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CSCI 150
Introduction to Digital and Computer System Design
Lecture 1: Digital Information Representations I

Jetic Gū

2020 Fall Semester (S3)

Overview

- Focus: Number Systems
- Architecture: Digital Circuits
- Textbook v4: Ch1 1.1, 1.2; v5: Ch1 1.1, 1.3
- Core Ideas:
    1. How information is represented in digital circuits
    2. Binary, Octal, Dec, Hex numbers

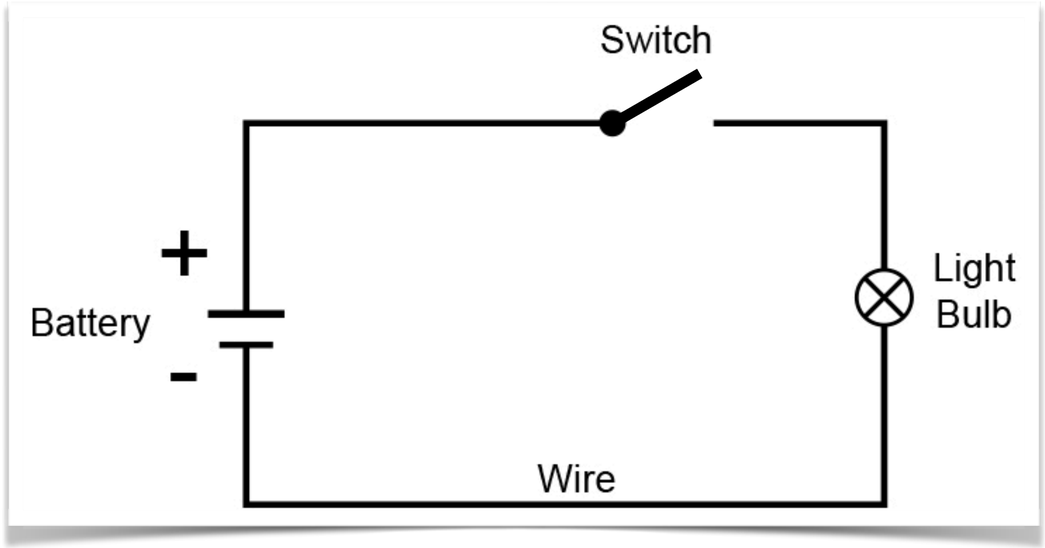
Basics

Analog vs Digital circuits;
Modern computer architectures;
Embedded systems;

Summary

Circuits

- Circuits
  - Loop of conductive material
  - Charge carriers flow continuously within



Concept

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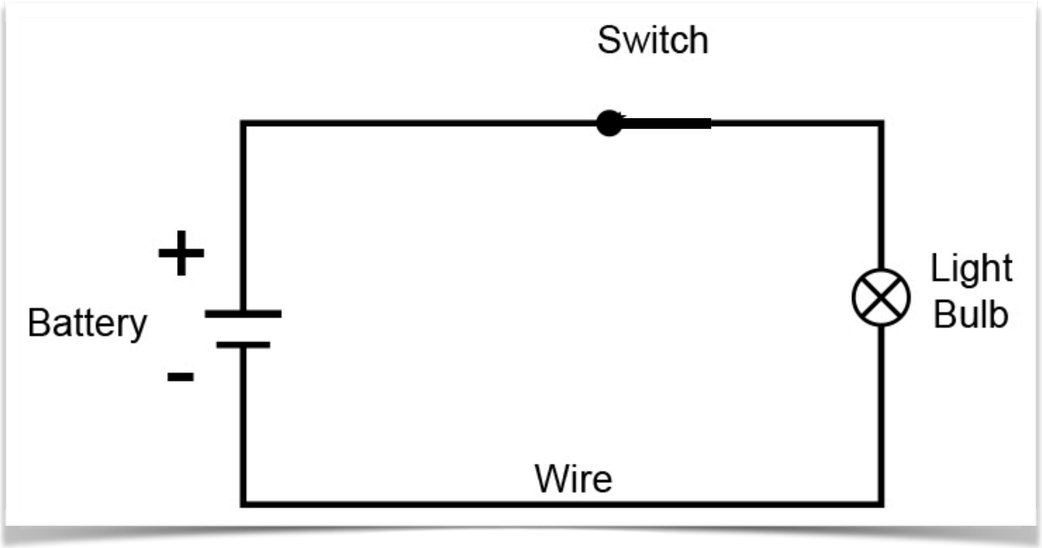

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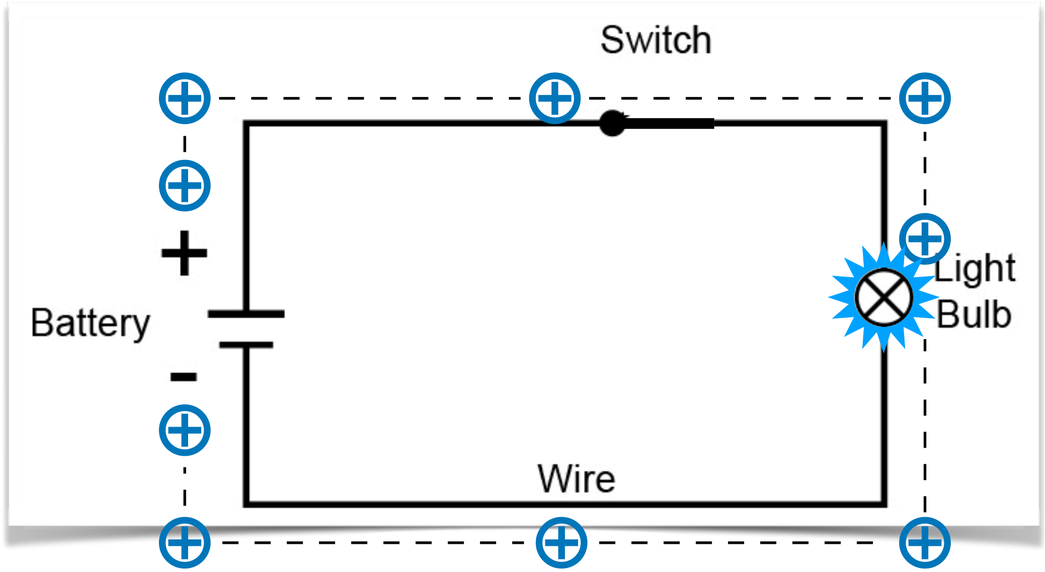
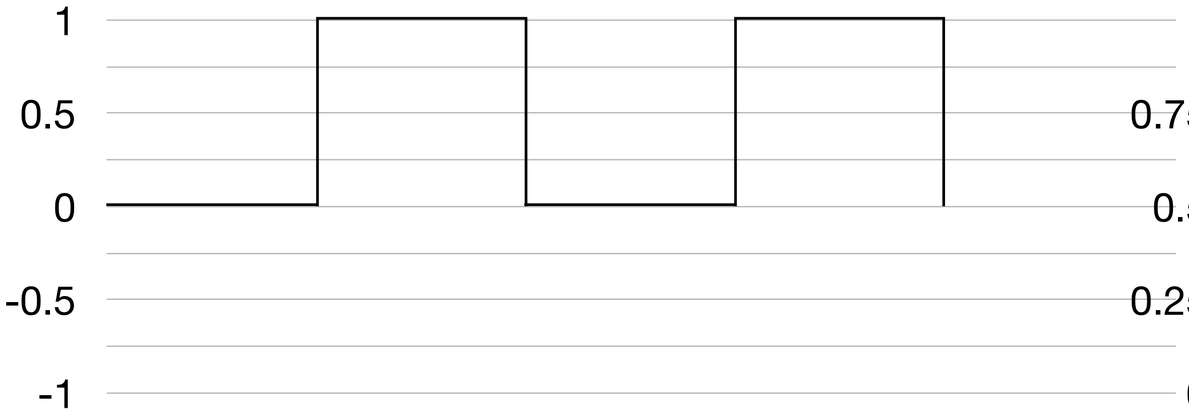


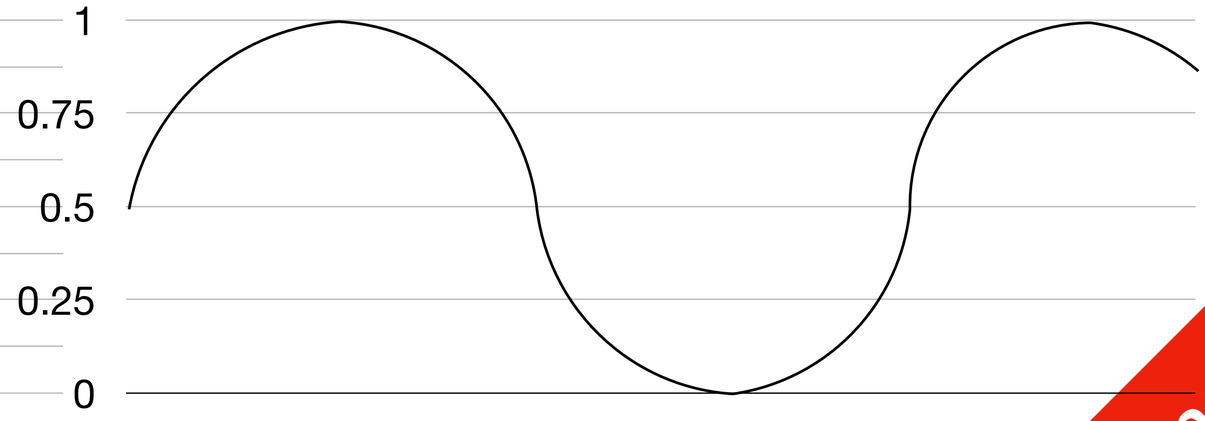
Concept

Circuits

- Digital Circuits
  - Process digital signals
  - Current/Voltage represent discrete logical and numeric values

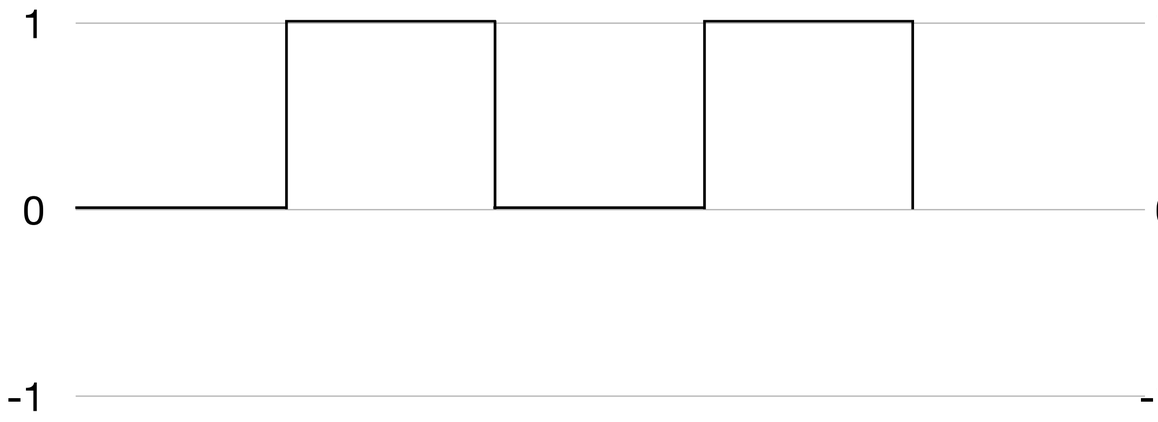


- Analog Circuits
  - Process analog signals
  - Current/Voltage vary continuously to represent information

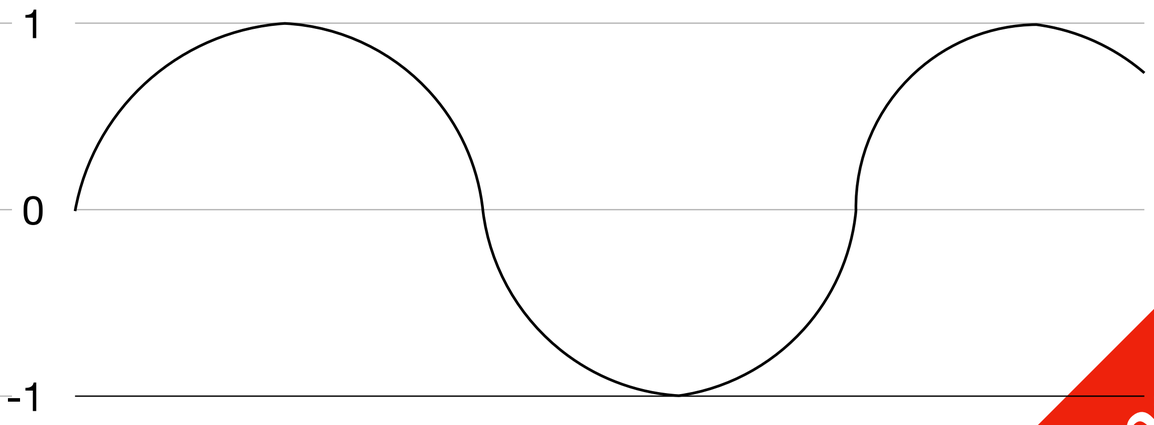


Circuits

- Digital Circuits
  - Computers
  - Blu-Ray Players



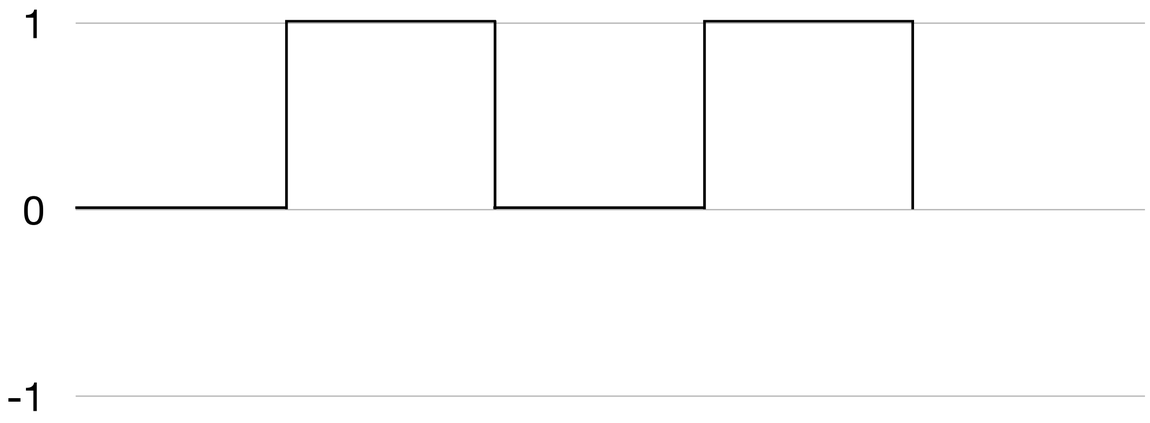
- Analog Circuits
  - Vinyl records
  - Radio



P1
Basics

Digital/Logical Circuits

- Basic signals
  - Low/High; On/Off; True/False; 1/0;



- Why might it be better than analog?
  - Resistant to noise
  - High precision
  - Faster

Concept

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Basics

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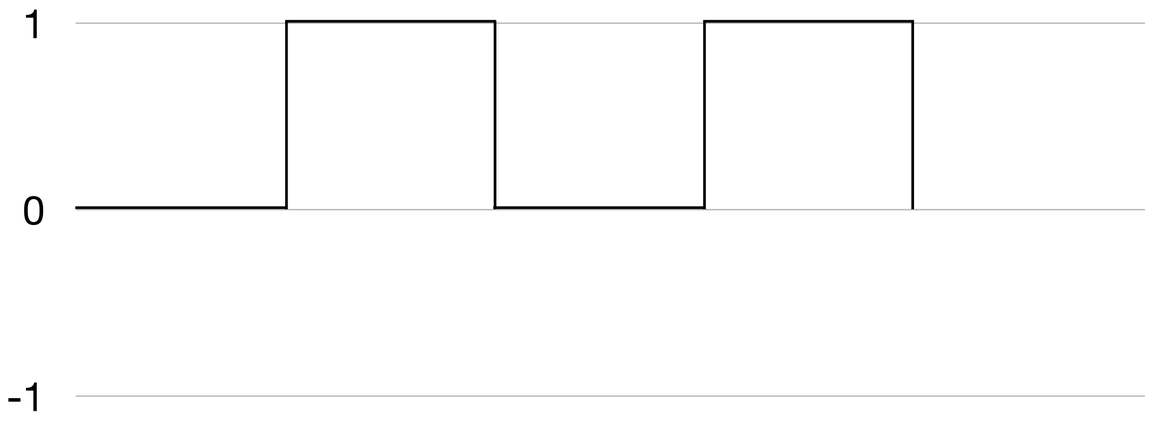

- Voltage is still continuous in digital circuits

Concept

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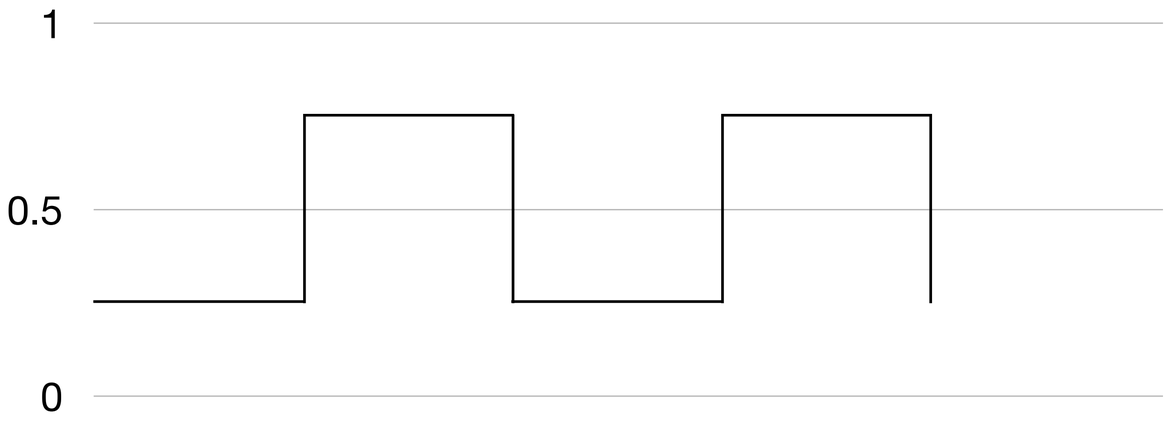

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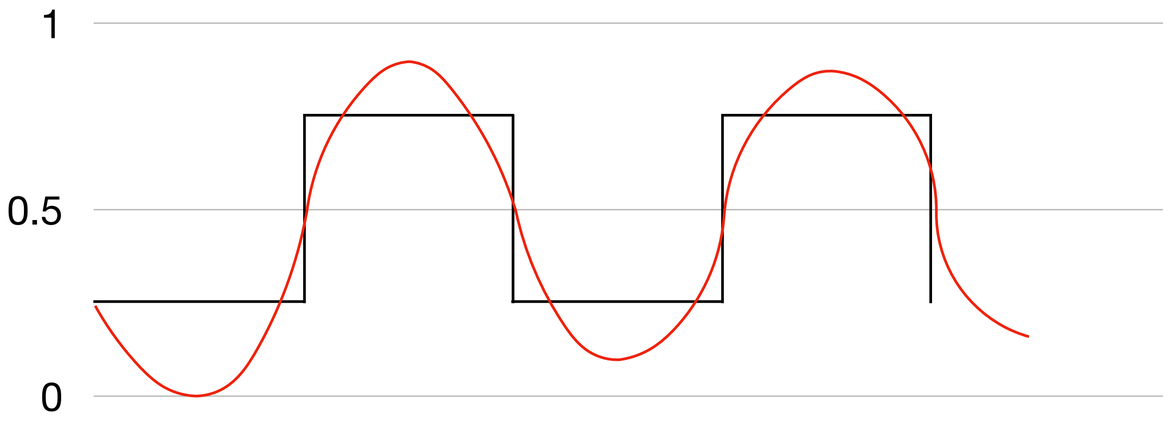

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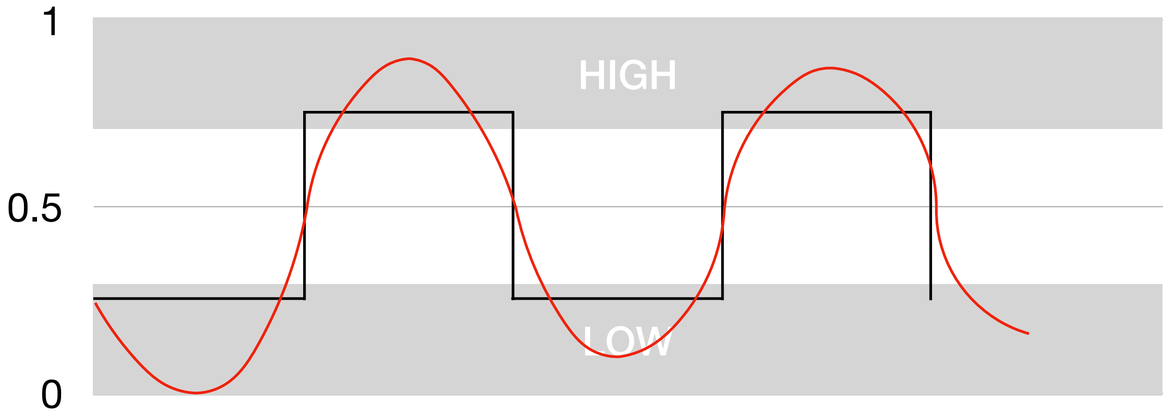

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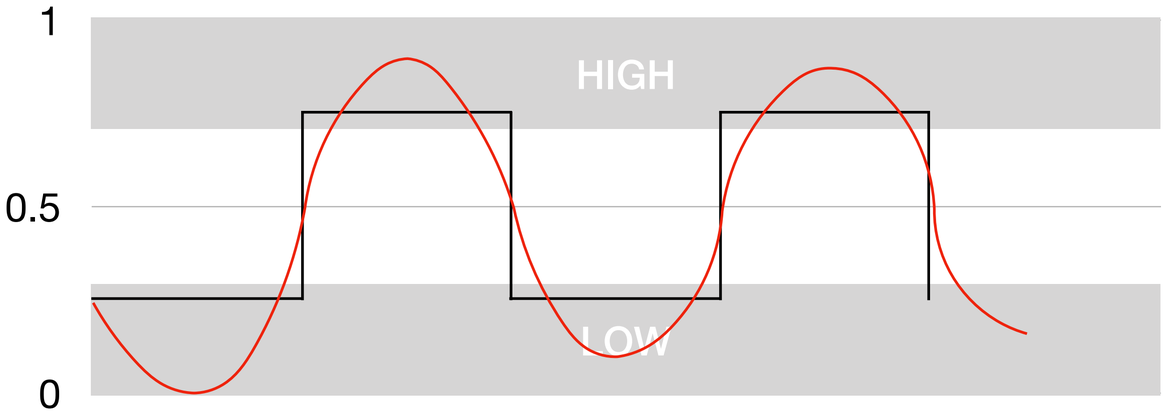

- Voltage is still continuous in digital circuits
- Approximation

Concept

Digital Integrated Circuits

- A "small" chip
  - filled with tiny components: transistors, logical gates, etc.
  - The scale of integration determined by the amount of these components
  - Inseparably associated and electrically interconnected

1. https://www.jedec.org/standards-documents/dictionary/terms/integrated-circuit-ic

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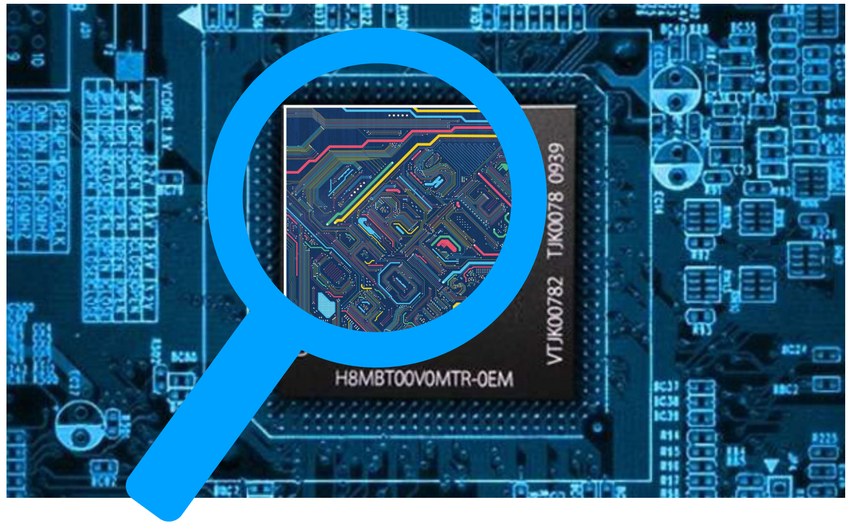

Concept

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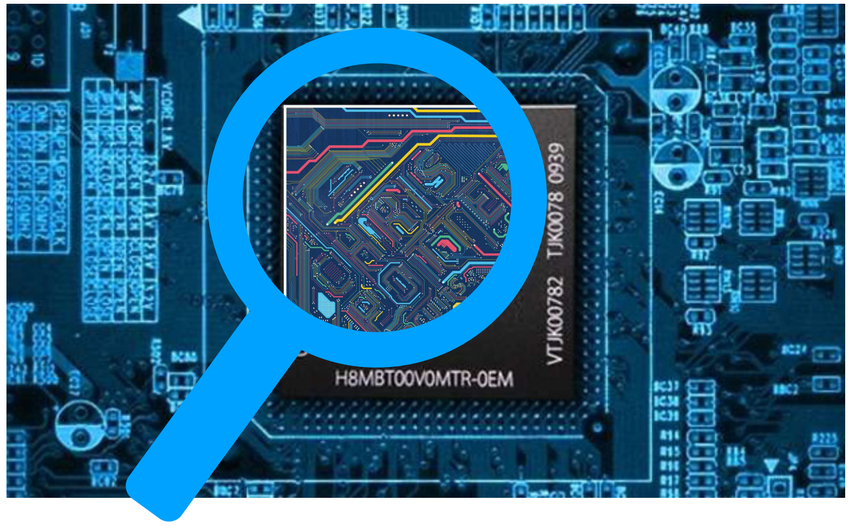
Digital Integrated Circuits

- SSI (Small Scale Integration)
  <100 components / <10 gates
- MSI (Medium Scale Integration)
  [100, 500) components / [10, 100) gates
- In LSI (Large Scale Integration)
  [500, 300000) components / <100 gates
- VLSI, ULSI, GSI
- *exact definition varies



Concept

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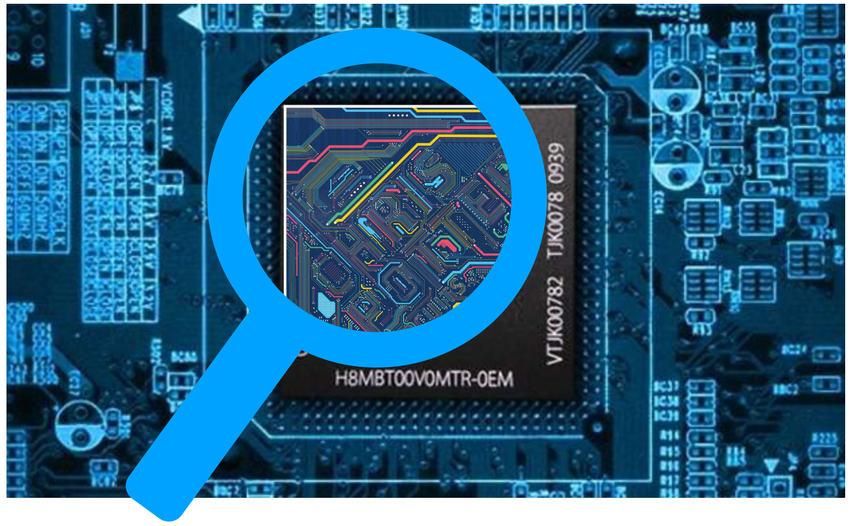

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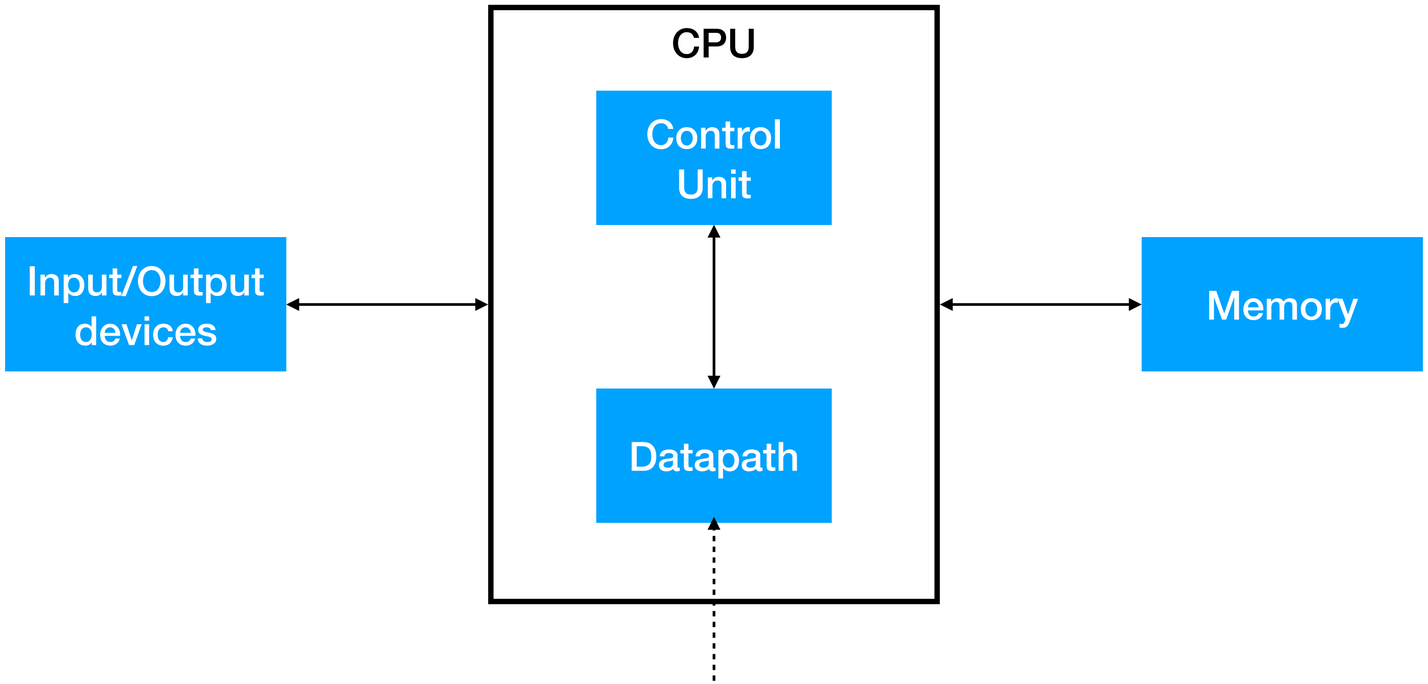
Computer



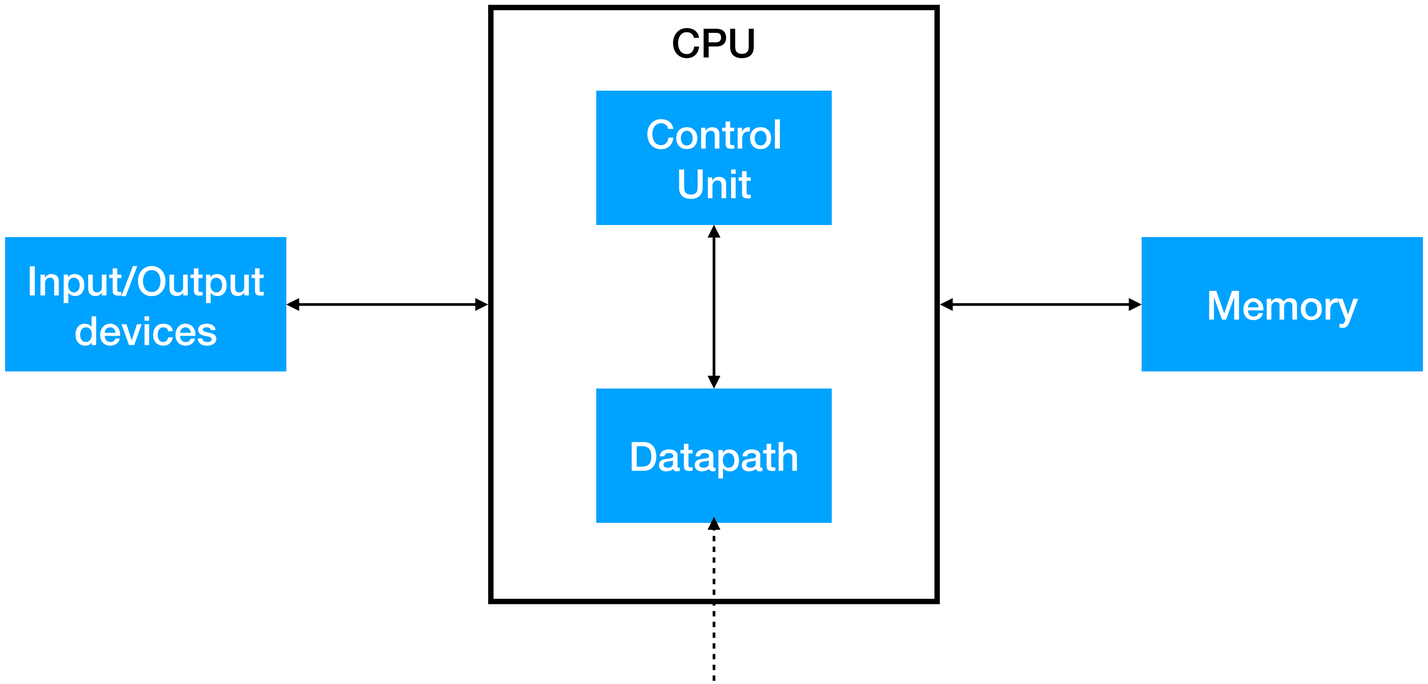
also called arithmetic unit, logical unit, etc.

Concept

1. Von Neumann Architecture

Computer

A very rough example



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Demo

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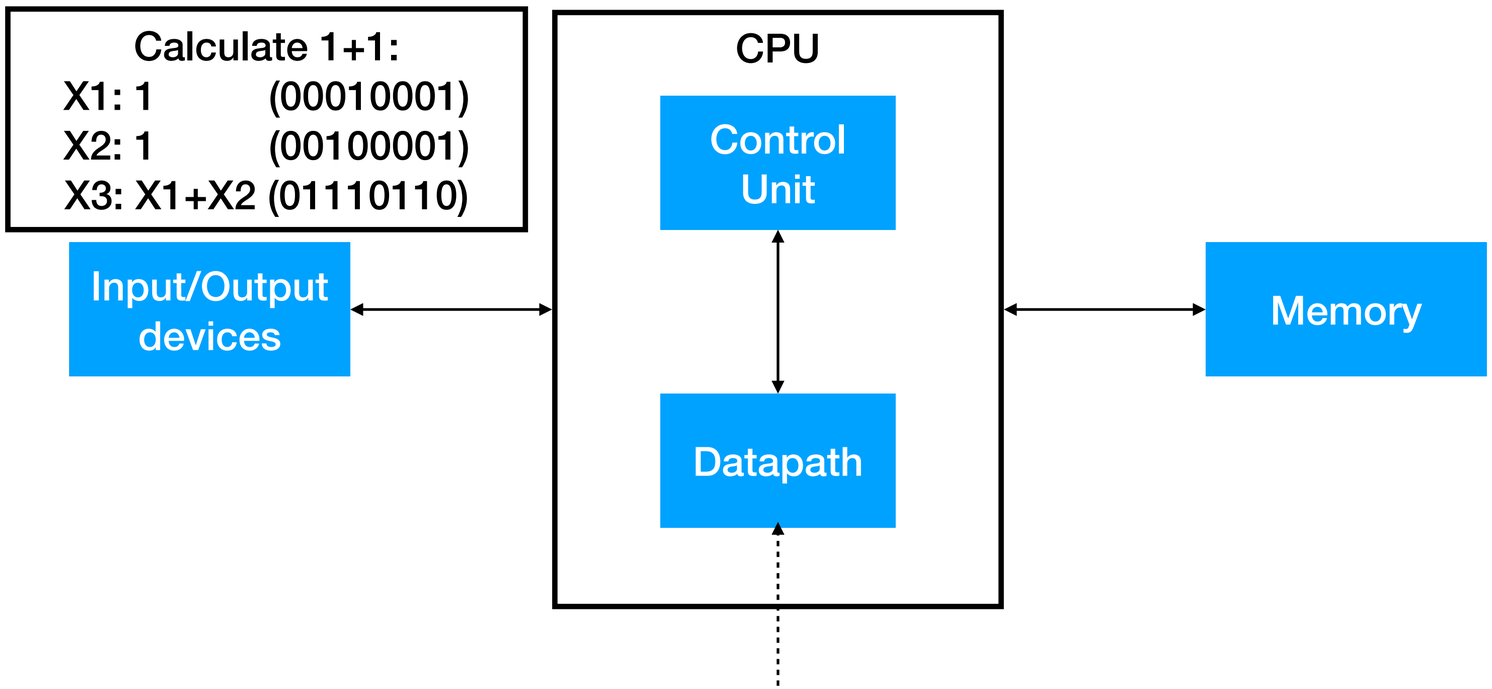

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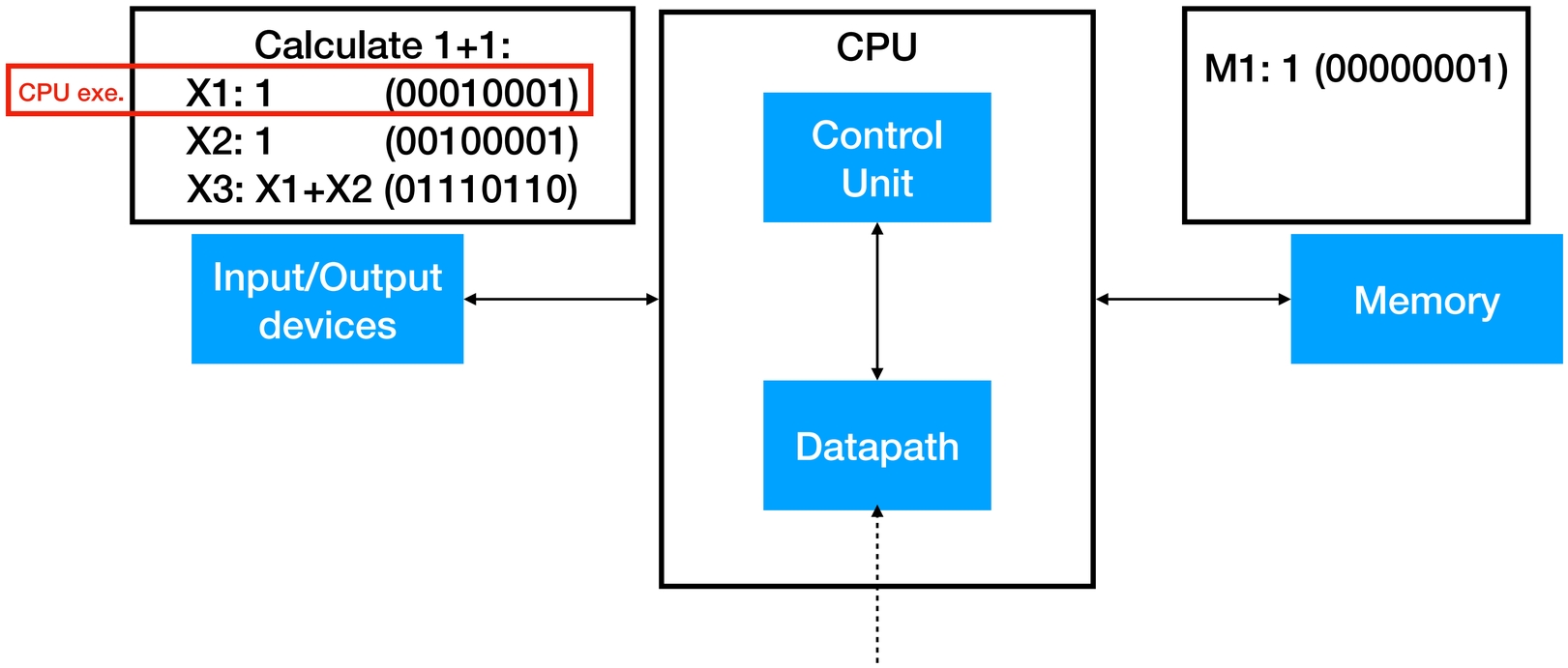

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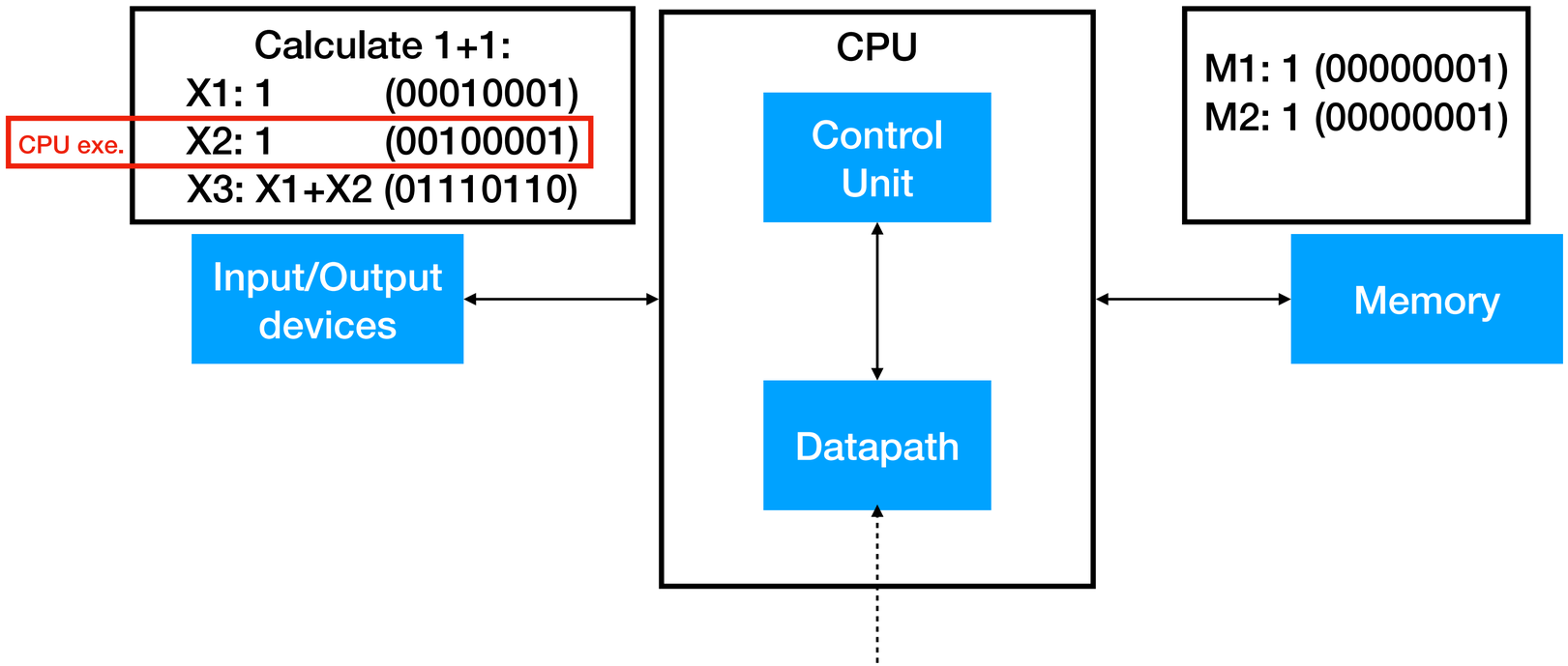

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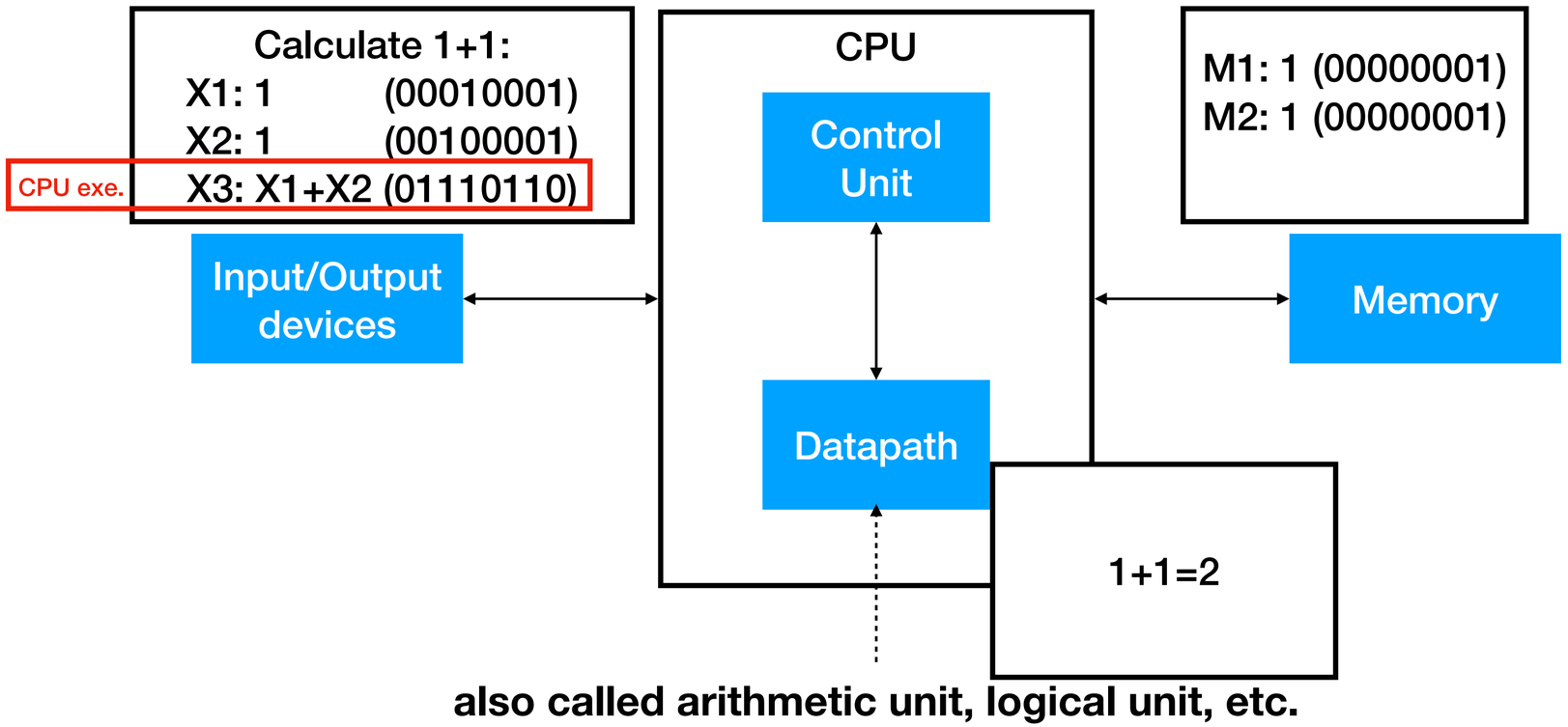

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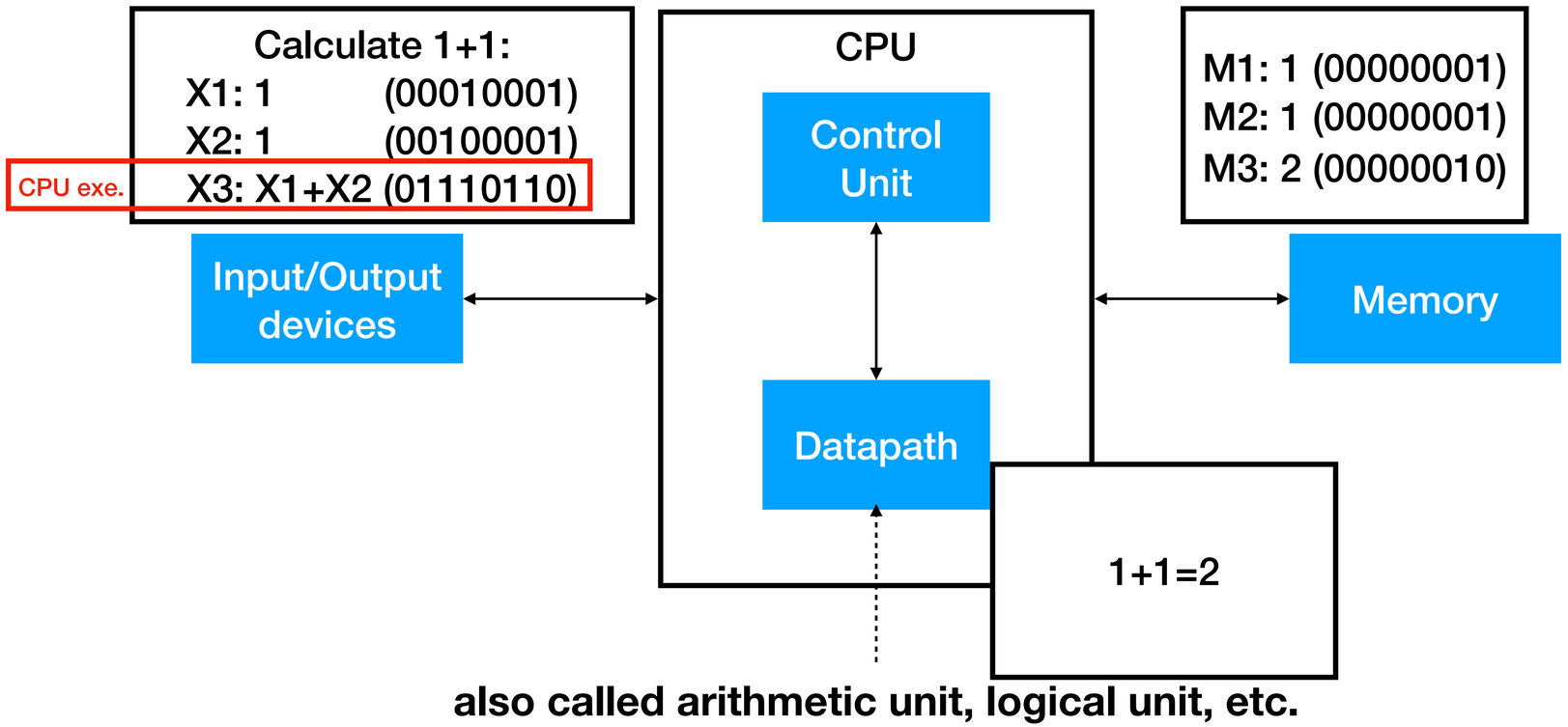

Demo

1. Von Neumann Architecture

Computer

What's it like compared to a human?

1. Von Neumann Architecture

Concept

Computer

What’s it like compared to a human?

- Input/Output devices

Concept

Computer

What's it like compared to a human?

- Input/Output devices
  - Interaction (Mouth, hands and feet, eyes, etc.)

Concept

Computer

What's it like compared to a human?

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- CPU + Memory

Concept

1. Von Neumann Architecture

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  - Processing information, thinking (Brain, short-term memory)

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- Storage?

Concept

1. Von Neumann Architecture

Computer

What's it like compared to a human?

- Input/Output devices
  - Interaction (Mouth, hands and feet, eyes, etc.)
- CPU + Memory
  - Processing information, thinking (Brain, short-term memory)
- Storage?
  - Part of I/O devices (Books, long-term memory)

Concept

1. Von Neumann Architecture

P1
Basics

Embedded Systems

Concept

Embedded Systems

- Similar to computers: processes information

Embedded Systems

- Similar to computers: processes information
- Difference

Embedded Systems

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  - Function is usually simpler, and very very specific

Embedded Systems

- Similar to computers: processes information
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  - Function is usually simpler, and very very specific
  - Not programmable

Concept

P1
Basics

Embedded Systems

Concept

Embedded Systems

- Example:

Embedded Systems

- Example:
  - USB devices, such as USB sticks

Embedded Systems

- Example:
  - USB devices, such as USB sticks
    - USB is a complex protocol

Embedded Systems

- Example:
  - USB devices, such as USB sticks
    - USB is a complex protocol
    - Data Transfer stages: Synchronisation; Packet transfer; Termination

P1
Basics

Embedded Systems

Concept

Embedded Systems

- Example:

Embedded Systems

- Example:
  - Coprocessors for streaming media

Embedded Systems

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Embedded Systems

- Example:
  - Coprocessors for streaming media
  - Modern media comes compressed
    - Older computer uses software packages to perform decoding (decompression and output pixels/analog acoustics)
    - Modern computers have dedicated embedded chips to perform decoding (e.g. H264 codec)

Concept

P1
Basics

Summary

Review

Summary

- Circuits

Review

Summary

- Circuits
  - Digital and Analog

Review

Summary

- Circuits
  - Digital and Analog
- Integrated systems

Review

Summary

- Circuits
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  - Von Neumann computers

Review

Summary

- Circuits
  - Digital and Analog
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  - Von Neumann computers
  - Embedded systems

Review

Number Systems

Binary, Octal and Hexadecimal Numbers;
Number Ranges

Summary

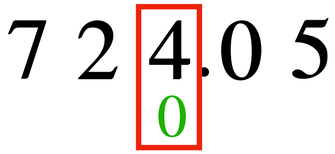
Decimal System

$$7\ 2\ 4.0\ 5$$

- Numbers as strings of digits, each ranging from 0-9
- The decimal system is of base(radix) 10

Review

Decimal System



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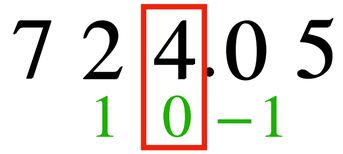

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Review

Decimal System

- Numbers as strings of digits, each ranging from 0-9
- The decimal system is of base(radix) 10

Review

P2
Number Systems

Decimal System

$$\begin{array}{ccccccc} 7 & 2 & 4 & . & 0 & 5 \\ 2 & 1 & 0 & & -1 & -2 \end{array}$$

$$= 7 \times 10^{2} + 2 \times 10^{1} + 4 \times 10^{0} + 0 \times 10^{-1} + 5 \times 10^{-2}$$

- Numbers as strings of digits, each ranging from 0-9
- The decimal system is of base(radix) 10

Review

Numbers of base N

- Default base: 10
- When there are numbers represented in different bases, attach base
  - Decimal: 754.05 -> $(754.05)_{10}$
  - e.g. Base 5: $(432.1)_5$ = ?

$$= 4 \times 5^2 + 3 \times 5^1 + 2 \times 5^0 + 1 \times 5^{-1} = (117.2)_{10}$$

Concept

Numbers of base N

- ALWAYS write down the base if not decimal!
  - Avoid confusion

Concept

Numbers of base N

- Convert binary number $(10100)_2$ to decimal

Example

P2
Number Systems

Numbers of base N

- Convert binary number $(10100)_2$ to decimal

2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
256	128	64	32	16	8	4	2	1

Example

P2
Number Systems

Numbers of base N

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2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
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Example

P2
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				16 x 1	**8 x 0**	**4 x 1**	**2 x 0**	**1 x 0**

Example

P2
Number Systems

Numbers of base N

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$$(10100)_2$$

$$16 \times 1 + 8 \times 0 + 4 \times 1 + 2 \times 0 + 1 \times 0$$

Example

P2
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$$(10100)_2$$

$$16 \times 1 + 8 \times 0 + 4 \times 1 + 2 \times 0 + 1 \times 0 = 20$$

Example

Numbers of base N

- Convert decimal number 24 to binary

Example

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$$24 = 12 \times 2 + 0$$

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Numbers of base N

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Example

Numbers of base N

- Convert decimal number 24 to binary

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Example

Numbers of base N

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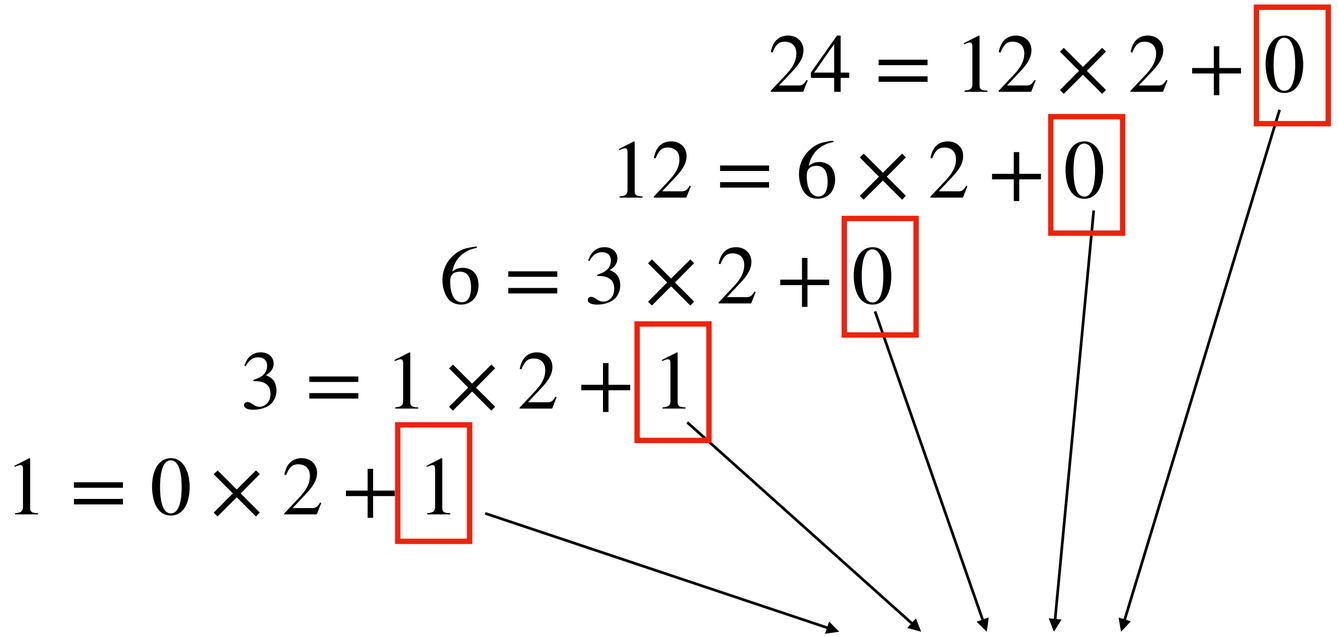

Example

Numbers of base N

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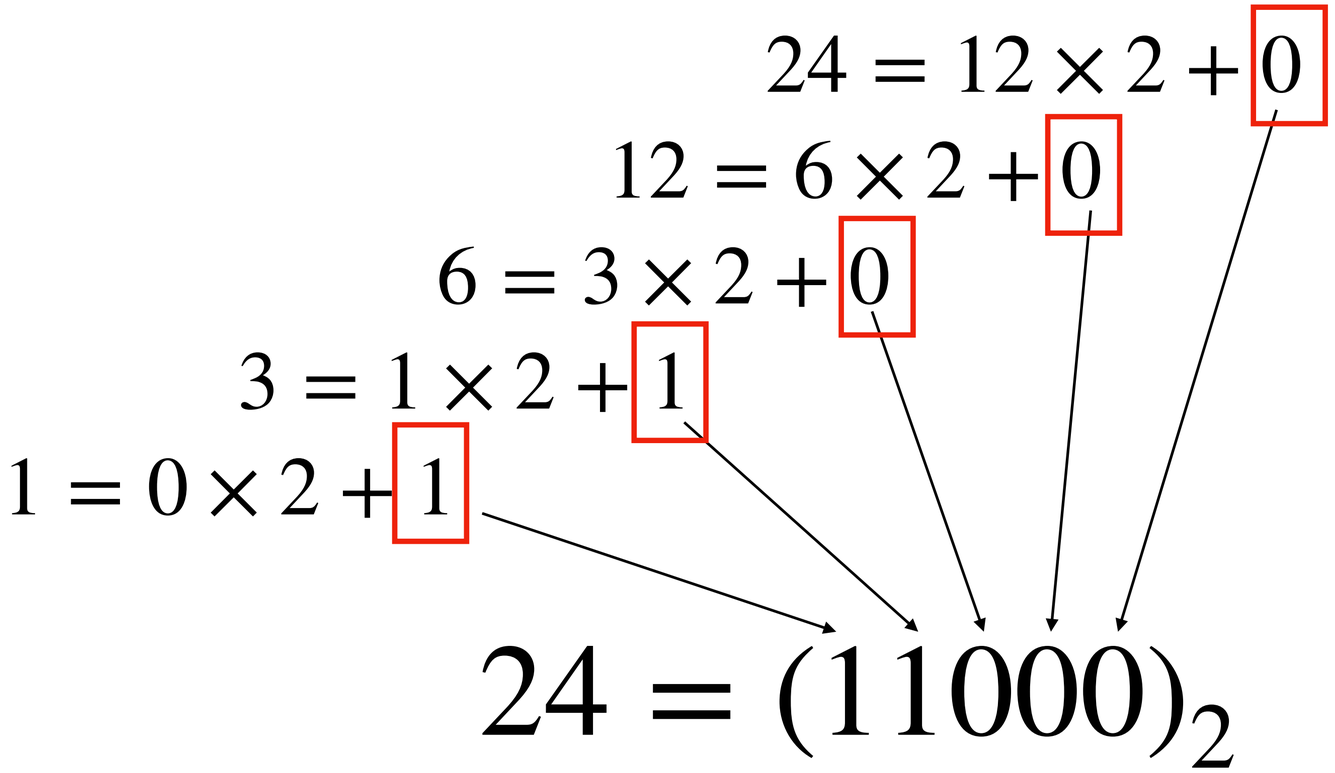

Example

Numbers of base N

- Convert decimal number 79 to hexadecimal

Hexadecimal digits
0-9 = $(0\text{-}9)_{16}$
10-15 = $(A\text{-}F)_{16}$

Example

Numbers of base N

- Convert decimal number 79 to hexadecimal

$$79 = 4 \times 16 + 15$$

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Example

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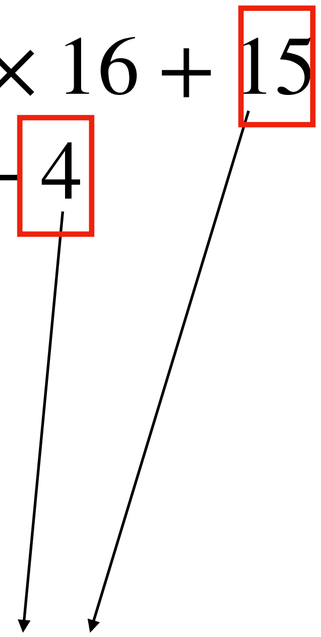

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$$79 = 4 \times 16 + 15$$

$$4 = 0 \times 16 + 4$$

$$79 = (4F)_{16}$$

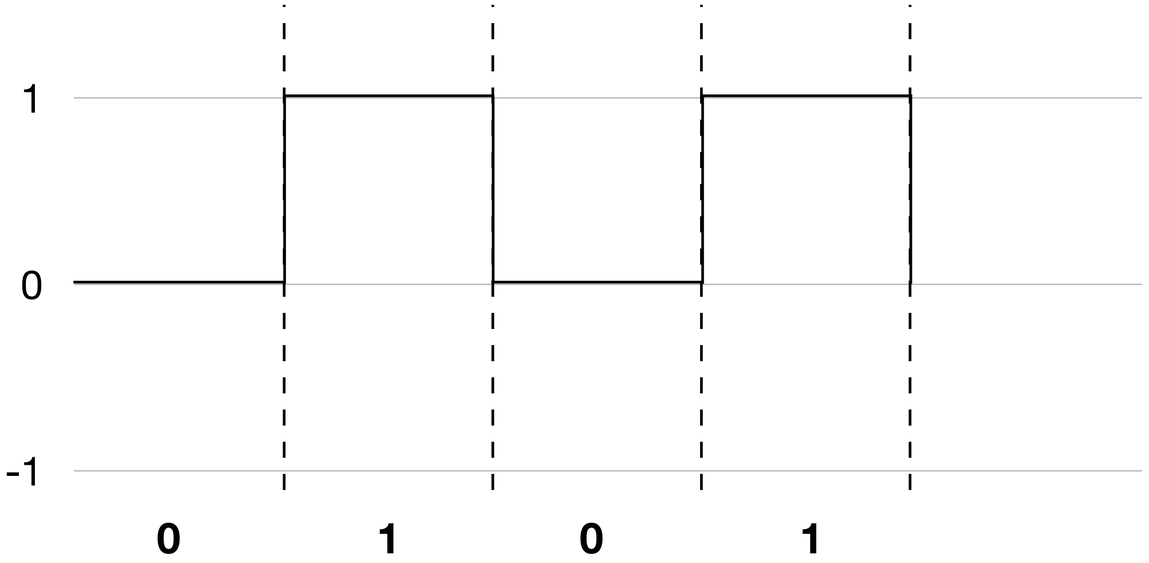
Example

Numbers of base N

- Conversion exercises
  - XXXX to binary; binary to XXXX
  - XXXX to decimal; decimal to XXXX

Example

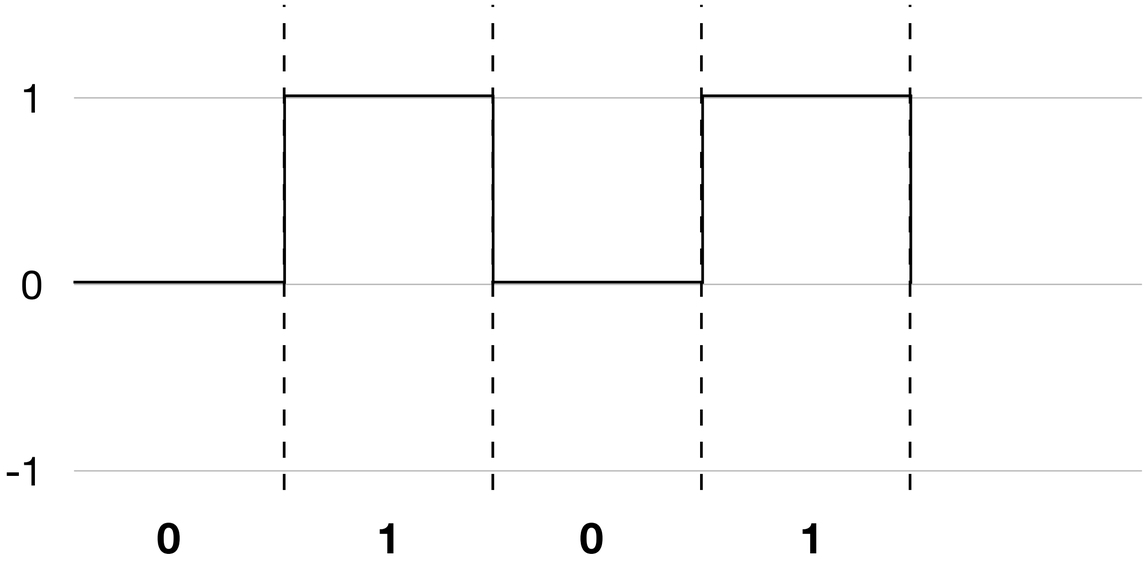
Binary System



- Base 2 system
- A number is represented with a string of 1s and 0s, each called a *bit*
- $(0101)_2 = 5$

Concept

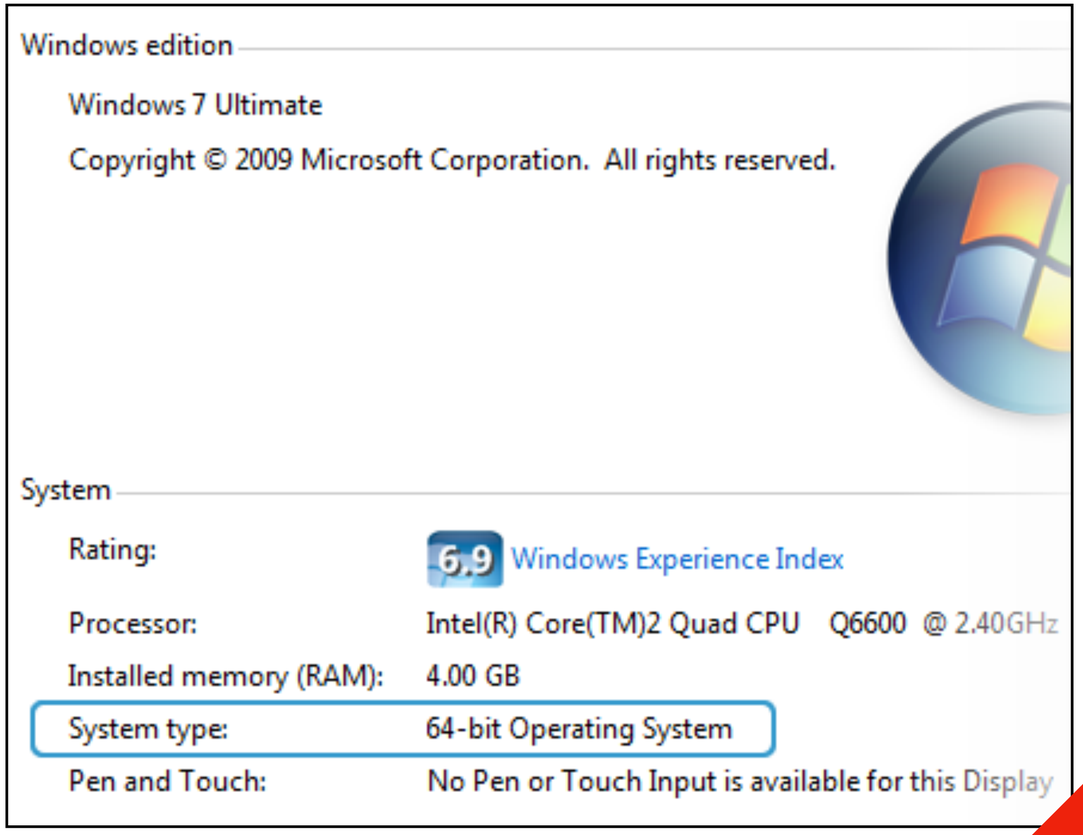
Binary System



- Is it possible to use different bases in a digital circuit?
- If it is possible, why haven't we seen it very often?

P2
Number Systems

Binary Systems in Computers

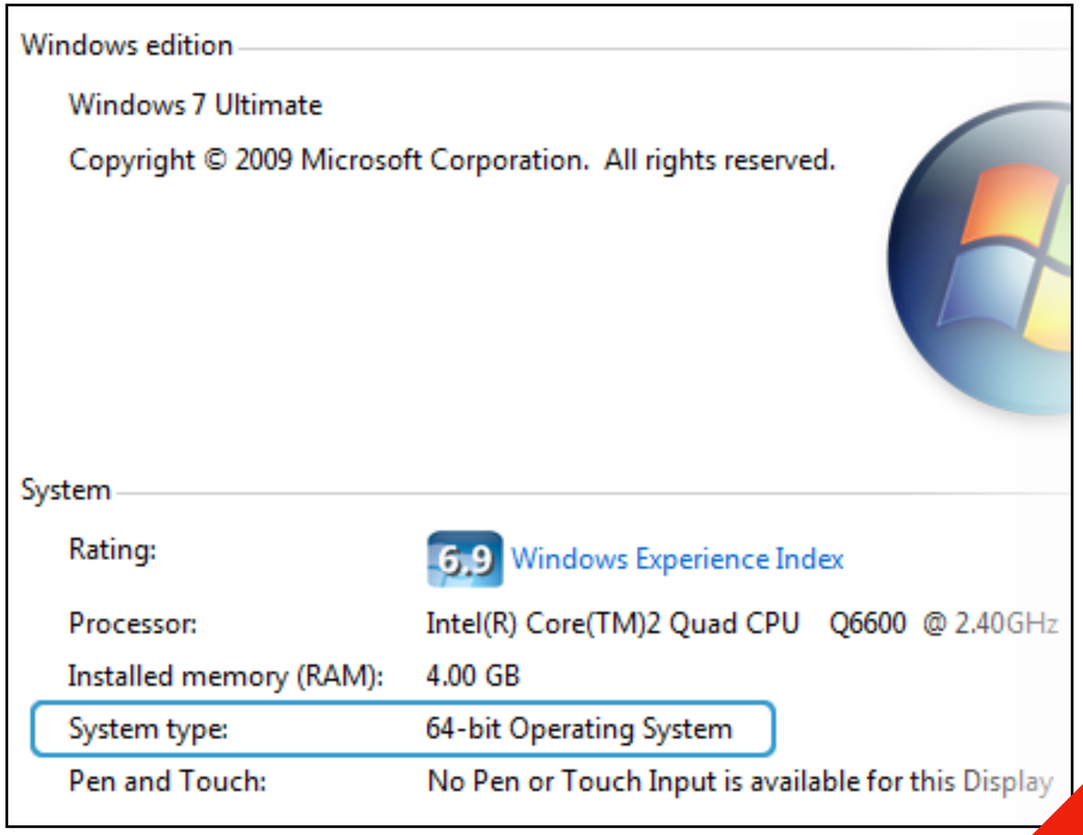


Concept

P2
Number Systems

Binary Systems in Computers

- Every 8bit is called a Byte

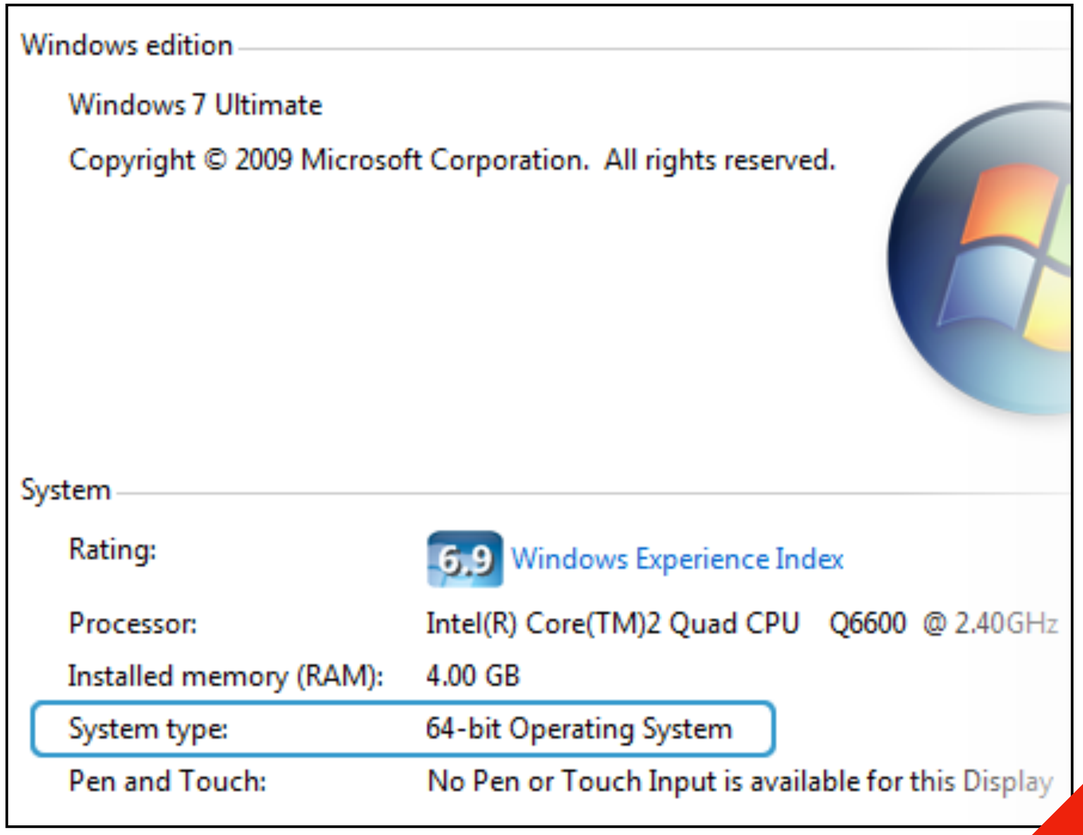


Concept

P2
Number Systems

Binary Systems in Computers

- Every 8bit is called a Byte
- 32bit OS



Concept

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Number Systems

Binary Systems in Computers

- Every 8bit is called a Byte
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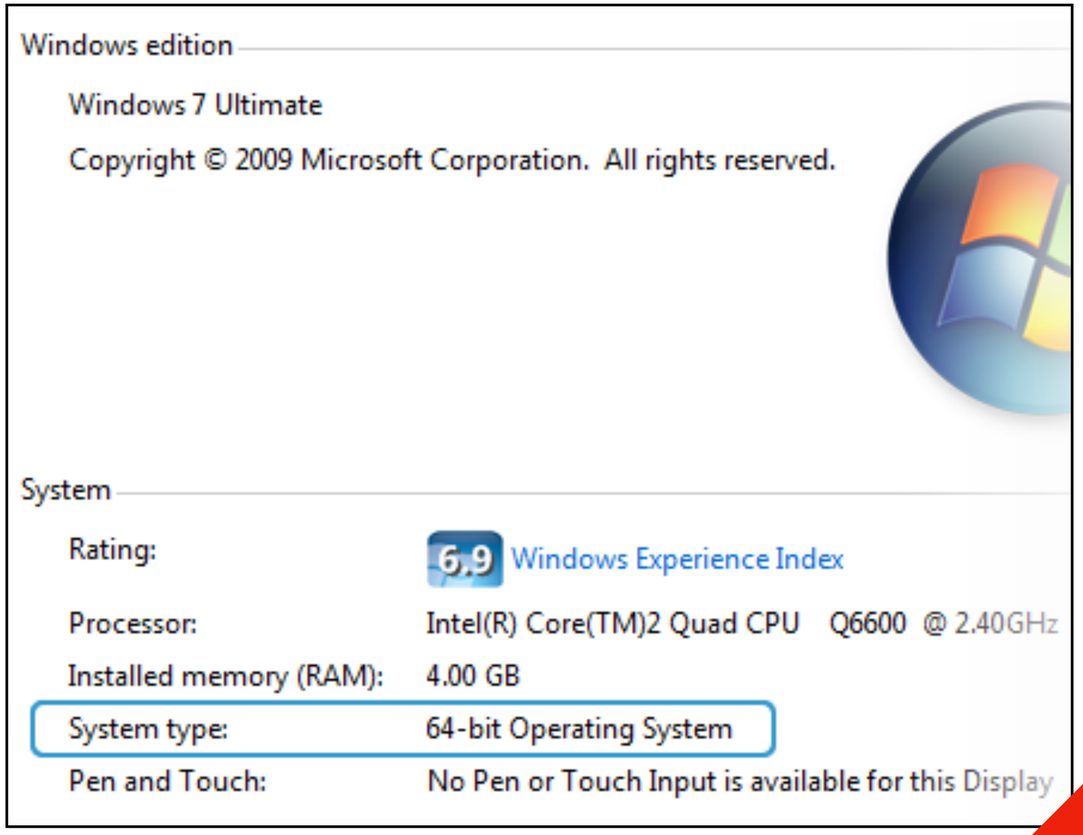
  - A single number is represented by 32bits

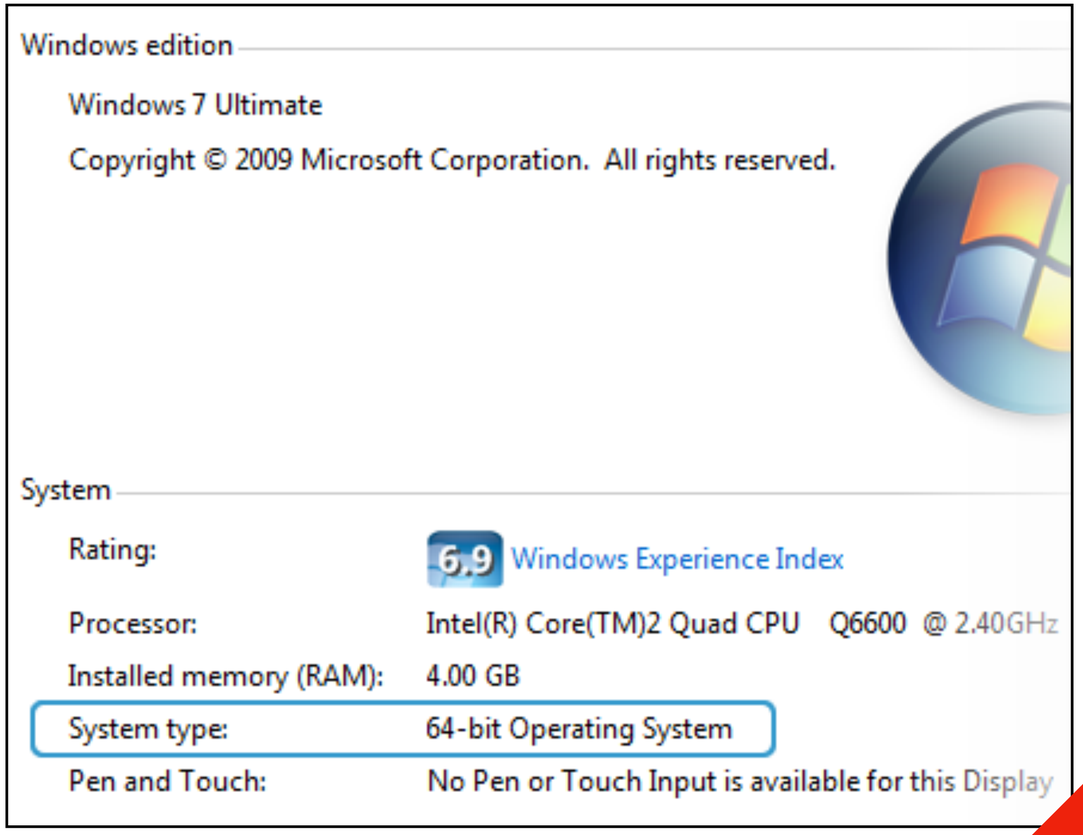


Concept

P2
Number Systems

Binary Systems in Computers

- Every 8bit is called a Byte
- 32bit OS
  - A single number is represented by 32bits
  - Range (int): 0 - 4,294,967,295



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Number Systems

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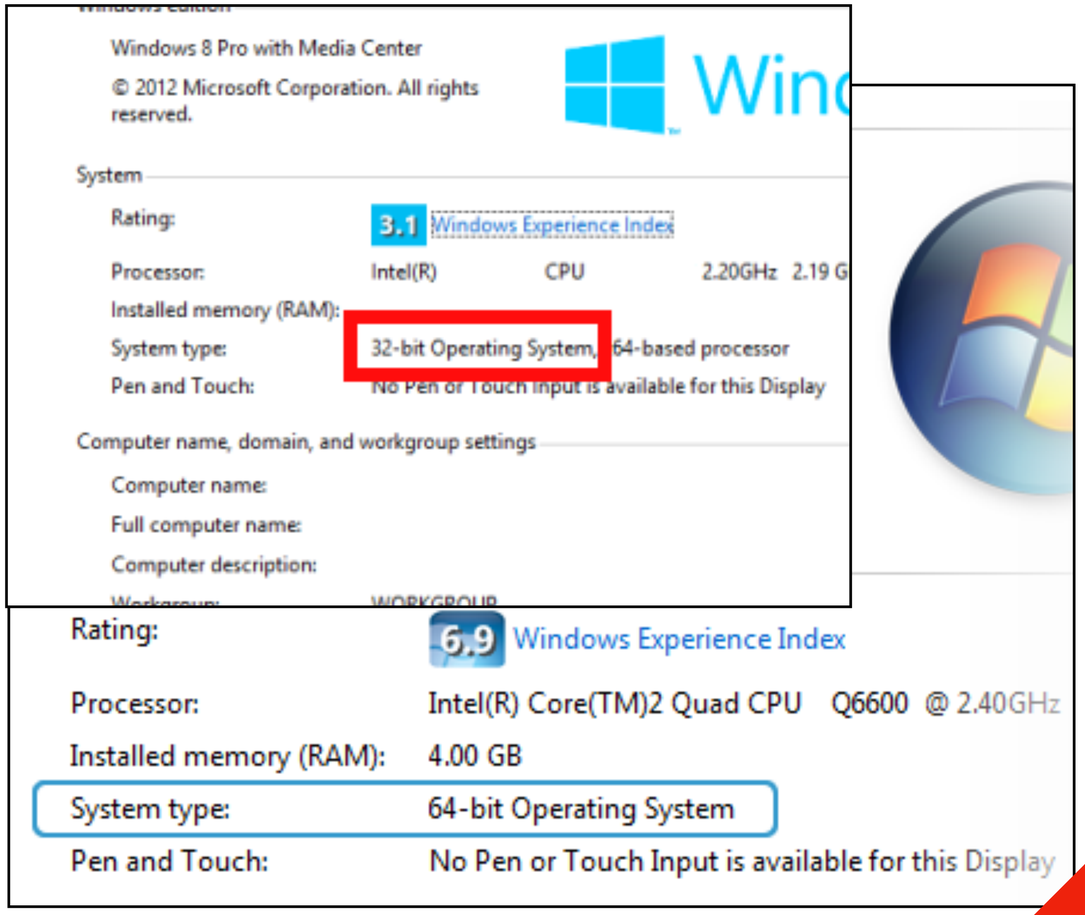
  - Range (int): 0 - 4,294,967,295
- OS vs Processor?



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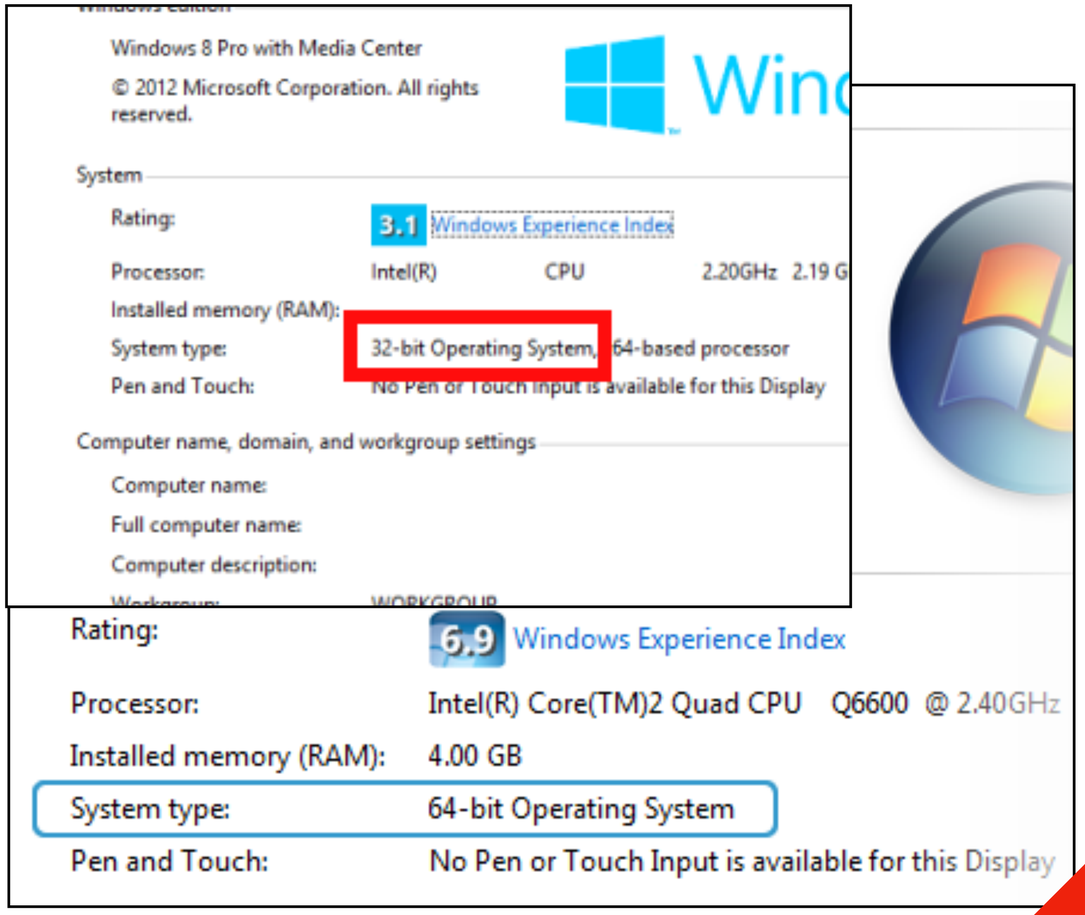
  - Compatibility mode



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- Tera, Peta, Exa, Zetta, Yotta

Concept

P2
Number Systems

Binary Systems in Computers

Concept

P2
Number Systems

Binary Systems in Computers

- What is the difference between MBps and Mbps?

Concept

P2
Number Systems

Binary Systems in Computers

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Concept

P2
Number Systems

Binary Systems in Computers

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Concept

Octal and Hexadecimal Systems

- Octal: base 8
  - digits: 0-7
- Hexadecimal: base 16
  - digits: 0-9, A-F (10-15)

Concept

Octal and Hexadecimal Systems

Decimal (Base 10)	Binary (Base 2)	Octal (Base 8)	Hexadecimal (Base 16)
00	0000	00	0
01	0001	01	1
02	0010	02	2
03	0011	03	3
04	0100	04	4
05	0101	05	5
06	0110	06	6
07	0111	07	7
08	1000	10	8
09	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

P1
Basics

Summary

Review

Summary

- Number systems of base N

Review

Summary

- Number systems of base N
- Binary systems

Review

Summary

- Number systems of base N
- Binary systems
- Octal and Hexadecimal systems

Review