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

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2020 Summer Semester (S2)

# 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

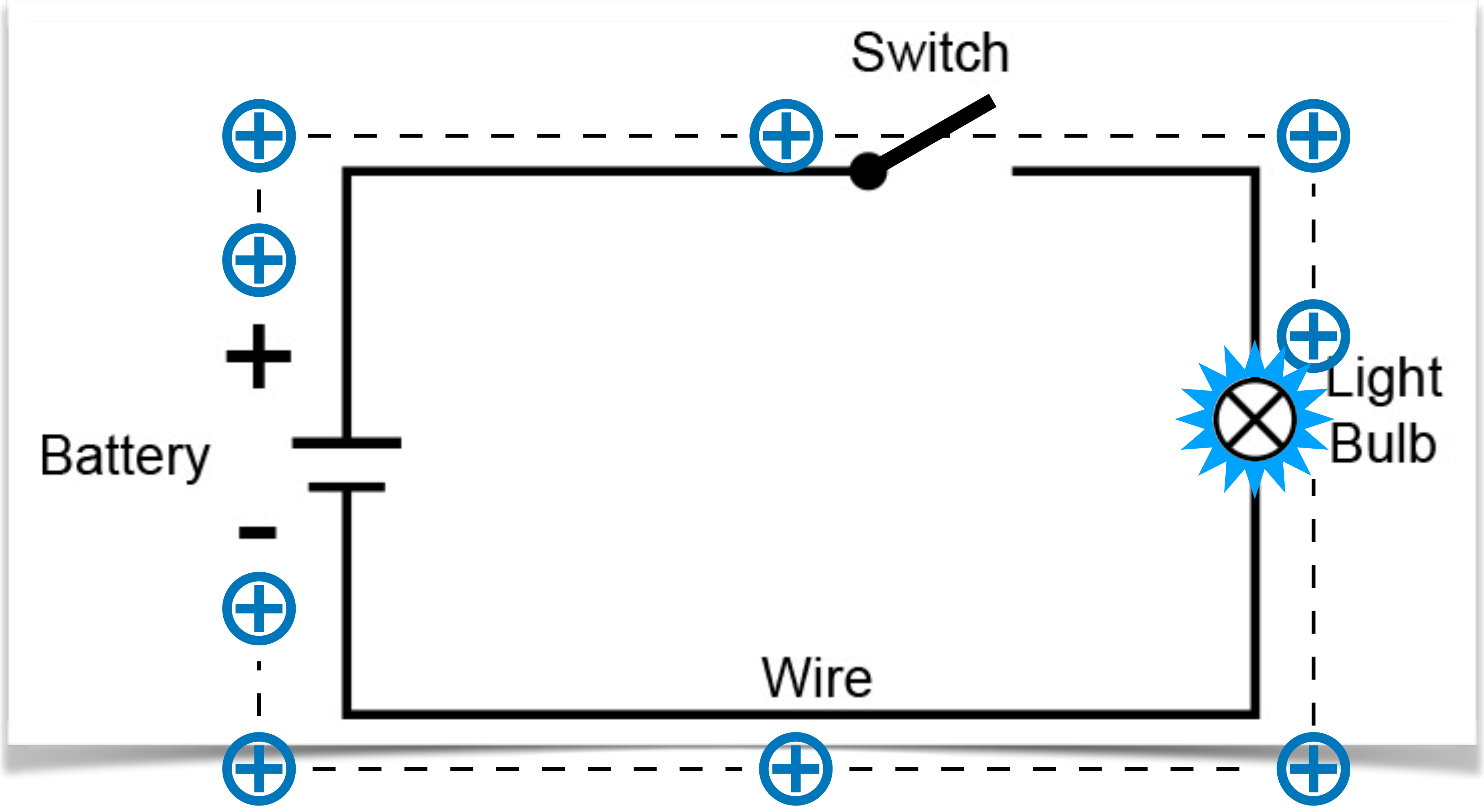
Analog vs Digital circuits;
Modern computer architectures;
Embedded systems;

Summary

P1
Basics

# Circuits

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

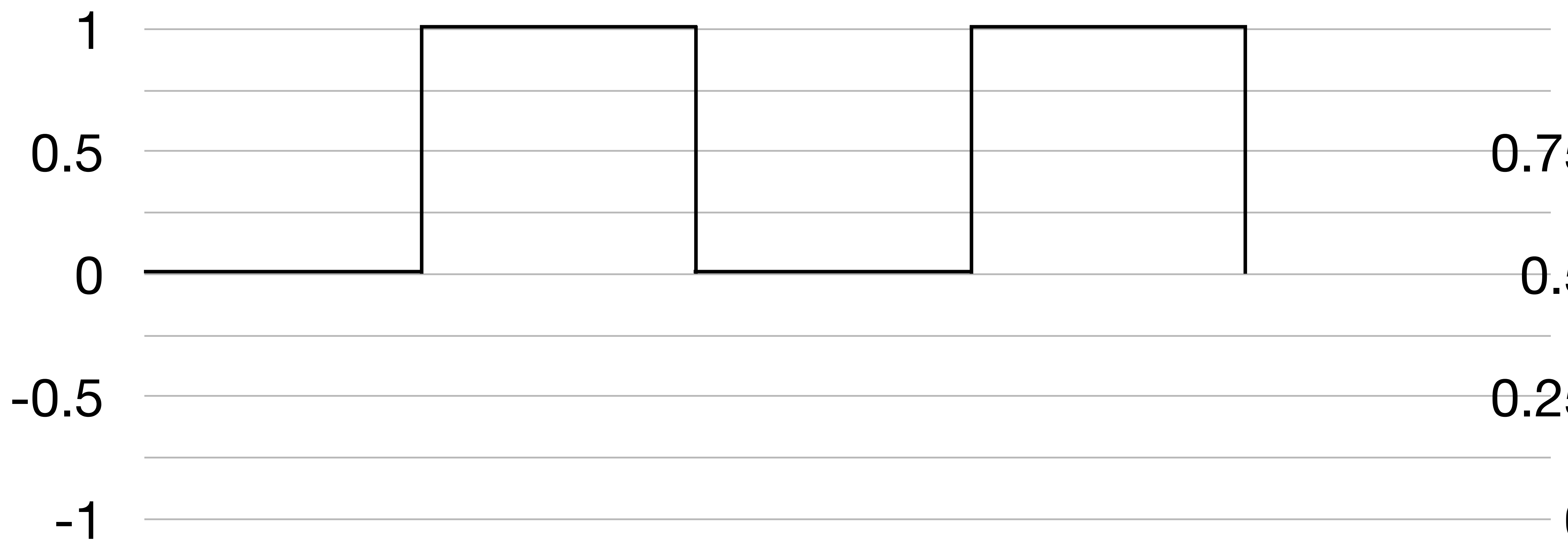



Concept

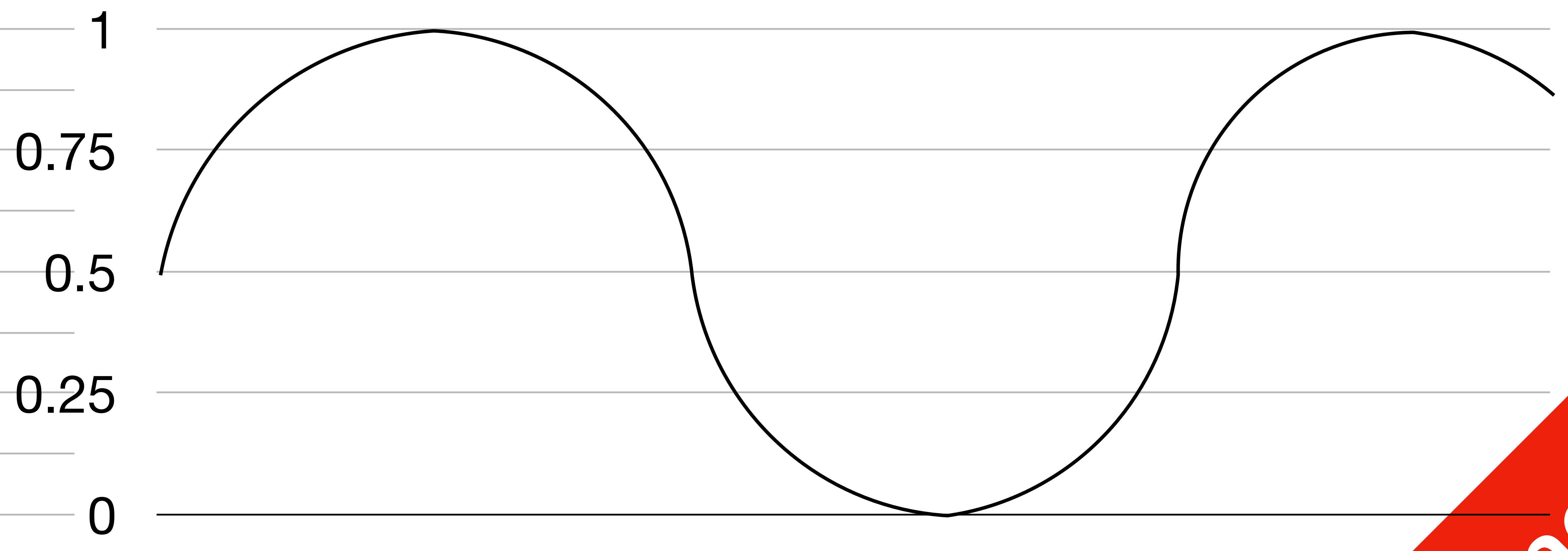
P1
Basics

# 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




Concept

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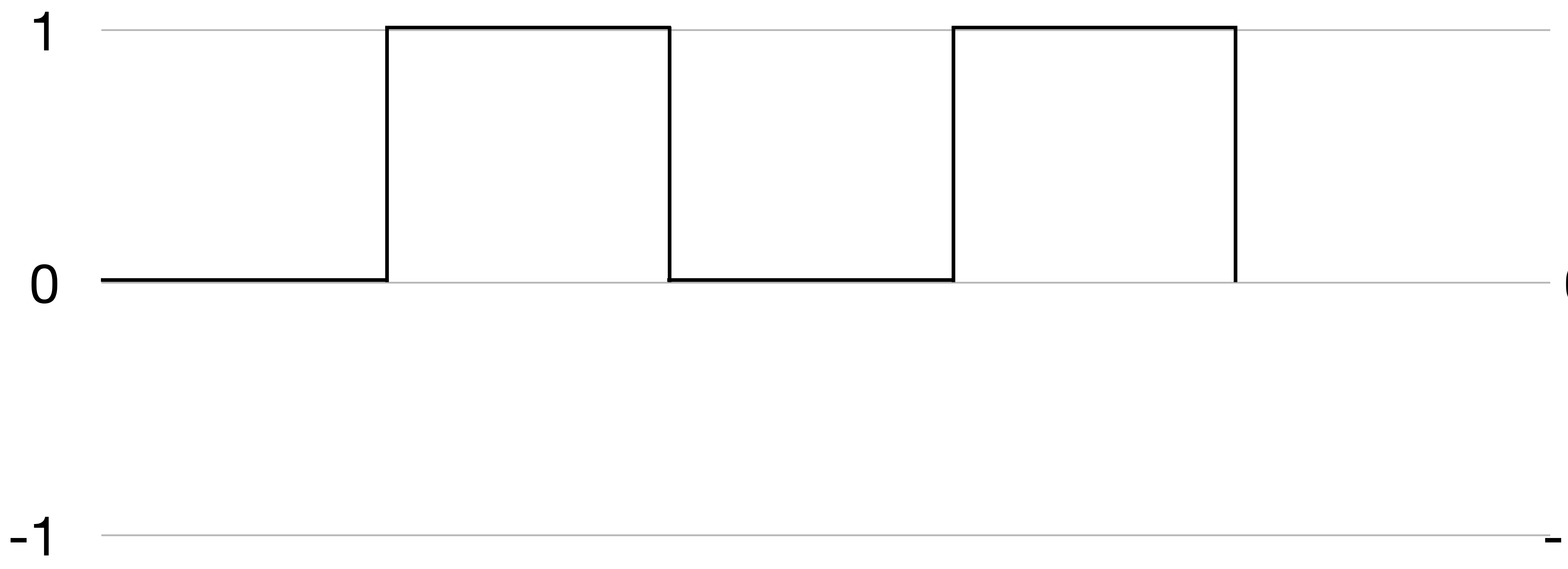
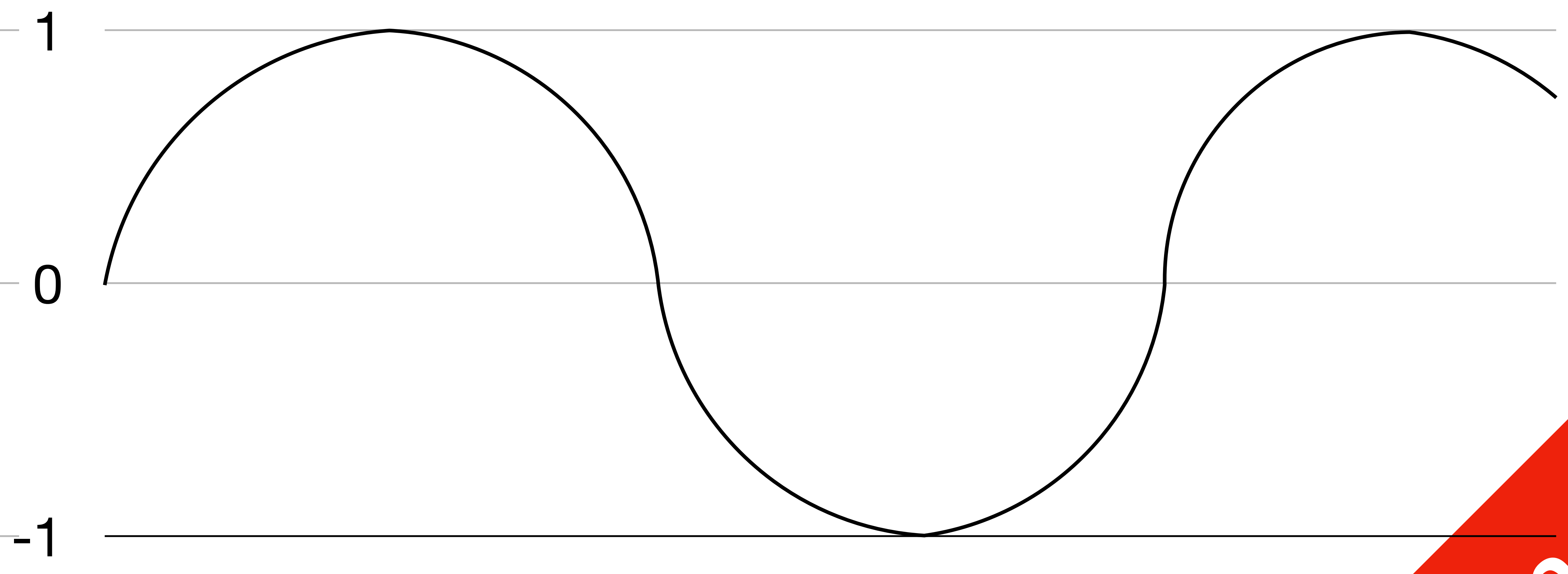
# Circuits

- Digital Circuits
  - Computers
  - Blu-Ray Players
- Analog Circuits
  - Vinyl records
  - Radio




Concept

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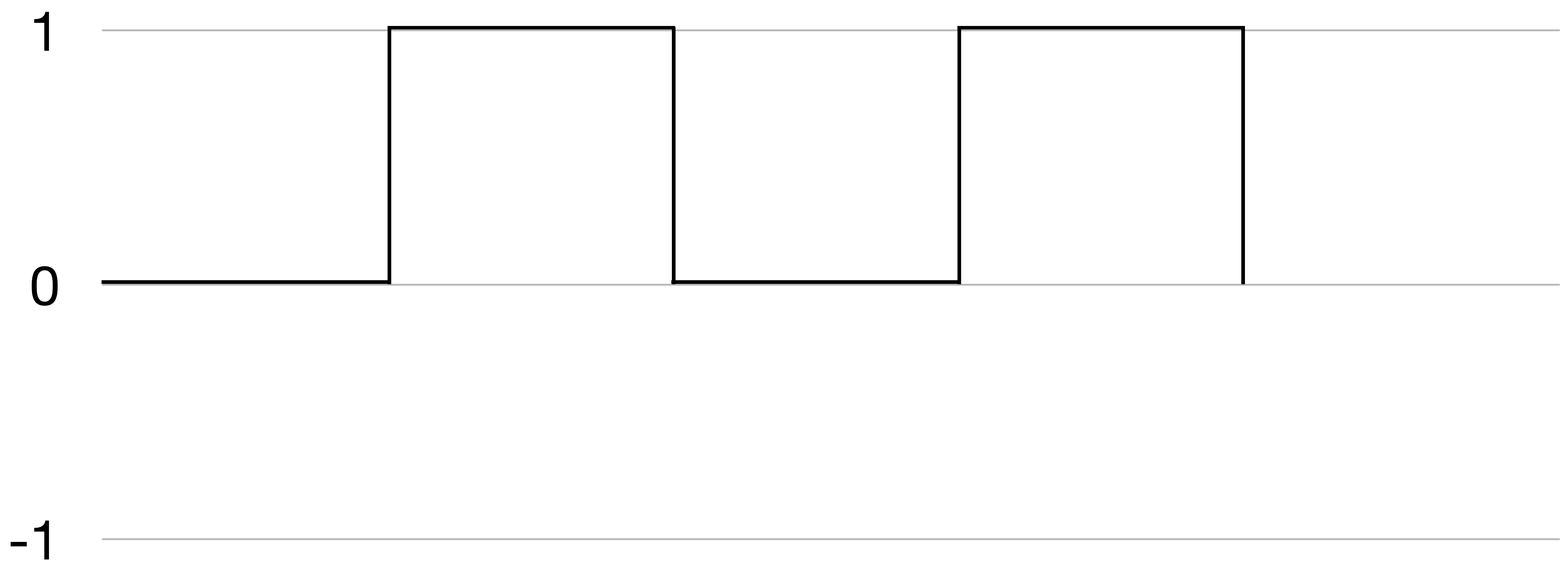
# Digital/Logical Circuits

- 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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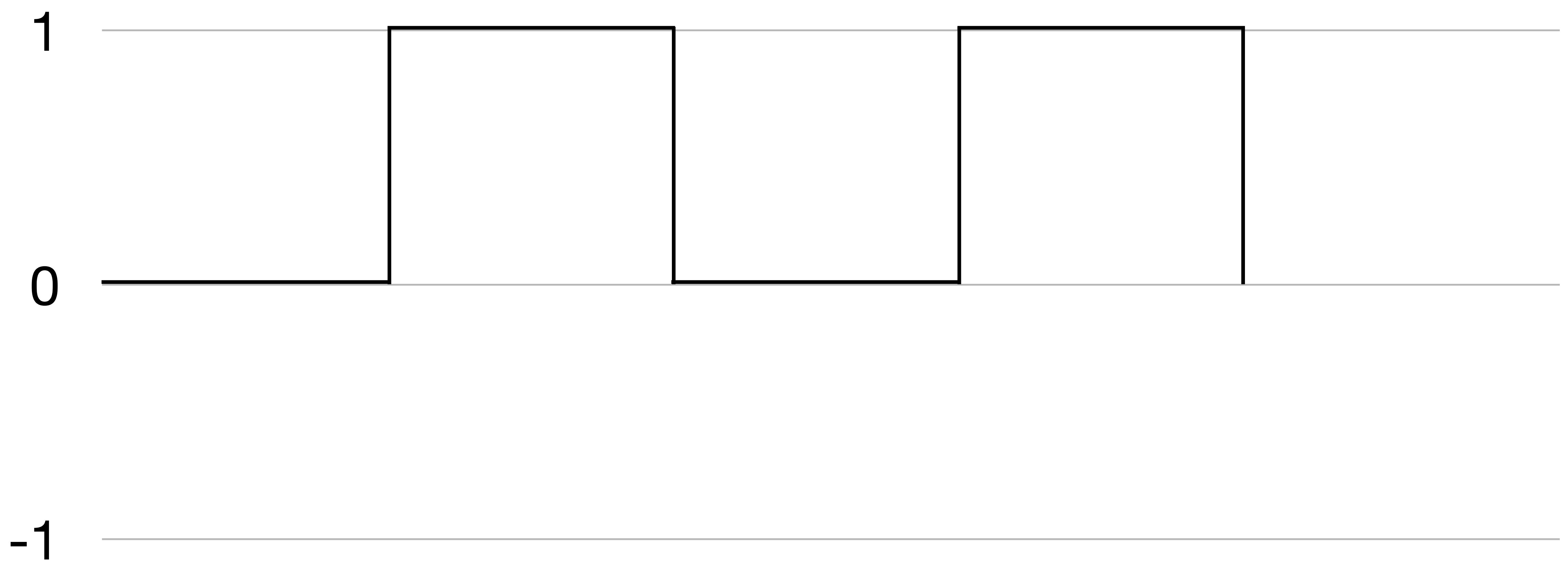
Basics

# Digital/Logical Circuits

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




- Voltage is still continuous in digital circuits

Concept

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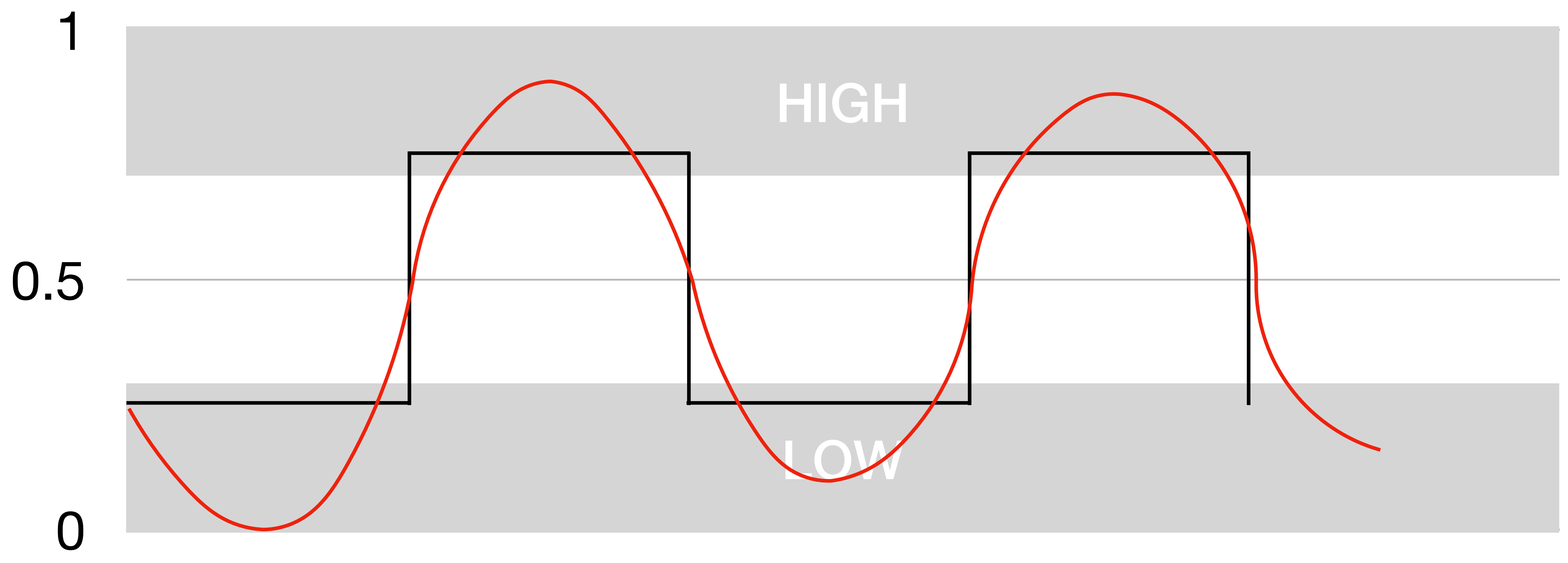
Basics

# Digital/Logical Circuits

- Basic signals
  - High/Low; On/Off; True/False; 1/0;
- Voltage is still continuous in digital circuits




Concept

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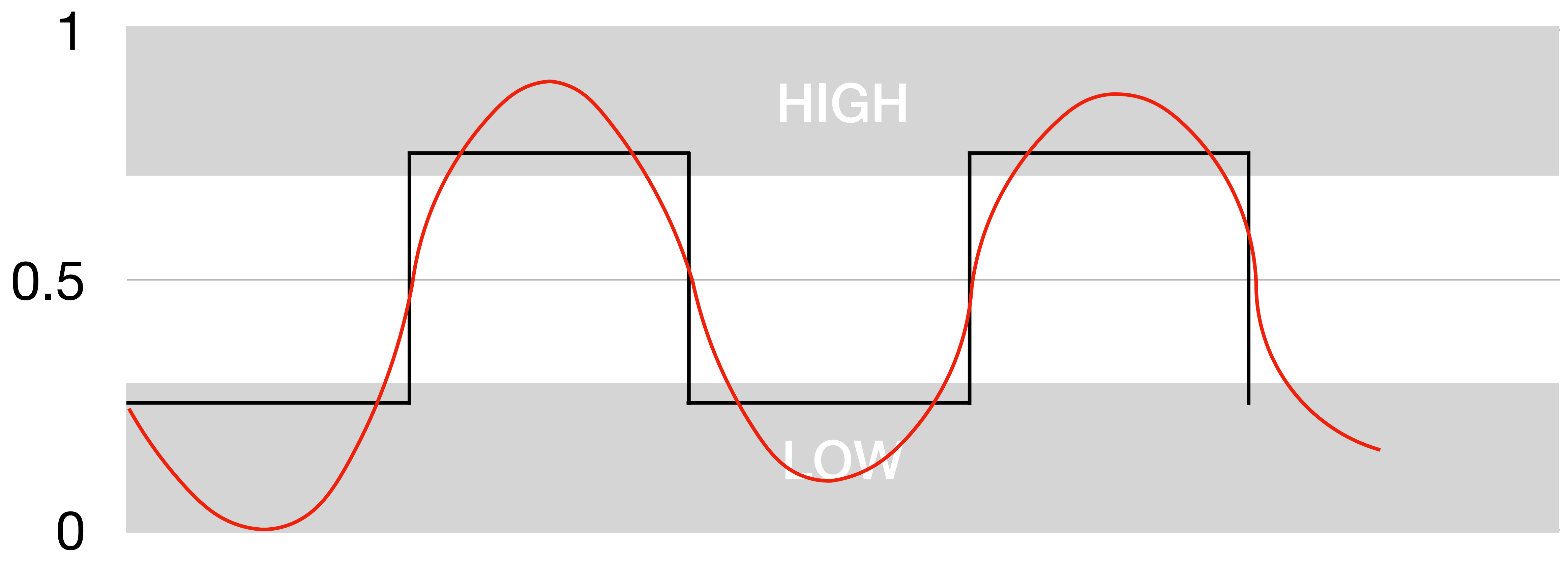
# Digital/Logical Circuits

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




- Voltage is still continuous in digital circuits
- Approximation

Concept

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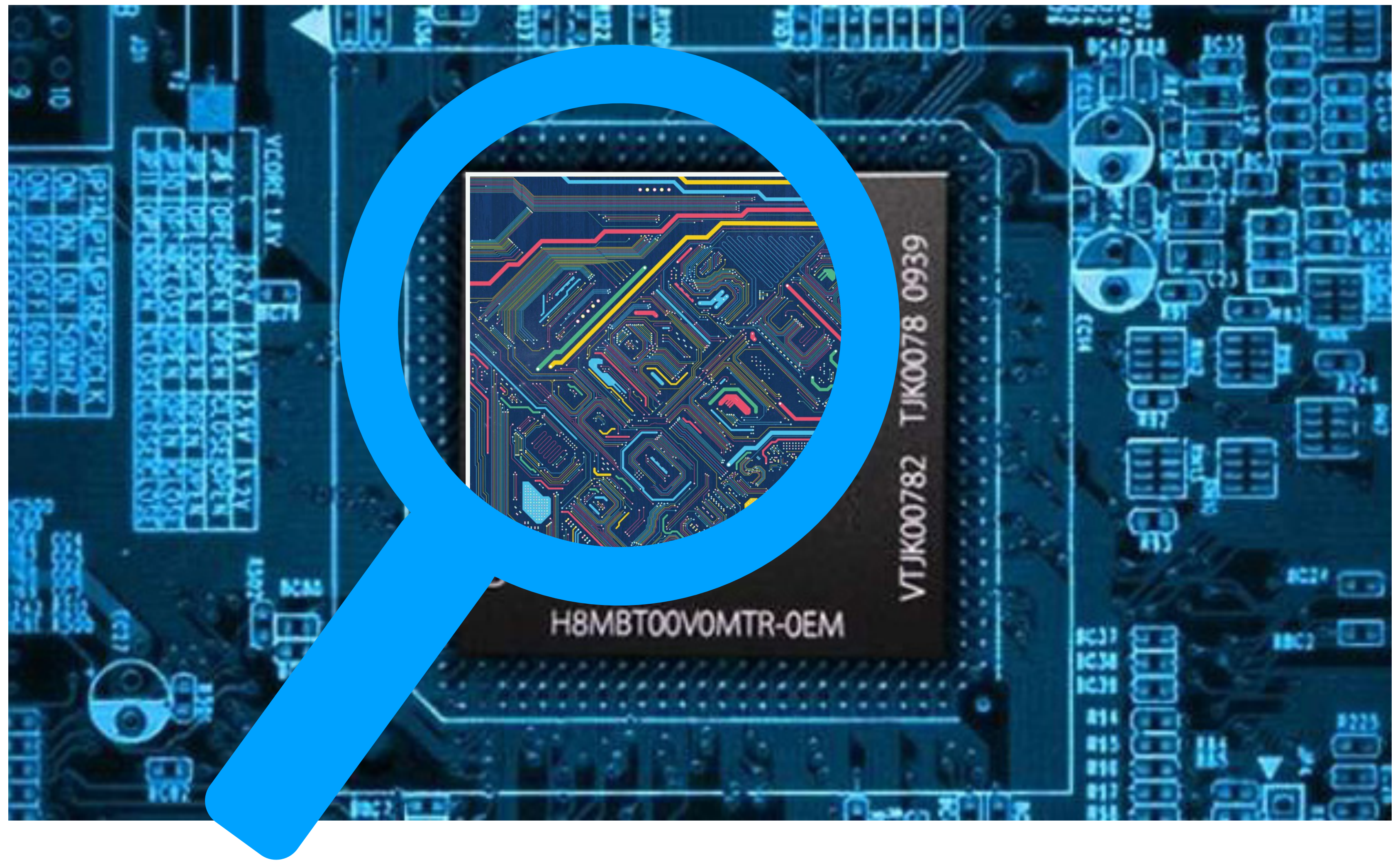
# Digital Integrated Circuits

- 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



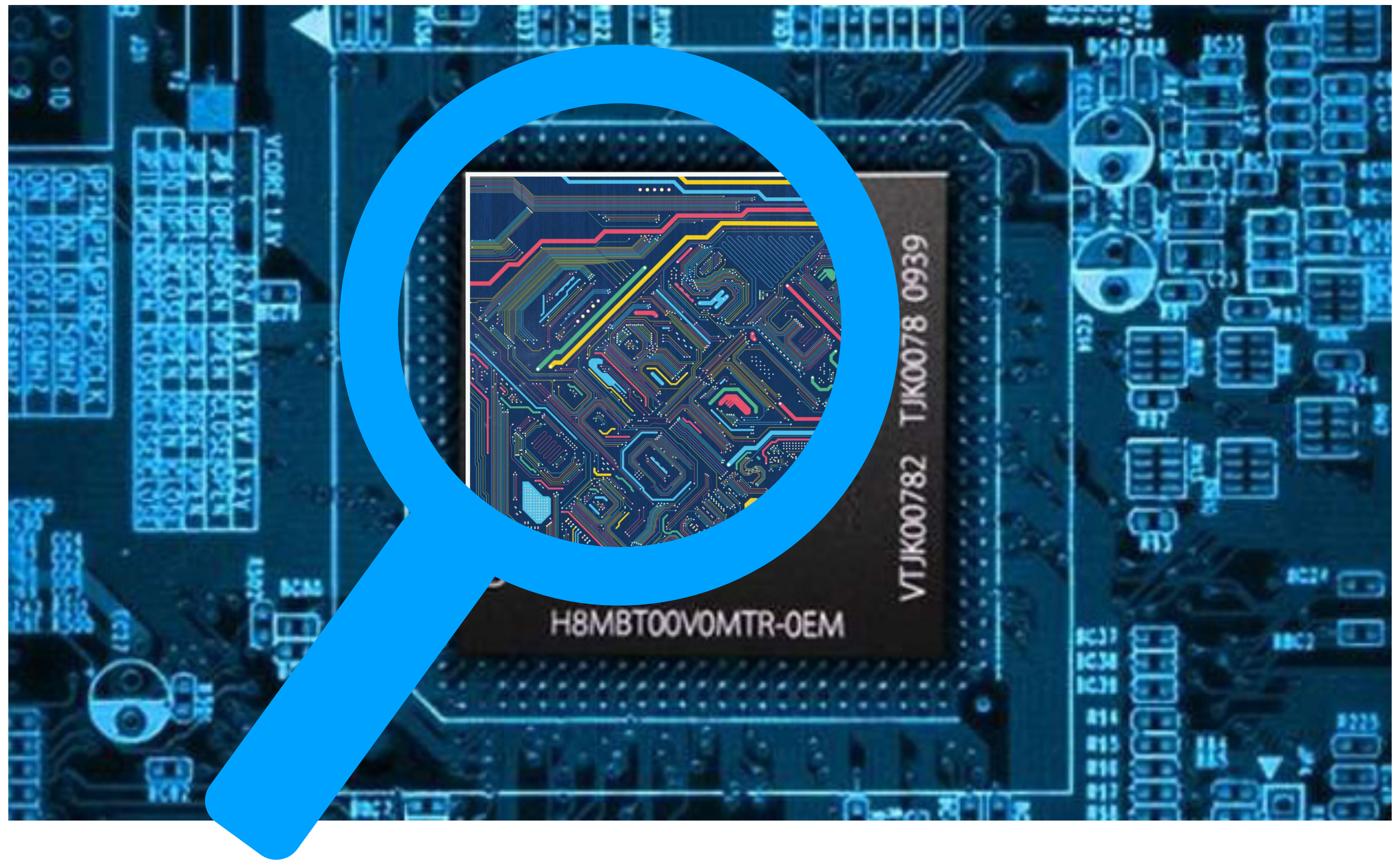

Concept

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

P1
Basics

# 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

1. https://www.daenotes.com/electronics/devices-circuits/integrated-circuits-ic

P1
Basics

# 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

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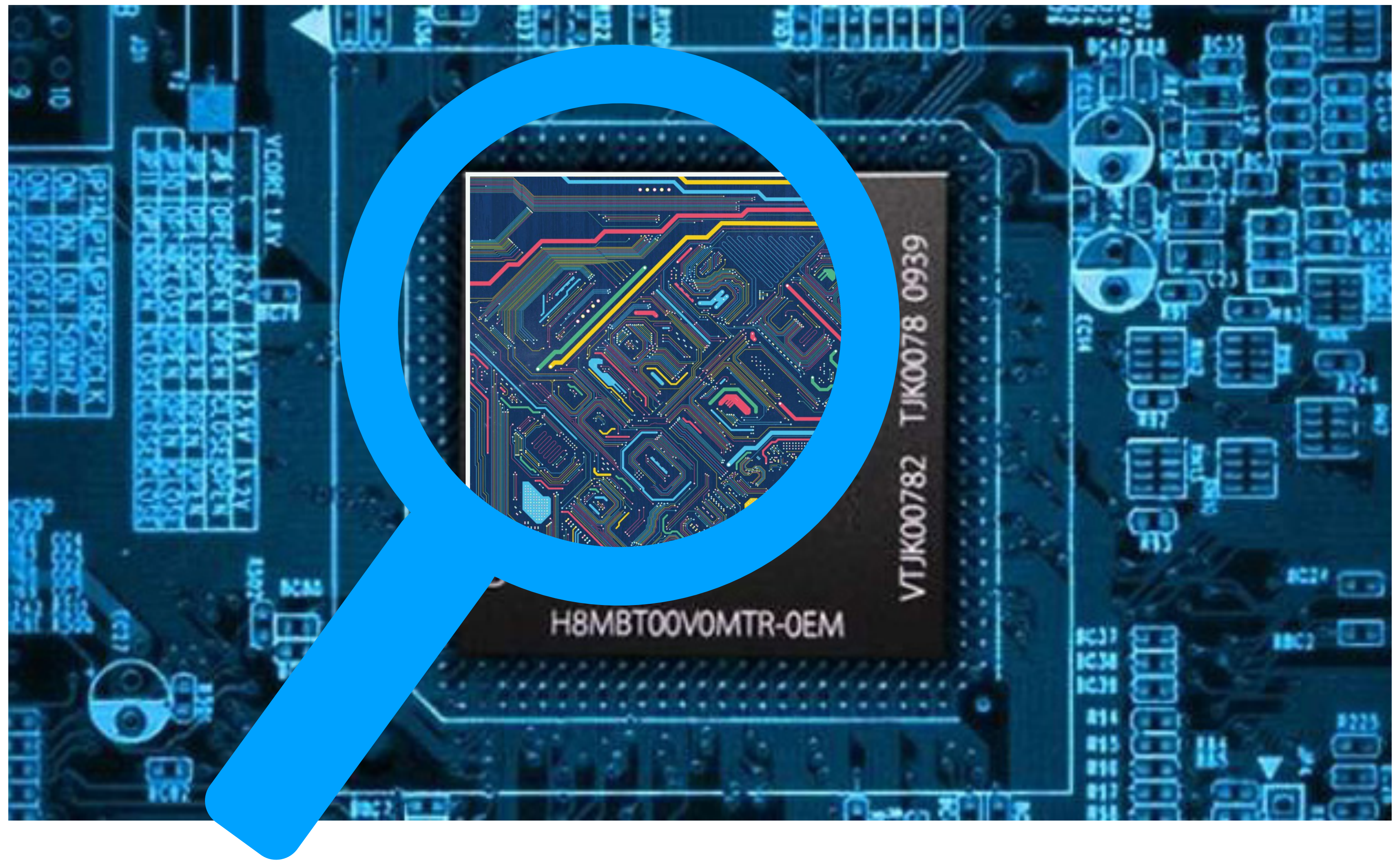


Concept

1. https://www.daenotes.com/electronics/devices-circuits/integrated-circuits-ic

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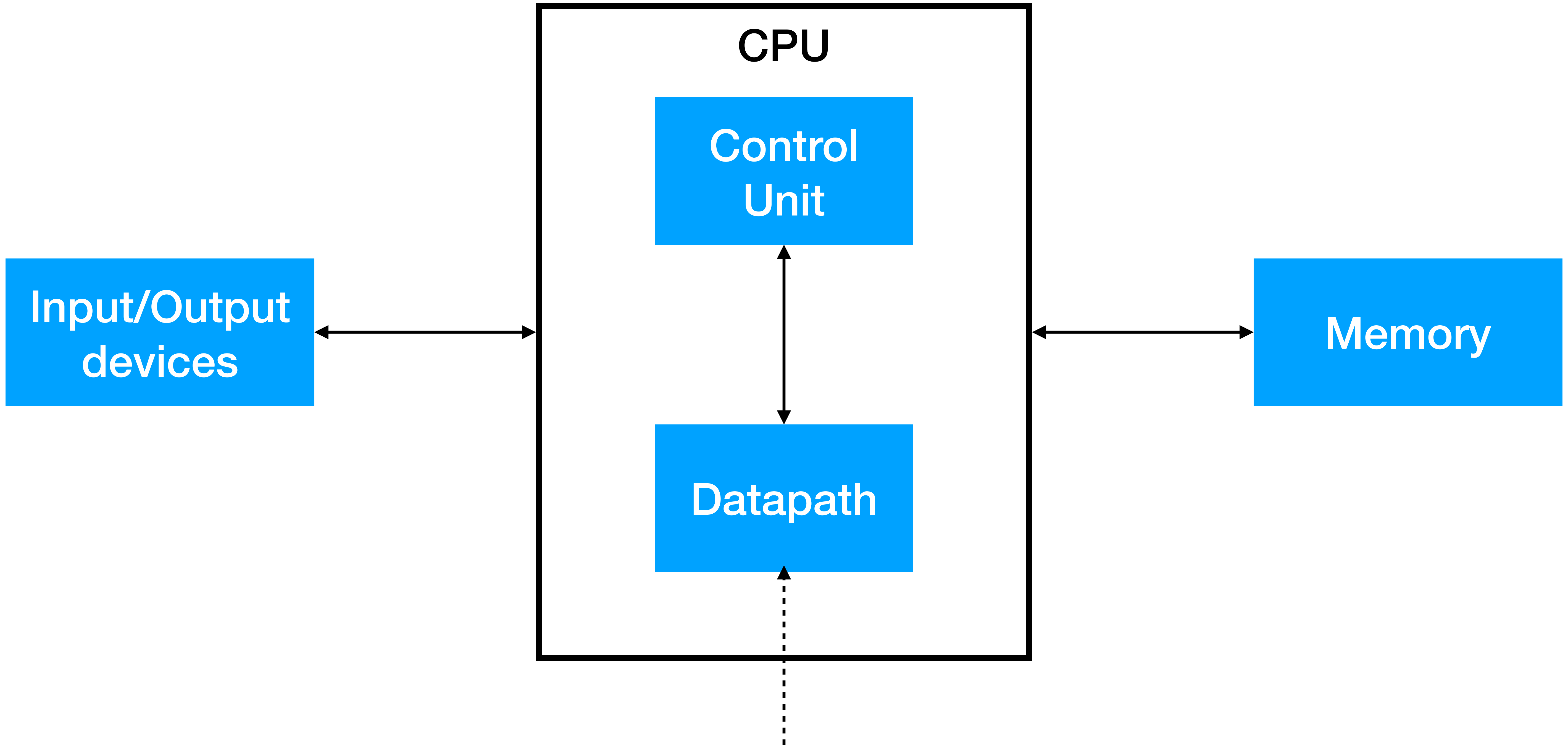
Basics

# Computer



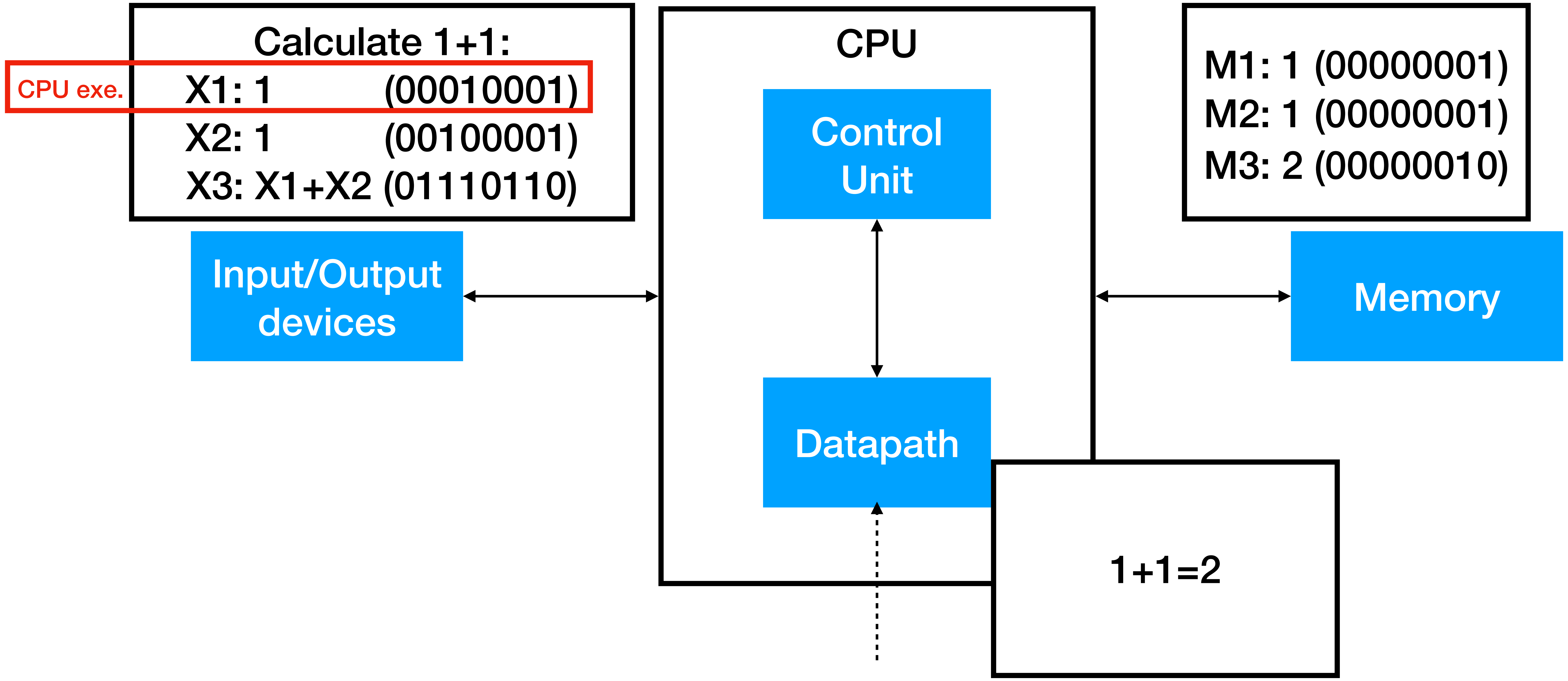

**also called arithmetic unit, logical unit, etc.**

Concept

1. Von Neumann Architecture

# Computer

A very rough example




**also called arithmetic unit, logical unit, etc.**

1. Von Neumann Architecture

Demo

P1
Basics

# 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

# Embedded Systems

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

Concept

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Basics

# Embedded Systems

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

Concept

# 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

# Summary

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

Review

# Number Systems

Binary, Octal and Hexadecimal Numbers;
Number Ranges

Summary

# Decimal System

| 7 | 2 | 4 | . | 0 | 5 |
|---|---|---|---|---|---|
| 2 | 1 | 0 | | −1 | −2 |

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

Review

# Decimal System

$$\underset{2}{7}\ \underset{1}{2}\ \underset{0}{\boxed{4}}.\underset{-1}{0}\ \underset{-2}{5}$$

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

- 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

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

**( 1 0 1 0 0 $)_2$**

**16 x 1 + 8 x 0 + 4 x 1 + 2 x 0 + 1 x 0 = 20**

Example

# Numbers of base N

- Convert decimal number 24 to binary

$$24 = 12 \times 2 + 0$$
$$12 = 6 \times 2 + 0$$
$$6 = 3 \times 2 + 0$$
$$3 = 1 \times 2 + 1$$
$$1 = 0 \times 2 + 1$$

$$24 = (11000)_2$$

Example

# Numbers of base N

- Convert decimal number 79 to hexadecimal

**Hexadecimal digits**

0-9 = $(0\text{-}9)_{16}$

10-15 = $(A\text{-}F)_{16}$

$$79 = 4 \times 16 + 15$$
$$4 = 0 \times 16 + 4$$

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

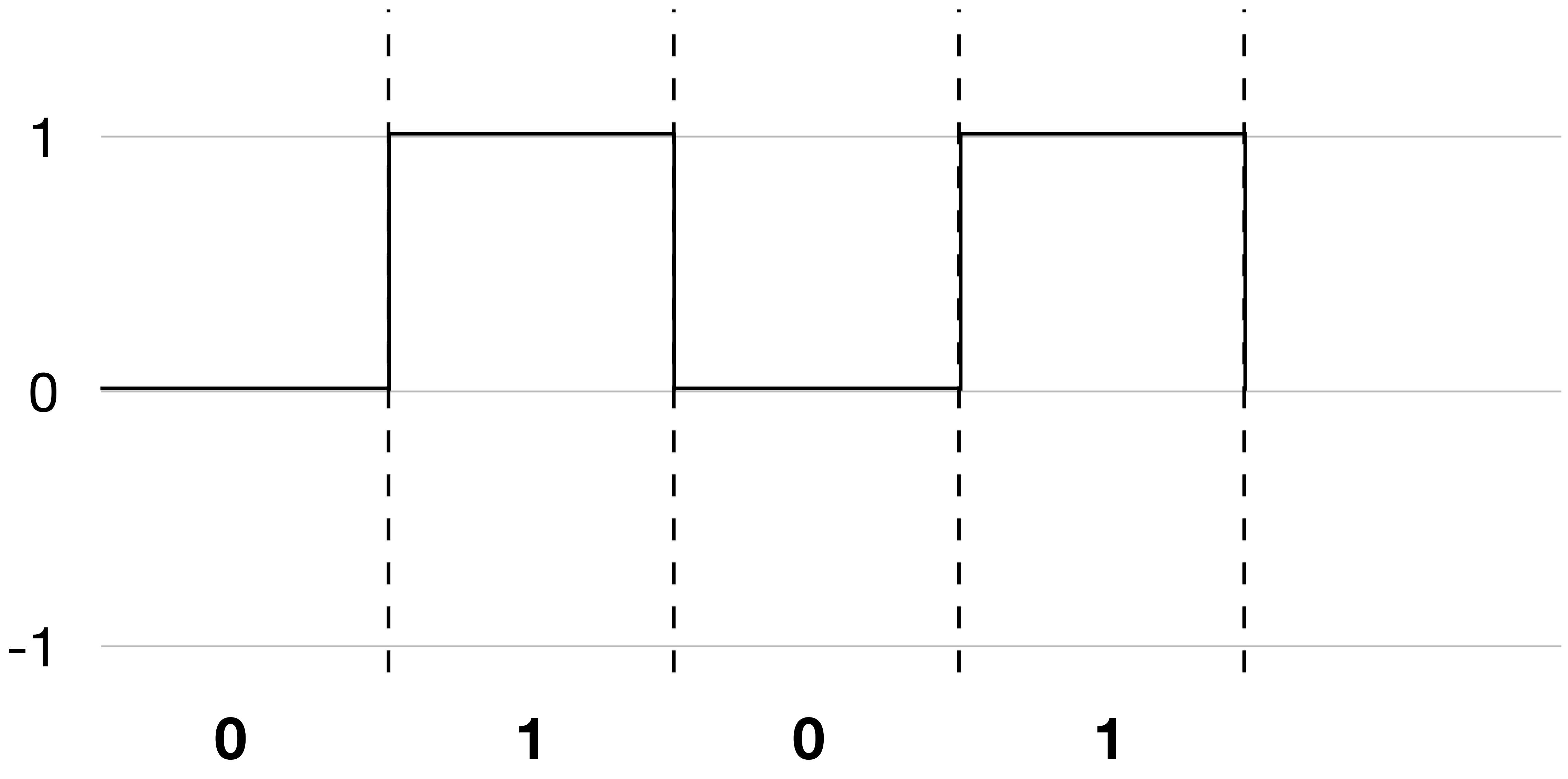
Example

# Numbers of base N

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

Example

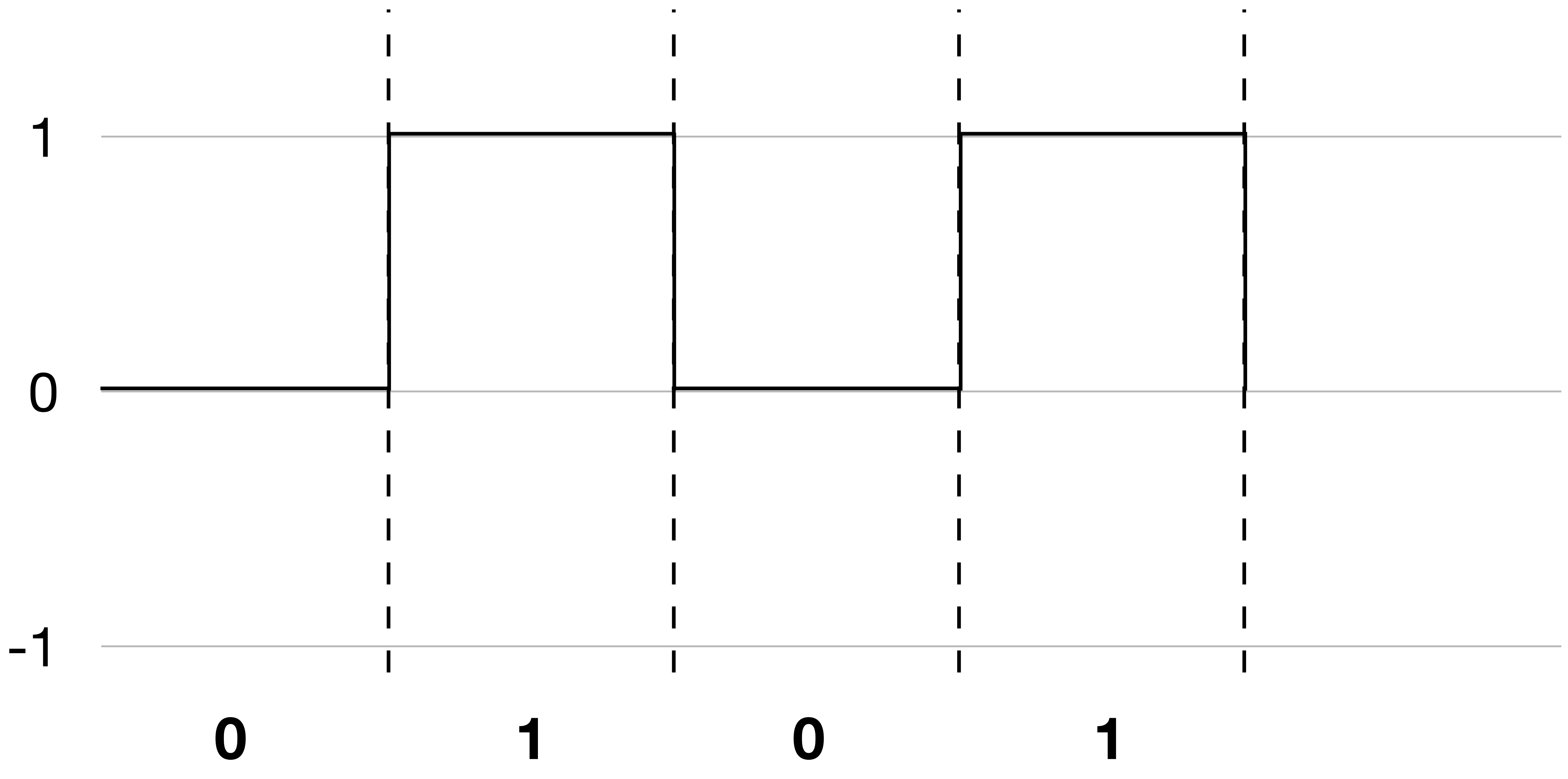
# Binary System




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

Concept

# Binary System



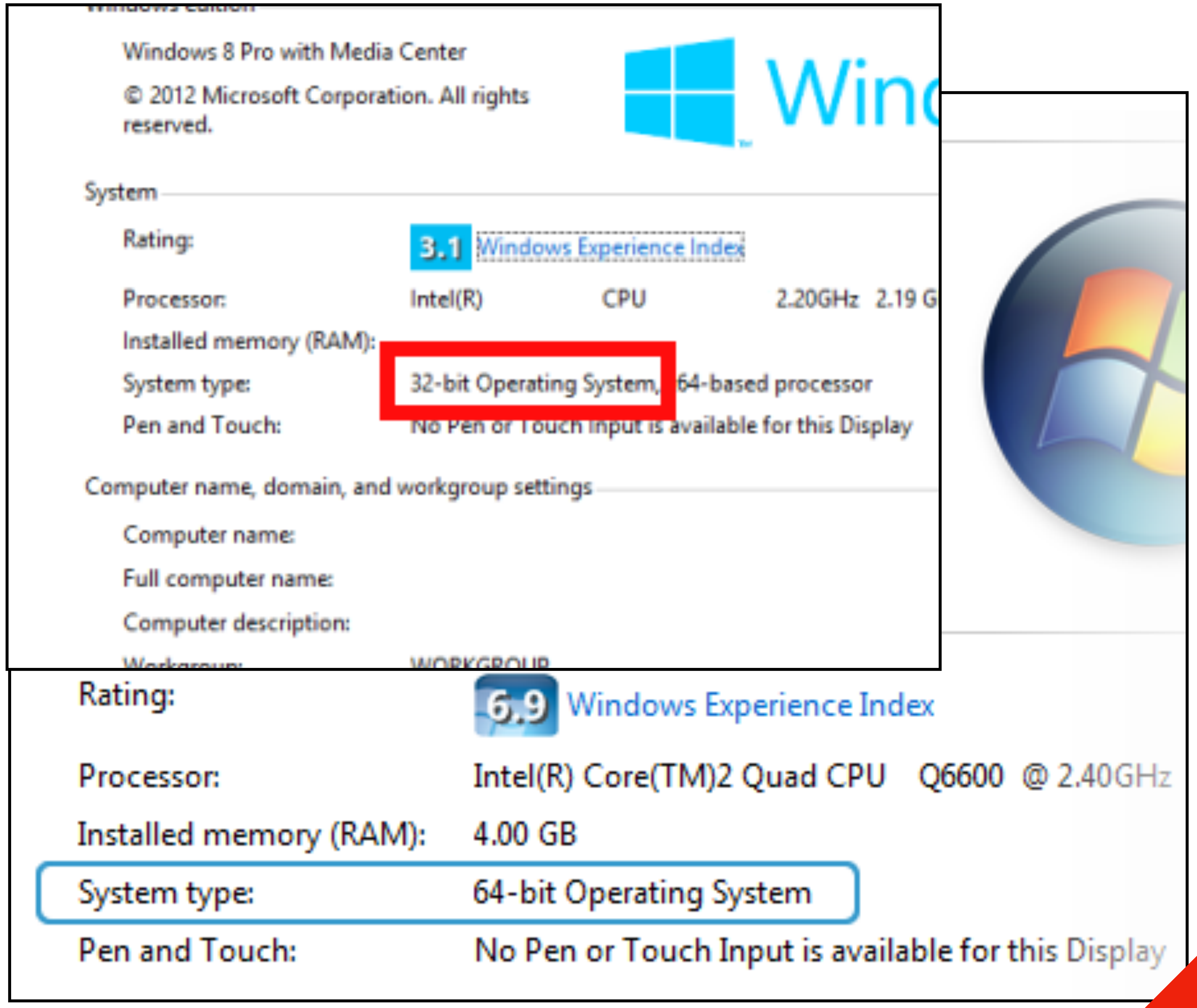

- Is it possible to use different bases in a digital circuit?
- If it is possible, why haven't we seen it very often?

Technical

P2
Number Systems

# Binary Systems in Computers

- Every 8bit is called a Byte
- 32bit OS
    - A single number is represented by 32bits
    - Range (int): 1 - 4,294,967,295
- OS vs Processor?
    - Compatibility mode




Concept

P2
Number Systems

# Binary Systems in Computers

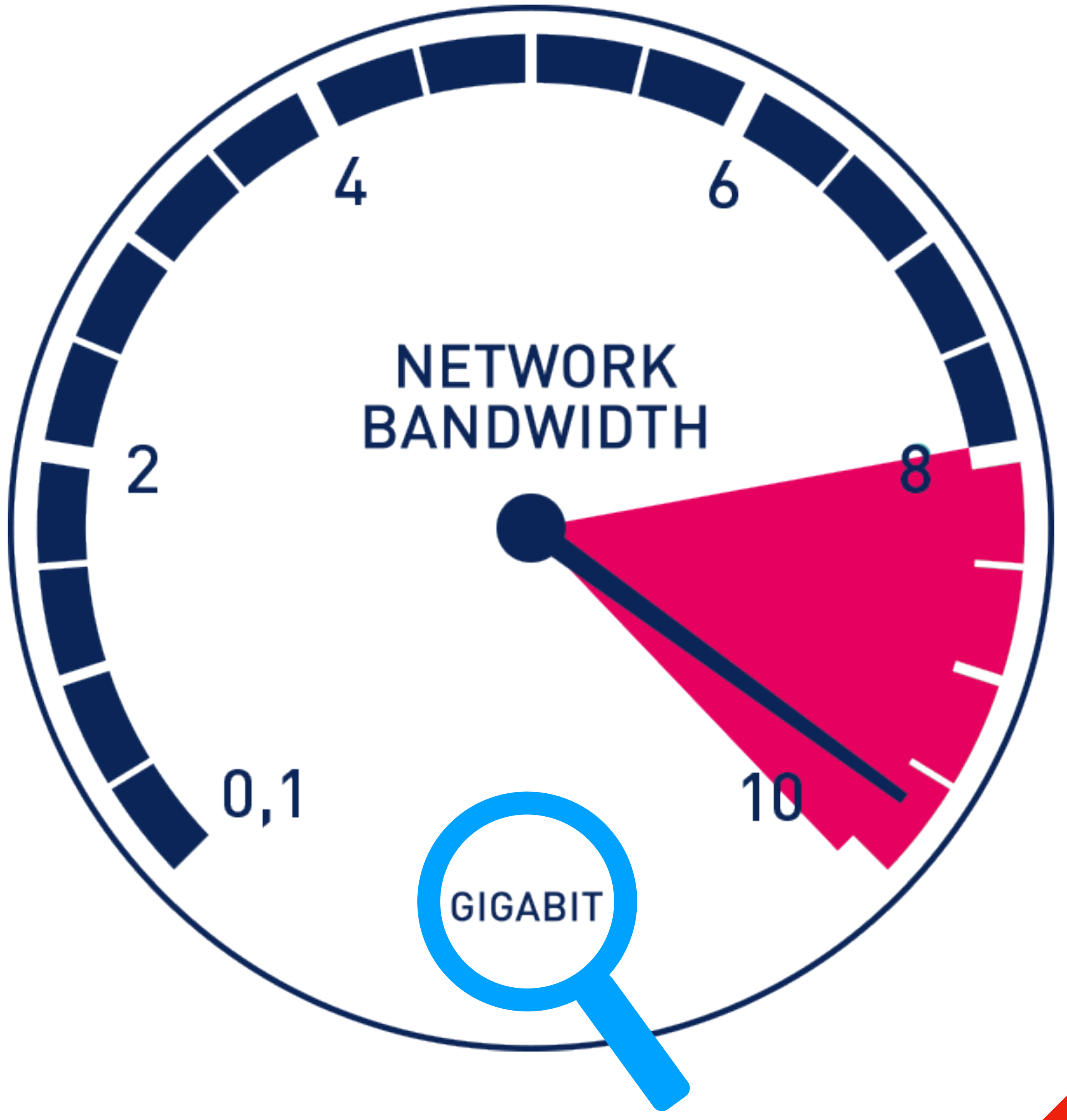
- Every 8bit is called a Byte
- 1,024 = $2^{10}$ is called K (Kilo)
- 1,024 x 1,024 = $2^{20}$ is called M (Mega)
- 1,024 x 1,024 x 1,024 = $2^{40}$ is called G (Giga)
- Tera, Peta, Exa, Zetta, Yotta

Concept

P2
Number Systems

# Binary Systems in Computers !

- What is the difference between MBps and Mbps?
  - MegaBytes per second vs MegaBits per second
  - 8x difference!




Concept

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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 |

Concept

P1
Basics

# Summary

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

Review