NUMBER SYSTEM

Decimal Number System
Binary Number System
Octal Number System
Hexadecimal Number System
ASCII, ISCII, UNICODE

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Understanding Number System

- Computers accept input and deliver output in the form of digital signals.
- A digital signal has only two states, represented by two voltage levels, high and low.
- For a computer to process numbers, it is important to be able to represent the numbers as digital signals.
- To achieve this, you need a number system that uses only two symbols to represent any number.
- The binary number system uses only two symbols, 0 and 1, to represent any number, and therefore provides a direct way of representing numbers in computers.
- Two other number systems, octal and hexadecimal, help represent binary numbers concisely, making it convenient to deal with large strings of 0s and 1s.

Understanding Number System

- A number system is known by its radix or base.
- The decimal number system uses 10 symbols, and therefore, has a radix or base of 10. The binary number system uses two symbols, and therefore, has a radix of 2.
- The radix of a number is usually written as a subscript with that number, where the number is written within parentheses, as shown in the following examples:
  - $(368)_{10}$
  - $(10101)_2$

Decimal Number System

- The decimal number system uses 10 symbols, and therefore has a radix or base of 10.
- Symbols are [0 to 9]
- Every digit in Decimal number system is identified from its position i.e. from right to left as (for e.g. 345) :-

Number	3	4	5
POSITIONAL VALUE	10^2	10^1	10^0

- It means : $3 \times 10^2 + 4 \times 10^1 + 5 \times 10^0 = 345$
- **3 x 100** + **4 x 10** + **5 x 1** = 345
- Left most digit will be MSD (most significant digit and right most digit will be LSD (least significant digit)

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Binary Number System

- The binary number system uses 2 symbols, and therefore has a radix or base of 2.
- Symbols are [0 and 1], also known as bits or binary digit
- Every bit in Binary number system is identified from its position i.e. from right to left as (for e.g. 110) :-

Binary Number	1	1	0
POSITIONAL VALUE	2^2	2^1	2^0

- It means : $1 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$ will give its decimal equivalent
- **1 x 4** + **1 x 2** + **0 x 1** = 6, So $(110)_2 = (6)_{10}$
- Left most digit will be MSB (most significant bit and right most digit will be LSB (least significant bit)

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Octal Number System

- The octal number system uses 8 symbols, and therefore has a radix or base of 8.
- Symbols are [0 to 7]
- Every bit in Octal number system is identified from its position i.e. from right to left as (for e.g. 140) :-

Binary Number	1	4	0
POSITIONAL VALUE	8^2	8^1	8^0

- It means : $1 \times 8^2 + 4 \times 8^1 + 0 \times 8^0$ will give its decimal equivalent
- **1 x 64** + **4 x 8** + **0 x 1** = 96, So $(140)_8 = (96)_{10}$

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Hex-Decimal Number System

- The Hex number system uses 16 symbols, and therefore has a radix or base of 16.
- Symbols are [0 to 9 and A to F]
- 10 is represented as A and so on
- Every bit in Hex number system is identified from its position i.e. from right to left as (for e.g. A2B) :-

Binary Number	A	2	B
POSITIONAL VALUE	16^2	16^1	16^0

- It means : $Ax16^2 + 2x16^1 + Bx16^0$ will give its decimal equivalent
- **10x256 + 2x16 + 11x1 = 2603, So $(A2B)_{16} = (2603)_{10}$**

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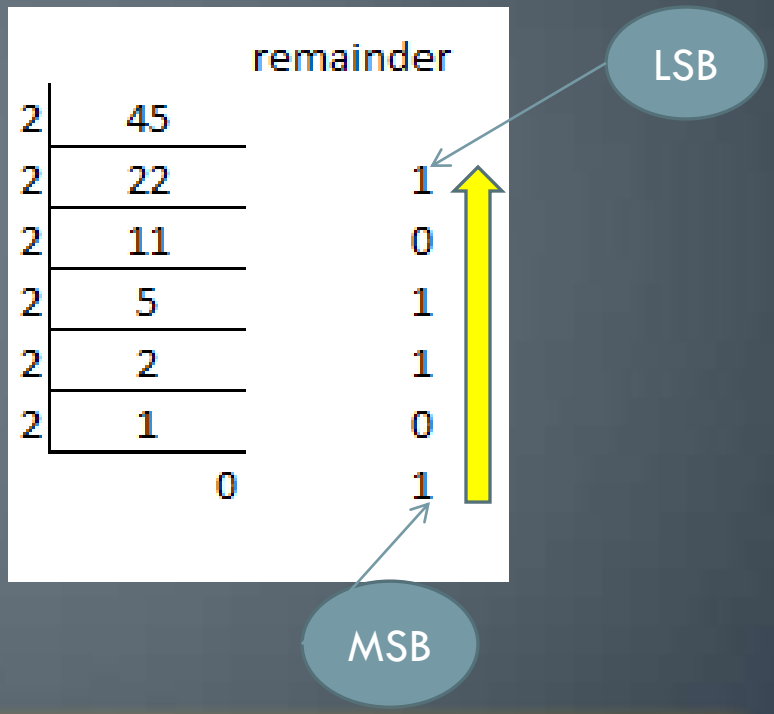
Conversion: Decimal to Binary

- At times, you need to covert a number from one number system to another.
- Distinct methods have been defined for conversion between each pair of number systems.
- You can convert a decimal number to its binary form by using the method of successive division by 2, the radix of the binary number system.
- Put the remainder to the right of quotient and repeat this process till the quotient becomes ZERO or ONE.
- Write down the remainders in reverse order to get equivalent binary number.

Example: Decimal to Binary

$(45)_{10}$ to $(?)_2$



ANSWER: $(101101)_2$

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Just a Minute...

- $(79)_{10}$ to $(\ ?\ )_2$
- $(30)_{10}$ to $(\ ?\ )_2$

Conversion: Binary to Decimal

- Multiply each bit of binary number by its place value i.e. 2^n
- Add the result.

$(10101101)_2$ to $(?)_{10}$

1	0	1	0	1	1	0	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

128 x 1	+	64 x 0	+	32 x 1	+	16 x 0	+	8 x 1	+	4 x 1	+	2 x 0	+	1 x 1

128	+	0	+	32	+	0	+	8	+	4	+	0	+	1

ANSWER: $(73)_{10}$

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Just a Minute...

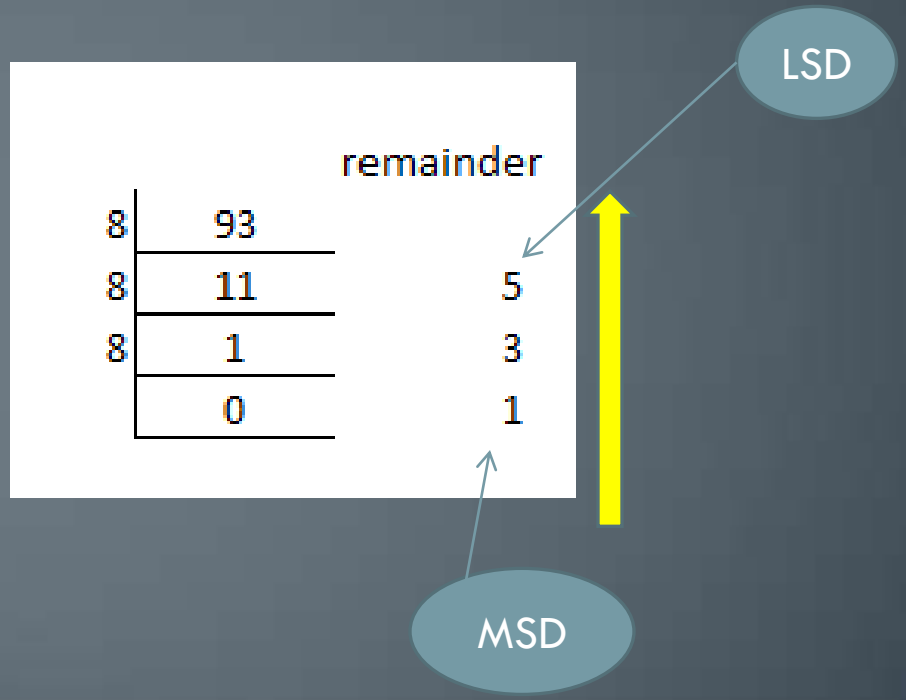
- $(1111110)_2$ to $(\ ?\ )_{10}$
- $(101010110101)_2$ to $(?)_{10}$

Conversion: Decimal to Octal

- You can convert a decimal number to its octal form by using the method of successive division by 8, the radix of the octal number system.
- Put the remainder to the right of quotient and repeat this process till the quotient becomes ZERO.
- Write down the remainders in reverse order to get equivalent octal number.

Example: Decimal to Octal

$(93)_{10}$ to $(?)_8$



ANSWER: $(135)_8$

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Just a Minute...

- $(173)_{10}$ to $(?)_{8}$
- $(243)_{10}$ to $(?)_{8}$

Conversion: Octal to Decimal

- Multiply each bit of octal number by its place value i.e. 8^n
- Add the result

$(237)_8$ to $(?)_{10}$

2	3	7
8^2	8^1	8^0

64x2	8x3	1x7

128	24	7

ANSWER: $(159)_{10}$

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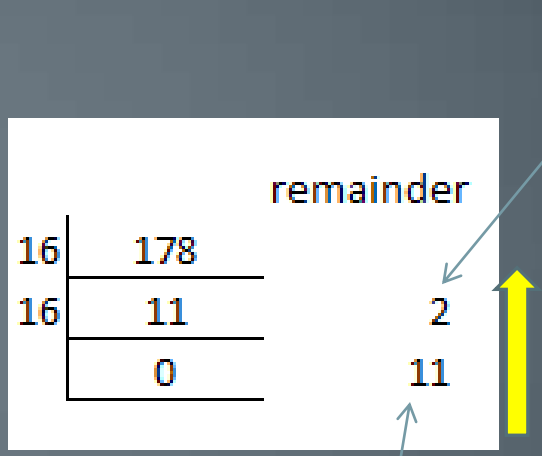
Conversion: Decimal to Hex-Decimal

- You can convert a decimal number to its octal form by using the method of successive division by 16, the radix of the hexadecimal number system.
- Put the remainder to the right of quotient and repeat this process till the quotient becomes ZERO.
- Write down the remainders in reverse order to get equivalent hexadecimal number.

Example: Decimal to Hexadecimal

$(178)_{10}$ to $(?)_{16}$



ANSWER: $(B2)_{16}$

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Just a Minute...

- $(233)_{10}$ to $(?)_{16}$
- $(79)_{10}$ to $(?)_{16}$

Conversion: Octal to Decimal

- Multiply each bit of hexadecimal number by its place value i.e. 16^n
- Add the result

$(A2B)_{16}$ to $(?)_{10}$

A	2	B
16^2	16^1	16^0
256x10	16x2	1x11
2560	32	11

ANSWER: $(2603)_{10}$

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Binary - Octal

- As number of bits increases, there is a need arises of grouping of bits.
- Octal number comprises of 3 bits i.e. 3 binary bits are used to represent octal number.

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

Conversion: Octal to Binary

$(352)_8$ to $(?)_2$

3	5	2
011	101	010

ANSWER: $(011101010)_2$

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

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Just a Minute...

- $(237)_8$ to $(\ ?\ )_2$
- $(206)_8$ to $(\ ?\ )_2$

Conversion: Binary to Octal

- It requires grouping of 3 bits from right hand side, if last group not consists of 3 bit then add 0 to make it group of 3 bit

$(1101011010)_2$ to $(?)_8$

MAKE GROUP OF 3 BITS

011 010 110 110

3 2 6 6

Extra 0 is padded to make it of 3 bits

ANSWER: $(3266)_8$

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Just a Minute...

- $(111000111001)_2$ to $(\ ?\ )_8$
- $(1010101010101)_2$ to $(\ ?\ )_8$

Binary - Hexadecimal

- Hexadecimal number comprises of 4 bits i.e. 4 binary bits are used to represent Hexadecimal number.

HEXADECIMAL	BINARY
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

HEXADECIMAL	BINARY
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

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Conversion: Hexadecimal to Binary

$(8BC2)_{16}$ to $(?)_2$

8	B	C	2
1000	1011	1100	0010

HEXADECIMAL	BINARY
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

HEXADECIMAL	BINARY
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

ANSWER: $(1000101111000010)_2$

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Just a Minute...

- $(CAFE)_{16}$ to $(\ ?\ )_2$
- $(78F9)_{16}$ to $(\ ?\ )_2$

Conversion: Binary to Hexadecimal

- It requires grouping of 4 bits from right hand side, if last group not consists of 4 bit then add 0 to make it group of 4 bit

$(1101011011001 10)_2$ to $(?)_{16}$

MAKE GROUP OF 4 BITS

0110 1011 0110 0110

6 B 6 6

Extra 0 is padded to make it of 4 bits

ANSWER: $(6B66)_8$

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Just a Minute...

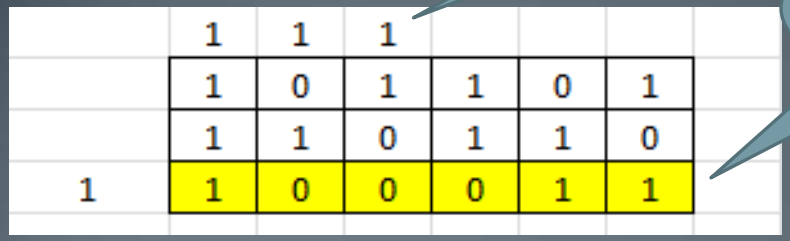
- $(1010101010101010101)_2$ to $(\ ?\ )_{16}$
- $(1100111110001101)_2$ to $(\ ?\ )_{16}$

BINARY ADDITION

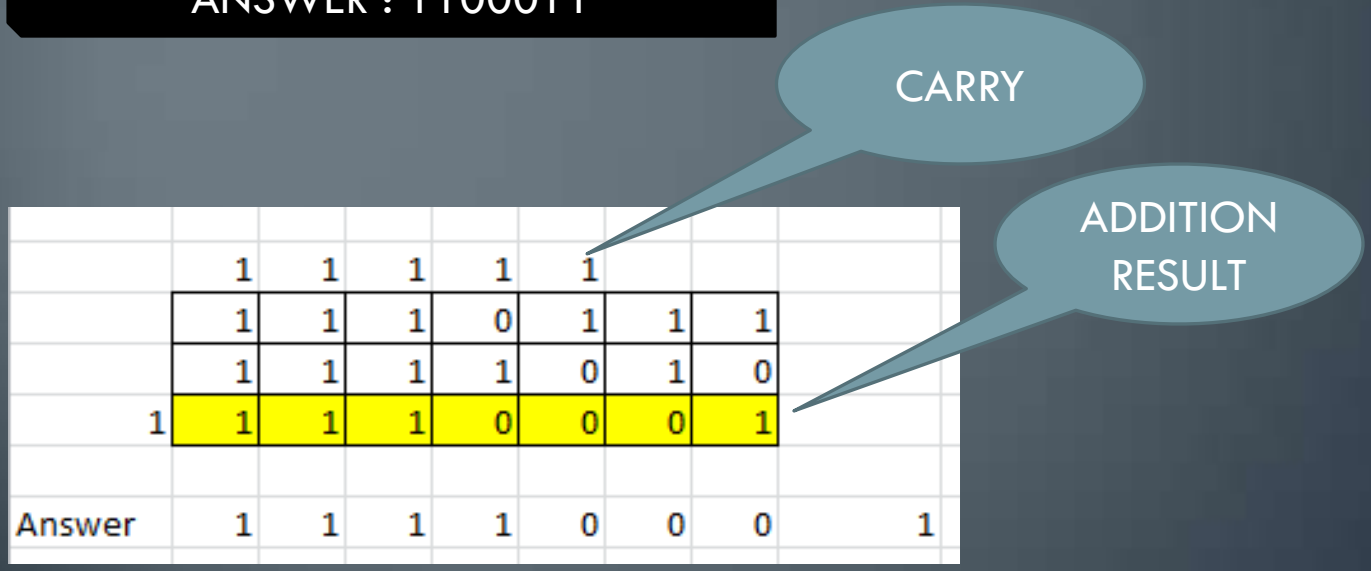
- To perform binary addition, we have to follow the simple rules like:
- 0 + 0 = 0
- 0 + 1 = 1
- 1 + 1 = 0 (and 1 carry to left)
- 1 + 1 + 1 = 1 (and 1 carry to left)

- *Note : if number of 1's is in even then result will be 0 and n no. of 1 will carry to left where n is the number of pair*
- *If the number of 1's in in odd the result will be 1 and n no. of 1 will carry to left where n is the number of pair*

Example



ANSWER : 1100011



ANSWER : 11110001

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Character / String Representation

- Computer must understand the character entered by user, for this purpose numeric code is assigned to each character used in computer.
- For example
  - A – Z assigned with code 65-90
  - a-z assigned with code 97-122
  - 0-9 assigned with code 48-57
- There are various encoding scheme available
  - ASCII
  - ISCII
  - UNICODE

ASCII

- Stands for American Standard code for information interchange.
- It is most widely used alphanumeric code for microcomputers and minicomputers.
- It is 7-Bit code, so it can represent maximum of $2^7 = 128$ code i.e. 128 possible characters.

Few ASCII Code and characters

CHARACTERS	DECIMAL CODE	7-BIT CODE
A	65	1000001
B	66	1000010
-	-	-
Z	90	1011010
a	97	1100001
-	-	-
z	122	1111010
ENTER KEY	13	0001101
$	36	0100100
+	43	0101011
-	-	-

BASED ON THESE VALUE WE CAN EASILY FIND ITS OCTAL & HEXADECIMAL REPRESENTATIO N

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Conversion of ASCII code in original message

- CONVERT THE FOLLOWING ASCII CODE INTTO ITS ORIGINAL MESSAGE
  - **1000101 1011000 1000001 1001101**
- To convert the above message we first convert the above 7-bit code into decimal value as –
- 1000101 = 69 (it is code of 'E')
- 1011000 = 88 (it is code of 'X')
- 1000001 = 65 (it is code of 'A')
- 1001101 = 77 (it is code of 'M')
- So the original message is **EXAM**

Converting message into ASCII Code

- CONVERT THE FOLLOWING MESSAGE INTO ASCII CODE
  - **STEP 1**
- To convert first find out the binary value (either from ASCII table) or manually we find out the decimal code then convert it in binary. For e.g. if 'A' is 65 then following the sequence we can find S = 83, T = 84, E = 69, P = 80
- SPACE = 32, 1 = 49
- Now convert the decimal into binary:
  - 83 = 1010011, 84 = 1010100, 69 = 1000101, 80 = 1010000
  - 32 = 0100000, 49 = 0110001
- So, original message:
- **1010011 1010100 1000101 1010000 0100000 0110001**

ISCII

- Stands for Indian Standard Code for Information Interchange
- ISCII we adopted in 1991, by Bureau by Indian Standards to have common standard for Indian scripts.
- It is 8-bit encoding scheme and can represent 2^8 =256 chars.
- It retain first 128 for ASCII code
- ASCII is able to represent Indian language characters like : Tamil, Telugu, Kannada, Oriya, Bengali, Assamese, Gujarati, etc.

UNICODE

- As we know ASCII and ISCII represent characters belonging to different language by assigned unique code to each characters.
- Need arises to have encoding scheme which can represent all the known language around the world. The result is UNICODE.
- It is the standard used worldwide now.
- Its variants are UTF-8, UTF-16, UTF-32
- Unicode 13.0 represent 143000 characters
- Supported by most OS, making it platform, vendor, application independent
- Allows data to be transported between different system without distortion.

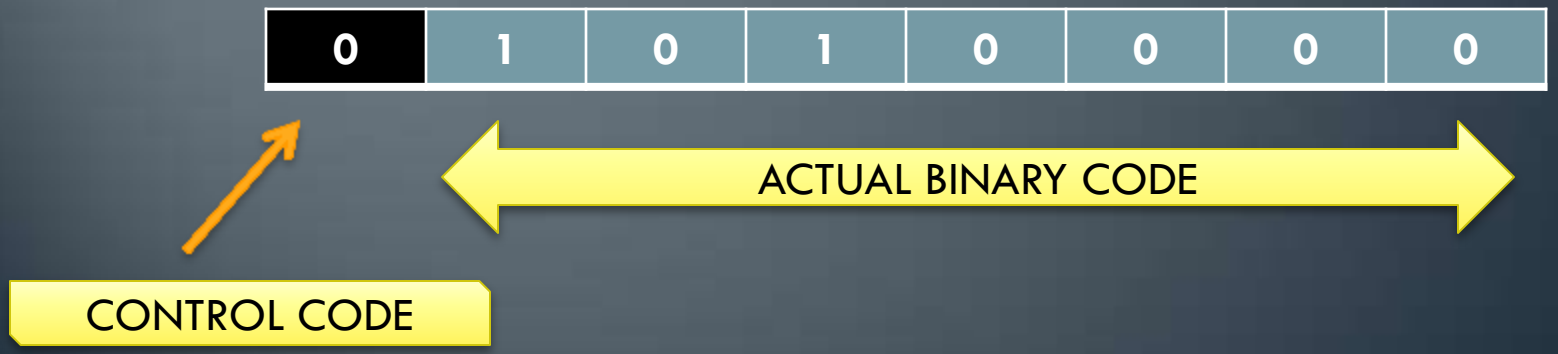
UTF-8 (Unicode Transformation Format)

- It is variable length encoding scheme that can represent each character in UNICODE character set.
- The code unit of UTF-8 is 8 bits i.e. OCTET
- UTF-8 can use 1 OCTET to maximum 6 OCTET depending upon the character it represent.
- Unicode code points are written as U+<codepoint> for e.g. U+0050 represent 'P"

Unicode Code Points (Decimal)	Unicode Code Points (Hex)	Number of octets used
U-0 to U-127	U+00 to U+07F	1 octet (8 bits)
U-128 to U-2047	U+80 to U+7FF	2 octets (16 bits)
U-2048 to U-65535	U+800 to U+FFFF	3 octets (24 bits)
U-65536 to U-2097151	U+10000 to U+1FFFFF	4 octets (32 bits)

UTF-8 (Unicode Transformation Format)

- 1 OCTET (8 BIT REPRESENTATION)
  - For 1 octet representation the left most bit act as control bit which stores ZERO (0)
  - The control bit is special bit that store the control code not the actual character. Rest of the bit stores the actual's binary code
  - For Example (U + 0050) (Binary value of P is 1010000)



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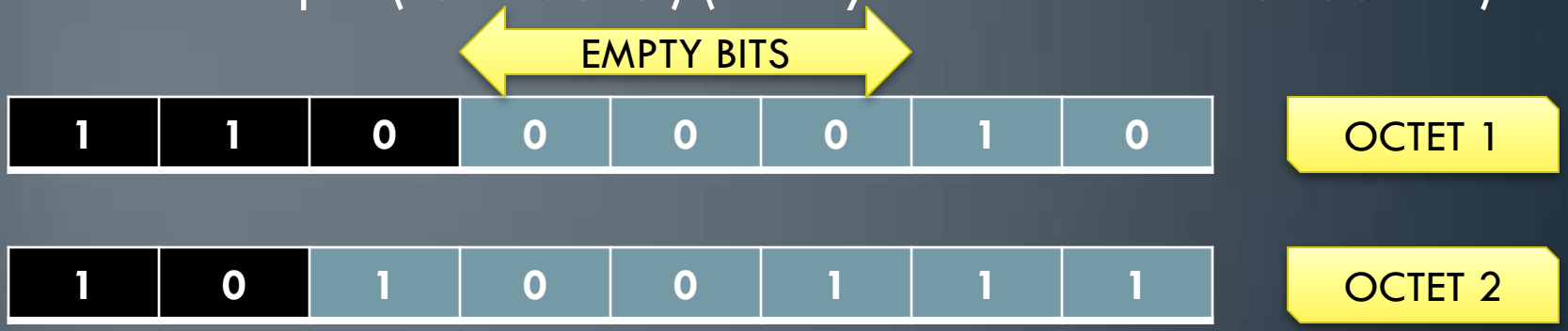
UTF-8 (Unicode Transformation Format)

- 2 OCTET (16 BIT REPRESENTATION)
  - First 3 bits (left most) of first octet will be 110
  - First 2 bits (left most) of second octet will be 10
  - For Example (U + 00A7) (Binary value of ♣ is 10100111)



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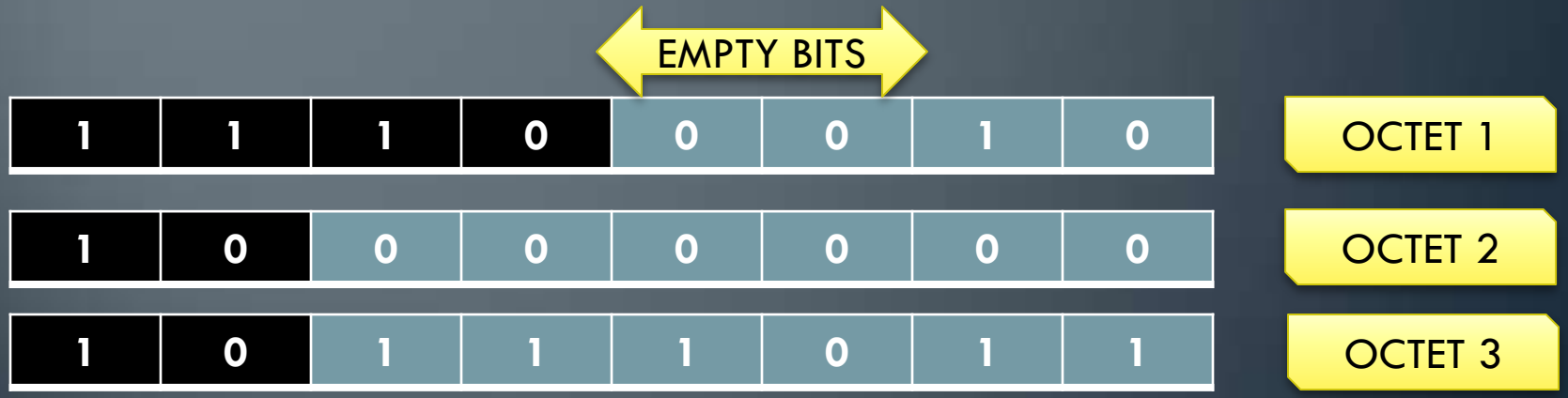
UTF-8 (Unicode Transformation Format)

- 3 OCTET (24 BIT REPRESENTATION)
  - First 4 bits (left most) of first octet will be 1110
  - First 2 bits (left most) of second octet will be 10
  - First 2 bits (left most) of third octet will be 10
  - For Example (U + 203B)
  - (Binary value of ※ is 1000000011011)



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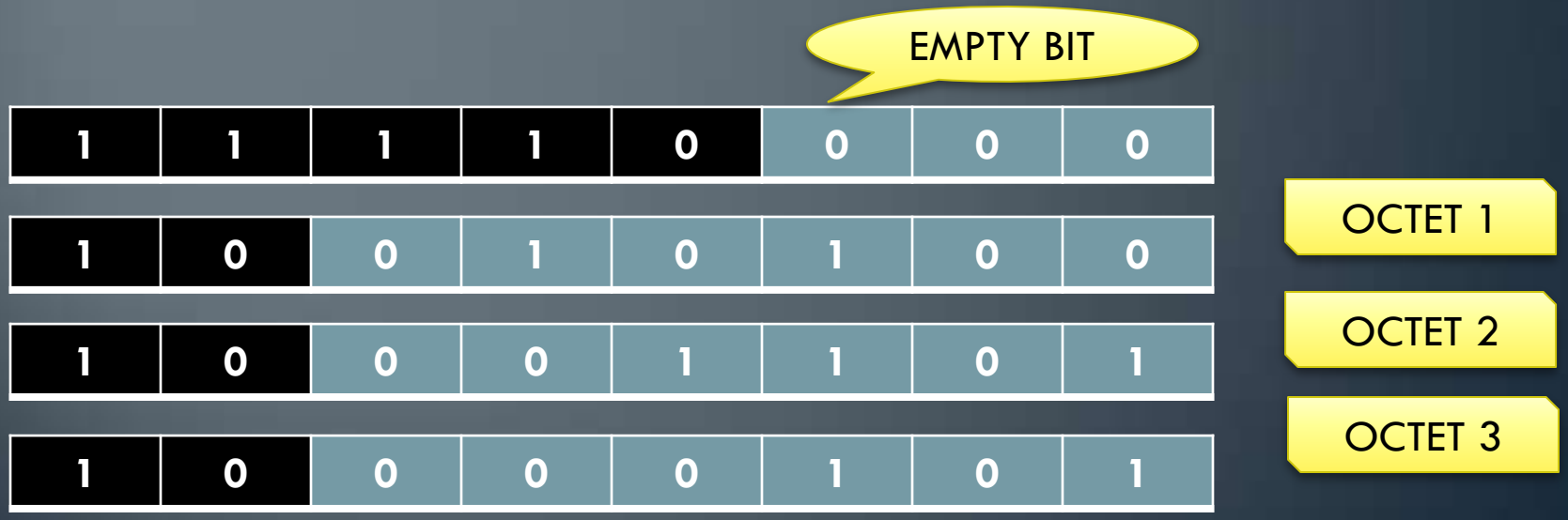
UTF-8 (Unicode Transformation Format)

- 4 OCTET (32 BIT REPRESENTATION)
  - First 5 bits (left most) of first octet will be 11110
  - First 2 bits (left most) of 2nd , 3rd , 4th octet will be 10
  - For Example (U + 12345)
  - (Binary value of □ is 00010010001101000101)



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UTF-32

- It is fixed length encoding scheme that uses exactly 4 bytes to represent all Unicode characters.
- It stores every character using 4 bytes
- Example: Consider the Symbol * [U+002A binary-00101010]

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	1	0	1	0	1	0