Microprocessor

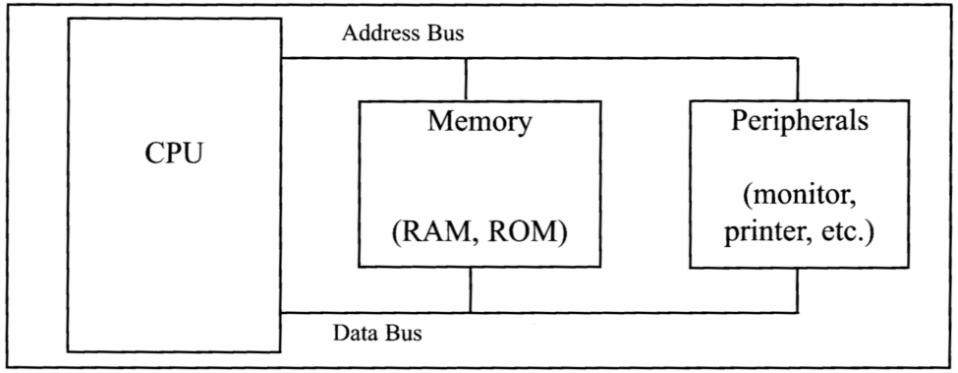
Ch.0 & Ch.1 Introduction to Microcontroller

OUTLINE

- What is microcontroller? (Ch. 1.1)
- 8051 Microcontroller (Ch. 1.2)
- Numbering and coding: binary, decimal, hexadecimal, ASCII (Ch. 0.1)
- Basic digital logics (Ch. 0.2)
- Operations of a computer (Ch. 0.3)

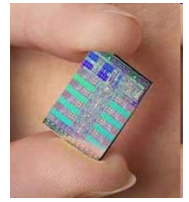
WHAT IS MICROCONTROLLER?

- **What are inside a computer?**
  - Central processing unit (CPU)
    - Execute (process) information stored in memory
  - Memory
    - Store information
    - Random access memory (RAM)
    - Read only memory (ROM)
  - I/O (input/output) devices
    - Also called peripherals
    - Monitor, keyboard, harddrive, CD-ROM, video card
  - Bus
    - Strip of wires connecting CPU, memory, and I/O devices

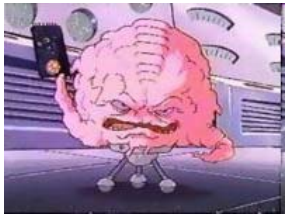


WHAT IS MICROCONTROLLER?

- **Microprocessor v.s. Microcontroller**
  - Microprocessor: a CPU on a single integrated chip (IC)
    - a special type of CPU
    - The brain of a computer
    - E.g.:
      - 8086, 80286, 80386, 80486, Pentium, Core 2 Duo, Core 2 Quad, …
      - K5, K6, Atholon, Atholon 64, Opteron, Phenon, …
      - PowerPC G4, PowerPC G5, Xenon, Broadway, Cell, …
    - Contains no RAM, no ROM, no I/O ports.



  - Microcontroller: a microprocessor, and RAM, ROM, I/O ports, and timer on a single chip. Also called MCU, μC, uC
    - "Computer on a chip"
    - Also called MCU (MicroController Unit)
    - Usually not as powerful as general purpose microprocessor
    - Low power consumption, small in size, low cost.
    - A lot of MCUs are application specific (as against the general purpose microprocessor).



MIRCOCONTROLLER: APPLICATIONS

- **Applications of micro-controller**
  - Home
    - TV, MP3 player, camera, DVD player, CD player, cell phone, alarm clock, microwave, refrigerator, washer/dryer, treadmill, air conditioner, Modem, ……
  - Office
    - Scanner, printer, fax machine, copier, wireless router, ……
  - Industry
    - Machinery, equipment, instrumentation, Rocket,……
  - Auto
    - ABS, airbag, instrumentation, climate control, transmission control, entertainment system, ……
- **Microcontroller is everywhere!**
  - Most of the applications requires the MCU to be
    - Small in size → the final product is small
    - Low cost → lower the price of the end product
    - Low power consumption → longer battery life
    - Simple (as long as it can have the job done) → low cost, small, low power consumption

MICROCONTROLLER: EMBEDDED SYSTEMS

- **Embedded system: a system with an embedded special-purpose computer designed to perform one or a few dedicated functions.**
  - Embedded system:
    - the embedded computer is just part of a bigger system.
    - The computer by itself cannot perform any meaningful functions.
    - E.g. a MCU embedded in a washer
  - Contrast to: general purpose computer (personal computer)
    - A PC itself is a complete system
    - You can use it to perform various tasks
  - Usually an MCU is embedded in a complete device including mechanical parts
    - E.g. camera, microwave
  - The operation software is embedded in hardware
    - E.g. the operation software is stored in the ROM on MCU.
    - Doesn't have separate device (CD, harddrive) to store programs.
  - All the applications of MCU can be considered as embedded systems

MICROCONTROLLER: COURSE CONTENTS

- **What are we going to learn in this course?**
  - What are inside a microcontroller?
    - the basic structure of a microcontroller
  - How to program a microcontroller?
    - Assembly language
    - C language
  - How to build a system with a microcontroller?
    - I/O ports
    - Hardware connection

OUTLINE

- What is microcontroller (Ch. 1.1)?
- **Introduction to 8051 (Ch. 1.2)**
- Numbering and coding: binary, decimal, hexadecimal, ASCII (Ch. 0.1)
- Basic digital logics (Ch. 0.2)
- Operations of a computer (Ch. 0.3)

8051

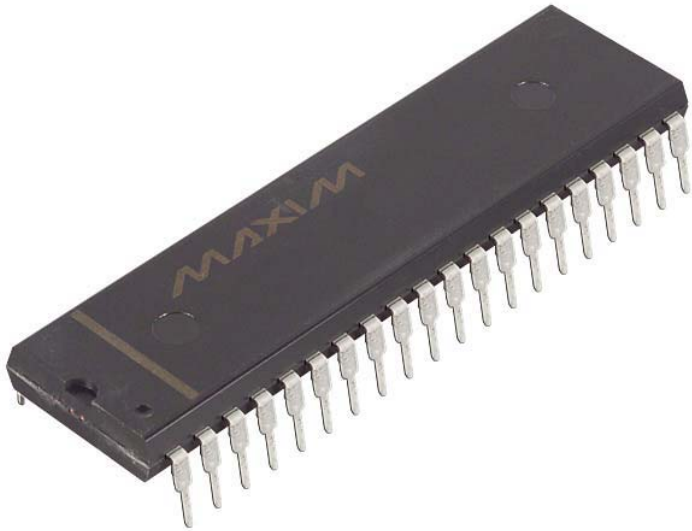
- **Four major 8-bit microcontrollors**
  - Freescale: 6811, Intel: 8051, Zilog: Z8, Microchip: PIC 16X
- **How do we decide which MCU to use?**
  - Speed
  - Power consumption
  - Amount of RAM and ROM on chip
  - Number of I/O pins
  - Cost per unit
  - Packaging
  - Availability
  - How easy is it to develop a product around it.
- **8051**
  - One of the most popular MCUs in the market.
    - Several manufactures are building 8051
    - Wide availability, low cost,
  - Clean structure: easy to learn, easy to use

8051: OVERVIEW

- **8051 MCU family**
  - There are different variations of 8051 by different manufactures
    - Intel: 8051, 8052
    - Dallas Semiconductor: DS89C4x0 (x = 2, 3, 4, 5)
    - Atmel: AT89C51
    - Philips
    - Texas Instruments
    - ……
  - They differ in speed, ROM/RAM size, packaging, timer, I/O pins, timer, operation voltage, and other peripherals
    - E.g. some of them have built in analog to digital converter (ADC).
  - They all support the same 8051 instruction set

8051: DS89C430

- **The 8051 chip that will be used in our lab**
  - DS89C430 by Dallas Semiconductor
    - ROM: 16 KB
    - RAM: 256 Bytes
    - I/O pins: 32
    - Timers: 3
    - Interrupts: 6
    - Clocks per machine cycle: 1
    - Operation voltage: 5V



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NUMBERING: DECIMAL AND BINARY

- **Decimal and binary number system**
  - Decimal: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
  - Binary: 0, 1 (used by computer)
  - Weight associated with each digit
    - Decimal: $256_{10} = 2\times10^2 + 5\times10^1 + 6\times10^0$
    - Binary: $101_2 = 1\times2^2 + 0\times2^1 + 1\times2^0$
  - Convert binary to decimal
    - Example
      - Convert 11001_2 to decimal number

NUMBERING: DECIMAL AND BINARY

- **Decimal and binary number system (Cont'd)**
  - Convert decimal to binary
    - Method 1: use the weight of digit
      - Example: convert 39_{10} to binary.

    - Method 2: divide the decimal by 2 repeatedly until the quotient becomes 0, and keep track of the remainder
      - Example: convert 39_{10} to binary

NUMBERING: HEXADECIMAL SYSTEM

- **Hexadecimal system: base-16 system**
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
  - Mainly used as a convenient representation of binary number
    - 4 binary digits → 1 hex digit
  - Convert binary to hexadecimal
    - Example: 111101_2
  - Convert hexadecimal to binary
    - Example: $29BH$

Number Systems

Decimal	Binary	Hex
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

NUMBERING: HEXADECIMAL SYSTEM

- **Hexadecimal system (Cont'd)**
  - Convert from hex to decimal
    - Use weights of digits ($...16^3,16^2,16^1,16^0$)
    - Example: converts $6FEH$ to decimal
  - Convert from decimal to hex
    - Method 1: use weight of digit
    - Method 2: keep divide by 16 and keep track of quotient
    - Example: convert 45_{10} to hex

NUMBERING: HEXADECIMAL SYSTEM

- **Hexadecimal system**
  - Counting
    - Decimal

      0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 …
    - Hex

      0 1 2 3 4 5 6 7 8 9 A B C D E F ?

      0 1 2 3 4 5 6 7 8 9 A B C D E F 10 11 12 13 14 ….

NUMBERING: ARITHMATIC

- **Binary addition**
  - Example: find the sum of 1101_2 and 1001_2

- **Hexadecimal addition**
  - Example: find the sum of 23D9H + 94BEH

NUMBERING: 2'S COMPLEMENT

- **2's complement**
  - To get 2's complement of a binary number
    - 1. Invert all bits (1 → 0, 0 → 1) ➔ 1's complement
    - 2. add 1 to the result
  - Example
    - Find the 2's complement of 01100011_2

  - Usually used to represent negative numbers, and to calculate the subtraction of binary numbers
  - We will discuss its application in Ch. 6, Arithmetic

NUMBERING: ASCII

- **ASCII**
  - American Standard Code for Information Interchange
  - Use binary patterns to represent numbers and English alphabet
  - Standard ASCII code
    - Each character is represented by 7-bit
    - Totally there are characters in the 7-bit ASCII table.
  - Extended ASCII code
    - Each character is represented by 8-bit
    - Totally there are characters in the 8-bit ASCII table.
  - The complete ASCII table can be found at Appendix F of Mazidi's book.

Hex	*Symbol*	*Hex*	*Symbol*
41	A	61	a
42	B	62	b
43	C	63	c
44	D	64	d
...	...	...	...
59	Y	79	y
5A	Z	7A	z

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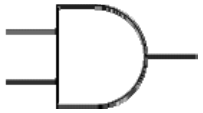
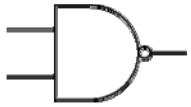
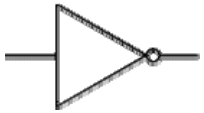
LOGIC

- **Binary logic**
  - Use two voltages to represent 0 and 1
    - E.g. 0V → '0', 5V → '1'
- **Logic gates**
  - AND 
  - NAND 
  - OR 
  - NOR 
  - XOR 
  - XNOR 
  - NOT 

Summary of 2-input logic							
Inputs		Output of each gate					
A	B	AND	NAND	OR	NOR	EX-OR	EX-NOR
0	0	0	1	0	1	0	1
0	1	0	1	1	0	1	0
1	0	0	1	1	0	1	0
1	1	1	0	1	0	0	1

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COMPUTER

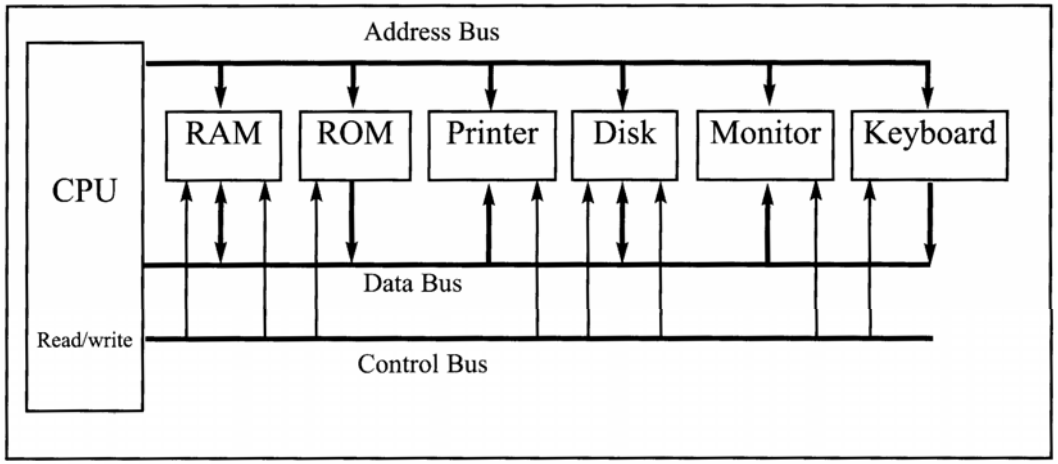
- **Terminology**
  - Bit (b): 0 or 1
  - Nibble: 4bits 0000, 0001, …, 1111
  - Byte (B): 0000 0000, ……., 1111 1111
  - Word (16 bits): 0000 0000 0000 0000, ……., 1111 1111 1111 1111
- **Prefix**
  - Kilo-: $2^{10} = 1024 \approx 10^3$
    - E.g. 1 kilobyte = 1KB = 1024 bytes = 1024 x 8 bits
    - E.g. 1 kilobit = 1Kb = 1024 bits
  - Mega-: $2^{20} = 1{,}024 \times 1{,}024 = 1{,}048{,}576 \approx 10^6$
    - E.g. 1 megabyte = 1MB = 1024 x 1024 bytes
  - Giga-: $2^{30} = 1{,}024 \times 1{,}024 \times 1{,}024 \approx 10^9$
  - Tera-: $2^{40} = 1{,}024 \times 1{,}024 \times 1{,}024 \times 1{,}024 \approx 10^{12}$
  - Peta-:
  - Exa-:

COMPUTER: STRUCTURE

- **Structure**
  - CPU: process information in memory
  - Memory
    - RAM (Random access memory) : temporary storage of programs that it is running
      - The data is lost if computer is turned off (volatile memory)
    - ROM (read only memory): contains programs and information essential for computer operation
      - E.g. when a computer is powered on, it will first execute a program stored in ROM to perform initialization before loading the operating system
      - It's permanent and usually cannot be changed by the user (non-volatile memory)
  - Peripherals
    - Serial port, parallel port, keyboard, monitor, ……

COMPUTER: STRUCTURE

- **Bus**
  - Strip of wires used to connect CPU with memory and peripherals
  - Data bus
    - The data lines used to carry information in and out of CPU.
    - The more data lines, the better the CPU
      - Analogy: highway with more lanes
    - Typical values: 8-bit, 16-bit, 32-bit, 64-bit
      - A 32-bit bus can send out 4-byte of data at one time
    - Bidirectional
      - Data can get in or out of CPU



COMPUTER: STRUCTURE

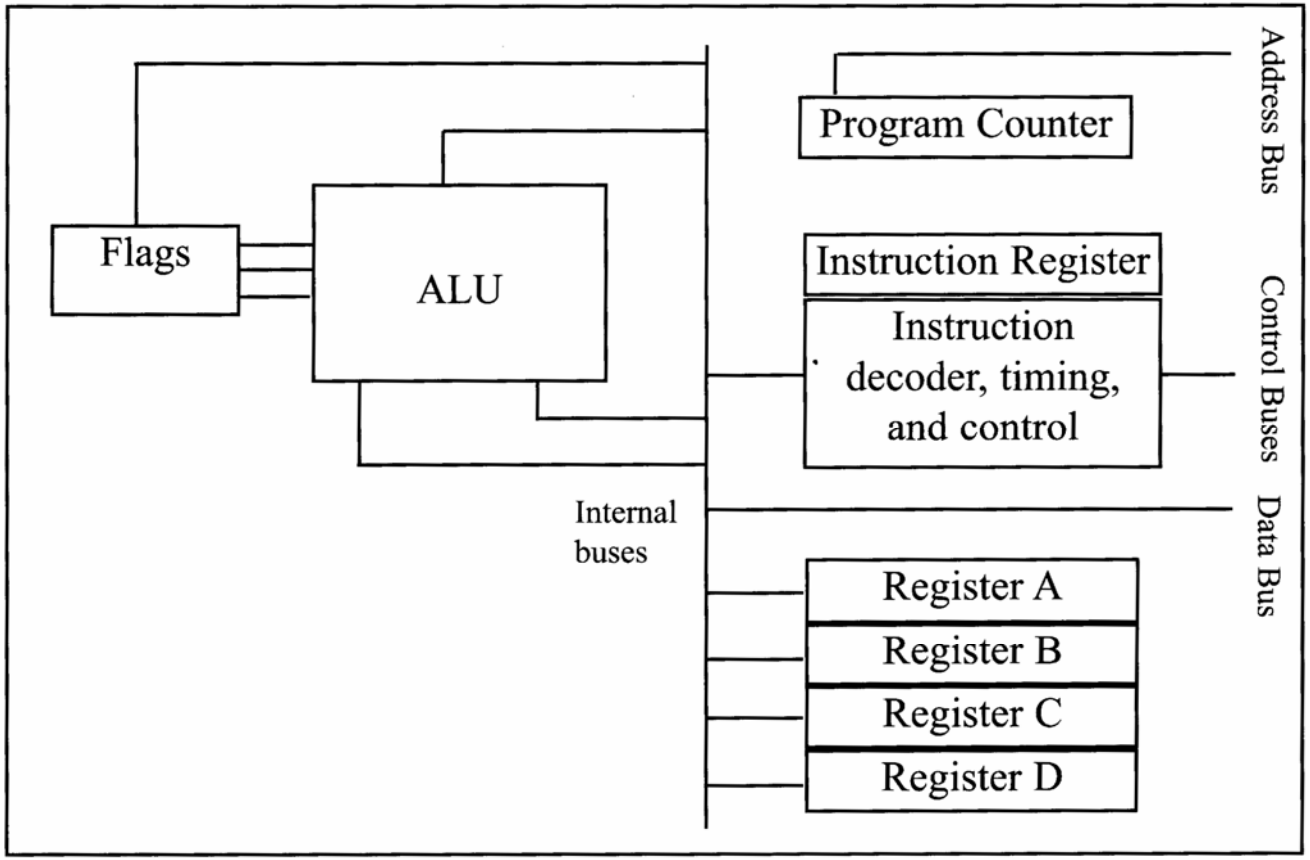
- **Bus (Cont'd)**
  - Address bus
    - Many devices are connected to a single data bus, how does the CPU know which device the data is from or to? → address bus!
    - Address bus is used to identify device and memory connected to CPU.
      - Each byte in memory has its unique address
    - If there are *n* address lines, then the total address range is 2^n bytes
      - E.g. 8-bit address line: $2^8 = 256$ bytes address range
      - E.g. 32-bit address line: $2^{32} = 4GB$ address range
        - » If the system has a total of 32-bit address lines, the maximum supported memory is 4GB.
    - Each device is assigned a range of addresses
      - E.g. 8-bit address line with 64-byte RAM, 32-byte ROM, 16 I/O ports
        - » RAM: address 0 – 63
        - » ROM: address 64 – 95
        - » I/O ports: address 96 – 112
        - » Printer: 113 – 114
        - » ……
    - Address bus is unidirectional → it's value can only be changed by CPU.

COMPUTER: STRUCTURE

- **Bus (Cont'd)**
  - Control bus
    - CPU sends control information to devices to control their operations
    - E.g. CPU sends read or write control information to the devices to indicate it wants to read from the device, or write data to the device.
  - The operation of a computer relies on the combination of the three buses
    - E.g. CPU wants to read a data byte from memory location 32.
      - 1. CPU set the value of the address bus to 32
      - 2. CPU use the control bus to put the memory in read mode
      - 3. CPU read the data byte on the data bus

COMPUTER: CPU

- **Inside CPU**
  - ALU (arithmetic logic unit)
    - Arithmetic functions (add, subtract, …)
    - Logic functions (and, or, not, …)



COMPUTER: CPU

- **CPU (Cont'd)**
  - Registers
    - Temporarily store information
    - Data read from memory or device will first be stored in registers, then CPU will process data in register
    - Calculation results will be store in register, then send out to memory
    - E.g. 3 + 5, 3 will be first loaded to register A, 5 will be first loaded to register B. Then CPU calculates 3+5, the result, 8, will be stored in register A.
    - Typical size: 8-bit, 16-bit, 32-bit (most popular nowadays), 64-bit

COMPUTER: CPU

- **CPU (Cont'd)**
  - Instruction register, instruction decoder, program counter
    - Instruction: a special binary pattern corresponds to a certain operation by CPU
      - E.g. 1011 0000 (B0H): move data to register A
      - E.g. 0000 0100 (04H): add a value to register A
    - Program is a sequence of instructions, and it is stored in memory
    - CPU reads the program from the memory, one instruction at a time, and the current instruction is temporarily stored in instruction register
    - The instruction decoder interprets the meaning of the instruction, so CPU can execute according to the instruction.
    - Program counter: point to the memory address of the next instruction to be executed.

COMPUTER: CPU

- **Example**
  - A program stored in the memory address range 1400 – 1406.

address	contents of memory
1400	(B0) code for moving a value to register A
1401	(21) value to be moved
1402	(04) code for adding a value to register A
1403	(42) value to be added
1404	(04) code for adding a value to register A
1405	(12) value to be added
1406	(F4) code for halt

PC					
IR					
RA					

PC: program counter. IR: instruction Register. RA: register A.