

Microprocessor

Ch.0 & Ch.1 Introduction to Microcontroller

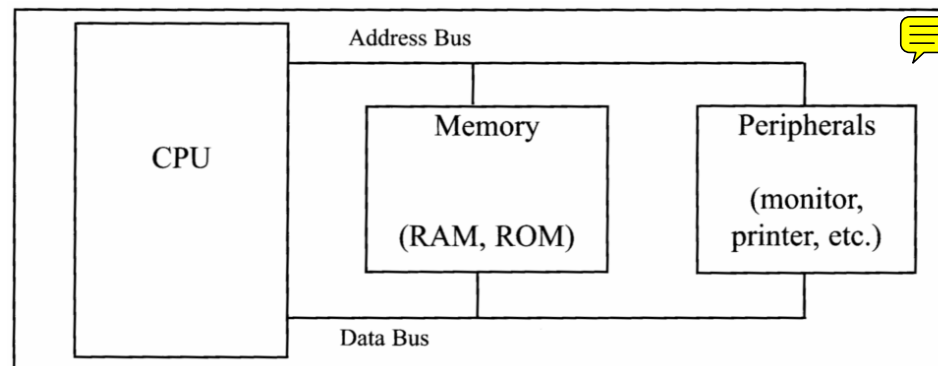
OUTLINE

- **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

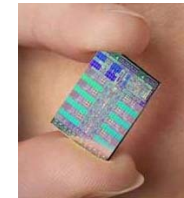


WHAT IS MICROCONTROLLER?

- **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, Athlon, Athlon 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 , μC

- “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 microcontrollers**
 - 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

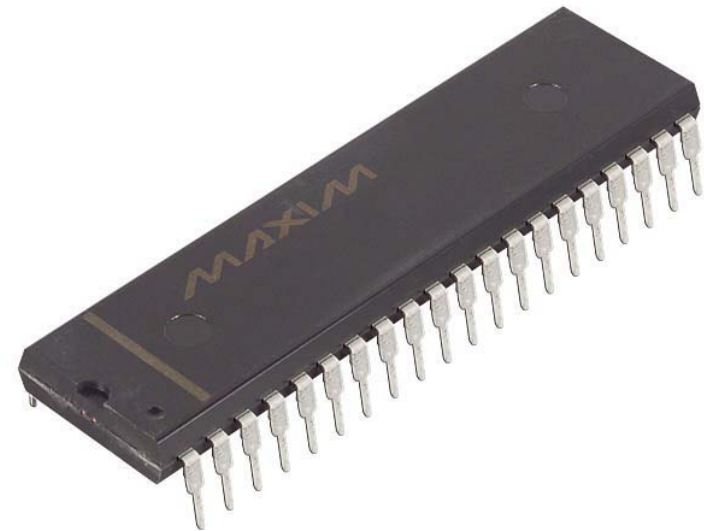
8051: OVERVIEW

- **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: $256_{10} = 2 \times 10^2 + 5 \times 10^1 + 6 \times 10^0$
 - Binary: $101_2 = 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$
- 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 $\rightarrow$ 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 ($\dots 16^3, 16^2, 16^1, 16^0$)
 - 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: ARITHMETIC

- **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 ($1 \rightarrow 0, 0 \rightarrow 1$) $\rightarrow$ 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.

<i>Hex</i>	<i>Symbol</i>	<i>Hex</i>	<i>Symbol</i>
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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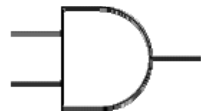
LOGIC

- **Binary logic**

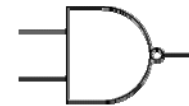
- Use two voltages to represent 0 and 1
 - E.g. 0V $\rightarrow$ '0', 5V $\rightarrow$ '1'

- **Logic gates**

- AND



NAND



- OR



NOR



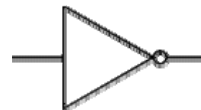
- XOR



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

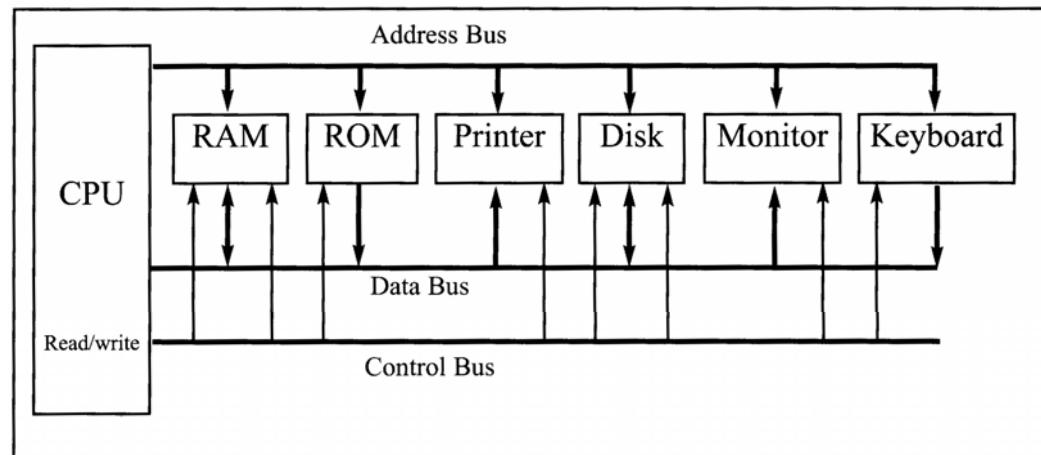
- **Structure**

- 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.

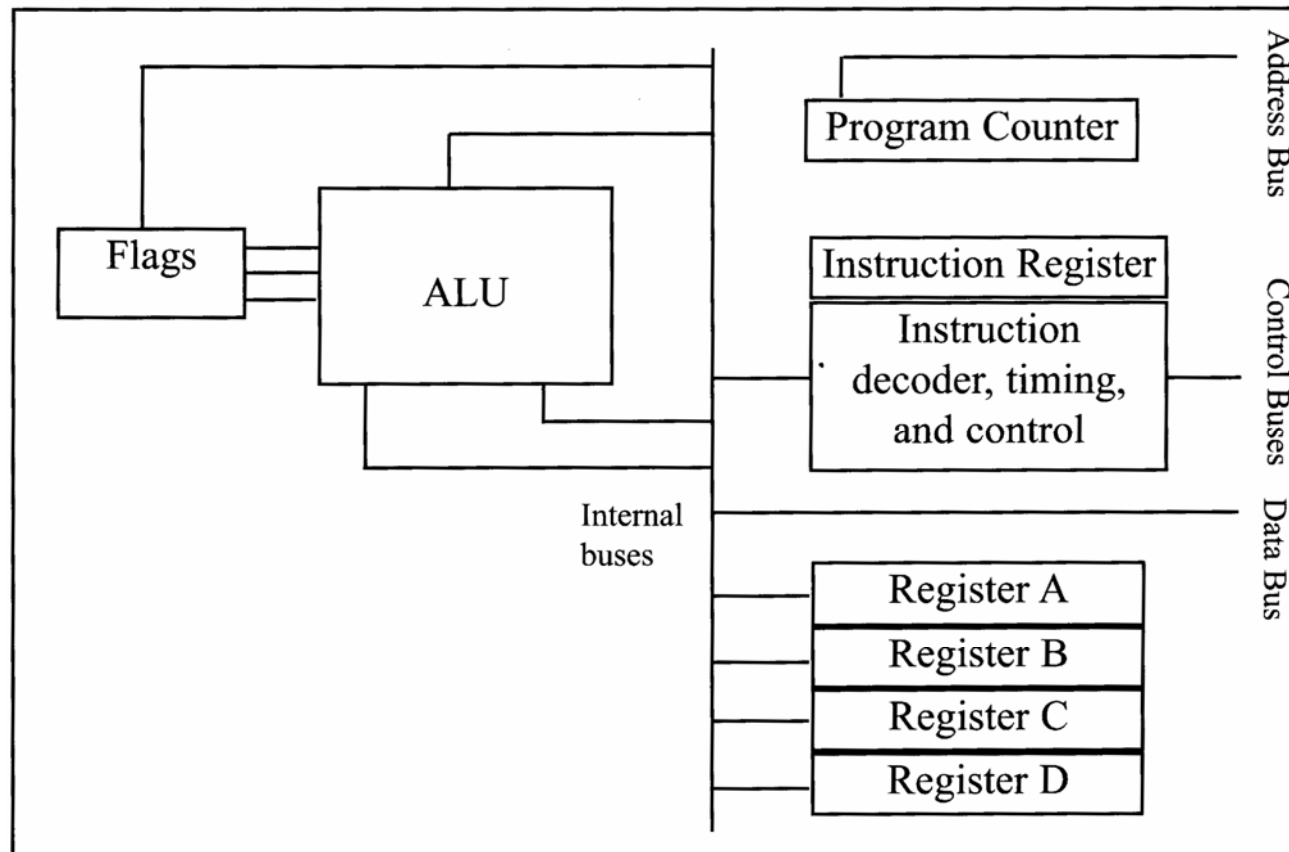
COMPUTER: STRUCTURE

- **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.