Week 03 - Storage

GE-161 Introduction to Information and Communication Technologies

Department of Information Technology
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Learning Objectives

1. Understand how data and programs are represented to a computer and be able to identify a few of the coding systems used to accomplish this.
2. Explain the functions of the hardware components commonly found inside the system unit, such as the CPU, memory, buses, and expansion cards.
3. Describe how new peripheral devices or other hardware can be added to a computer.
4. Understand how the computer system's CPU and memory components process program instructions and data.
5. Name and evaluate several strategies that can be used today for speeding up the operations of a computer.
6. List some technologies that may be used in the future computers.

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Overview

- This chapter covers:
  - How computers represent data and program instructions
  - How the CPU, memory, and other components located inside the system unit are arranged, as well as the characteristics of the components
  - How the CPU performs processing tasks
  - Strategies to speed up a computer today and to create faster computers in the future

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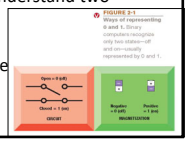
Data and Program Representation

- In order to be understood by a computer, data and programs need to be represented appropriately
- Coding systems: Used to represent data and programs in a manner understood by the computer
- Digital computers: Can only understand two states, off and on (0 and 1)
- Digital data representation: The process of representing data in digital form so it can be understood by a computer



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Digital Data Representation

- Bit: The smallest unit of data that a binary computer can recognize (a single 1 or 0)
- Byte = 8 bits
- Byte terminology used to express the size of documents and other files, programs, etc.
- Prefixes are often used to express larger quantities of bytes: kilobyte (KB), megabyte (MB), gigabyte (GB), terabyte (TB), etc.

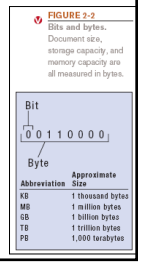

FIGURE 2-2
Bits and bytes. Document size, storage capacity, and memory capacity are all measured in bytes.

Abbreviation	Approximate Size
KB	1 thousand bytes
MB	1 million bytes
GB	1 billion bytes
TB	1 trillion bytes
PB	1,000 terabytes

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The Binary Numbering System

- Numbering system: A way of representing numbers
- Decimal numbering system
  - Uses 10 symbols (0-9)
- Binary numbering system
  - Uses only two symbols (1 and 0) to represent all possible numbers
- In both systems, the position of the digits determines the power to which the base number (such as 10 or 2) is raised

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The Binary Numbering System

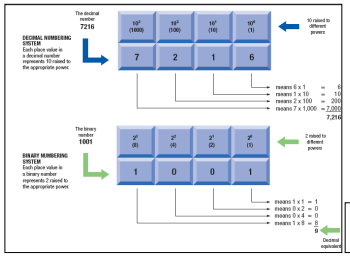

FIGURE 1-3
Examples of using the decimal and binary numbering systems.

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Coding Systems for Text-Based Data

- ASCII and EBCDIC
  - ASCII (American Standard Code for Information Interchange): coding system traditionally used with personal computers
  - EBCDIC (Extended Binary-Coded Decimal Interchange Code): developed by IBM, primarily for mainframe use

CHARACTER	ACSII
0	00110000
1	00110001
2	00110010
3	00110011
4	00110100
5	00110101
A	01000001
B	01000010
C	01000011
D	01000100
E	01000101
F	01000110
+	00101011
!	00100001
#	00100011

FIGURE 2-4
Some extended ASCII code examples.

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Coding Systems for Text-Based Data

- Unicode: newer code (32 bits per character is common); universal coding standard designed to represent text-based data written in any ancient or modern language
  - Replacing ASCII as the primary text-coding system

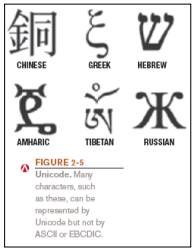

FIGURE 2-5
Unicode. Many characters, such as these, can be represented by Unicode but not by ASCII or EBCDIC.

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Coding Systems for Other Types of Data

- Graphics (still images such as photos or drawings)
  - Bitmapped images: A variety of bit depths are possible (4, 8, 24 bits)
    - More bits = more colors

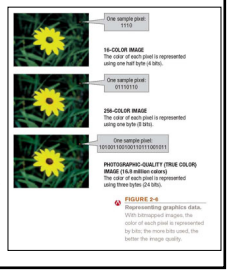

FIGURE 2-6
Representing graphics data. With bitmapped images, the color of each pixel is represented by bits; the more bits used, the better the image quality.

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Coding Systems for Other Types of Data

- Audio data: Must be in digital form in order to be stored on or processed by a computer
  - Often compressed when sent over the Internet
    - MP3 files
- Video data: Displayed using a collection of frames, each frame contains a still image
  - Amount of data can be substantial, but can be compressed
  - *frames per second* (*fps*)

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Representing Programs: Machine Language

- Machine language: Binary-based language for representing computer programs the computer can execute directly
  - Early programs were written in machine language.
  - Today's programs still need to be translated into machine language in order to be understood by the computer
- Most programs are written in other programming languages
  - Language translators are used to translate the programs into machine language

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Quick Quiz

1. Another way to say “one million bytes” is
   a. one kilobyte
   b. one gigabyte
   c. one megabyte
2. True or False: MP3 files are stored using 0s and 1s.
3. The _____ numbering system is used by computers to perform mathematical computations.

Answers:
1) c; 2) True; 3) binary

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Inside the System Unit

- System unit: The main case of a computer
  - Houses the processing hardware for a computer
  - Also contains storage devices, the power supply, and cooling fans
  - Houses the CPU, memory, interfaces to connect to peripheral devices (printers, etc), and other components such as CD/DVD drives
  - With a desktop computer, usually looks like a rectangular box

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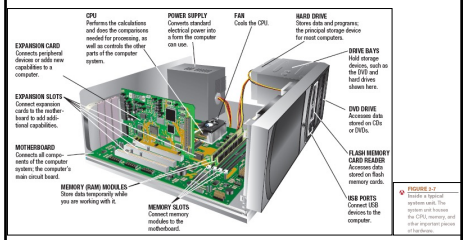
Inside the System Unit



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The Motherboard

- Computer chip: A very small pieces of silicon or other semi-conducting material onto which integrated circuits are embedded
- Circuit board: A thin board containing computer chips and other electronic components
- Motherboard or system board: The main circuit board inside the system unit
  - All devices must connect to the motherboard
  - External devices (monitors, keyboards, mice, printers) typically connect by plugging into a port exposed through the exterior of the system unit
  - Wireless devices connect through a transceiver or wireless networking technology (like Bluetooth)

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The CPU

- Central processing unit (CPU): circuitry and components packaged together and connected directly to the motherboard
  - Does the vast majority of processing for a computer
  - Also called a processor; called a microprocessor when talking about personal computers
- Dual-core CPU: Contains the processing components (cores) of two separate processors on a single CPU
- Quad-core CPU: Contains 4 cores
- Typically different CPUs for desktop computers, portable computers, servers, mobile devices, consumer devices, etc.
- Often made by Intel or AMD

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The CPU

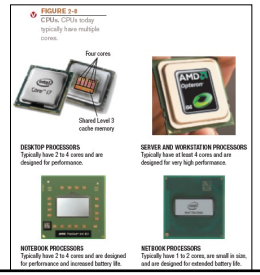

FIGURE 2-8 CPUs. CPUs today typically have multiple cores.

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The CPU

TYPE OF PROCESSOR	NAME	NUMBER OF CORES	CLOCK SPEED	TOTAL CACHE MEMORY LEVEL 1	LEVEL 2	LEVEL 3
DESKTOP	Intel Core i7 AMD Phenom II	4 2–4	2.66–3.33 GHz 2.4–3.2 GHz	64 KB* 128 KB*	256 KB* 512 KB*	8 MB 4–6 MB
SERVER/ WORKSTATION	Intel Xeon (5500 series) AMD Opteron (3rd generation)	2 or 4 4 or 6	1.86–3.2 GHz 2.0–3.1 GHz	64 KB* 128 KB*	256 KB* 512 KB*	4–8 MB 6 MB
NOTEBOOK	Intel Core 2 Mobile AMD Turion X2 Mobile	1, 2, or 4 2	1.06–3.06 GHz 2.0–2.5 GHz	64 KB* 128 KB*	1–12 MB 1–2 MB*	none none
NETBOOK	Intel Atom AMD Athlon Neo	1–2 1	800 MHz–2 GHz 1.6 MHz	56 KB* 128 KB*	512 KB* 512 KB*	none none

*Per core

FIGURE 2-9 Some examples of current Intel and AMD CPUs.

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Processing Speed

- CPU clock speed: One measurement of processing speed
  - Measured in megahertz (MHz) or gigahertz (GHz)
  - Higher CPU clock speed = more instructions processed per second
- Alternate measure of processing speed is the number of instructions a CPU can process per second
  - Megaflops, gigaflops, teraflops
- Other factors (CPU architecture, memory, bus speed, amount of RAM, etc.) also affect the overall processing speed of a computer
- Benchmark tests: Can be used to evaluate overall processing speed

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Word Size and Cache Memory

- Word size: The amount of data that a CPU can manipulate at one time
  - Typically 32 or 64 bits
- Cache memory: Special group of very fast memory chips located on or close to the CPU
  - Level 1 is fastest, then Level 2, then Level 3
  - More cache memory typically means faster processing
  - Usually internal cache (built into the CPU)
  - Often some cache dedicated to each core; may also have some shared cache accessible by any core

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Bus Width, Bus Speed, and Bandwidth

- Bus: An electronic path over which data can travel
- Bus width: The number of wires in the bus over which data can travel
- Bus width and speed determine the throughput (or bandwidth) of the bus
  - The amount of data that can be transferred by the bus in a given time period

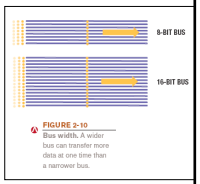

FIGURE 2-10
Bus width. A wider bus can transfer more data at one time than a narrower bus.

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Memory

- Memory refers to chip based storage
- RAM (random access memory): Computer's main memory
  - Consists of chips arrange on a circuit board called a memory module plugged into the motherboard
  - Stores essential parts of operating system, programs, and data the computer is currently using
  - Adequate RAM is needed to run programs
  - Volatile: Contents of RAM is lost when the computer is shut off
  - Most personal computers use SD-RAM
  - MRAM and PRAM: non-volatile RAM under development

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Memory

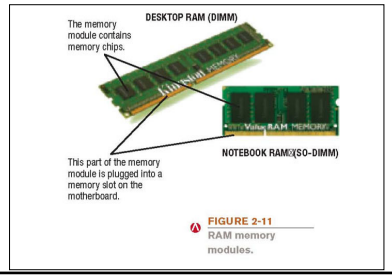

FIGURE 2-11
RAM memory modules.

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Memory

- Registers: High-speed memory built into the CPU; used by the CPU
- ROM (read-only memory): Non-volatile chips located on the motherboard into which data or programs have been permanently stored
  - Retrieved by the computer when needed
  - Being replaced with flash memory for firmware
- Flash memory: Type of nonvolatile memory that can be erased and reprogrammed
  - Some flash memory chips are used by the computer
  - Flash memory chips are also used in flash memory storage media (sticks, cards, and drives)

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Fans, Heat Sinks, and Other Cooling Components

- Heat: A continuing problem for CPU and computer manufacturers
- Fans: Used on most personal computers
- Heat sinks: Small components typically made out of aluminum with fins that help to dissipate heat
- Water cooling systems: Cool the computer with liquid-filed tubes
- Notebook cooling stands
- Other cooling methods (such as ion pump cooling systems) are under development

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Fans, Heat Sinks, and Other Cooling Components

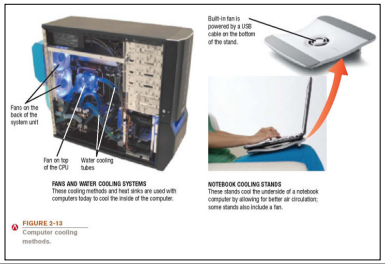

FIGURE 2-13 Computer cooling methods.

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Expansion Slots, Expansion Cards, and ExpressCards

- Expansion slot: A location on the motherboard into which expansion cards are inserted
- Expansion card: A circuit board used to add additional functionality or to attach a peripheral device
- ExpressCard modules: Designed for notebook computer expansion

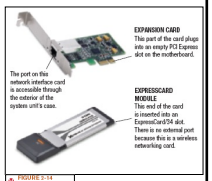

FIGURE 2-14 Expansion cards and ExpressCard modules. These are most often used with desktop and notebook computers, respectively.

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Buses

- Bus: An electronic path within a computer over which data travels
  - Expansion bus: Connects the CPU to peripheral (typically input and output) devices
  - Memory bus: connects CPU directly to RAM
  - Frontside bus: connects CPU to I/O bridge
  - PCI and PCI Express (PCIe) bus
  - Universal Serial Bus (USB)
  - FireWire/IEEE 1394 bus

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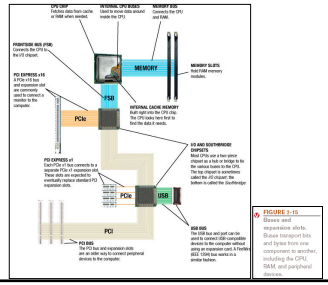
Buses



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Ports and Connectors

- Port: A connector on the exterior of a computer's system unit to which a device may be attached
  - Monitor (VGA, DVI, HDMI)
  - Network
  - Modem
  - USB
  - FireWire
  - Keyboard
  - SCSI
  - MIDI
  - IrDA
  - Flash memory card slots
  - Game
  - Audio
  - eSATA

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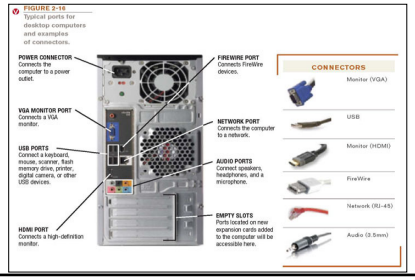
Ports and Connectors



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Ports and Connectors

- Many desktop computers come with a variety of ports on the front of the system unit for easy access
- A wired or wireless hub can connect many devices to a single USB or FireWire port

FIGURE 3-17 USB hubs. A USB hub can be used to connect multiple USB devices to a single USB port.

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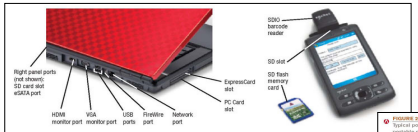
Ports and Connectors

- Notebook and netbook computers have ports similar to desktop computers, but often not as many
- UMPCs and mobile devices typically have less ports
  - An SD slot is common for both memory cards and to connect peripheral devices



Possible 3-18 Typical ports for portable computers.

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Quick Quiz

Which type of memory is erased when the power goes out?

a. ROM
b. RAM
c. flash memory

2. True or False: The CPU can also be called the motherboard.
3. A(n) electronic path within a computer over which data travels is called a(n) _____.

Answers:

1) b; 2) False; 3) bus

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How the CPU Works

- CPU: Consists of a variety of circuitry and components packaged together
  - Transistor: Key element of the microprocessor
    - Made of semi-conductor material that acts like a switch controlling the flow of electrons inside a chip
- Today's CPUs contain hundreds of millions of transistors; the number doubles about every 18 months (Moore's Law)

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Typical CPU Components

- Arithmetic/Logic Unit (ALU): Performs integer arithmetic and logical operations
- Floating Point Unit (FPU): Performs decimal arithmetic
- Control unit: Coordinates and controls activities
- Prefetch unit: Tries to fetch data and instructions before they are needed from cache or RAM
- Decode unit: Translates instructions so they are understood by the control unit, ALU, and FPU
- Internal cache and registers: Store data and instructions needed by the CPU
- Bus interface unit: Allows the core to communicate with other CPU components

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Typical CPU Components

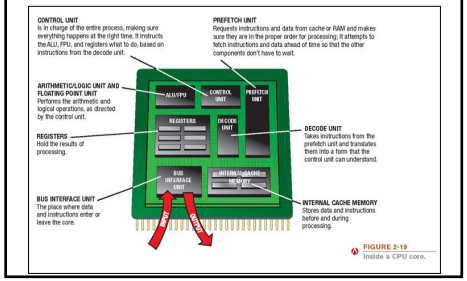

FIGURE 2-19
Inside a CPU core.

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The System Clock and the Machine Cycle

- System clock: Timing mechanism within the computer system that synchronizes the computer's operations
  - Each signal is a cycle
  - Number of cycles per second = hertz (Hz)
  - Many PC system clocks run at 200 MHz
  - Computers can run at a multiple or fraction of the system clock
    - For instance, with a CPU clock speed of 2 GHz, the CPU clock "ticks" 10 times during each system clock tick
  - During each CPU clock tick, one or more pieces of microcode are processed

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The System Clock and the Machine Cycle

- Machine cycle: The series of operations involved in the execution of a single machine level instruction
  - Fetch: The program instruction is fetched
  - Decode: The instructions are decoded so the control unit, ALU, and FPU can understand them
  - Execute: The instructions are carried out
  - Store: The original data or the result from the ALU or FPU execution is stored in the CPU's registers

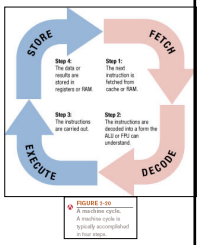

FIGURE 2-20
A machine cycle.
A machine cycle is typically accomplished in four steps.

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Making Computers Faster and Better Now and in the Future

- Improving performance today
  - Add more memory
  - Perform system maintenance
    - Uninstall programs properly
    - Consider placing large files on external storage devices
    - Delete temporary files
    - Error check and defragment
    - Scan for viruses and spyware
    - Clean out dust once or twice a year
  - Buy a larger or second hard drive
  - Upgrade your Internet connection
  - Upgrade your video graphics card

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Making Computers Faster and Better Now and in the Future

- Strategies for faster and better computers
  - Improved architecture: Smaller components, faster bus speeds, multiple CPU cores, etc.
  - Improved materials: New backing materials, flexible circuits, etc.
  - Pipelining: Allows multiple instructions to be processed at one time
  - Multiprocessing and parallel processing: Use multiple processors to speed up processing

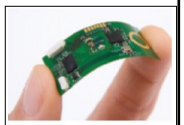

FIGURE 2-23
Flexible processors.

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Pipelining

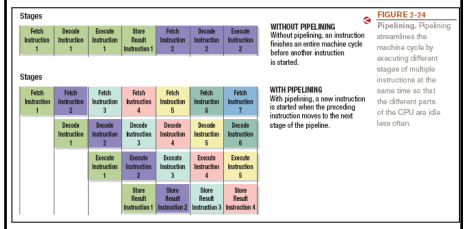

FIGURE 2-24
Pipelining. Pipelining streamlines the machine cycle by executing different stages of multiple instructions at the same time so that the different parts of the CPU are idle less often.

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Future Trends

- Nanotechnology: The science of creating tiny computers and components less than 100 nanometers in size
  - Carbon nanotubes used in many products today
  - Nanoparticles and nanosensors
  - Future applications may be built by working at the individual atomic and molecular levels

FIGURE 2-25
Carbon nanotubes make this bike frame very strong, but light.

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Future Trends

- Quantum computing: Applies the principles of quantum physics and quantum mechanics to computers
  - Utilizes atoms or nuclei working together as quantum bits (qubits)
  - Qubits function simultaneously as the computer's processor and memory and can represent more than two states
  - Expected to be used for specialized applications, such as encryption and code breaking

FIGURE 2-24
Quantum computers. The vial of liquid shown here contains the 7-qubit computer used by IBM researchers in 2001 to perform the most complicated computation by a quantum computer to date—factoring the number 15.

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Future Trends

- Optical computer: Uses light, such as from laser beams or infrared beams, to perform digital computations
  - Opto-electronic computers use both optical and electronic components
- Silicon photonics: The process of making optical devices using silicon manufacturing techniques
  - Silicon based light sensor
- Terascale computing: The ability to process one trillion floating-point operations per second
  - Expected to be needed for future applications
- 3D chips: Contain transistors that are layered to cut down on the surface area required

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Quick Quiz

1. Optical computers use which of the following to transmit and process data?
   a. Liquid
   b. Light
   c. Silicon
2. True or False: If your computer is running slowly, adding more memory might speed it up.
3. A quantum bit is known as a(n) _____.

Answers:

1) b; 2) True; 3) qubit

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Summary

- Data and Program Representation
- Inside the System Unit
- How the CPU Works
- Making Computers Faster and Better Now and In the Future

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Summary
- Data and Program Representation
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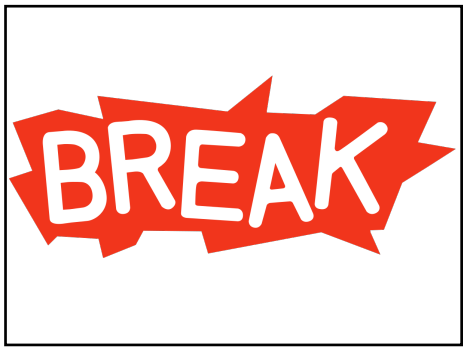

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