Introduction to Microcontroller

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Embedded System

- You are used to chips like the Pentium and the Athlon, but in terms of installed machines these are a small portion of total computer use. Think how many computers you have at home?

- Digital cameras, video cameras, TVs, mobile phones, calculators, micro-wave ovens etc all contain processors.In order for a microprocessor to be used, other components such as memory, or components for receiving and sending data must be added to it.

- On the other hand, microcontroller is designed to be all of that in one.
- No other external components are needed for its application because all necessary peripherals are already built into it.
- Thus, we save the time and space needed to construct devices.
- The PICmicro was originally designed around 1980 by General Instrument as a small, fast**, inexpensive embedded microcontroller** with strong I/O capabilities.

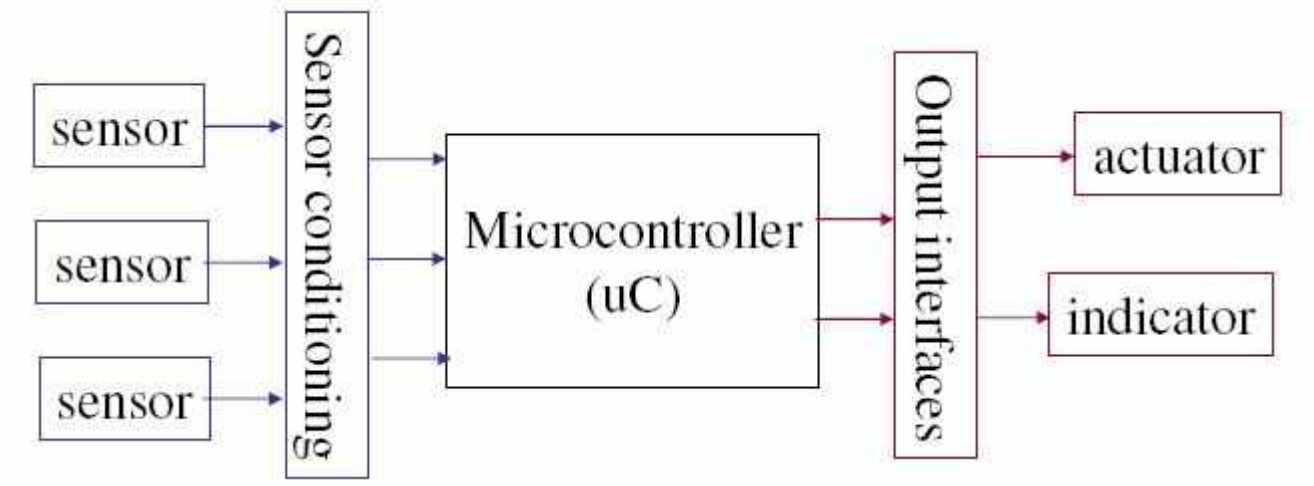
Characteristics of Embedded System

- Embedded computers have to be very low cost, simple and reliable.
- They can not use any moving parts (disk drives) because:
  1. power hungry
  2. bulky
  3. expensive

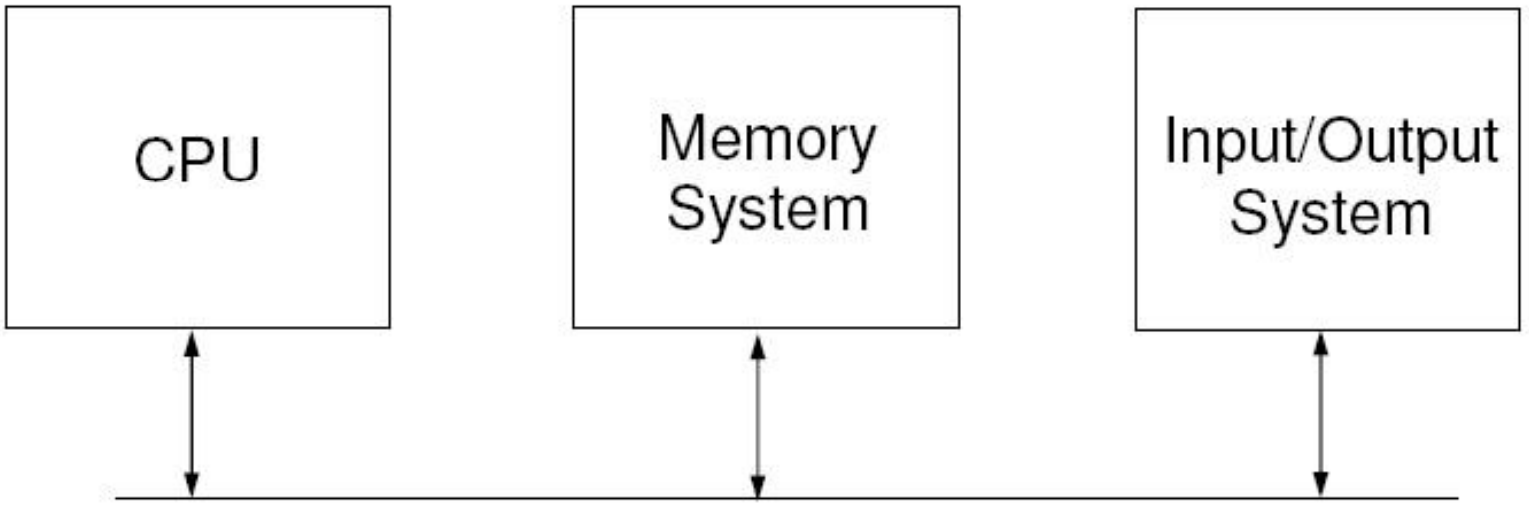
Features of Embedded System

- Program in Read Only Memory – ROM
- Limited RAM storage – variables only not code
- Built in I/O devices
- Use very little power

Embedded System General Block Diagram



Components of a Computer System



Microcontroller

- Microcontrollers, as the name suggests, are small controllers
- They are like single chip computers that are often embedded into other systems to function as processing/controlling unit
- For example, the remote control you are using probably has microcontrollers inside that do decoding and other controlling functions
- They are also used in automobiles, washing machines, microwave ovens, toys ... etc, where automation is needed
- The key features of microcontrollers include:
  - High Integration of Functionality
    - Microcontrollers sometimes are called single-chip computers because they have on-chip memory and I/O circuitry and other circuitries that enable them to function as small standalone computers without other supporting circuitry

- Field Programmability, Flexibility
  - Microcontrollers often use EEPROM or EPROM as their storage device to allow field programmability so they are flexible to use
  - Once the program is tested to be correct then large quantities of microcontrollers can be programmed to be used in embedded systems

- Easy to Use
  - Assembly language is often used in microcontrollers and since they usually follow a RISC architecture, the instruction set is small
  - The development package of microcontrollers often includes an assembler, a simulator, a programmer to "burn" the chip and a demonstration board
  - Some packages include a high level language compiler such as a C compiler and more sophisticated libraries

Microcontroller, Microprocessor and Microcomputer

- A **microcontrollers** are is like a single chip computers that are often embedded into other systems to function as processing/controlling unit
  - Microcontrollers are used in a wide number of electronic systems such as:
    - Engine management systems in automobiles
    - Keyboard of a PC
    - Electronic measurement instruments (such as digital multimeters, frequency synthesisers, and oscilloscopes)
- A **microprocessor** is a programmable digital electronic component that incorporates the functions of a central processing unit (CPU) into a single IC package
  - These functions are
    - The ability to execute a stored set of instructions to carry out user defined tasks
    - The ability to be able to access external memory chips to both read and write data from and to the memory

- Types of Memory can be obtained as either:
  - Read Only Memory (ROM)
    - This is memory that can only be read, the data being stored in the memory device during its manufacture
    - Once data has been written onto ROM memory, it cannot be easily removed and is designed for 'read only' use
    - ROM is referred to as being non-volatile as it retains its contents even when the power is turned off
  - Erasable Programmable Read Only Memory (EPROM)
    - This is similar to ROM type memory but the user can program it
    - The contents of the memory can be erased from the memory by exposing the memory chip to ultraviolet radiation for a short period of time
    - It can therefore be used many times over
  - Electrically Erasable Programmable Read Only Memory (EEPROM)
    - Similar to EPROM but has part or all of the memory contents erased by the microprocessor

- Both ROM and EPROM memory are used to hold the program code of a microprocessor used in an embedded system, ie. a microprocessor used in an application where the program code is always the same and is designed to execute every time the system is switched on
- Most development work is done using EPROM or EEPROM type memory, ROM memory being used in the final production version (when all the program code has been fully tested)

- Random Access Memory (RAM)
  - All microprocessor systems need memory that can be both read from and written to - such memory is RAM
  - RAM got its name because early read-write memories were sequential, and did not allow random access. RAM memory is used to store dynamic data (that will change during the operation of the program)

- RAM takes the form of integrated circuits that allow the stored data to be accessed in ANY order — that is, at random and without the physical movement of the storage medium or a physical reading head
- The word "random" infers that any piece of data can be returned quickly, and in a constant time, regardless of its actual physical location, in relation to the previous data storage location
- The key benefit of RAM is that retrieval times are short and consistent. The disadvantages of RAM are cost, and the loss of data when power is turned off (volatile).

- A typical microprocessor system will contain both ROM (could be EPROM, EEPROM, or ROM) to store the program code, and RAM to store dynamic data

Input/Output (I/O)

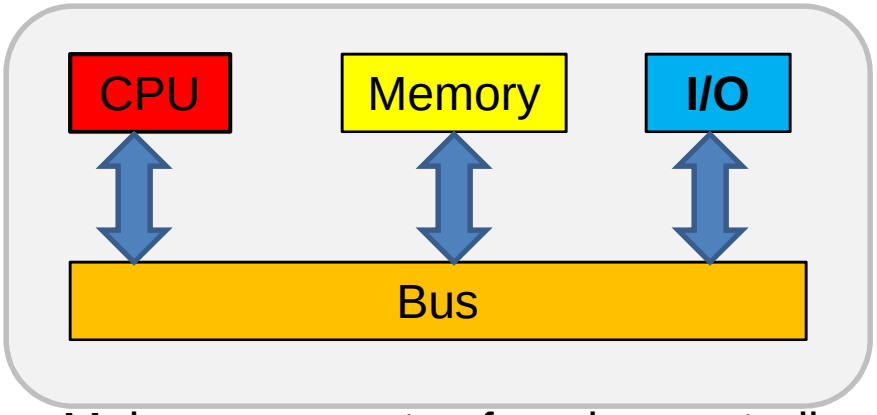
- I/O (input/output) is the collection of interfaces that different functional devices, of any information processing system, use to communicate with each other
- Every information transfer is an output from one device and an input into another
- For instance, on a computer, a keyboard and mouse are considered input devices while monitors and printers are considered output devices
- Typical devices for communication between computers, such as modems and network cards, operate as both input and output devices
- I/O can be:
  - A number of digital bits formed into a number of digital inputs or outputs called a port
  - These are usually eight bits wide and thus referred to as a BYTE wide port. i.e. byte wide input port, byte wide output port

- A serial line from the microprocessor (Transmit or TX) and a serial line to the microprocessor (Receive or RX) allowing serial data in the form of a bit stream to be transmitted or received via a two wire interface
- Other I/O devices such as Analogue to Digital Converters (ADC) and Digital to Analogue Converters (DAC), Timer modules, Interrupt controllers etc. (which will be discussed later in the context of microcontrollers)

- These are relatively complex sub systems that can be obtained as separate Ics
- They are connected to the microprocessor in a similar manner to that of the memory devices.
- Indeed, they often contain their own memory to support internal operations (i.e. registers)

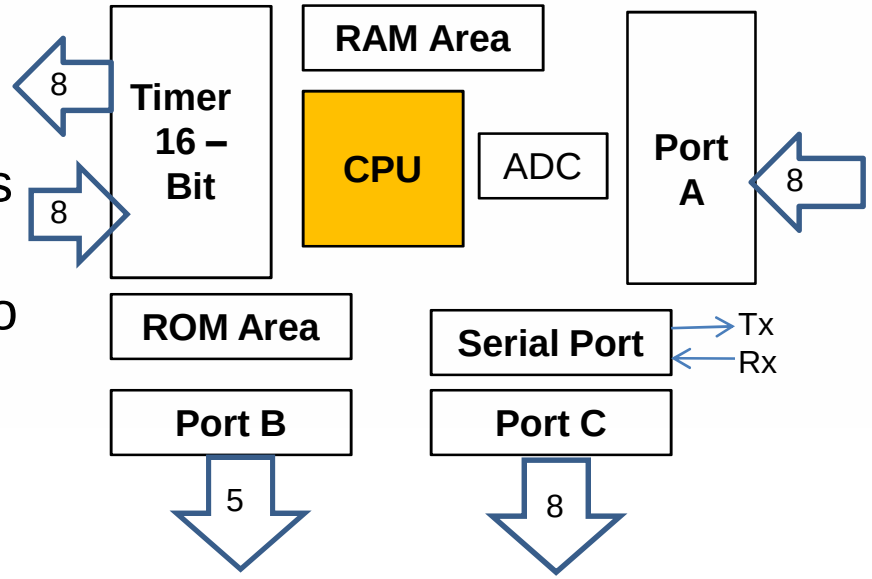
Microcontroller Hardware

- Basically, a microcontroller is a device which integrates a number of the components of a microprocessor system onto a single chip (IC), with the following common features:
  - The CPU core - ranging from simple 4-bit processors to sophisticated 32/64-bit processors
  - Memory (both ROM and RAM)
  - Some parallel digital I/O



Main components of a microcontroller

- Most microcontrollers will also combine other devices such as:
  - A **Timer module** to allow the microcontroller to perform tasks for certain time periods
  - A **serial I/O** port to allow data to flow between the microcontroller and other devices such as a PC or another microcontroller
  - An **ADC** to allow the microcontroller to accept analogue input data for processing
- The **CPU** is the processing module of the microcontroller.



A single chip microcontroller and CPU

- Microcontrollers are nowadays brimming with added functionality on this single IC and often include:
  - Communications Peripherals: SPI, I2C™, UART, CAN, USB, Ethernet, IrDA®, LIN
  - Control Peripherals: capture/compare, counters, real-time clock & calendar, motor control & PWM
  - Integrated Display Drivers: LED, LCD
  - On-chip internal oscillators and Phase-Locked Loop (closed loop feedback control)
  - Analog Peripherals: A/D Converters, comparators, op amps, brown-out detection & reset, low voltage detection, temperature sensors, D/A Converters and voltage regulators

Memory in a microcontroller

The amount of memory contained within a microcontroller varies between different microcontrollers

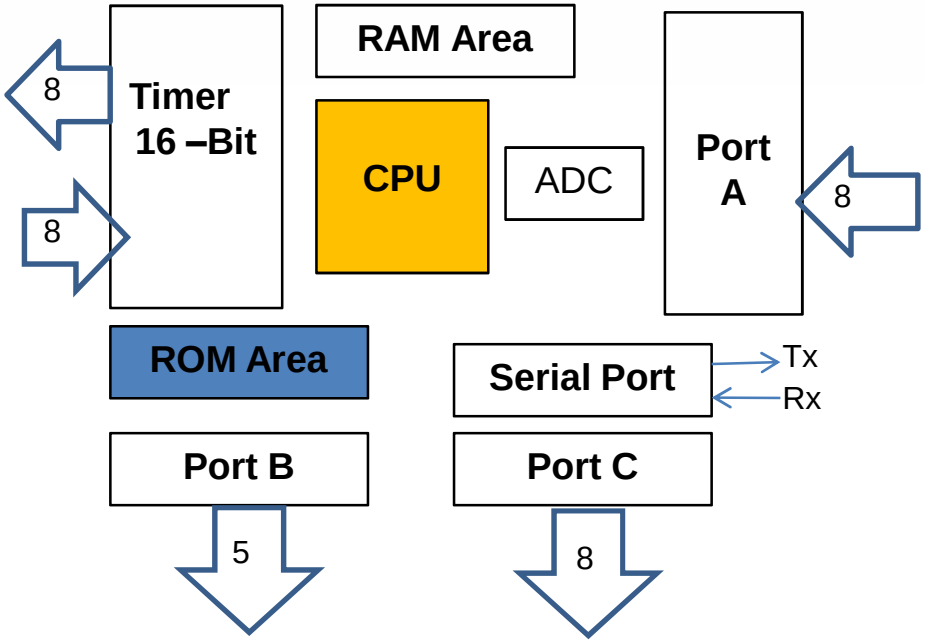
Some may not even have any integrated memory (eg. Hitachi 6503, now discontinued)

However, most modern microcontrollers will have integrated memory

The memory will be divided up into ROM and RAM, with typically more ROM than RAM

Microcontroller ROM

- The ROM of a microcontroller is used to store the application program



- Typically, the amount of ROM type memory will vary between around 512 bytes and 4096 bytes
- Some 16 bit microcontrollers such as the Hitachi H8/3048 can have as much as 128 Kbytes of ROM type memory
- ROM type memory, as has already been mentioned, is used to store the program code
- ROM memory can be either ROM (as in One Time Programmable memory), EPROM, or EEPROM

Microcontroller RAM

- The microcontroller RAM is used to store data