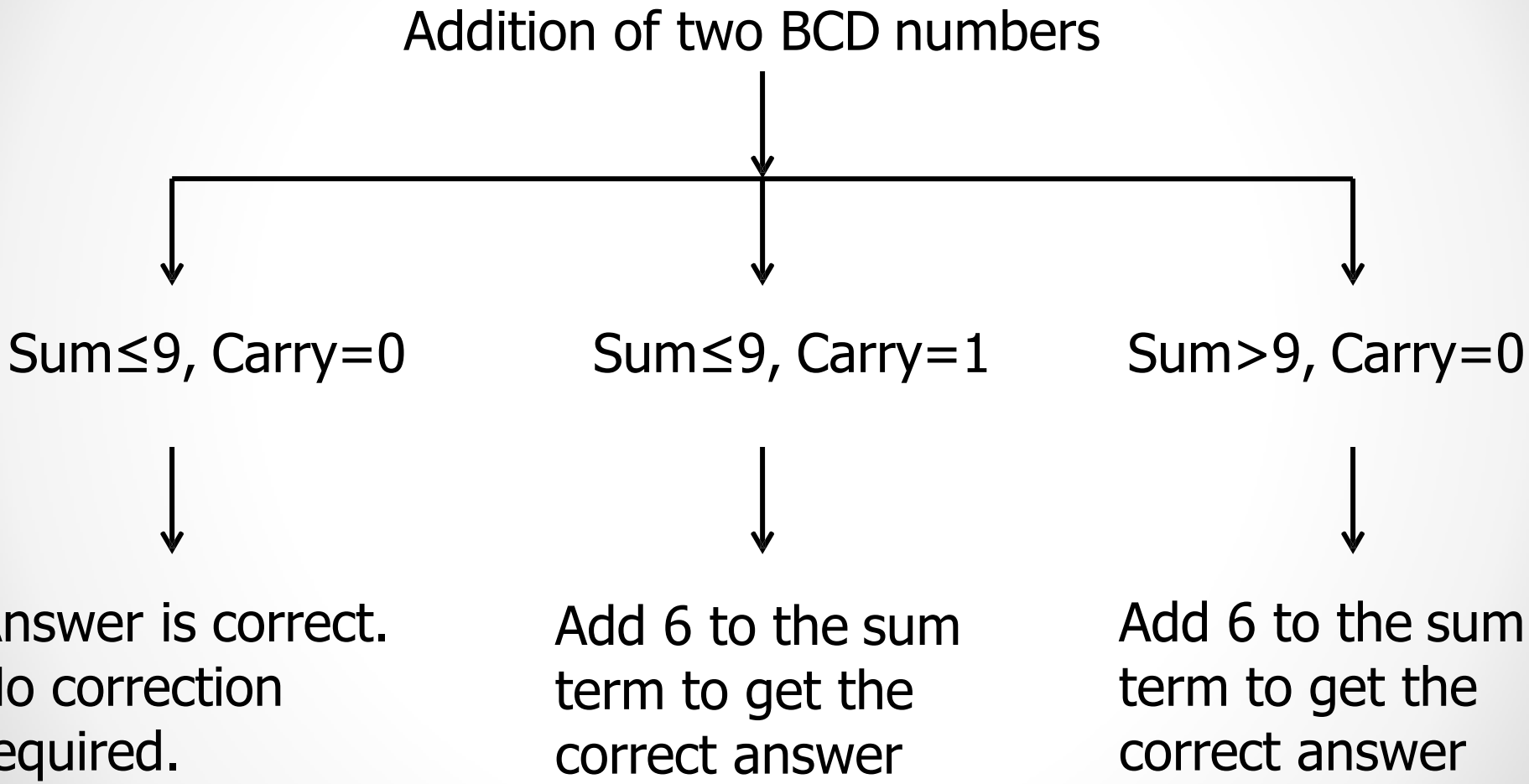
- If there is no carry & the sum term is not an illegal code, no correction is needed.

BCD Addition

- If there is a carry out of one group to the next group or if the sum term is an illegal code then 6 i.e. 0110 is added to the sum term of that group and resulting carry is added to the next group.

- This is done to skip the six illegal states.

BCD Addition



BCD Addition

Example: Perform in BCD $(57)_{10}+(26)_{10}$

BCD Addition

Example: Perform in BCD $(57)_{10}+(26)_{10}$

	57		0	1	0	1	0	1	1	1
+	26	+	0	0	1	0	0	1	1	0
	83		0	0	1	1	1	1	1	0	1

Final Carry 0

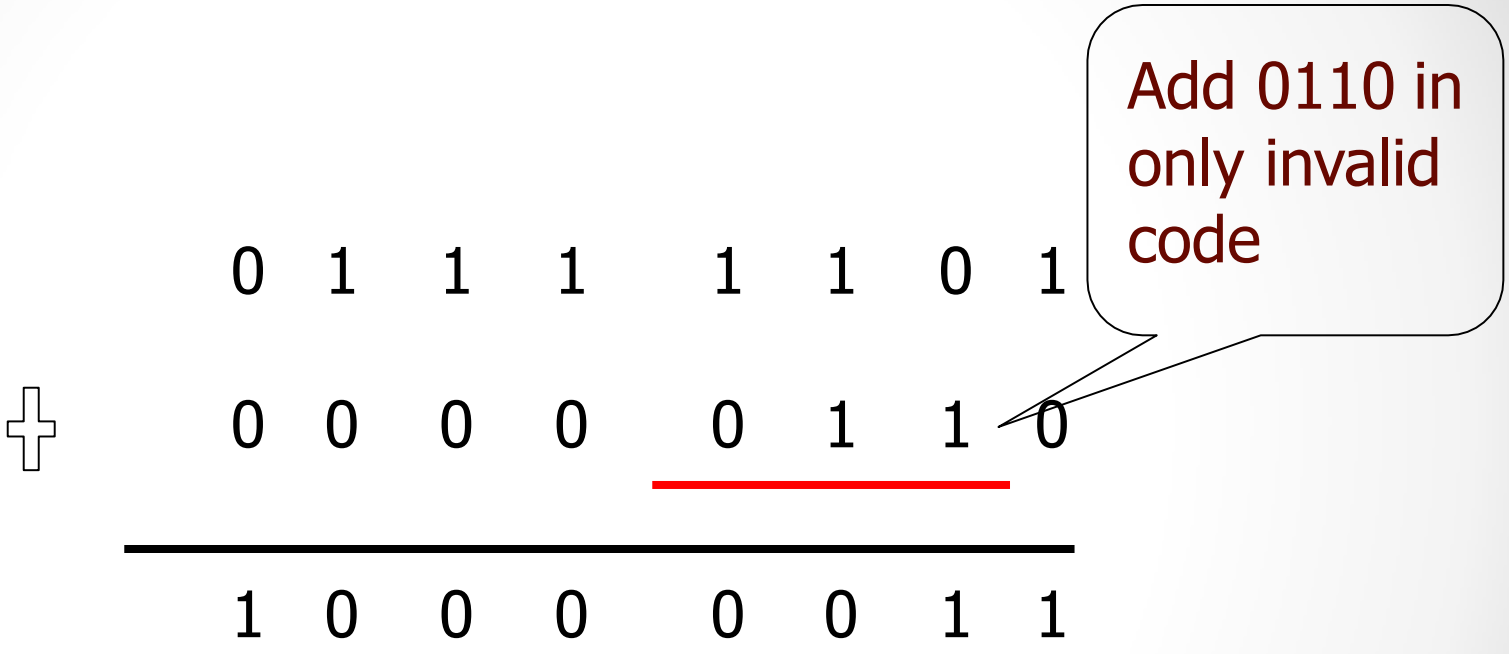
Valid BCD Code

Invalid BCD Code

Thus we have to add 0110 in illegal BCD code

Example

Continue



$$(57)_{10} + (26)_{10} = (83)_{10}$$

Exercise

- Perform BCD Addition

1. $(275)_{10} + (493)_{10}$ 2. $(109)_{10} + (778)_{10}$

3. $(88.7)_{10} + (265.8)_{10}$

4. $(204.6)_{10} + (185.56)_{10}$

BCD Subtraction

- The BCD subtraction is performed by subtracting the digits of each 4 bit group of the subtrahend from the corresponding 4 bit group of the minuend in binary starting from the LSD.

BCD Subtraction

- If there is no borrow from the next higher group then no correction is required .

- If there is a borrow from the next group, then 0110 is subtracted from the difference term of this group.

BCD Subtraction

Example: Perform in BCD $(38)_{10} - (15)_{10}$

BCD Subtraction

Example: Perform in BCD $(38)_{10} - (15)_{10}$

38	0 0 1 1	1 0 0 0
− 15	− 0 0 0 1	0 1 0 1
23	0 0 0 1 0	0 0 1 1

Final Borrow 0

Valid BCD Code

Valid BCD Code

No borrow, hence difference is correct

Exercise

- Perform BCD Subtraction

1. $(920)_{10} - (356)_{10}$
2. $(79)_{10} - (27)_{10}$
3. $(476.7)_{10} - (258.9)_{10}$
4. $(634.6)_{10} - (328.7)_{10}$

9's Complement

- The nine's complement of a BCD number can be obtained by subtracting each digit of BCD from 9.

Ex. Nine's complement of 168

```
    9  9  9
  - 1  6  8
  ---------
    8  3  1
```

9's complement of 168 is 831

BCD Subtraction using 9'sComplement

- Obtain 9's complement of subtrahend
- Add minuend with 9's complement of subtrahend
- If a carry is generated then add it to the sum to obtain the final result.
- If a carry is not produced then the result is negative hence take the 9's complement of the result.

BCD Subtraction using 9's Complement

Example: Perform in BCD using 9's complement $(83)_{10} - (21)_{10}$

BCD Subtraction using 9's Complement

Example: Perform in BCD using 9's complement $(83)_{10} - (21)_{10}$

9's complement of 21 99-21=78

Add 83 with 9's complement of 21 i.e. 78

83		1	0	0	0	0	0	1	1
78	+	0	1	1	1	1	0	0	0
		1	1	1	1	1	0	1	1

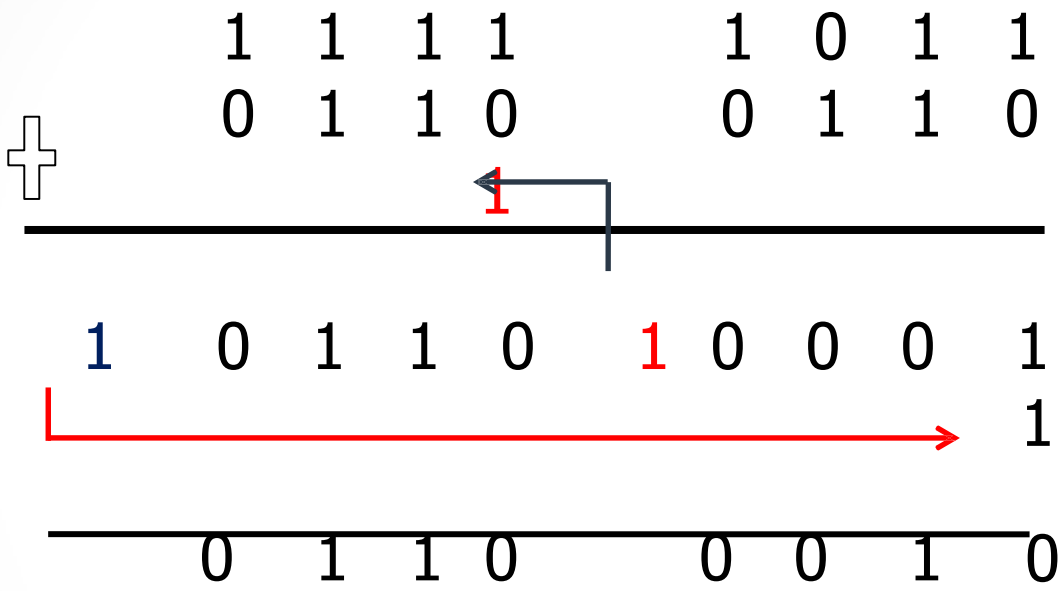
Invalid BCD Code

Invalid BCD Code

Thus we have to add 0110 in illegal BCD code

Example:

continue.....



$$(83)_{10} - (21)_{10} = (62)_{10}$$

Exercise

- Perform BCD Subtraction using 9's Complement

1. $(274)_{10} - (86)_{10}$
2. $(93)_{10} - (615)_{10}$
3. $(574.6)_{10} - (279.7)_{10}$
4. $(376.3)_{10} - (765.6)_{10}$

10’s Complement

- The 10’s complement of a BCD number can be obtained by adding 1 in 9’s complement.

Ex. 10’s complement of 168

```
    9  9  9
−   1  6  8
-------------
    8  3  1
+           1
-------------
    8  3  2
```

10’s complement of 168 is 832

BCD Subtraction using 10's Complement

- Obtain 10's complement of subtrahend
- Add minuend with 10's complement of subtrahend
- If a carry is generated, discard carry and result is positive and in its true form.
- If a carry is not produced then the result is negative hence take the 10's complement of the result.

BCD Subtraction using 10's Complement

Example: Perform in BCD using 10's complement $(83)_{10} - (21)_{10}$

BCD Subtraction using 10's Complement

Example: Perform in BCD using 10's complement $(83)_{10} - (21)_{10}$

9's complement of 21 99-21=78

10's complement of 21 78+1=79

Add 83 with 10's complement of 21 i.e. 79

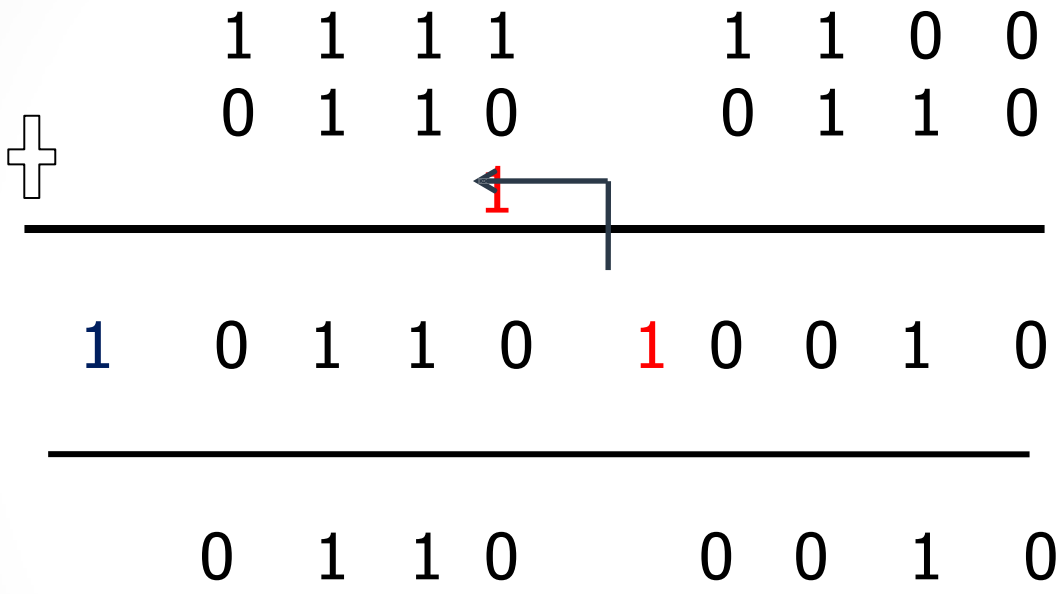
83		1	0	0	0	0	0	1	1
79	+	0	1	1	1	1	0	0	1
		1	1	1	1	1	1	0	0

Invalid BCD Code

Invalid BCD Code

Thus we have to add 0110 in illegal BCD code

Example: continue.....



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Exercise

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Gray Code

- ✓ The gray code is non-weighted code.
- ✓ It is not suitable for arithmetic operations.
- ✓ It is a cyclic code because successive code words in this code differ in one bit position only i.e. unit distance code

Binary to Gray Code Conversion

- ✓ If an n bit binary number is represented by $B_n, B_{n-1},.....B_1$ and its gray code equivalent by $G_n,G_{n-1},.....G_1$ where [ ] and [ ] are the MSBs, then gray code bits are obtained from the binary code as follows;

*where the symbol represents Exclusive-OR operation

Binary to Gray Code Conversion

Example 1: Convert 1011 Binary Number into Gray Code

Binary to Gray Code Conversion

Example 1: Convert 1011 Binary Number into Gray Code

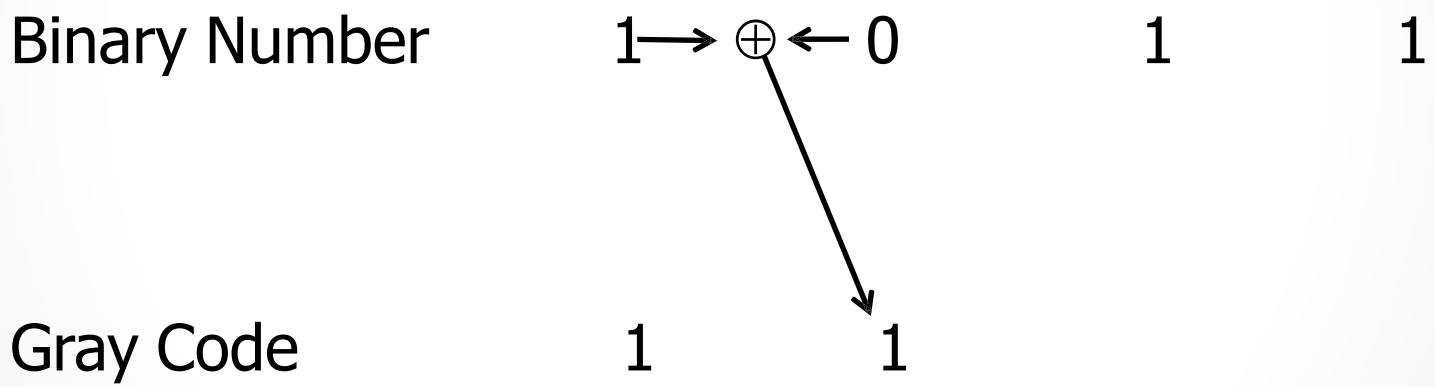
Binary Number	1	0	1	1

Example 1: Continue

Binary Number	1	0	1	1
	↓			
Gray Code	1			

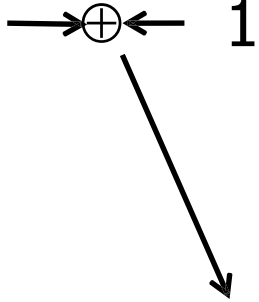
Example 1:

Continue



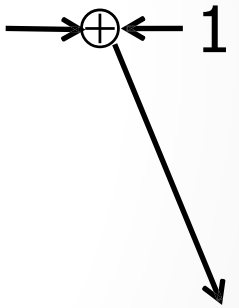
Example 1: Continue

Binary Number	1	0	1	1
Gray Code	1	1	1	

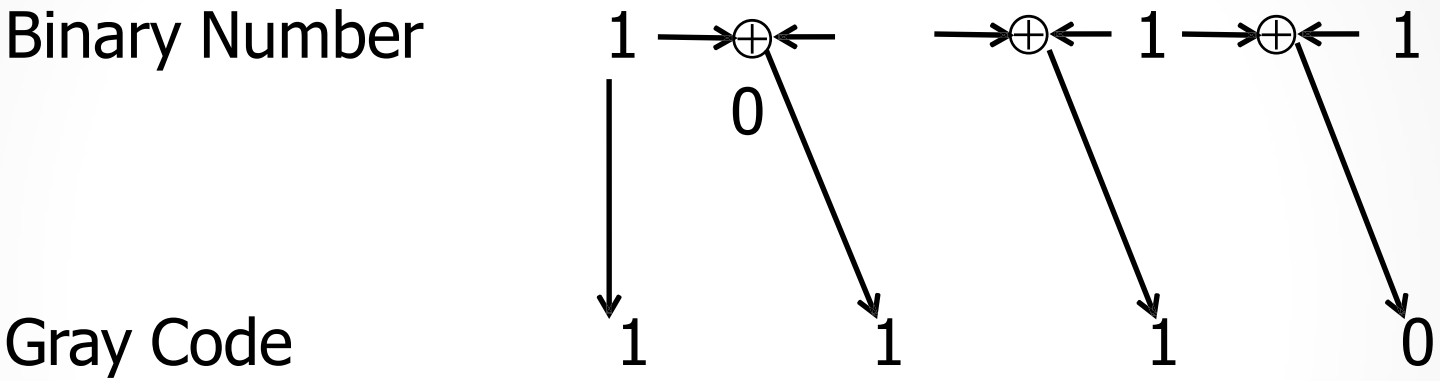


Example 1: Continue

Binary Number	1	0	1	1
Gray Code	1	1	1	0



Example 1: Continue

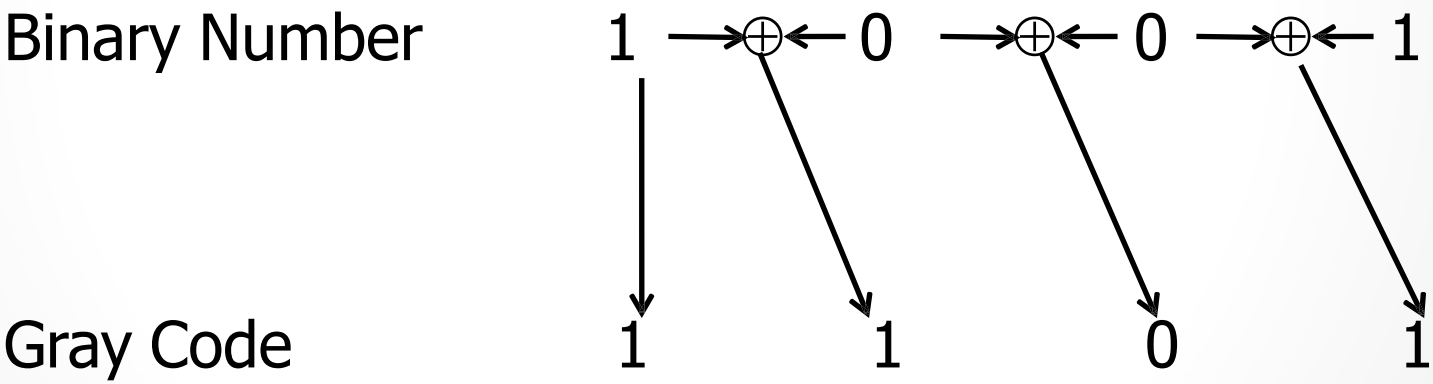


Binary to Gray Code Conversion

Example 2: Convert 1001 Binary Number into Gray Code

Binary to Gray Code Conversion

Example 2: Convert 1001 Binary Number into Gray Code

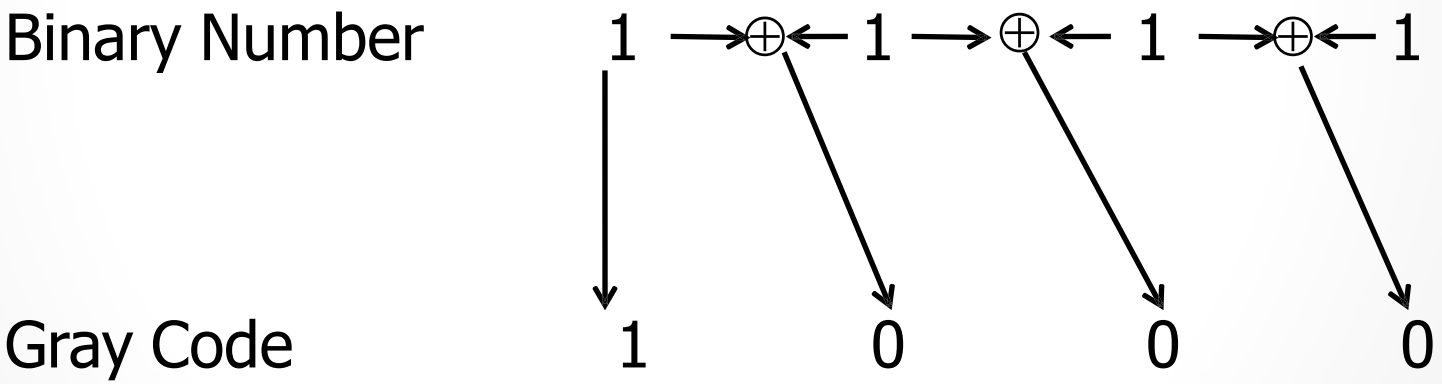


Binary to Gray Code Conversion

Example 3: Convert 1111 Binary Number into Gray Code

Binary to Gray Code Conversion

Example 3: Convert 1111 Binary Number into Gray Code

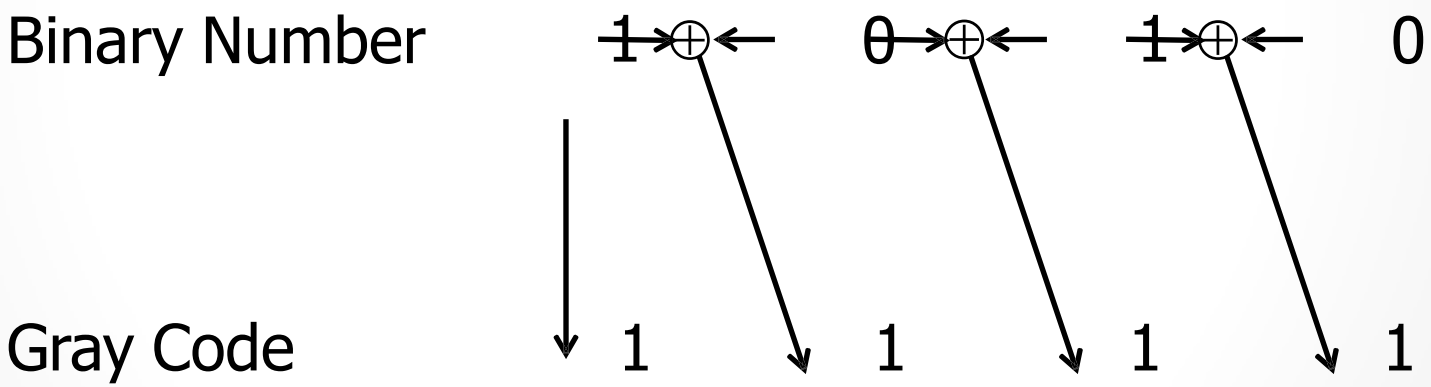


Binary to Gray Code Conversion

Example 4: Convert 1010 Binary Number into Gray Code

Binary to Gray Code Conversion

Example 4: Convert 1010 Binary Number into Gray Code



Binary and Corresponding Gray Codes

Decimal No.	Binary No.	Gray Code
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111
11	1011	1110
12	1100	1010
13	1101	1011
14	1110	1001
15	1111	1000

Exercise

- Convert following Binary Numbers into Gray Code

    1. $(1011)_2$
    2. $(110110010)_2$
    3. $(101010110101)_2$
    4. $(100001)_2$

Gray Code to Binary Conversion

- ✓ If an n bit gray code is represented by $G_n, G_{n-1}, \ldots\ldots G_1$ and its binary equivalent then binary bits are obtained $B_n, B_{n-1}, \ldots\ldots B_1$ from gray bits as follows;

$B_n = G_n$	$B_{n-1} = B_n \oplus G_{n-1}$	$B_{n-2} = B_{n-1} \oplus G_{n-2}$	$B_1 = B_2 \oplus G_1$

*where the symbol $\oplus$ represents Exclusive-OR operation

Gray Code to Binary Conversion

Example 1: Convert 1110 Gray code into Binary Number.

Gray Code to Binary Conversion

Example 1: Convert 1110 Gray code into Binary Number.

Gray Code	1	1	1	0

Example 1:

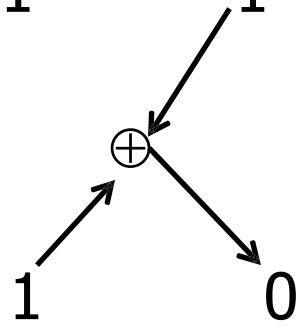
Continue

Gray Code	1	1	1	0
	↓			
Binary Number	1			

Example 1:

Continue

Gray Code 1 1 1 0

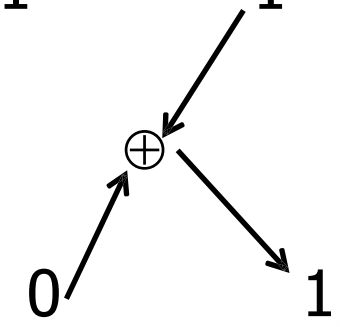


Binary Number 1 0

Example 1:

Continue

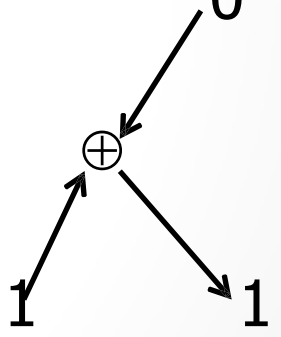
Gray Code	1	1	1	0
Binary Number	1	0	1	



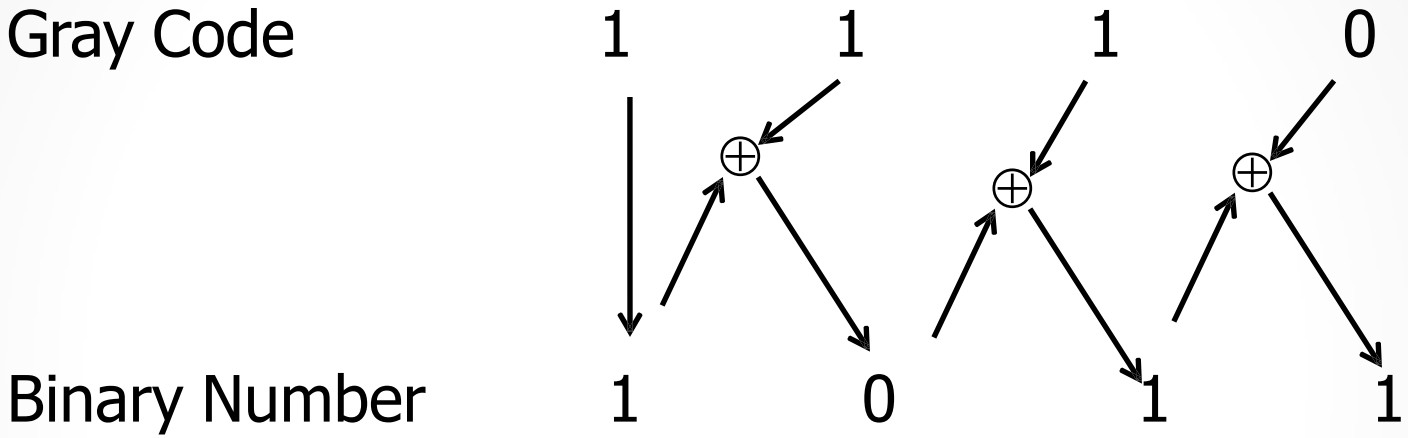
Example 1:

Continue

Gray Code	1	1	1	0
Binary Number	1	0	1	1



Example 1: Continue

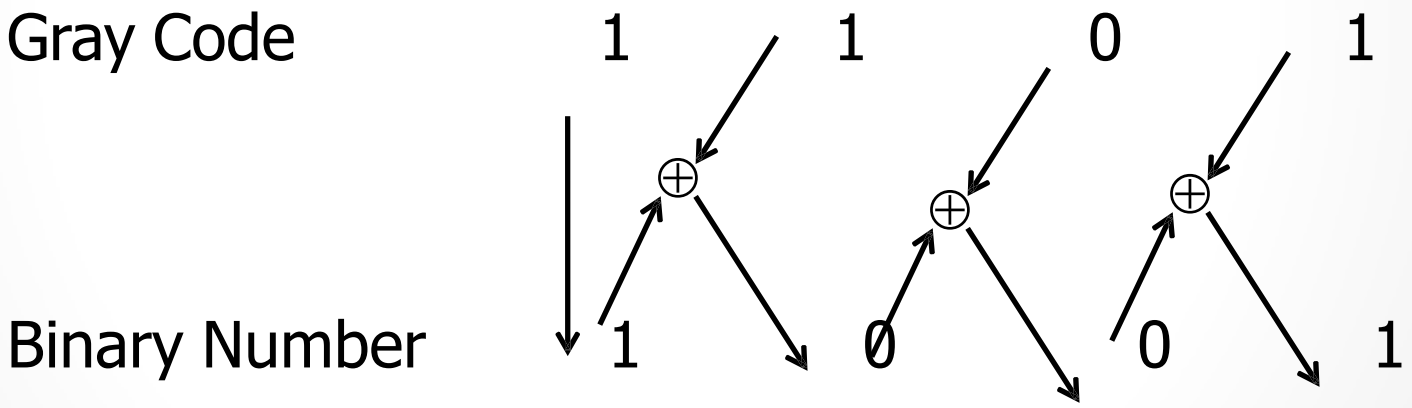


Gray Code to Binary Conversion

Example 2: Convert 1101 Gray code into Binary Number.

Gray Code to Binary Conversion

Example 2: Convert 1101 Gray code into Binary Number.

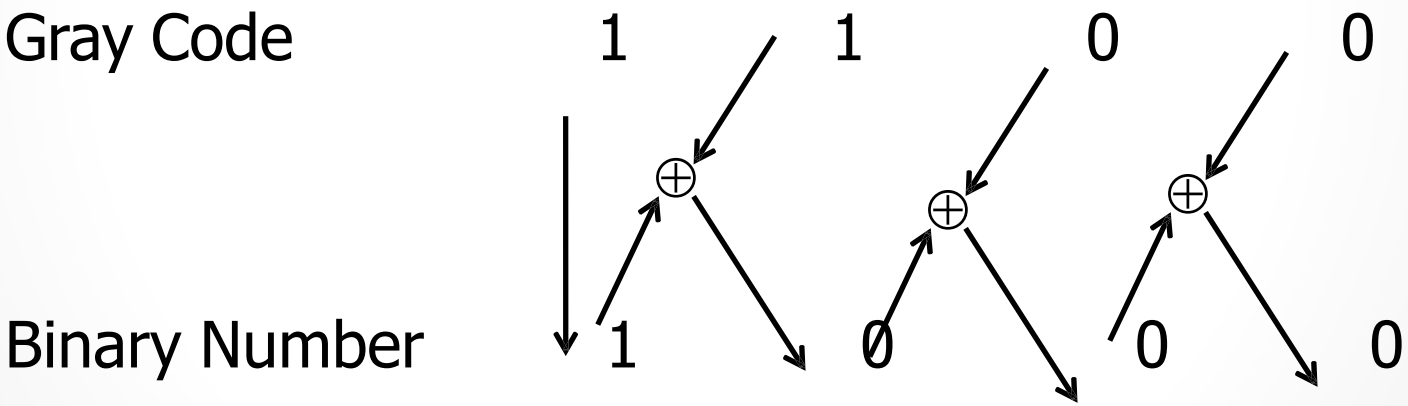


Gray Code to Binary Conversion

Example 3: Convert 1100 Gray code into Binary Number.

Gray Code to Binary Conversion

Example 3: Convert 1100 Gray code into Binary Number.



Exercise

- Convert following Gray Numbers into Binary Numbers

    1. $(1111)_{GRAY}$
    2. $(101110)_{GRAY}$
    3. $(100010110)_{GRAY}$
    4. $(11100111)_{GRAY}$

Excess-3 Code (XS-3)

- ✓ The Xs-3 is non-weighted BCD code.
- ✓ This code derives its name from the fact that each binary code word is the corresponding 8421 code word plus 0011.
- ✓ It is a sequential code & therefore can be used for arithmetic operations.
- ✓ It is a self complementing code

Excess-3 Code (XS-3)

Decimal No.	BCD Code	Excess-3 Code= BCD + Excess-3
0	0000	0011
1	0001	0100
2	0010	0101
3	0011	0110
4	0100	0111
5	0101	1000
6	0110	1001
7	0111	1010
8	1000	1011
9	1001	1100

Excess-3 Code (XS-3)

Example 1: Obtain Xs-3 Code for 428 Decimal

Excess-3 Code (XS-3)

Example 1: Obtain Xs-3 Code for 428 Decimal

	4	2	8
	0100	0010	1000
+	0011	0011	0011
	0111	0101	1011

Exercise

- Convert following Decimal Numbers into Excess-3 Code

    1. $(40)_{10}$
    2. $(88)_{10}$
    3. $(64)_{10}$
    4. $(23)_{10}$

ASCII Codes

- ✓ The **American Standard Code for Information Interchange** is a character-encoding scheme originally based on the English alphabet.
- ✓ ASCII codes represent text in computers, communications equipment, and other devices that use text.
- ✓ Most modern character-encoding schemes are based on ASCII, though they support many additional characters.

ASCII Codes

- ✓ ASCII developed from telegraphic codes. Its first commercial use was as a seven-bit tele-printer code promoted by Bell data services.
- ✓ Work on the ASCII standard began on October 6, 1960, with the first meeting of the American Standards Association's (ASA) X3.2 subcommittee.
- ✓ The first edition of the standard was published during 1963.

ASCII Codes

- ✓ ASCII includes definitions for 128 characters: 33 are non-printing control characters (many now obsolete) that affect how text and space is processed and 95 printable characters, including the space (which is considered an invisible graphic)

ASCII Codes

				B7	0	0	0	0	1	1	1	1
				B6	0	0	1	1	0	0	1	1
				B5	0	1	0	1	0	1	0	1
B4	B3	B2	B1		0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	‘	p
0	0	0	1	1	SOH	DC1	|	1	A	Q	a	q
0	0	1	0	2	STX	DC2	“	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	‘	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	“	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FC	,	<	L	\	l	!
1	1	0	1	13	CR	GS		=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~

Online Tutorials

- ✓ http://nptel.ac.in/video.php?subjectId=117106086
- ✓ http://www.electronics-tutorials.ws/binary/bin_1.html

Thank You