# ULI101: INTRODUCTION TO UNIX / LINUX AND THE INTERNET

## WEEK 4: LESSON 1

## DATA REPRESENTATION
## NUMBERING CONVERSION

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# LESSON 1 TOPICS

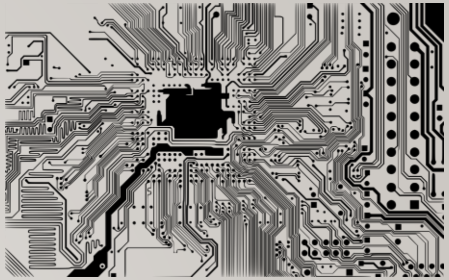
**Data Representation**

- Purpose
- Decimal, Binary, Octal, Hexadecimal Numbering Systems
- Numbering Conversion Methods
- Demonstration

**Perform Week 4 Tutorial**

- Investigation 1
- Review Questions (Questions 1 – 5)

# DATA REPRESENTATION



## Data Representation

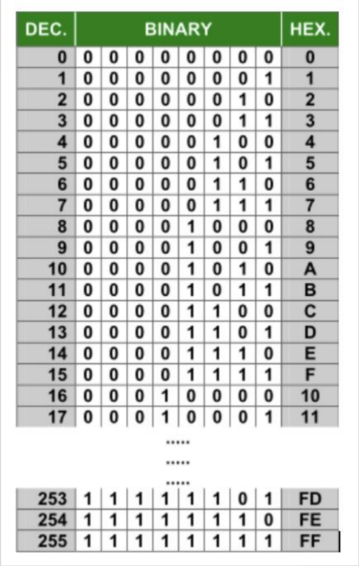
Digital computers are **electronic devices** that contain a series of **circuits** and **voltage levels** that can store / represent data.

Binary numbers can represent those series of circuits with voltage levels. Those binary numbers (0's and 1's) are combined in a sequence to form a **byte**.

Bytes are used to represent **numbers** or **characters**.

It is the job of the computer program to understand if those bytes (series of o's and/or 1's) represent numbers or characters (eg. in **C programming**, declaring a variable with a **data type**)

Understanding how the computer stores numbers and characters can be useful when **administrating computer systems** and **creating programs** to be run on computer systems.



| DEC. | BINARY | | | | | | | | HEX. |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |
| 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 5 |
| 6 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 |
| 7 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 7 |
| 8 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 |
| 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 9 |
| 10 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | A |
| 11 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | B |
| 12 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | C |
| 13 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | D |
| 14 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | E |
| 15 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | F |
| 16 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 10 |
| 17 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 11 |
| | | | | ...... | | | | | |
| | | | | ...... | | | | | |
| | | | | ...... | | | | | |
| 253 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | FD |
| 254 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | FE |
| 255 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | FF |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 0 | NUL | DLE | space | 0 | @ | P | ` | p |
| 1 | SOH | DC1 XON | ! | 1 | A | Q | a | q |
| 2 | STX | DC2 | " | 2 | B | R | b | r |
| 3 | ETX | DC3 XOFF | # | 3 | C | S | c | s |
| 4 | EOT | DC4 | $ | 4 | D | T | d | t |
| 5 | ENQ | NAK | % | 5 | E | U | e | u |
| 6 | ACK | SYN | & | 6 | F | V | f | v |
| 7 | BEL | ETB | ' | 7 | G | W | g | w |
| 8 | BS | CAN | ( | 8 | H | X | h | x |
| 9 | HT | EM | ) | 9 | I | Y | i | y |
| A | LF | SUB | * | : | J | Z | j | z |
| B | VT | ESC | + | ; | K | [ | k | { |
| C | FF | FS | , | < | L | \ | l | \| |
| D | CR | GS | - | = | M | ] | m | } |
| E | SO | RS | . | > | N | ^ | n | ~ |
| F | SI | US | / | ? | O | _ | o | del |

# DATA REPRESENTATION

## Numbering Conversion:

Computers have evolved over time. During that time, humans have interfaced with the computer by *binary* numbers, or by using **short-cuts** such as **<u>octal</u>** or **<u>hexadecimal</u>** numbers.

**Computer Networking / Support Specialists** and **Computer Programmers** occasionally need to convert between numbering systems:

- Converting **decimal** numbers to **binary** number for URLs (subnetting)
- Converting **decimal** numbers to **hexadecimal** numbers to format webpages (with web-safe colours)
- Converting **binary** numbers to **octal** numbers for setting file permissions in Unix/Linux

Before performing numbering conversions, we need to better understand the **decimal**, **binary**, **octal** and **hexadecimal** numbering systems.

| DEC. | BINARY | | | | | | | | HEX. |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |
| 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 5 |
| 6 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 |
| 7 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 7 |
| 8 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 |
| 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 9 |
| 10 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | A |
| 11 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | B |
| 12 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | C |
| 13 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | D |
| 14 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | E |
| 15 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | F |
| 16 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 10 |
| 17 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 11 |
| | | | | ..... | | | | | |
| | | | | ..... | | | | | |
| | | | | ..... | | | | | |
| 253 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | FD |
| 254 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | FE |
| 255 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | FF |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 0 | NUL | DLE | space | 0 | @ | P | ` | p |
| 1 | SOH | DC1 XON | ! | 1 | A | Q | a | q |
| 2 | STX | DC2 | " | 2 | B | R | b | r |
| 3 | ETX | DC3 XOFF | # | 3 | C | S | c | s |
| 4 | EOT | DC4 | $ | 4 | D | T | d | t |
| 5 | ENQ | NAK | % | 5 | E | U | e | u |
| 6 | ACK | SYN | & | 6 | F | V | f | v |
| 7 | BEL | ETB | ' | 7 | G | W | g | w |
| 8 | BS | CAN | ( | 8 | H | X | h | x |
| 9 | HT | EM | ) | 9 | I | Y | i | y |
| A | LF | SUB | * | : | J | Z | j | z |
| B | VT | ESC | + | ; | K | [ | k | { |
| C | FF | FS | , | < | L | \ | l | \| |
| D | CR | GS | - | = | M | ] | m | } |
| E | SO | RS | . | > | N | ^ | n | ~ |
| F | SI | US | / | ? | O | _ | o | del |

# DATA REPRESENTATION

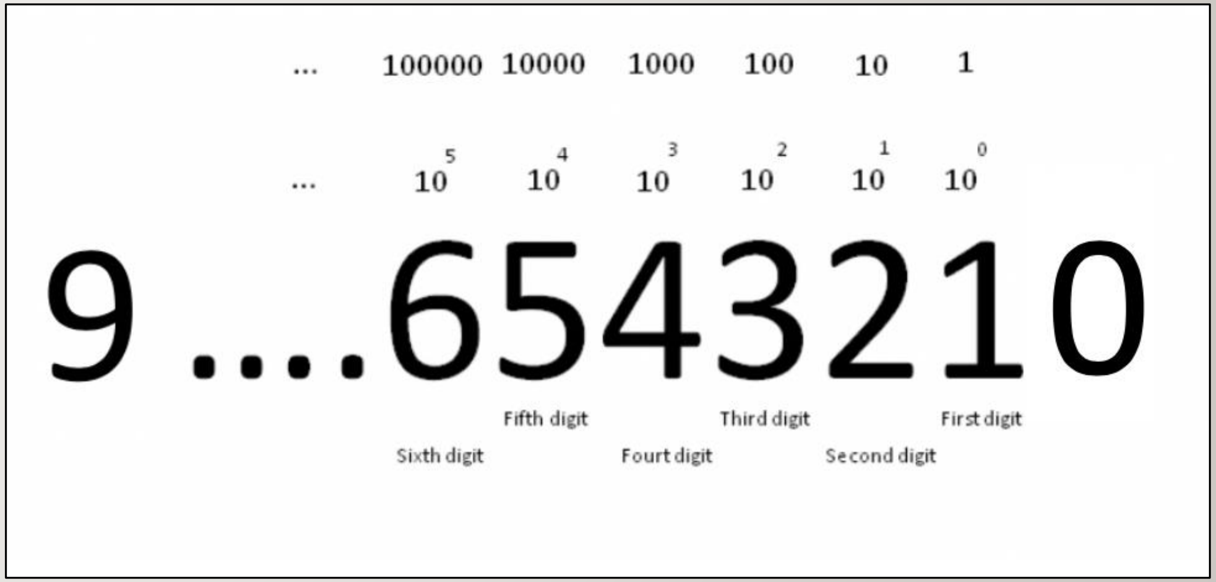
## Decimal Numbering System (Humans)

The numbering system used by **humans**.

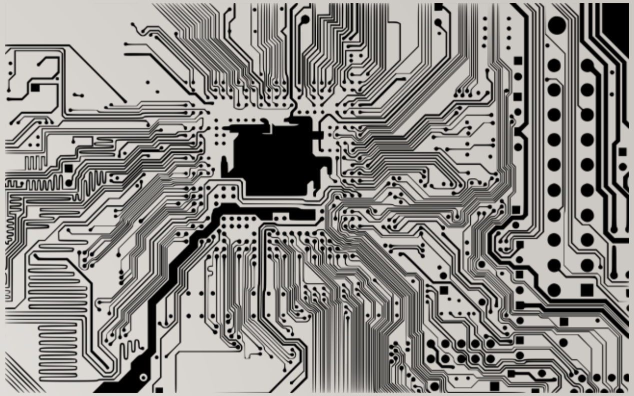
The **decimal** numbering system consists of **digits** ranging from **0** to **9**.

The fact that **humans** started counting on their **fingers** and **thumbs** most likely lead to the development of this numbering system.

The decimal numbering system is based on **sums of the power of 10** which provides a framework for mathematic calculations.

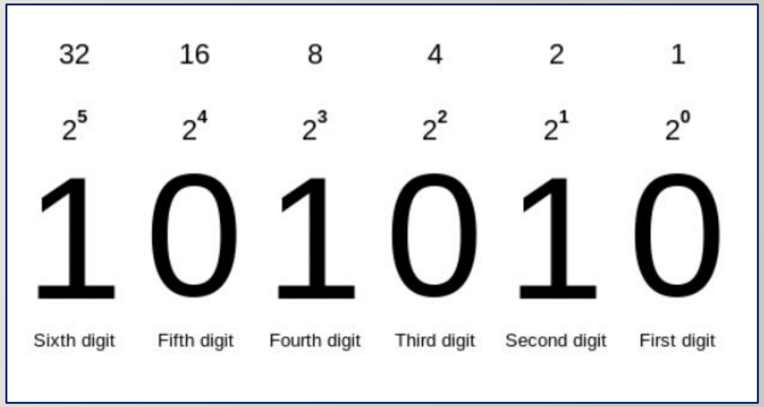


# DATA REPRESENTATION



**Binary Numbers (Computers)**

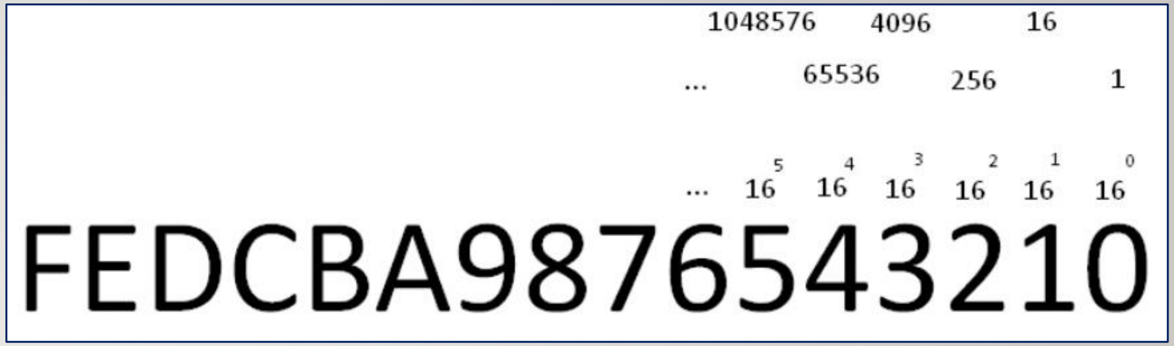
Digital computers have **circuits** which representing data in terms of voltage levels. Multiple circuits are used to represent data (in the form of *binary* numbers).




The **binary** numbering system consists of digits ranging from **0** to **1**. The numbering system is based on sums of the power of **2**.

Referring to the diagram to the right, the value of each decimal digit consists of the value (placeholder) multiplied by the corresponding power of 2. For example, $\mathbf{2^0}$ , $\mathbf{2^1}$, $\mathbf{2^2}$, etc. which move in a **right-to-left** direction.

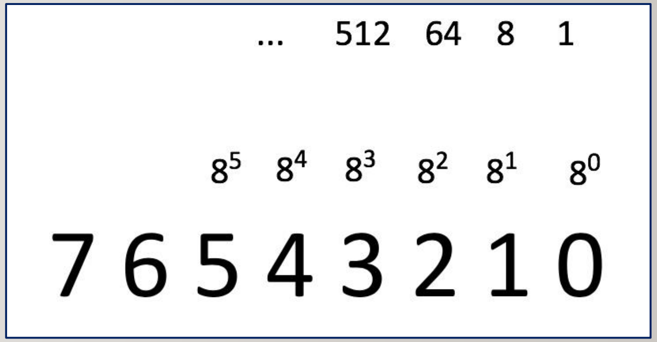
# DATA REPRESENTATION




## Octal / Hexadecimal Numbers (short-cuts)

The **octal** and **hexadecimal** numbering systems consist of digits ranging from **0 to 7** and ranging from **0 to F** respectively.

The **octal** and **hexadecimal** numbering system are based on sums of the power of **8** and **16** respectively. For *hexadecimal* numbers, values for **10 to 15** are represented by the characters **A to F** respectively.



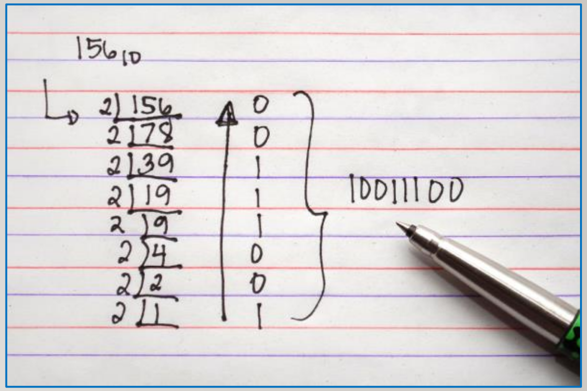

These numbering systems are useful since they are **both multiples of 2** (binary) and can be used as **short-cuts** to represent a series of binary numbers:

**1 octal digit = 3 binary digits**

**1 hexadecimal digit = 4 binary digits**).

why choose 8, 16, 32 : power to binary (2^3, 2^4, 2^5)

# DATA REPRESENTATION




**Performing Numbering Conversion**

You will learn **several numbering conversion methods** in this course:

1. **Binary** to **Decimal**
2. **Decimal** to **Binary**
3. **Octal** to **Binary** / **Binary** to **Octal**
4. **Hexadecimal** to **Binary** / **Binary** to **Hexadecimal**
5. **Octal** to **Hexadecimal** / **Hexadecimal** to **Octal**

**NOTE:** Each of these techniques are **unique**. You will be expected not only to perform these calculations on a *quiz / midterm exam / final exam* but also **show your work** and **use the same technique show in these slides** to obtain full marks.

# DATA REPRESENTATION

## Numbering Conversion Method 1: Binary to Decimal

When converting **binary** numbers to **decimal** numbers, perform the following steps:

1. Write down the binary number.
2. Starting from the **right-side**, draw **L**'s below the binary number moving to the left (refer to diagram on right).
3. Starting on the *rightmost* "**L**", multiply the value (placeholder) by **2** to the power of zero.
4. Continually repeat **step #3** moving leftwards, increasing the power of 2 by **1** (refer to diagram on right).
5. Add up the results to obtain the decimal value equivalent.

**NOTE:** To convert *octal* and *hexadecimal* numbers to **decimal**, replace the number **2** (in red in the diagram to the right) with **8** (for *octal*) or **16** (for *hexadecimal*).

1 1 0 0 1 0 0 1

$1 \text{ x } 2^0 = 1 \text{ x } 1 = 1$

$0 \text{ x } 2^1 = 0 \text{ x } 2 = 0$

$0 \text{ x } 2^2 = 0 \text{ x } 4 = 0$

$1 \text{ x } 2^3 = 1 \text{ x } 8 = 8$

$0 \text{ x } 2^4 = 0 \text{ x } 16 = 0$

$0 \text{ x } 2^5 = 0 \text{ x } 32 = 0$

$1 \text{ x } 2^6 = 1 \text{ x } 64 = 64$

$1 \text{ x } 2^7 = 1 \text{ x } 128 = 128$

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# DATA REPRESENTATION

## Instructor Demonstration

Your instructor will now demonstration how to perform a **Binary** to **Decimal** conversion

# DATA REPRESENTATION

bc command is used for command line calculator. It supports Arithmetic operators, Increment or Decrement operators, Assignment operators
Comparison or Relational operators, Logical or Boolean operators
Math functions, Conditional statements, Iterative statements

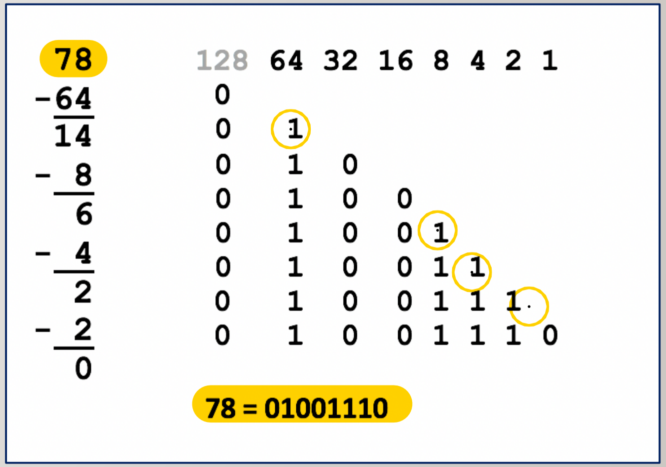
ibase and obase define the conversion base for input and output numbers. The default for both input and output is base 10.

## Numbering Conversion Method 2: Decimal to Binary

1. bc
2. obase = 2
3. type the decimal number you want to convert to binary :113

When converting **decimal** numbers to **binary** numbers, perform the following steps:

1. Write down the **decimal number** to be converted.
2. On the *right-side*, write the number **1** and moving **leftwards**, keep doubling the numbers until that number is **greater than** the decimal number to be converted (refer to the diagram on the right).
3. Starting on the left-side of those doubled numbers, compare that number with the decimal number. If that number if less than or equal to the decimal number, then write a **1** below and subtract that number from the decimal number to get a remainder. If the number is greater than decimal number (or remainder), then write a **0** below.
4. Repeat **step #3** (moving rightwards and comparing the number with the decimal's remainder)




有必要就在前面加0

**NOTE:** If you are converting to **8-bit**, **32-bit**, etc., add **leading zeros** if necessary.

# DATA REPRESENTATION

## Instructor Demonstration

Your instructor will now demonstration how to perform a **Decimal** to **Binary** conversion

# DATA REPRESENTATION

Because you are setting the input base first, then when you set the output base, the 16 will be interpreted according to the input base (2). It appears that the 6 in 16 is simply interpreted is a binary 1 bit in this case, and so the output base gets set to binary 11 or decimal 3.

To work around this, you can set the output base before you set the input base:

## Numbering Conversion Method 3: Octal to Binary / Binary to Octal

*Binary to Octal*

$2^3 = 8$

1. One octal number represents 3 binary numbers, so starting from right-side, group binary digits into groups of 3 (add leading zeros if necessary).
2. Write (4)(2)(1) under each group of 3 binary numbers.
3. Multiply the value or "placeholder" (i.e. 0's and 1's) by the corresponding (4)(2)(1) for each group to obtain the octal number (refer to diagram of binary to octal conversion).

1. bc
2. obase = 8
3. ibase = 2

101001110

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| X | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| | (4) | (2) | (1) | (4) | (2) | (1) | (4) | (2) | (1) |
| = | | 5 | | | 1 | | | 6 | |

*Octal to Binary*

1. One octal number represents 3 binary numbers, so space-out the octal numbers to make space for a binary number.
2. Write (4)(2)(1) under each octal number.
3. Write 0's or 1's for each group of binary numbers to add up to the corresponding octal number (refer to diagram of octal to binary conversion).

1. bc
2. obase = 2
3. ibase = 8

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | | | 3 | | | 5 | |
| (4) | (2) | (1) | (4) | (2) | (1) | (4) | (2) | (1) |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |

# DATA REPRESENTATION

## Instructor Demonstration

Your instructor will now demonstration how to perform an **Octal** to **Binary** conversion and a **Binary** to **Octal** conversion.

# DATA REPRESENTATION

## Numbering Conversion
## Method 4: Hexadecimal to Binary / Binary to Hexadecimal

*Binary to Hexadecimal* 2^4 =16

- **One hexadecimal number** represents **4 binary numbers**, so starting from right-side, group binary digits into **groups of 4** (add leading zeros if necessary).
- Write **(8)(4)(2)(1)** under <u>each</u> group of 4 binary numbers.
- Multiply the placeholders (i.e. **0**'s and **1**'s) by the corresponding (8)(4)(2)(1) for each group to obtain the octal number.
- Convert values from **10** to **15** to **A** to **F**
(refer to diagram of *binary to hexadecimal* conversion)

1. bc
2. obase = 16
3. ibase = 2

101111000101

| 1 0 1 1 | 1 1 0 0 | 0 1 0 1 |
|---|---|---|
| (8) (4) (2) (1) | (8) (4) (2) (1) | (8) (4) (2) (1) |
| 11 | 12 | 5 |
| B | C | 5 |

101111000101 = BC5

A – 10
B – 11
C – 12
D – 13
E – 14
F – 15

*Hexadecimal to Binary*

- **One hexadecimal number** represents **4 binary numbers**,
so space-out the hexadecimal numbers to make space for a binary number.
- Convert letters **A** to **F** to **10** to 15 (refer to diagram of *binary to hexadecimal* conversion)
- Write **(8)(4)(2)(1)** under <u>each</u> hexadecimal number.
- Write **0**'s or **1**'s for each group of binary numbers to add up to the corresponding hexadecimal number (refer to diagram of *hexadecimal to binary* conversion).

1. bc
2. obase = 2
3. ibase = 16

D5F

| D | 5 | F |
|---|---|---|
| (8) (4) (2) (1) | (8) (4) (2) (1) | (8) (4) (2) (1) |
| 1 1 0 1 | 0 1 0 1 | 1 1 1 1 |

A – 10
B – 11
C – 12
D – 13
E – 14
F – 15

# DATA REPRESENTATION

## Instructor Demonstration

Your instructor will now demonstration how to perform a
**Hexadecimal** to **Binary** conversion and a **Binary** to **Hexadecimal** conversion.

# DATA REPRESENTATION

**Numbering Conversion Method 5:**
**Octal to Hexadecimal / Hexadecimal to Octal**

To convert using the method, simply use binary as a "**bridge**".

*Example:*

- To convert octal to hexadecimal, convert octal to binary, then convert binary to hexadecimal.
- To convert hexadecimal to octal, convert hexadecimal to binary, then convert binary to octal.

```
Octal -> binary -> Hexadecimal

Hexadecimal -> binary -> Octal
```

# DATA REPRESENTATION

## Instructor Demonstration

Your instructor will now demonstration how to perform an
**Octal** to **Hexadecimal** conversion and a **Hexadecimal** to **Octal** conversion.

# HOMEWORK

## Getting Practice

Perform **Week 4 Tutorial**

**(Due: Friday Week 5 @ midnight for a 2% grade)**:

- INVESTIGATION 1: NUMBERING CONVERSIONS
- LINUX PRACTICE QUESTIONS (Questions **1 – 5**)