

Chapter 1: Information and Communication Technology ICT

Hardware Tools

Free Software Course

Math and Computer Science Department

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Chapter Outline

- 1 ICT Overview
- 2 ICT Tools
- 3 Computers
- 4 Architecture of a Computer
 - CPU
 - RAM
 - Storage System
 - Input/Output System

ICT Overview

What is ICT?

Definition

Information and communication Technology (ICT) refers to the use of computers, storage, networking, and other physical devices, infrastructure, to create, process, store, secure, and exchange all forms of electronic data.

Key Components:

- Computer science techniques
- Audiovisual and multimedia systems
- Internet and telecommunications
- Interactive interfaces

ICT Capabilities

ICT enables users to:

Communication:

- Connect with others
- Share information
- Collaborate remotely

Information Access:

- Access global information
- Research and discovery
- Real-time data retrieval

Data Management:

- Store information
- Manipulate data
- Process content

Content Creation:

- Produce multimedia
- Create interactive content
- Transmit in various formats

ICT Tools Overview

The main ICT tools are organized into four categories:

- 1 **Computers** - Processing devices
- 2 **Software** - Programs and applications
- 3 **Communication Networks** - Connectivity infrastructure
- 4 **Smart Chips** - Intelligent embedded systems

Computers

What is a Computer?

Definition

A computer is a standalone electronic machine designed to be used by one person at a time for information processing. More specifically, a computer (also known as a microcomputer or Personal Computer) consists of both hardware components (the physical parts you can touch and feel) and software components (the instructions that tell the computer what to do).

Two fundamental concepts:

- **Hardware:** Physical material constituting computers, PCs, external equipment
- **Software:** Programs and applications that run on a computer



Types of computers

Common Types:

- Desktop Computer
- Laptop
- Tablet
- Smartphone
- Smartwatch

Typical Uses:

- Writing emails
- Web browsing
- Creating documents
- Entertainment
- Communication

Desktop Computer

Fixed Location Computing



Definition

A desktop computer is a microcomputer primarily designed to meet the computational needs of a single user at a fixed location.

Figure: Desktop Computer

Advantages:

- Best value for money
- High performance capabilities
- Easy to upgrade
- Multiple expansion slots
- Longer lifespan
- Multiple ports available

Popular For:

- Office work
- Gaming
- Content creation
- Software development

Operating Systems: Windows, Mac OS, Linux (Ubuntu)

Laptop

Portable Computing



Design

Laptops, small enough to fit in your lap, has a clamshell unit, a screen on the top half and an integrated keyboard and trackpad on the bottom.

Figure: Laptop Computer

Advantages:

- Portability
- Built-in battery
- Integrated components
- Work anywhere

Trade-offs:

- Power-optimized components
- Reduced performance
- Limited upgradeability
- Higher cost per performance

Tablet

Media Consumption Device

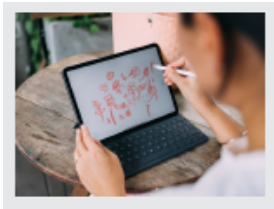


Figure: Tablet

Purpose

Designed for portability and media consumption

Key Features:

- Touchscreen interface (primary input/output)
- Screen size comparable to laptops
- Mobile operating systems (iOS/Android)
- Wi-Fi and cellular connectivity options

Optimal Uses

- Watching videos in kitchen
- Reading in subway stations
- Web conferences in airport lounges
- Gaming and entertainment apps

Smartphone

Portable Computer with Cellular Connectivity



Defenition

Smartphones are portable computers that connect to the Internet using cellular telephone networks. Apple kickstarted the smartphone era by launching the iPhone in 2007

Core Capabilities:

- Cellular internet connectivity
- Touchscreen primary input
- App ecosystems (iOS/Android)
- Email, word processing, spreadsheets
- Camera, GPS, sensors

Replaced Devices:

- Cameras
- Camcorders
- Flashlights
- Alarm clocks
- Radios
- Maps

Power Comparison

Modern smartphones are more powerful than Apollo 11 guidance computers!

Smartwatch

Wrist-Worn Microcomputer



Newest Category

Microcomputers worn on the wrist with unique health-focused capabilities

Components:

- RAM, storage, CPU
- Cellular chips or phone pairing
- Bluetooth connectivity
- Various sensors

Health Monitoring:

- Heart rate
- Blood oxygen levels
- Body temperature
- Step count
- Sleep cycles
- Fall detection

Form Factors & Architecture

Physical Differences, Similar Foundations

Form Factor Definition

Physical size and shape of a computer device measured by outside dimensions

Despite Physical Differences, All Share:

- Similar hardware components (memory, storage, CPU, input/output)
- Similar software components (operating system, applications)
- Ability to communicate and share information
- Von Neumann architecture (1945): Input → Processing → Output

Modern Integration

When you snap a photo on your phone, it can immediately appear on your desktop, smartwatch, and other devices simultaneously

Summary

Choosing the Right Microcomputer

Selection Criteria

Choose based on your primary use case and mobility requirements

Device Type	Best For	Key Advantage
Desktop	Gaming, Office Work	Performance & Value
Laptop	Mobile Productivity	Portability
Tablet	Media Consumption	Touch Interface
Smartphone	Daily Communication	Always Connected
Smartwatch	Health Monitoring	Wearable Convenience

Remember

All microcomputers can work together in an integrated ecosystem!

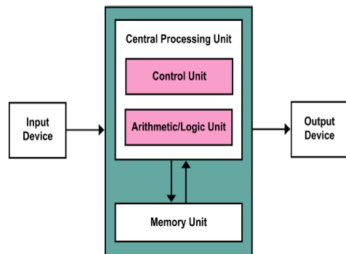
Architecture of a Computer

Architecture of a Computer: The Von Neumann Model

The Von Neumann architecture (1945)

decomposes the computer into four distinct functional units:

- **Input Unit:** Receives data and instructions from external sources (keyboard, mouse, sensors)
- **Memory Unit:** Stores both data and program instructions temporarily
- **Processing Unit (CPU):** Executes instructions and performs computations
- **Output Unit:** Presents processed results to users (monitor, speakers, printers)



Key Insight: This fundamental architecture from 1945 remains essentially unchanged in modern microcomputers - from smartphones to supercomputers.

Processing Cycle

Input → Process → Output

Arithmetic Logic Unit (ALU)

Role: Performs basic operations, like a calculator

Operations performed:

- **Arithmetic operations:**

- Addition, subtraction, sign change, etc.

- **Logical operations:**

- Complements, AND, OR, XOR, NOT, NAND, etc.

- **Comparisons:**

- Equality test, greater than, less than, "or equal" equivalents

- **Other operations:**

- Shifts and rotations (sometimes externalized)

Control Unit (Sequencer)

Function: Responsible for "sequencing" operations

Specific tasks:

- **Decode instructions:** Interprets the binary instruction fetched from memory to determine the required operation and involved components.
- **Choose registers to use:** Selects appropriate CPU registers for storing operands, intermediate results, or final outputs based on the decoded instruction.
- **Initialize registers at startup:** Sets initial values in key registers during system boot to prepare the CPU for instruction execution.
- **Communicate with memory and peripherals through I/O unit:** Coordinates data exchange between the CPU, memory, and external devices using control signals and I/O protocols.

CPU

The Processor (CPU): The Brain of the Computer I

Definition

The Central Processing Unit (CPU) is the brain of the computer that performs all computations necessary to execute user commands. Modern CPUs implement the Von Neumann architecture and contain billions of transistors that act as switches, rapidly switching between 0 and 1 to perform digital computations.



The Processor (CPU): The Brain of the Computer II

A processor is composed of:

- **Calculation unit** (performs arithmetic/logic operations)
- **Control unit** (manages instruction execution)
- **Input-output unit** (handles data transfer)
- **Clock** (synchronization signal)
- **Registers** (ultra-fast internal memory)
- **Transistors** (billions of electronic switches)

The Transistor Revolution

Intel 4004 (1971): 2,300 transistors, \$0.10 each

Modern CPUs (2022): 100+ billion transistors, \$0.0000003 each

Result: 250,000× cost reduction, 20 million× performance increase

Moore's Law

Transistor count doubles every 2 years (since 1965) - enabling faster, smaller, cheaper computers

Transistor Count and CPU Performance I

Cost, Capability, and Innovation Over Time

Context

Transistors are the fundamental building blocks of CPUs. Their count directly affects switching speed, instruction throughput, and cost efficiency. Comparing CPUs from 1971 and 2022 reveals dramatic improvements in performance and affordability.

Specifications

CPU	Year	Transistors	Cost/Tr.	Switches/s
Intel 4004	1971	2.3×10^3	\$0.10	7.36×10^5
AMD EPYC 7773X	2022	2.6×10^{10}	3×10^{-7}	1.44×10^{13}

Transistor Count and CPU Performance II

Cost, Capability, and Innovation Over Time

Exercise: Analyze Transistor Impact

Assuming each instruction requires 8 transistor switches.

- Estimate the speed by instructions per second for each CPU.
- **1. Calculate Performance Gain:** How many times more instructions per second does the AMD EPYC 7773X perform compared to the Intel 4004?
- **2. Calculate Cost Efficiency:** How many times cheaper is the cost per transistor in 2022 compared to 1971?

Processor Characteristics I

Architecture (programmer's view):

- **Instruction Set Architecture (ISA):** Defines the set of operations the CPU can execute, shaping how software interacts with hardware.
- **Register Widths:** Indicates the size of internal data registers (e.g., 8, 16, 32, 64, 128 bits), which affects how much data can be processed per instruction.
- **I/O and Memory Access:** Specifies how the processor communicates with memory and peripherals, including addressing modes and data transfer protocols.

Variable Characteristics:

- **Microarchitecture:** Refers to the internal design and implementation of the processor, including pipelines, caches, and execution units.
- **Clock Frequency:** Measures how many cycles the CPU completes per second (in MHz or GHz); higher frequency generally means faster execution.

Processor Characteristics II

- **Manufacturing Process:** Indicates the size of transistors (in nanometers); smaller nodes allow more transistors, lower power consumption, and higher density.
- **Number of Cores:** Represents how many independent processing units the CPU has; more cores enable better multitasking and parallel execution.

RAM

What is RAM?

Random Access Memory Fundamentals

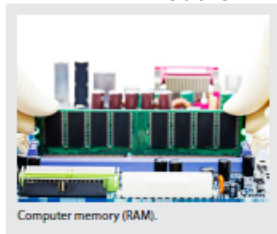
Definition

Random Access Memory (RAM) is much faster than all other storage devices and is used to temporarily store computer instructions and data that need frequent access.

Key Characteristics:

- Temporary storage (volatile memory)
- Significantly faster than storage devices
- Stores active programs and data
- Lost when power is turned off

RAM Module



Physical RAM stick

How RAM Works in Practice

Real-World Example

Chrome Browser Example

When you launch Chrome browser, the CPU needs RAM to:

- Store the Chrome program temporarily
- Hold webpages you are viewing
- Track all changes you are making
- Cache frequently accessed data

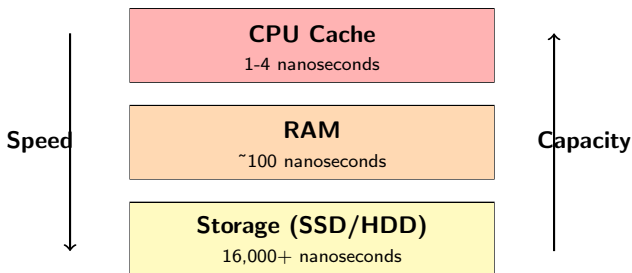
Performance Impact

If you open too many browser tabs and consume all available RAM:

- Browser becomes slow
- Applications might crash
- System uses slower storage as backup (virtual memory)

Memory Hierarchy

Speed vs. Capacity Trade-offs



Multiple Cache Levels:

- L1 Cache: Fastest, smallest (within CPU)
- L2 Cache: 4× slower than L1
- L3 Cache: Shared between cores

Virtual Memory & Page Files

When RAM Runs Out

Virtual Memory Concept

When RAM is full, computers use storage space as an extension of RAM, called the **page file** or **virtual memory**.

Consequences:

- Significant performance decrease
- Applications become sluggish
- Increased storage wear
- Higher power consumption

Solutions:

- Close unused applications
- Use Task Manager
- Add more RAM

Performance Tip

Hard drives are many times slower than RAM, so avoid relying on virtual memory for optimal performance.

Task Manager: RAM Monitoring

Identifying Memory Usage

Accessing Task Manager

Windows Methods:

- Right-click Start button → Task Manager
- Keyboard shortcut: Ctrl + Shift + Esc

Task Manager Features:

- View memory consumption by app
- Identify CPU usage patterns
- End unresponsive processes
- Monitor system performance

Example:

*Snagit app consuming
highest memory Use "Processes"
tab to identify memory-heavy
applications*

Understanding Data Units

Bits, Bytes, and Beyond

Fundamental Units

- **Bit:** Binary digit (0 or 1) - smallest unit of information
- **Byte:** 8 bits - can represent one character

Unit	Size	Example Usage
Kilobyte (KB)	1,024 bytes	Small text document
Megabyte (MB)	1,024 KB	High-quality photo
Gigabyte (GB)	1,024 MB	Movie file, RAM capacity
Terabyte (TB)	1,024 GB	Large storage drives

Binary Representation

All information (text, photos, audio, video) is converted to binary format (1s and 0s) for computer processing and storage in RAM.

RAM Requirements by Usage

Crucial's Recommendations

User Type	Activities	RAM Needed
Casual User	Internet browsing, email, music, videos	8GB
Intermediate User	Word processing, spreadsheets, graphics, multitasking	16GB
Professional/Gamer	High-performance gaming, multimedia editing, 3D modeling	32GB+

Key Consideration

Your computer usage patterns determine RAM requirements. More RAM allows for better multitasking and prevents system slowdowns.

Important Note

RAM is only operational when powered - even momentary power loss clears all

Types of RAM I

Memory Technologies, Performance Metrics, and Evaluation Exercise

Common RAM Types

RAM technologies vary in form factor, power efficiency, and performance characteristics:

Desktop RAM:

- DIMM (Dual In-line Memory Module)
- Higher capacity and frequency options
- Better thermal dissipation
- Ideal for multitasking and upgrades

Laptop RAM:

- SO-DIMM (Small Outline DIMM)
- Compact and energy-efficient
- Optimized for mobile platforms
- Limited upgrade flexibility

Types of RAM II

Memory Technologies, Performance Metrics, and Evaluation Exercise

Key Performance Metrics

- **Frequency (MHz):** Number of cycles per second. Higher frequency enables faster data transfer.
- **CAS Latency (CL):** Number of clock cycles between a request and data availability. Lower CL means quicker response.
- **Access Time (ns):** Actual delay in nanoseconds. Calculated as:

$$\text{Access Time} = \frac{\text{CL}}{\text{Frequency}} \times 1000$$

Combines latency and speed to reflect real-world responsiveness.

- **Bandwidth (MB/s):** Maximum data transfer rate. Calculated as:

$$\text{Bandwidth} = \frac{\text{Frequency} \times \text{Bus Width} \times \text{Channels}}{8}$$

Higher bandwidth supports more simultaneous data movement.

Types of RAM III

Memory Technologies, Performance Metrics, and Evaluation Exercise

- **Channel Configuration:** Refers to how many independent memory channels are used in parallel—commonly single, dual, or quad-channel. Each channel is typically 64 bits wide. More channels allow simultaneous data paths, increasing effective bandwidth.

Types of RAM I

Evaluation Exercise

Given the following specifications, determine which RAM offers the best performance:

Module	Type	Freq (MHz)	CL	Channels	Bus Width
A	DDR4	2400	15	1	64
B	DDR4	3200	16	2	64
C	DDR5	4800	40	2	64
D	DDR4	3600	18	2	64

Tasks:

- Compute access time and bandwidth for each module.
- Rank modules by performance.
- Justify your choice for a multitasking desktop (access time $\leq 15ns$ and bandwidth $\geq 10GB/s$).

Types of RAM II

Evaluation Exercise

Solution

Access Time (ns):

- A: $\frac{15}{2400} \times 1000 = 6.25 \text{ ns}$
- B: $\frac{16}{3200} \times 1000 = 5.00 \text{ ns}$
- C: $\frac{40}{4800} \times 1000 = 8.33 \text{ ns}$
- D: $\frac{18}{3600} \times 1000 = 5.00 \text{ ns}$

Bandwidth (MB/s):

- A: $\frac{2400 \times 64 \times 1}{8} = 19,200 \text{ MB/s}$
- B: $\frac{3200 \times 64 \times 2}{8} = 51,200 \text{ MB/s}$
- C: $\frac{4800 \times 64 \times 2}{8} = 76,800 \text{ MB/s}$
- D: $\frac{3600 \times 64 \times 2}{8} = 57,600 \text{ MB/s}$

Ranking:

- 1 D: Balanced latency (5 ns) and highest DDR4 bandwidth (57.6 GB/s)
- 2 B: Same latency, slightly lower bandwidth (51.2 GB/s)
- 3 C: Highest bandwidth (76.8 GB/s) but highest latency (8.33 ns)

RAM Analogy: Worker's Pocket Tools

Understanding RAM Function

The Analogy Explained

- **Worker** = CPU (the processor)
- **Pockets** = RAM (quick access to tools)
- **Truck** = Storage (all tools stored, slower access)

Key Insight: Having frequently used tools (data/instructions) readily available in pockets (RAM) dramatically speeds up work completion, just as RAM speeds up CPU operations.

RAM's Impact on Performance

Critical Component for Speed

Why RAM Matters

RAM is one of the most critical components for speeding up a computer.

Sufficient RAM leads to:

- Smooth multitasking
- Fast application switching
- Responsive system
- No virtual memory usage

Insufficient RAM leads:

- Slow application loading
- System freezes/crashes
- Heavy disk usage
- Poor user experience

Buying Decision

RAM requirement is one of the key decisions you need to make before purchasing a computer. Consider your usage patterns and choose accordingly.

RAM Summary

Key Takeaways

Essential Points

- 1 RAM provides fast, temporary storage for active programs and data
- 2 Memory hierarchy: Cache → RAM → Storage (fastest to slowest)
- 3 Virtual memory uses storage when RAM is full (performance penalty)
- 4 RAM requirements depend on usage: 8GB casual, 16GB intermediate, 32GB+ professional
- 5 RAM is volatile - contents lost when power is removed

Performance Tip

Monitor RAM usage with Task Manager and consider upgrading if you frequently use virtual memory or experience slowdowns.

Questions?

Storage System

What is Computer Storage? I

The Foundation of Data Persistence

Definition

Computer storage is the technology that stores software (operating system and applications) and data on the computer. Storage is also popularly known as hard drives.

Key Characteristics:

- **Non-volatile** - retains data when power is off
- Stores operating systems and applications
- Holds user data (documents, media, etc.)
- Much slower than RAM but much larger capacity

Storage Devices

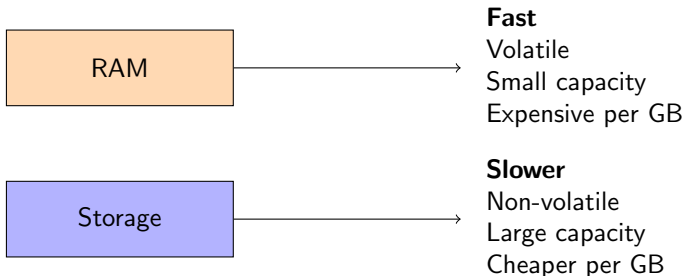


Critical Difference from RAM

Unlike RAM, storage retains data even after power is turned off, making it essential for permanent data storage throughout your computing life.

Storage vs RAM: Key Differences I

Understanding the Storage Hierarchy



Storage vs RAM: Key Differences II

Understanding the Storage Hierarchy

Boot Process

When computer powers on: Operating system loads from **storage** → **RAM** → CPU processes it

Why Both Are Needed

RAM provides speed for active tasks, while storage provides persistent data retention and large capacity for all your files and programs.

Understanding File Sizes I

Storage Requirements by Content Type

Content Type	Typical Size	Storage Needs
Text Document	Few KB	Minimal-thousands fit in 1GB
Photo	4-5MB	Moderate-200-250per GB
High-res Photo	10-20 MB	Higher - 50-100 per GB
MP3 Song	5 MB	Moderate-200 songs per GB
CD Quality Song	50 MB	High - 20 songs per GB
4K Video	1 GB/minute	Very High-1 minute per GB

Planning Storage Needs

Your storage requirements depend heavily on the type of content you work with. Video creators and photographers need significantly more storage than text-based workers.

Storage Units and Prefixes

From Bytes to Yottabytes

Unit	Size	Real-World Example
Byte	8 bits	One character
Kilobyte (KB)	1,024 bytes	Small text file
Megabyte (MB)	1,024 KB	Digital photo, MP3 song
Gigabyte (GB)	1,024 MB	HD movie, typical storage unit
Terabyte (TB)	1,024 GB	Modern hard drive capacity
Petabyte (PB)	1,024 TB	Large data center storage
Exabyte (EB)	1,024 PB	Global data storage
Zettabyte (ZB)	1,024 EB	Internet-scale data
Yottabyte (YB)	1,024 ZB	Theoretical maximum

Hard Disk Drives (HDD) I

Magnetic Storage Technology

How HDDs Work:

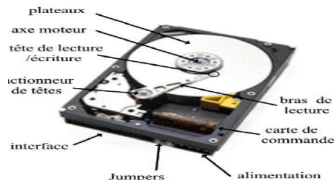
- Store data on rotating magnetic platters
- Use read/write heads to access data
- Data stored as magnetic field directions
- Platters spin at high speeds (5400-7200 RPM)

Advantages:

- Cheaper per GB
- Higher storage capacities
- Proven, mature technology

Disadvantages:

HDD Components



Magnetic platters and read heads

Hard Disk Drives (HDD) II

Magnetic Storage Technology

- Heavy and noisy
- Slower data access
- Higher power consumption
- Mechanical parts can fail

Solid State Drives (SSD) I

Flash Memory Technology

How SSDs Work:

- Use transistors to store data
- No moving mechanical parts
- Store data as electrical charges
- Instant access to any location

Advantages:

- Much faster access times
- Silent operation
- Lower power consumption
- More durable (shock resistant)
- Lighter weight

Disadvantages:

- More expensive per GB

SSD Components



Flash memory chips

Solid State Drives (SSD) II

Flash Memory Technology

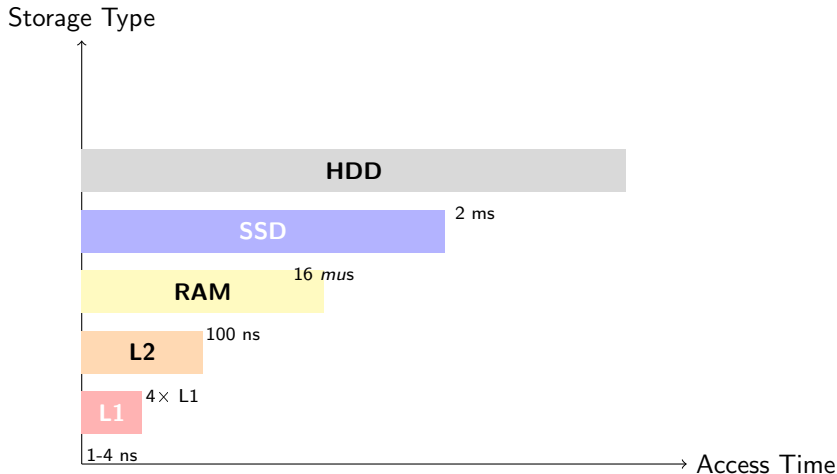
- Limited write cycles

Modern Trend

Most newer computers come with SSDs as primary storage due to performance benefits.

Storage Performance Comparison I

Speed Differences in Perspective



Storage Performance Comparison II

Speed Differences in Perspective

Performance Facts (2020 data)

- SSD is **160 times slower** than RAM
- HDD is **125 times slower** than SSD
- Cache is **10-100 times faster** than RAM

Portable Flash Drives I

USB Sticks and External Storage

Portable Flash Drive Features:

- Compact SSD-based storage
- USB connector for easy portability
- Often used as promotional items
- Plug-and-play functionality
- Available in various capacities

Common Uses:

- Transfer files between computers
- Backup important documents
- Portable application storage
- Emergency boot drives

USB Flash Drive



Also
called USB sticks or thumb drives

Portable Flash Drives II

USB Sticks and External Storage

Safety Tip: Proper Ejection

Always "Eject" portable drives before removal:

- Right-click drive in File Explorer
- Select "Eject"
- Wait for "safe to remove" message

This prevents data corruption and file damage.

External Storage Solutions I

Expanding Your Storage Capacity

External Storage Types

- **External Hard Drives:** High capacity, cost-effective
- **External SSDs:** Fast, portable, durable
- **USB Flash Drives:** Ultra-portable, moderate capacity

Connection Methods:

- USB-A (traditional)
- USB-C (modern, faster)
- Thunderbolt (high-speed)
- eSATA (legacy)

Use Cases:

- Backup and archiving
- Media storage
- File transfers
- System cloning

External Storage Solutions II

Expanding Your Storage Capacity

Capacity Planning

Consider your needs: 1TB for general use, 2-4TB for media creators, 8TB+ for professional backup solutions.

Storage Systems Summary I

Key Takeaways

Essential Points

- 1 Storage provides **non-volatile** data retention (survives power loss)
- 2 **HDDs**: Cheaper, larger capacity, slower, mechanical
- 3 **SSDs**: Faster, more durable, expensive, no moving parts
- 4 File sizes vary dramatically: text (KB) to 4K video (GB per minute)
- 5 External storage expand capacity and provide backup
- 6 Choose storage strategy based on your usage patterns and budget

Storage Systems Summary II

Key Takeaways

Best Practices

- Use SSD for operating system and frequently used programs
- Use HDD for bulk storage of media files
- Always maintain backups (local + cloud)
- Properly eject removable storage devices

Questions?

Input/Output Systems

Definition: Information exchanges between processor and associated peripherals

System components:

- **Inputs:** Data sent by peripherals to central unit
 - Disk, network, keyboard, sensors
- **Outputs:** Data sent by central unit to peripherals
 - Disk, network, screen, printer, actuators

Simple Example:

- Keyboard typing → Input codes to processor
- Processor → Display results on screen (output)

Input Peripherals

Data Entry Devices:

- Keyboards, mice, touchscreens
- Microphones, webcams
- Graphics tablets, styluses

Reading Devices:

- Barcode scanners, QR code readers
- Optical character recognition (OCR)
- Magnetic card readers

Pointing Devices:

- Computer mice, trackballs
- Touchpads, pointing sticks

Output Peripherals

Visual Output:

- Monitors, displays, projectors
- Printers (laser, inkjet, 3D)
- LED panels, digital signage

Audio Output:

- Speakers, headphones
- Sound systems

Input/Output Peripherals:

- Touchscreens
- Network interface cards
- Storage devices (USB drives, external HDD)