Chapter 1: Information and Communication Technology ICT

Hardware Tools

Free Software Course

Math and Computer Science Department

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Chapter Outline

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

Purpose

Designed for portability and media consumption

Figure: Tablet

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 $\rightarrow$ Processing $\rightarrow$ 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

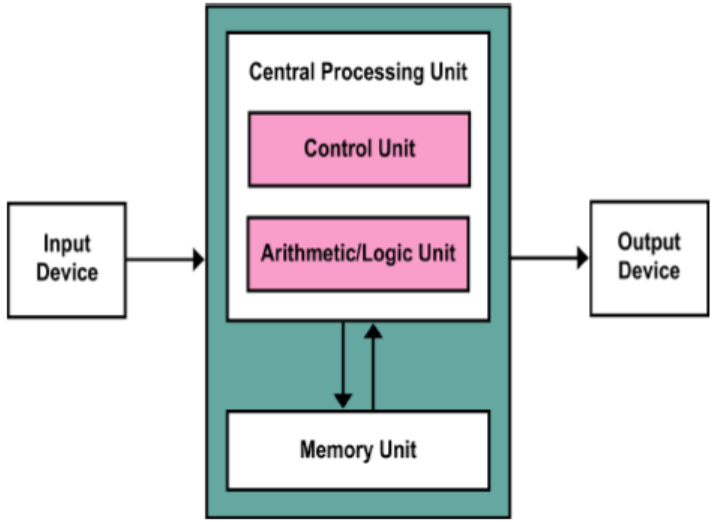
All microcomputers can work together in an integrated ecosystem!

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 switching capacity per second for each CPU.

- **1. Performance Gain:** How many times more instructions per second does the AMD EPYC 7773X perform compared to the Intel 4004?
- **2. 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.