COMP2121: Microprocessors and Interfacing

Introduction to Microprocessors

http://www.cse.unsw.edu.au/~cs2121

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- Bus
- Memory hierarchy

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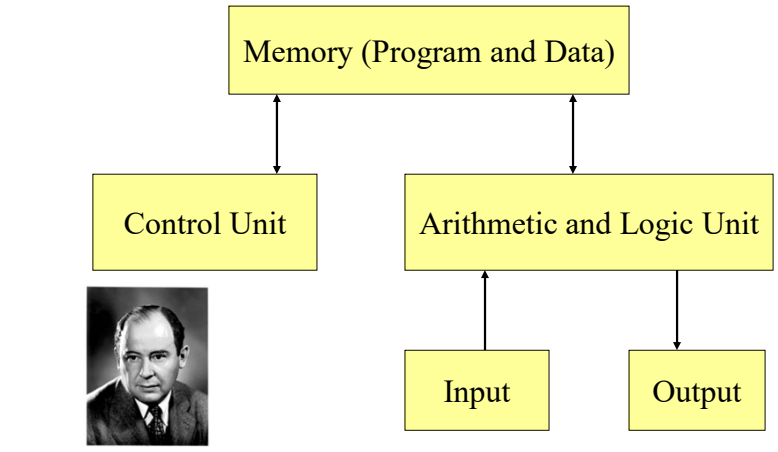
Von Neumann Architecture (1/4)



John von Neumann in the 1940s

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Von Neumann Architecture (2/4)

- Memory
  - Stores both program and data
- Control unit
  - Directs the operations of the other units by providing timing and control signals.
- ALU
  - Performs arithmetic and logical operations such as addition, subtraction, multiplication and division.

EDVAC, one of the first electronic stored program computers

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Von Neumann Architecture (3/4)

- Input
  - An input device gets data from users
  - Examples are keyboards, mice, webcams, microphones, and secondary storage devices (hard disks, floppy disks, CD–ROMs etc) .
- Output
  - An output device sends data to users.
  - Typical output devices are monitors, printers, modems, and secondary storage devices.

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Von Neumann Architecture (4/4)

• ALU and control unit are collectively called CPU (Central Processing Unit)

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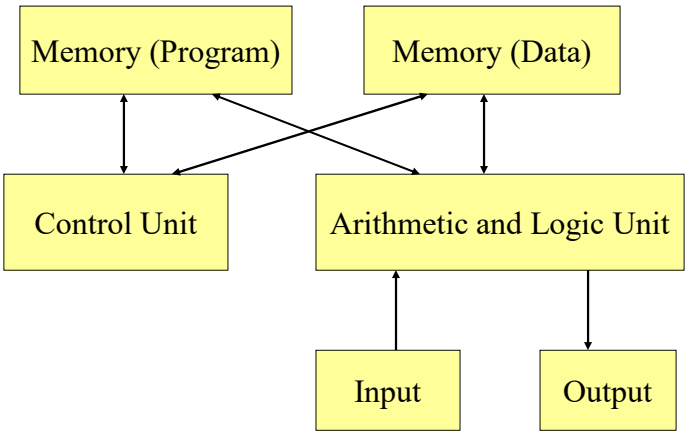
Harvard Architecture (1/2)



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Harvard Architecture (2/2)

- Program and data are stored in separate memories, allowing accessing program and data at the same time.
- AVR microcontrollers use Harvard architecture.

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Computer Bus

- A bus is a set of parallel conductors that transfer data between different components of a computer.
- A bus has three main parts:
  - Data bus
    - ❖ Carries data
  - Address bus
    - ❖ Carries the address of data
  - Control bus
    - ❖ Carries control signals

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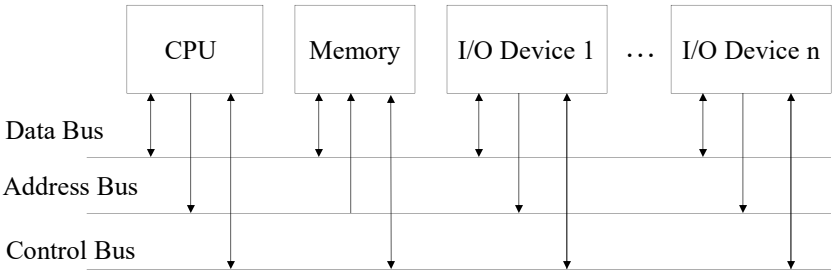
Bus-Oriented Computer Architecture



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Microprocessors

- A microprocessor is a CPU on a single Integrated Circuit (IC).
- A microprocessor can manipulate numbers of a fixed width only at a time.
  - For example, a 8-bit microprocessor can do addition and subtraction of two 8-bit numbers at a time.

The first microprocessor Intel's 4004 was introduced in 1971

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Intel's Microprocessors (1/3)

Name	Date	Transistors	Microns	Clock speed	Data width	MIPS
8080	1974	6,000	6	2 MHz	8 bits	0.64
8088	1979	29,000	3	5 MHz	16 bits, 8 bit bus	0.33
80286	1982	134,000	1.5	6 MHz	16 bits	1
80386	1985	275,000	1.5	26 MHz	32 bits	5
80486	1989	1,200,000	1	25 MHz	32 bits	20
Pentium	1993	3,100,000	0.8	60 MHz	32 bits, 64 bit bus	100
Pentium I	1997	7,500,000	0.35	233 MHz	32 bits, 64 bit bus	300
Pentium II	1999	9,500,000	0.25	450 MHz	32 bits, 64 bit bus	~510
Pentium 4	2000	42,000,000	0.18	1.5 GHz	32 bits, 64 bit bus	~1,700
Pentium 4 "Prescott"	2004	125,000,000	0.09	3.6 GHz	32 bits, 64 bit bus	~7,000

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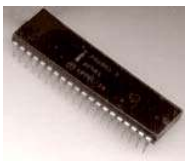
Intel's Microprocessors (2/3)

• The date is the year that the processor was first introduced.

• Transistors is the number of transistors on the chip.

• Microns is the width, in microns, of the smallest wire on the chip. For comparison, a human hair is 100 microns thick. As the feature size on the chip goes down, the number of transistors rises.



The Intel 8080 was the first microprocessor in a home computer

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Intel's Microprocessors (3/3)

• Clock speed is the maximum rate that the chip can be clocked at.

• Data Width is the width of the ALU. For example, an 8-bit ALU can do the addition, subtraction and multiplication of two 8-bit numbers, while a 32-bit ALU can manipulate 32-bit numbers.

• MIPS stands for "millions of instructions per second" and is a rough measure of the performance of a CPU.

Intel Pentium 4 processor

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Microcontrollers

• A microcontroller (also MCU or μC) is a computer-on-a-chip.

• In addition to the usual arithmetic and logic elements of a general purpose microprocessor, the microcontroller typically integrates additional elements such as read-write memory for data storage, read-only memory, such as flash for code storage, EEPROM for permanent data storage, peripheral devices, and input/output interfaces.

• Microcontrollers are frequently used in embedded systems such as automobile engine control systems, remote controls and office machines.

Microprocessors and microcontrollers are everywhere in our daily lives

Atmel AVR ATmega8

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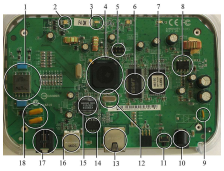
Embedded Systems

• An **embedded system** is a special-purpose computer system designed to perform one or a few dedicated functions. It is usually *embedded* as part of a complete device including hardware and mechanical parts.

• Examples:

  • Consumer electronics: Personal digital assistants (PDAs), mp3 players, mobile phones, videogame consoles, digital cameras and DVD players.

  • Transportation systems: Inertial guidance systems, GPS receivers, anti-lock braking system (ABS), Electronic Stability Control (ESC/ESP) and automatic four-wheel drive.



Network router, an example of an **embedded system**. Labelled parts include a microprocessor (4), RAM (6), and flash memory (7).

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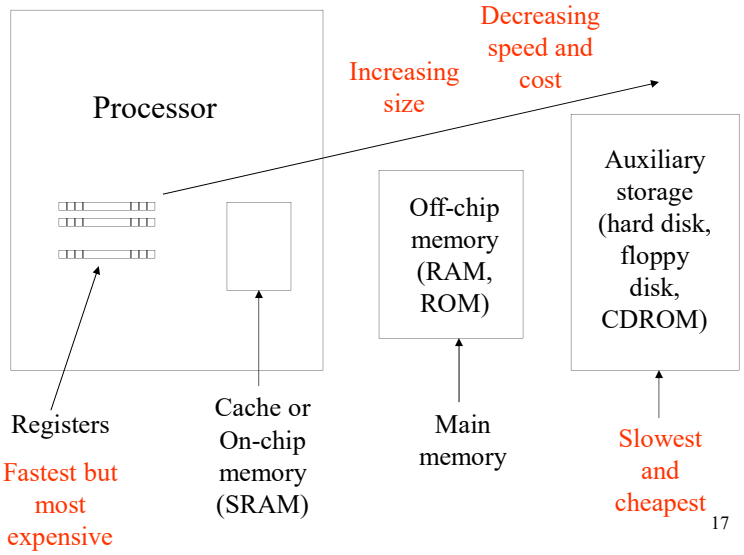
Computer Memory Hierarchy



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Registers

- A small amount of storage on the CPU whose contents can be accessed more quickly than other storages available elsewhere.
- Most, but not all, microprocessors operate on the principle of moving data from main memory into registers, operating on them, then moving the result back into main memory—a so-called load-store architecture.
- Each register has a fixed length. A n–bit register can store n-bit information.
- The number of registers of a microprocessor is small.

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Cache Memory

- A high speed memory located on CPU or next to CPU that is managed by hardware.
- CPU uses cache memory as a high speed buffer to temporarily store data and instructions.
- Data and instructions are loaded into cache memory by its associated hardware without software's help.
- When accessing data and instructions, CPU first tries to get them from cache. If they are not there, CPU will load them from the main memory.
- Modern microprocessors have separate cache memories for data and instructions.

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RAM

- A type of computer memory that can be accessed randomly; that is, any byte of memory can be accessed without touching the preceding bytes.
- Two types: DRAM (Dynamic Random Access Memory) and SRAM (Static Random Access Memory).
  - The two types differ in the technology they use to hold data.
  - SRAM is faster and much more expensive.
  - DRAM needs to be refreshed thousands of times per second while SRAM does not need to be refreshed.
  - Both types of RAM are volatile, meaning that they lose their contents when the power is turned off.

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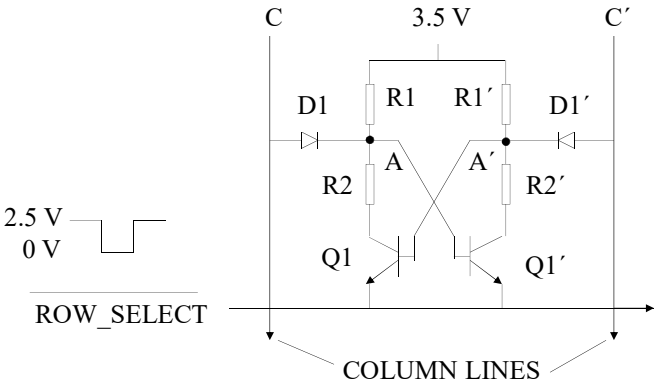
Static RAM Cells

- A static memory cell is a flip-flop.
- The transistors could be bipolar or MOS devices.
- The following figure shows a typical static memory cell.



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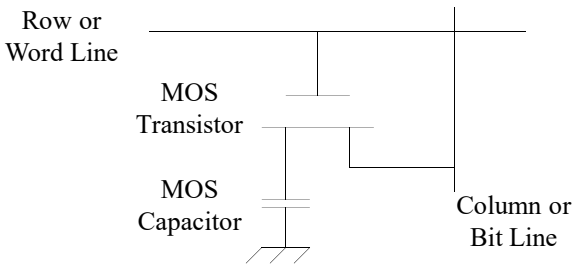
Dynamic RAM Cells

- A dynamic cell is a capacitor where absence or presence of charge denotes a stored one or zero.
- The following figure shows a typical dynamic memory cell.
  - ❑ The MOS capacitor can be written to by activating the row, or word, line to turn the MOS transistor on and charge the capacitor through the column, or bit, line.
  - ❑ The cell can be read by turning the transistor on and sensing a voltage on the column.



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ROM

• ROM (Read Only Memory) is a type of non-volatile memory, meaning that the contents will not be lost when the power is turned off.

• There are various types of ROM memory chips.

- Mask programmable ROM are programmed during the manufacturing stage and cannot be programmed by user.
- Other ROM devices are field programmable and may be programmed by the user. These are called programmable read only memories.
  - EPROMs are electrically programmable and erased by irradiating the chip through a quartz window with ultraviolet (UV) light.
  - Another type of programmable read only memory is the electrically erasable PROM (EEPROM).

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EEPROM Memory

- EEPROM can be programmed and erased without removing the chip from the circuit in use.
- The time required to write is longer than a comparable RAM chip.
- There is a maximum number of times it can be programmed (the industry standard as of 1993 is 10,000 program/erase cycles).
- EEPROM is used to store small amount of data that must be saved when power is off, e.g., system configuration.

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Flash Memory

- Similar to the EEPROM.
- Its drawback is that the entire memory or page must be erased where single locations can be erased and reprogrammed in the EEPROM devices.
- Flash memory takes smaller die area than EEPROM for the same capacity because in flash memory the erase circuits are shared by large blocks of cells (often 512×8), while in EEPROM each cell usually needs a read, write and erase transistor.
- Flash memory is used to save larger amounts of static data and code.

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Reading Material

1. Chapter 9, Microcontrollers and Microcomputers by Fredrick M. Cady.

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