Microcomputers I – CE 320

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Announcements

- Notices will be posted on Blackboard
- Things will be posted on Blackboard
  - Lecture slides
  - Homework sheets
  - Lab materials
  - Grades

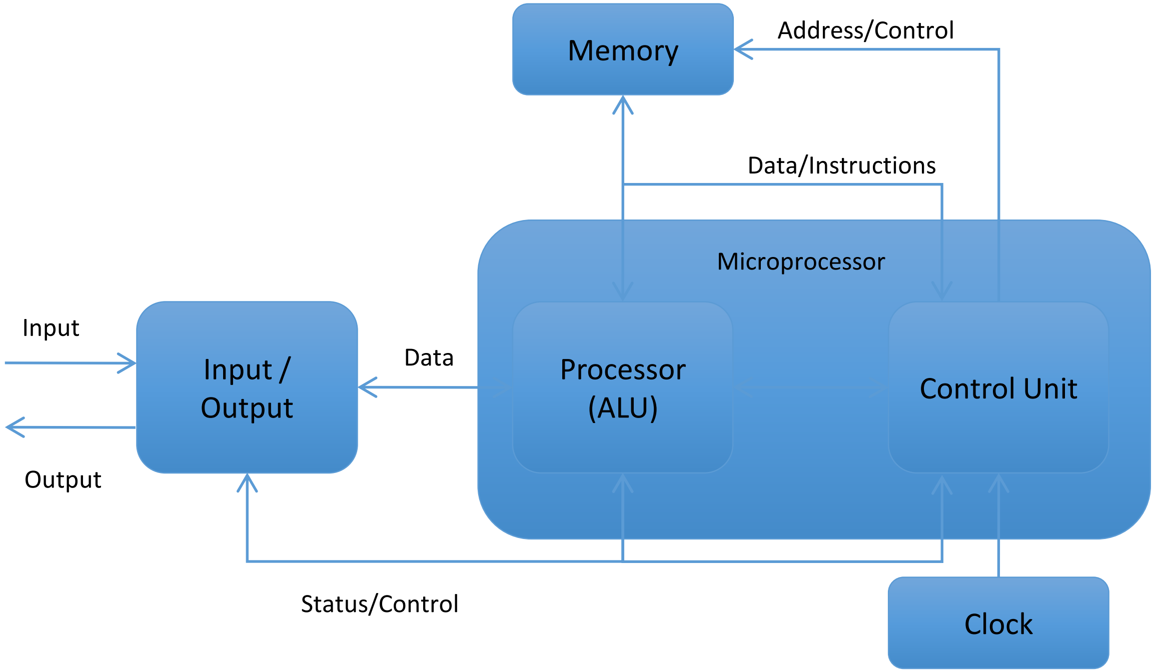
Lecture 1:
Introduction to Microcomputers

Today’s Topics

- What is a microcomputer?
- Why do we study microcomputers?
- What are embedded systems?
- Two basic types of microcomputer architectures
- Internal components of a microcomputers

Microcomputer

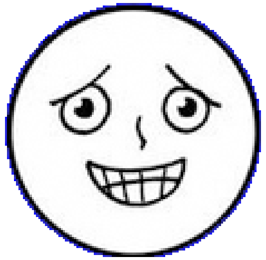
- Major components of the computer - the processor, one or more memory ICs, one or more I/O ICs, and the clock
- A single printed circuit board usually connects the ICs, making a computer called a ***microcomputer***



Another definitions

Microcomputers, Microcontrollers, and Microprocessors

- Microcomputer
  - Relatively small and inexpensive computer that is contained on one or a few chips.
- Microcontroller
  - A single-chip microcomputer.
- Microprocessor
  - Also known as CPU is the portion of a microcomputer that is in charge of most of the internal operations.



There is no single and clear definition of these terms.

Microprocessor

- The earlier processors were implemented in one or multiple printed circuit boards (PCBs).

- With the advancement of integrated circuit (IC) technology, a complete processor can now be implemented in one IC (an IC is often called a chip).

- A microprocessor is a processor implemented in a single IC.

What are some disadvantages of microprocessors?

Microprocessor
Disadvantages

1-

- The microprocessor does not have on-chip memory.

  - The designer needs to add external memory chips and other glue logic circuit such as decoder and buffer chips to provide program and data storage.

Micro**processor**
Disadvantages - continued

2-

- The microprocessor **cannot drive the input/output (I/O) devices** directly.
  - This is because the microprocessor may not have enough current to drive the I/O devices or the voltage levels between the microprocessor and I/O devices may be incompatible.

Microprocessor
Disadvantages - continued

3-

- The microprocessor **does not have peripheral functions** such as parallel I/O ports, timers, analog-to-digital (A/D) converter, communication interface, and so on.
- These functions must be implemented using external chips.

Microcontroller

- A microcontroller (MCU) incorporates the processor and one or more of the following modules in one very large-scale integrated circuit (VLSI):
  - Memory
  - Timer functions
  - Serial communication interfaces such as:
    - Universal Synchronous Asynchronous Receiver Transmitter (USART)
    - Serial peripheral interface (SPI)
    - Inter-integrated circuit (I2C)
    - Controller area network (CAN)
  - A/D converter
  - Digital-to-analog (D/A) converter
  - Direct memory access (DMA) controller
  - Parallel I/O interface (equivalent to the function of Intel 8255)
  - Memory component interface circuitry
  - Software debug support hardware

A Quick Introduction of HCS12 Microcontroller
HCS12 (=68HC12 or 9S12) family microprocessor

- The Motorola 68HC12 was introduced in 1996 as an upgrade for the 68HC11.
- Features:
  - Bus clock rate of 25 MHz
  - 16-bit CPU
  - 8-bit or 16-bit PWM
  - CAN, SPI, I2C
  - Standard 64-KB address space support
  - Multiplexed (address and data) external bus
  - 0 to 4 KB of on-chip EEPROM
  - 2 KB to 14 KB of on-chip SRAM
  - 10-bit A/D converter
  - 16 KB to 512 KB of on-chip flash memory (or ROM)
  - Etc. etc. etc.
- Target Market:
  - Automotive and process control applications

Why do we study Microcomputers?

- Embedded systems use microcontrollers or microcomputers.
- Some interesting statistics (from a few years ago)
  - An average American interacts with 300 or more embedded systems every day.

  - 95% of all microprocessors will be sold each year for embedded systems.

  - IEEE estimated that over 700,000 people worldwide were employed writing code for embedded system in 2007.






What Are Embedded Systems?

Embedded Systems

- An embedded system is a **special-purpose** computer system designed to perform a **dedicated function**.

- An embedded system is a computer system with a dedicated function **<u>within a larger system.</u>**

Embedded Systems

- Unlike a general-purpose computer, such as a personal computer, an embedded system <u>performs one or a few predefined tasks</u>, usually with very specific requirements, and often includes task-specific hardware and mechanical parts not usually found in a general-purpose computer.

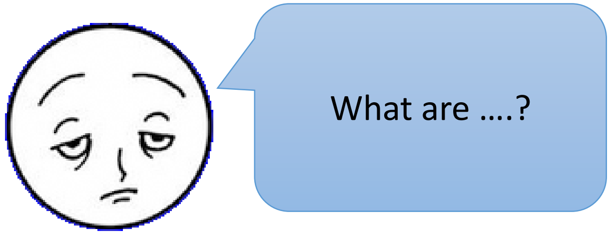
- Since the system is dedicated to specific tasks, design engineers can optimize it, reducing the size and cost of the product.
- Embedded systems are often mass produced, benefiting from economy of scale.

General-Purpose System

Special-Purpose System

What Are Some Application Examples of Embedded Systems?

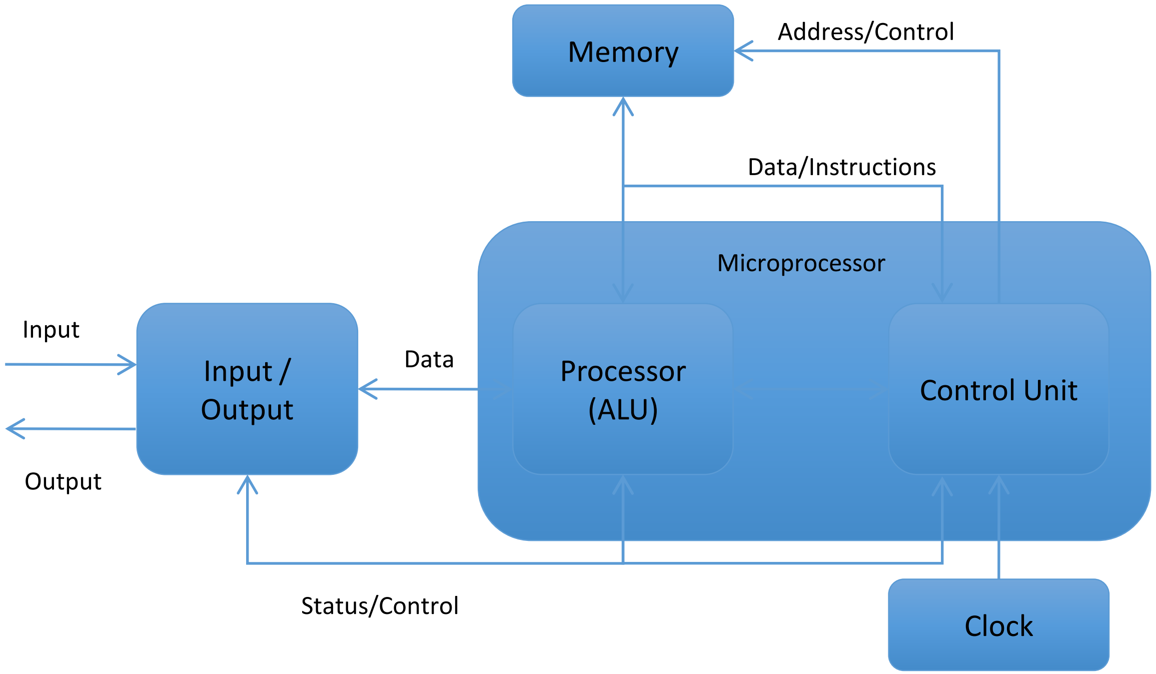
Basic Architecture
Princeton and Harvard



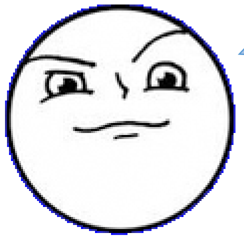
- There are many other architectures in use. They will be discussed in a computer architecture course.
- Here, we will cover two major architecture of microcomputers.
  - Princeton and Harvard architecture
  - The main difference is the memory structure
- Princeton Architecture*
  - Known as Von Neumann architecture
  - Single memory contains both the program code and the data.
- Harvard Architecture
  - Two separate memories. One contains only data while the other is containing only program code.

Princeton Architecture
Known as Von Neumann

- No separate memory space for program code and data

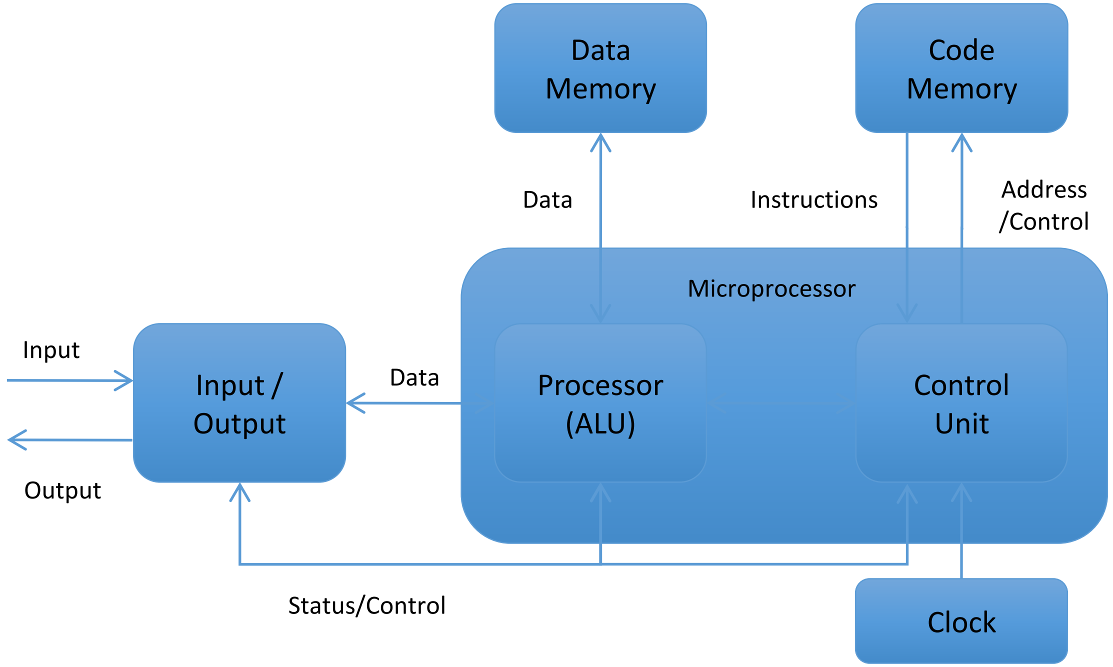


Harvard Architecture



OK.. I see. One clear distinction of these two is whether two separate memory units exist or not.

- Two separate memory units
- The length of an instruction could be different from the data size
- Both data and a program instruction can be read at the same time



Major Components of Microcomputer

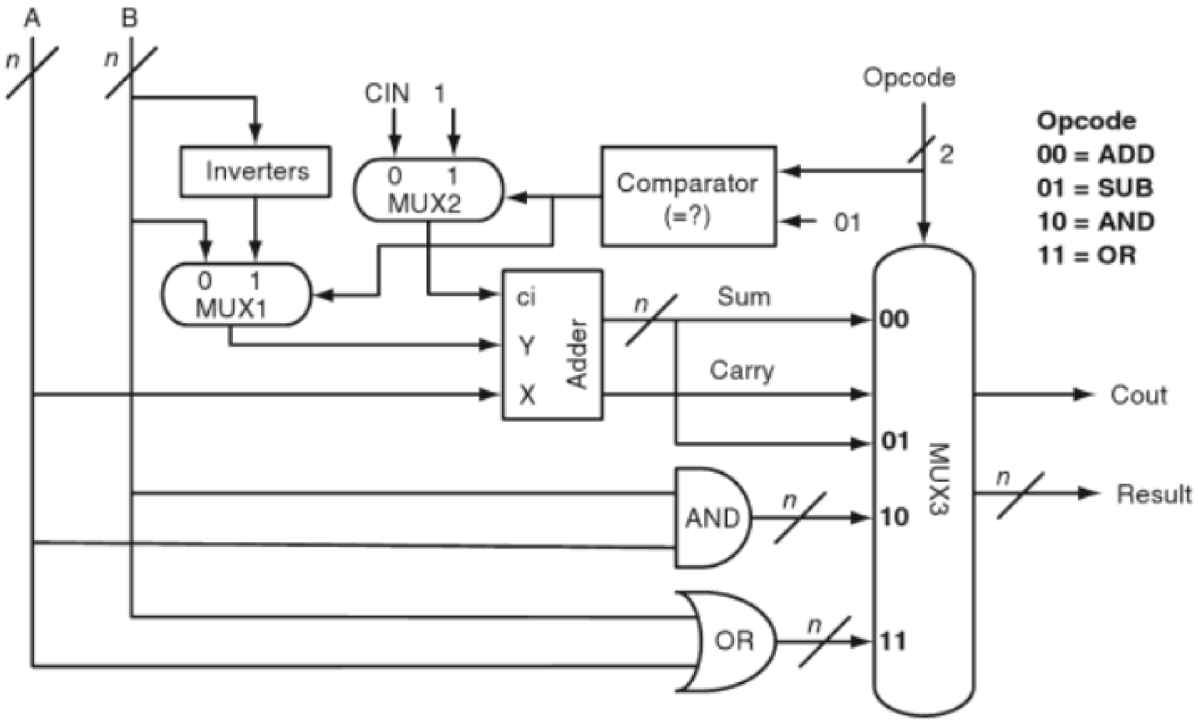
- Consists of:
  - The processor
  - Memory
  - Input & output devices

Major components
1. Processor

- Also referred to as the central processing unit (CPU).
- Is responsible for performing all of the computational operations.
- A processor consists of <u>three</u> major components:
    1. Arithmetic logic unit (ALU)
    2. Control unit
    3. Registers

Major components
1. Processor – Arithmetic Logic Unit

- The ALU performs arithmetic and logic operations requested by the user's program.
- The ALU performs operations such as addition, subtraction, AND, and OR
- E.g.



Major components
1. Processor – Control Unit

- A unit to control machine instructions.
- A machine instruction is a combination of 0s and 1s.
- To simplify hardware design, instruction lengths are limited to a few choices that are a multiple of 8 bits.
  - E.g., the HCS12 microcontroller has instructions that are 8 bits, 16 bits, 24 bits, 32 bits, 40 bits, and 48 bits.
- A machine instruction consists of:
  - **Operation code**
  - **Operand**

Major components
1. Processor – Control Unit

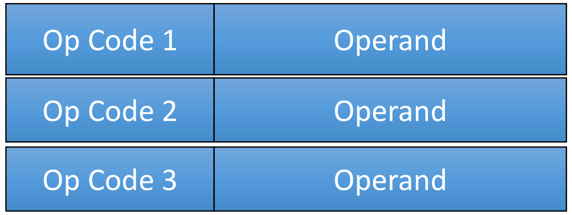
- Operation Code (Op Code for short)
  - This tells the ALU what operation to perform and how to interpret the operand.
  - All instructions **must** have an op code.

- Operand
  - The operand contains the data that ALU will perform the action on.
  - Some operands include several numbers for op codes that specify more complex actions.
  - Some operation codes that perform simple tasks do not need to have operands.

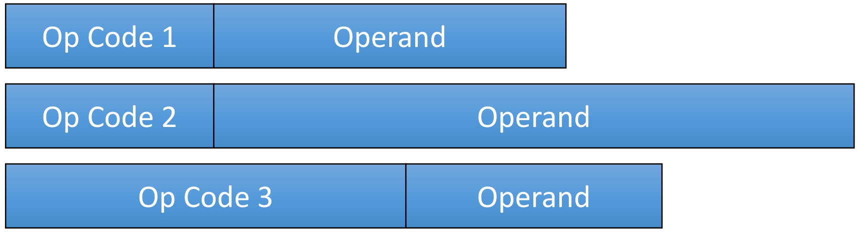
Major components
1. Processor – Control Unit

A machine instruction may have a:

- Fixed length
  - Each instruction is the same number of bits as all others.



- Variable length*
  - The length of each instruction may be different.



Major components
1. Processor – Control Unit

- To make the instruction execution time predictable, a ***clock*** signal is used to synchronize and set the pace of instruction execution.

- Since a program consists of many machine instructions, there is a need to keep track of what instruction to execute next. The control unit has a register called **program counter (PC)** that serves this function.

  - Whenever the processor fetches an instruction from memory, the PC will be incremented by the length of that instruction so that it points to the next instruction.

  - The fetched instruction will be placed in the instruction register (IR), decoded, and executed.

Major components
1. Processor – Registers

- A register is a storage location (groups of D flip-flops) inside the CPU.
- It is used to hold data and/or a memory address during the execution of an instruction.
- Because the register is very close to the CPU, it can provide fast access to *operands* for program execution.
- The number of registers varies greatly from processor to processor.

Major components
1. Processor – Registers

- A processor may add a special register called an **accumulator** and include it as one of the operands for most instructions.
  - Using the accumulator as one of the operands can shorten the instruction length.
  - Freescale HCS12 microcontroller use this approach.

- Other processors, for example, Microchip PIC32, may include many general-purpose data registers (16 or 32) in the CPU and allow any data register to be used as any operand of most instructions with two or three operands.
  - This provides great freedom to the compiler during the program translation process.

Major components
2. Memory

- Memory is a place where program code (**instructions**) and **data** are stored.

- A memory system may consist of one or multiple memory chips.

- Memory is organized as an array of memory locations.

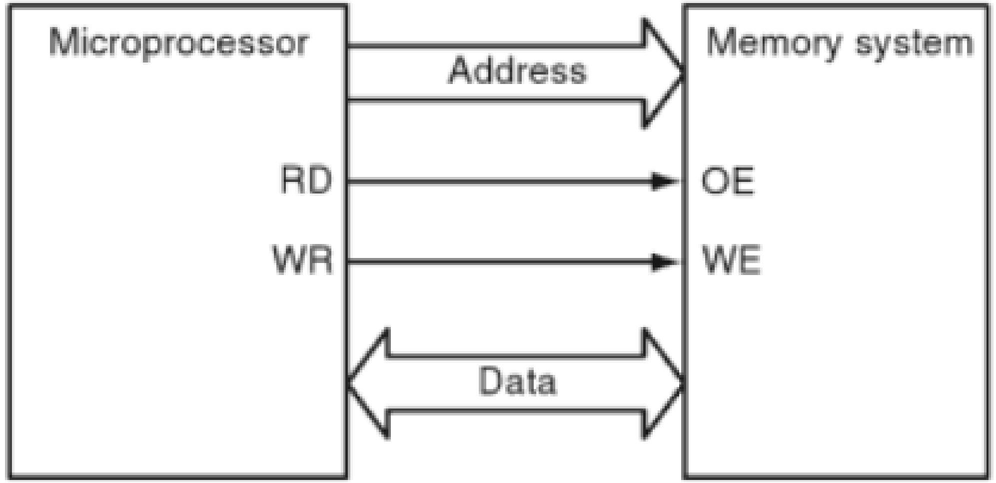
- A Memory location may hold any number of bits (4 bits, 8 bits, 16 bits,…)

Major components
2. Memory - continued

- The memory organization is indicated by **m X n**; where:
  - **m** specifies the number of memory locations.
  - **n** specifies the number of bits in each location.
- To simplify the quantification of memory, the following units are often used:
  - Kilobyte (KB): k = 2^{10} = 1024
  - Megabyte (MB): M = 2^{20} = 1,048,576
  - Gigabyte (GB): G = 2^{30} = 1,073,741,824

Major components
2. Memory - continued

- Every memory location has two components: ***contents*** and ***address***.



- The ***content*** indicated by an ***address*** can be interpreted by the microprocessor as one of two things.
  - **Instruction code** are used as inputs into the control unit and determine how it operates. A group of instruction is called a program.
  - **Data** are the numbers to be processed or the results of operations in the processor.

Major components
3. Input/Output

- The Input/Output (I/O for short.) block represents the interface between the internals of the microcomputer and the outside world.
- Keyboard, LED and LCD display, printers for example.

Questions?

Wrap-up
What we’ve learned

- The definitions of microcomputers, microcontroller, and microprocessor
- The importance of microcomputers in the real world
- Princeton* and Harvard architectures
- Processor, control unit, memory, and I/O are the major components of microcomputers.

What to Come

- Review number systems
- Introduction to the HCS12/9S12