# AVR Microcontroller: History & Features

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## Lecture-3

## Reference: Second chapter of textbook

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# Lecture Objective

Upon completion of this lecture, the students will be able to:

- Compare and contrast microprocessors and microcontrollers
- Explain the concept of embedded system
- Determine criteria before considering a microcontroller
- Compare and contrast the various members of the AVR family

# Contents

- Microcontrollers & Embedded processors
  - Overview of the AVR family

# Microcontrollers & Embedded processors

- Microcontroller vs. General Purpose Microprocessor:

**What is microprocessor?**

The microprocessor is the electronic components. It is kind of computer processor that resides on single or multiple integrated circuits (IC). This IC contains many other electronics components such as a resistor, transistor, diode… The microprocessor performs all the functions of the central processing system. One way it differs from CPU as it occupies small space and resides on only a couple of integrated circuits

It does not have I/O peripheral component and internal memory. So it requires external components such as RAM, ROM, timer, Serial interface, I/O port to operate.

**How does Microprocessor work?**

Microprocessor holds the number of instruction. Every instruction consists of multiple steps such as fetch, decode, executes and store. While running instruction in the microprocessor, it executes multiple steps as Fetch the input, Decode instruction, Execute instruction, Store result back in the memory.

Here, Instruction gets fetched and Input to is given using external I/O components. The microprocessor executes an instruction. The result gets stored in the externally connected memory unit.

- Microcontroller vs. General Purpose Microprocessor:

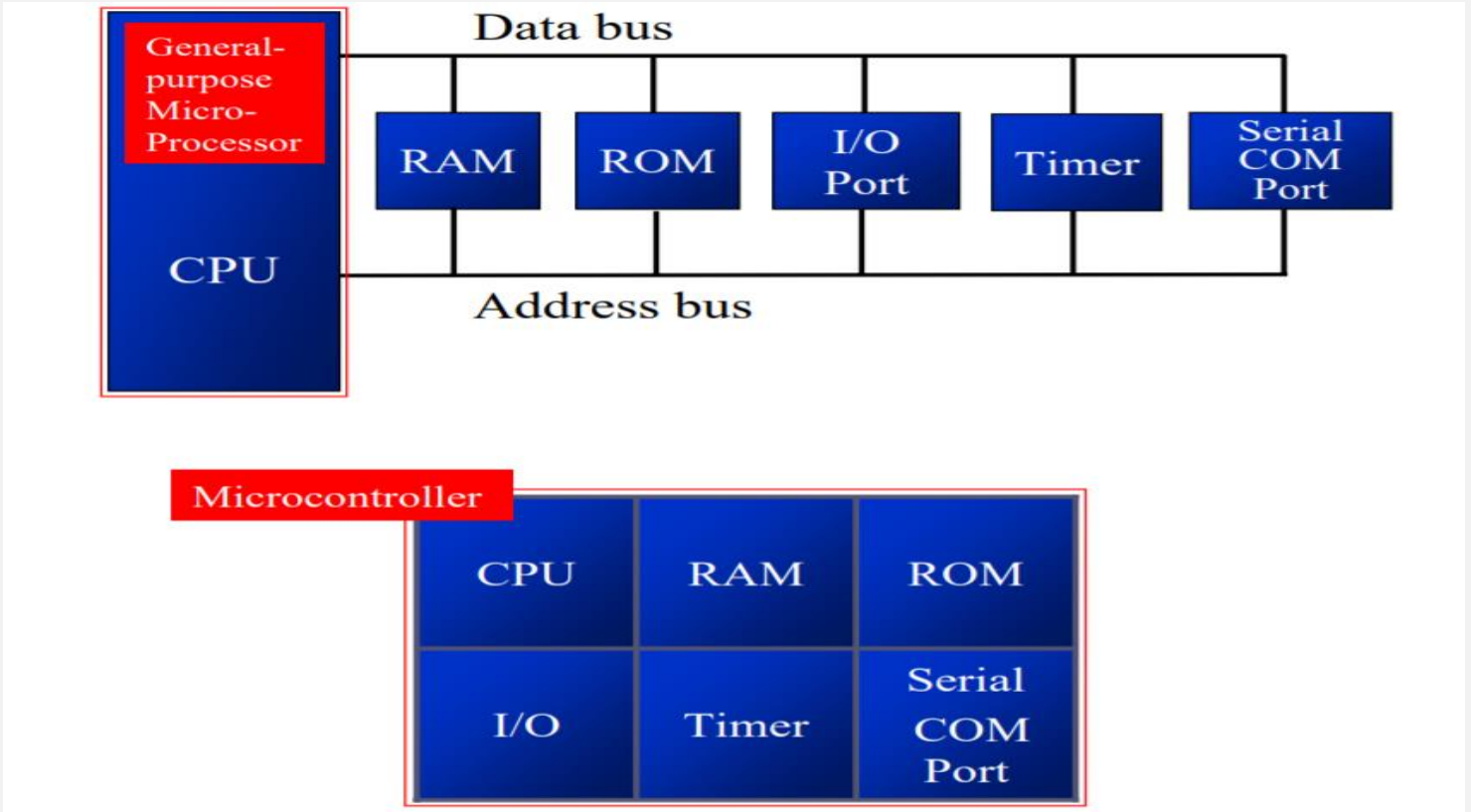
**What is microcontroller ?**

The microcontroller is the electronic device. It has processing unit along with fixed sized ROM, RAM, and other required peripheral components. These all the components are embedded on the single chip.

As it has all the components required to process and store data, it is also called as mini computer or computer on the single chip.

**Microcontroller vs. General Purpose Microprocessor:**

How is microprocessor different from the microcontroller?



**General-purpose microprocessors:**

- Must add RAM, ROM, I/O ports, and timers externally to make them functional
- Makes the system bulkier and much more expensive
- Have the advantage of versatility on the amount of RAM, ROM, and I/O ports

**Microcontroller:**

- The fixed amount of on-chip ROM, RAM, and number of I/O ports makes them ideal for many applications in which cost and space are critical
- In many applications, the space it takes, the power it consumes, and the price per unit are much more critical considerations than the computing power

What are the more specifications about microprocessor and microcontroller?

- **Computer System Vs Embedded System**: Microprocessor widely used in the computer system. And microcontroller is used in embedded system.

If the microprocessor is the heart of computer system then microcontroller is the heart of the embedded system.

- **Architecture**: The microprocessor uses Von Neumann architecture where data and program present in the same memory module. The microcontroller uses Harvard architecture. In this module, data and program get stored in separate memory.

The microcontroller can access data and program at the same time as it is in a separate memory.

- **Memory and I/O Components:** The microprocessor can not operate without peripheral components. It has only processing unit and we have to attach all the required components externally to operate.

  Whereas microcontroller has small processing unit along with internal memory to store and I/O components to give input. So it can work independently.

- **Circuit Size and its Complexity:** As we have to connect components externally, microprocessor circuit becomes large and complex. In microcontroller all the components are internally connected, its circuit becomes too small.

- **Power Consumption:** Microprocessor requires external components and its circuit is also a complex one. It requires more power consumption. So it is difficult to operate microprocessor using battery power.

The microcontroller has very low external components. it manages all its operation inside the single chip. So it consumes very low power supply as compared to the microprocessor. We can operate microcontroller on the externally connected stored power such as a battery.

- **Power Saving Feature:** The microcontroller can have multiple modes of operation such as higher performance, balance, idle or power saving mode. So if we operate microcontroller in power saving mode, the power consumption reduce even more.

Most of the Microprocessor does not have this power saving feature.

- **Processing Speed:** The microprocessor has very less internal registers. It has to rely on external storage. So all the memory operations are carried out using memory based external commands. Results in high processing time.

The microcontroller has many registers for instruction execution. Fetching data and storing data require internal commands. So its execution and processing time are lower than the microprocessor.

- **Examples:** Intel Pentium series processor, core 2 duo, dual core, Intel i3, i5 are the examples of Microprocessor that are widely used.

Microcontrollers are produced by many hardware manufacturer companies such Motorola, Philips, Microchips, ATMEL…

- **Efficient Techniques to use in Compact System:** The microcontroller can be used in the compact system as it has a small size. So microcontroller is better and efficient technique in the compact system than the microprocessor.
- **Cost:** Microprocessor requires external components to operate. So the Cost of the microprocessor is higher than the microcontroller.
- **Uses:** The microprocessor is used in desktop personal computer, laptop… The microcontroller is used in an embedded system such as MP3 player, Television, Refrigerator, Washing Machine…

# Microcontrollers for Embedded system

**What is an embedded system?**

- An embedded system is a microprocessor-based computer hardware system with software that is designed to perform a dedicated function, either as an independent system or as a part of a large system. At the core is an integrated circuit designed to carry out computation for real-time operations.
- Complexities range from a single microcontroller to a suite of processors with connected peripherals and networks; from no user interface to complex graphical user interfaces. The complexity of an embedded system varies significantly depending on the task for which it is designed.
- Embedded system applications range from digital watches and microwaves to hybrid vehicles. As much as 98 percent of all microprocessors manufactured are used in embedded systems.

# Microcontrollers for Embedded system

**How an Embedded System Works:**

- Embedded systems are managed by microcontrollers or digital signal processors (DSP), application-specific integrated circuits (ASIC), field-programmable gate arrays (FPGA), GPU technology, and gate arrays. These processing systems are integrated with components dedicated to handling electric and/or mechanical interfacing.
- Embedded systems programming instructions, referred to as firmware, are stored in read-only memory or flash memory chips, running with limited computer hardware resources. Embedded systems connect with the outside world through peripherals, linking input and output devices.

# Basic Structure of an Embedded System:

The basic structure of an embedded system includes the following components:

- **Sensor**: The sensor measures and converts the physical quantity to an electrical signal, which can then be read by an embedded systems engineer or any electronic instrument. A sensor stores the measured quantity to the memory.
- **A-D Converter**: An analog-to-digital converter converts the analog signal sent by the sensor into a digital signal.
- **Processor & ASICs:** Processors assess the data to measure the output and store it to the memory.
- **D-A Converter**: A digital-to-analog converter changes the digital data fed by the processor to analog data
- **Actuator**: An actuator compares the output given by the D-A Converter to the actual output stored and stores the approved output.

# Future Trends in Embedded Systems:

- The industry for embedded systems is expected to continue growing rapidly, driven by the continued development of Artificial Intelligence (AI), Virtual Reality (VR) and Augmented Reality (AR), machine learning , deep learning, and the Internet of Things (IoT). The cognitive embedded system will be at the heart of such trends as: reduced energy consumption, improved security for embedded devices, cloud connectivity and mesh networking, deep learning applications, and visualization tools with real time data.
- According to a 2018 report published by QYResearch, the global market for the embedded systems industry was valued at $68.9 billion in 2017 and is expected to rise to $105.7 billion by the end of 2025.

**Embedded system:**

- An embedded product uses a microprocessor (or microcontroller) to do one task and one task only
- There is only one application software that is typically burned into ROM

**General-purpose system:**

- A PC, in contrast with the embedded system, can be used for any number of applications.
- It has RAM memory and an operating system that loads a variety of applications into RAM and lets the CPU run them
- A PC contains or is connected to various embedded products and each one peripheral has a microcontroller inside it that performs only one task

# Some Embedded Products Using Microcontrollers:

**Office:**

- Telephones, computers, security systems, fax machines, microwave, copier, laser printer, color printer, paging

**Home:**

- Appliances, intercom, telephones, security systems, garage door openers, answering machines, fax machines, home computers, TVs, cable TV tuner, VCR, camcorder, remote controls, video games, cellular phones, musical instruments, sewing machines, lighting control, paging, camera, pinball machines, toys, exercise equipment

**Auto:**

- Trip computer, engine control, air bag, ABS, instrumentation, security system, transmission control, entertainment, climate control, cellular phone, keyless entry

# X86 PC Embedded applications:

- There are times that a microcontroller is inadequate for the task
- Many manufactures of general-purpose microprocessors have targeted their microprocessor for the high end of the embedded market
- When a company targets a general purpose microprocessor for the embedded market, it optimizes the processor used for embedded systems
- Very often the terms embedded processor and microcontroller are used interchangeably
- One of the most critical needs of an embedded system is to decrease power consumption and space

# X86 PC Embedded applications:

- In high-performance embedded processors, the trend is to integrate more functions on the CPU chip and let designer decide which features he/she wants to use
- Many manufactures of general-purpose microprocessors have targeted their microprocessor for the high end of the embedded market
- In many cases using x86 PCs for the high-end embedded applications
  - Saves money and shortens development time
  - A vast library of software already written
  - Windows is a widely used and well understood platform

# Choosing a microcontroller:

- 8-bit microcontrollers
  - Motorola's 68HC08/68HC11
  - Intel's 8051
  - Zilog's Z8
  - Microchip's PIC
- There are also 16-bit and 32-bit microcontrollers made by various chip makers

# Criteria for Choosing a microcontroller:

- The most important factor is that the microcontroller should be cost-efficient and work capably to handle the dedicated task. Some questions that should be asked while deciding on a microcontroller are as follows:

1. What is the maximum speed of the microcontroller?
2. What is the amount of RAM and ROM on chip?
3. How easy it is to upgrade to higher upgrade or lower consumption versions?
4. Is the microcontroller readily available at cheaper rates?
5. What is the number of I/O pins and timer on the chip?

# Criteria for Choosing a microcontroller:

- Meeting the computing needs of the task at hand efficiently and cost effectively
  - Speed
  - Packaging
  - Power consumption
  - The amount of RAM and ROM on chip
  - The number of I/O pins and the timer on chip
  - How easy to upgrade to higher performance or lower power-consumption versions
  - Cost per unit

# Criteria for Choosing a microcontroller:

- Availability of software development tools such as compilers, assemblers, and debuggers
- Wide availability and reliable sources of the microcontroller
  - The 8051 family has the largest number of diversified (multiple source) suppliers
    - Intel (original)
    - Atmel
    - Philips/Signetics
    - AMD
    - Infineon (formerly Siemens)
    - Matra
    - Dallas Semiconductor/Maxim

Have a Wonderful Journey with Microcontroller !