COMP9032: Microprocessors and Interfacing

Introduction to Microprocessors

http://www.cse.unsw.edu.au/~cs9032

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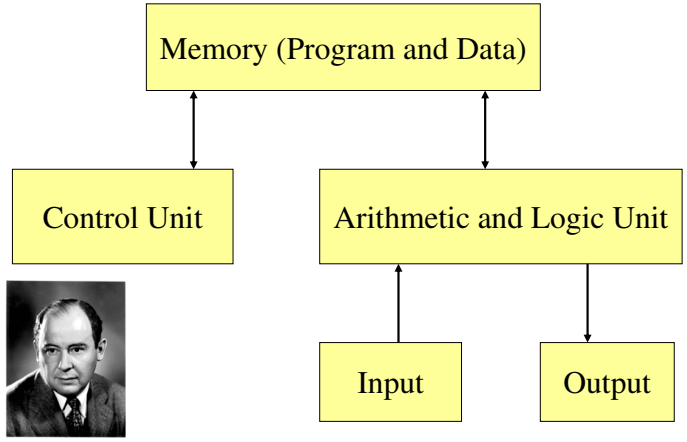
Von Newman Architecture (1/3)



John von Neumann in the 1940s

Von Newman Architecture (2/3)

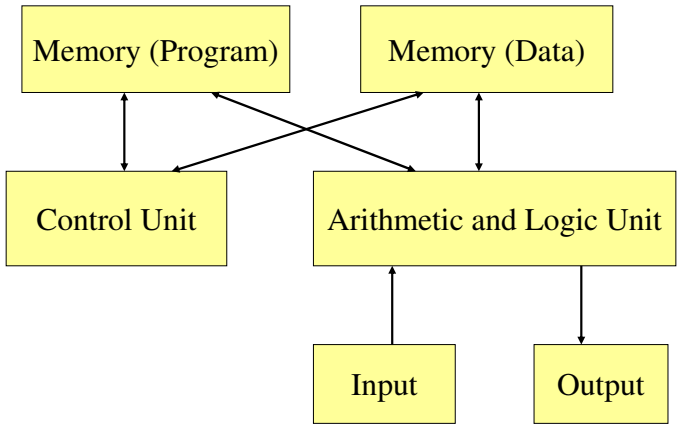
- Memory
  - Stores both program and data
- Control unit
  - Directs the operations of the other units by providing timing and control signals.
- ALU
  - Performs arithmetic and logical operations such as addition, subtraction, multiplication and division.

EDVAC, one of the first electronic stored program computers

Von Newman Architecture (3/3)

- Input
  - Gets the input (data and program) from users
- Output
  - Sends the output to users
- ALU and control unit are collectively called CPU (Central Processing Unit)

Harvard Architecture (1/2)



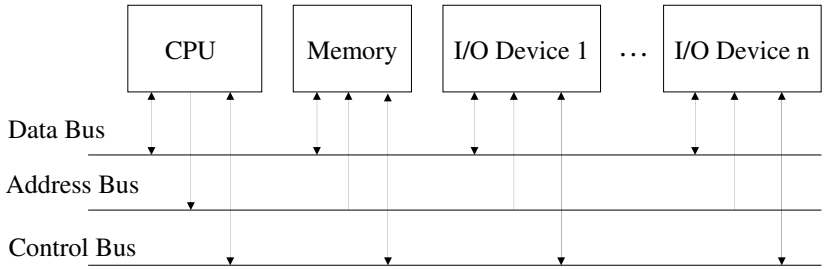
Harvard Architecture (2/2)

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

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

Bus-Oriented Computer Architecture



Microprocessors

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

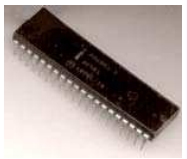
The first microprocessor Intel's 4004 was introduced in 1971

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

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

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

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 life

Atmel AVR ATmega8

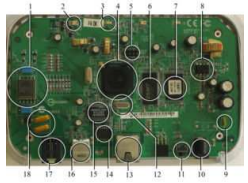
Embedded Systems

• 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:

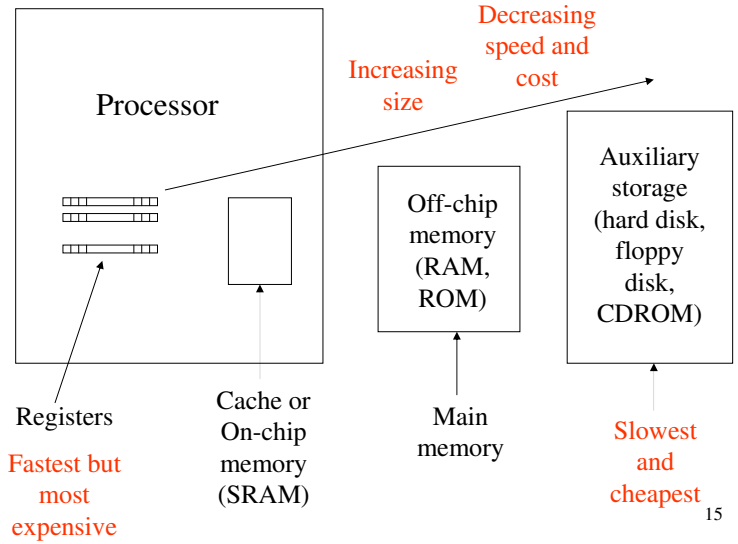
  • Consumer electronics: Personal digital assistants (PDAs), mp3 players, mobile phones, videogame consoles, digital cameras and DVD players.

  • 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).

Computer Memory Hierarchy



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.

• On a microprocessor of n-bits, each register can store n-bit data. For example, on an 8-bit microprocessor each register can can store 8 bit data.

• The number of registers on a microprocessor is small.

Cache Memory

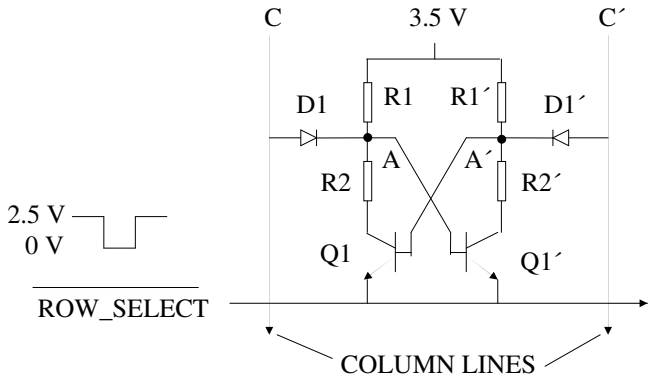
- A high speed memory located on CPU or next to CPU that is managed by hardware.
- CPU uses cache memory as a high speed buffer to temporarily store data and instructions.
- Data and instructions are loaded into cache memory by its associated hardware without software's help.
- When accessing data and 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.

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.

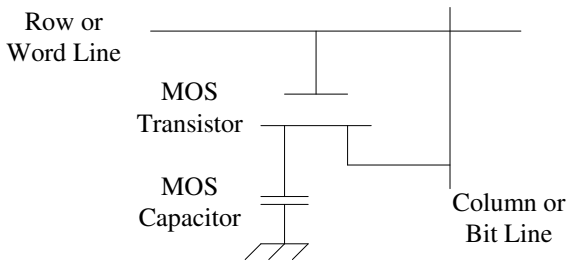
Static RAM Cells

- 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.



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.



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.

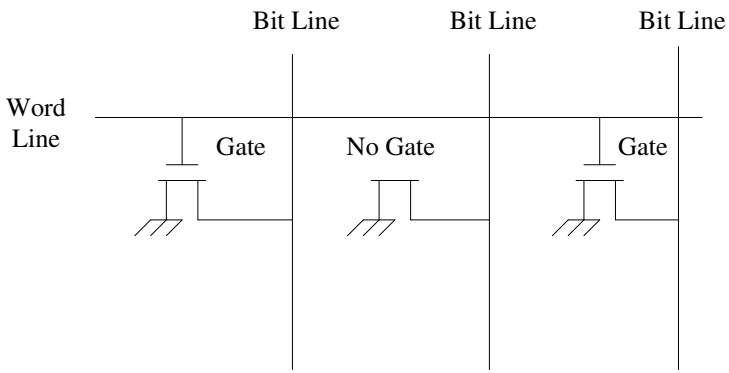
§ Other ROM devices are field programmable and may be programmed by the user. These are called programmable read only memories., and include UV-erasable PROMs (EPROMs), one-time programmable (OTP) EPROMs, and fusible-link PROMs.

§ EPROMs are electrically programmable are erased by irradiating the chip through a quartz window with ultraviolet (UV) light.

§ An OTP EPROM is an EPROM without the window so that once programmed, it cannot be erased.

§ Another type of programmable read only memory is the electrically erasable PROM (EEPROM), which can be programmed and erased while in use.

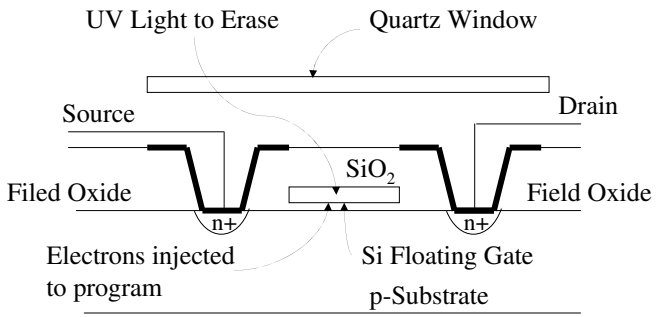
ROM Memory Cells (1/2)



ROM Memory Cells (2/2)

- The ROM memory cell is simply a wire or connection made or not made in the programming process.
- The binary information is represented by the presence or absence of the gate on the MOS transistor.
- Activating the word line puts a one or zero on the bit line.

EPROM Memory Cells (1/2)



EPROM Memory Cells (2/2)

- The EPROM cell is a MOS transistor without a connection to the gate.
- To program the EPROM, the chip is placed into a PROM programmer and during the programming cycle, the address and data are sent to the chip and the programming voltage is applied. To change the state of the gate, electrons are either injected by an avalanche mechanism into the silicon floating gate or not. After the programming, the channel between the source and and the drain either conducts or does not.
- If the chip needs to be erased, it must be placed into the PROM eraser. The ultraviolet light irradiated from the PROM eraser disperses any charge stored in the floating gate back into the substrate and erases the memory.

EEPROM Memory

- The EEPROM is a further development of the EPROM.
- A second polysilicon gate, called the control gate, is added above the floating gate.
- A control voltage may be applied to the gate to program and erase the cell by injecting or disperse electrons in the floating gate.
- 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).

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.

Reading Material

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