**UNIT 2**

**8051 MICROCONTROLLER SYSTEM**

**Module: Mechatronics Embedded Systems**

**Module Code: MTT05209**

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## 2.0 Introduction

Modern embedded systems require small, fast, reliable, and programmable controllers capable of controlling electronic devices automatically. One of the most widely used controllers in embedded systems is the **8051 microcontroller**.

The 8051 microcontroller is used in:

- Industrial automation
- Robotics
- Home automation
- Medical equipment
- Communication systems
- Traffic light control systems

Unlike a microprocessor, a microcontroller contains:

- CPU
- Memory
- Input/output ports
- Timers
- Communication circuits

inside one chip.

This makes the 8051 suitable for embedded and control applications.

In this unit, students will study:

- Architecture of 8051
- Internal components
- Registers
- Memory organization

- Timers
- Interrupts
- Input/output ports
- Programming concepts
- Applications of 8051 systems

### 2.1 What is a Microcontroller?

**Definition**

A microcontroller is a compact integrated circuit designed to control embedded systems and electronic devices automatically.

It contains:

- CPU
- Memory
- Input/output ports
- Timers
- Communication circuits

all inside one chip.

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**Difference Between Microprocessor and Microcontroller**

| Feature | Microprocessor | Microcontroller |
|---|---|---|
| Memory | External | Built-in |
| I/O Ports | External | Built-in |
| Size | Larger system | Compact system |
| Cost | High | Low |
| Application | Computers | Embedded systems |

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## 2.2 Introduction to 8051 Microcontroller

The 8051 microcontroller was developed by Intel in 1981.

It became one of the most popular microcontrollers because:

- It is simple
- Low cost
- Reliable
- Easy to program

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**Features of 8051**

- 8-bit microcontroller
- 4 KB ROM
- 128 bytes RAM
- 32 input/output lines – used to connect LEDs, switches, sensors, motors etc.
- Two timers/counters – Special units used for creating time delays (timer), counting events/pulses (counter). Eg blinking LED every 1 second, counting objects passing sensor
- Serial communication capability – Ability to communicate/send data to other devices one bit at a time. Eg communicating with computer, sensors, another microcontroller
- Interrupt handling system
- On-chip oscillator – Built in clock generator that produces timing pulses for the microcontroller (it acts like heartbeat that keeps all operations synchronized and running)

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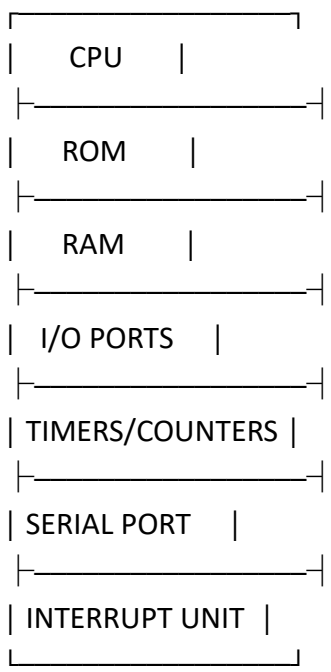
**Applications of 8051**

| **Application** | **Function** |
|---|---|
| Traffic lights | Timing control |
| Robots | Motion control |
| Home automation | Device control |

| Application | Function |
|---|---|
| Security systems | Monitoring |
| Medical equipment | Signal processing |

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### 2.3 Block Diagram of 8051 Microcontroller




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### 2.4 Central Processing Unit (CPU)

The CPU is the brain of the microcontroller.

Functions:

- Executes instructions
- Performs calculations
- Controls system operations

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### Main Parts of CPU

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### 1. Arithmetic Logic Unit (ALU)

Performs:

- Addition
- Subtraction
- Logical operations

Examples:

- AND
- OR
- XOR

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**2. Control Unit**

Controls:

- Data flow
- Instruction execution
- Timing operations

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**3. Registers**

Registers are temporary storage locations inside CPU.

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**Types of Registers**

| **Register** | **Function** |
|---|---|
| Accumulator (A) | Stores calculation results |
| B Register | Used in multiplication/division |
| Program Counter | Stores next instruction address |
| Stack Pointer | Points to stack memory |

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**2.5 Memory Organization of 8051**

Memory stores:

- Programs
- Instructions
- Data

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**Types of Memory**

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**1. ROM (Read Only Memory)**

Stores permanent programs.

Characteristics:

- Non-volatile
- Program storage memory

8051 contains:

- 4 KB ROM

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**2. RAM (Random Access Memory)**

Temporary data storage.

Characteristics:

- Volatile
- Stores temporary variables

8051 contains:

- 128 bytes RAM

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**Memory Map of 8051**

The internal memory is divided into:

- Register banks
- Bit-addressable area
- General-purpose RAM

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**2.6 Input and Output Ports**

8051 contains four I/O ports:

**Port Pins**

Port 0 8 pins

Port 1 8 pins

Port 2 8 pins

Port 3 8 pins

Total:

4×8=32 I/O lines.

Hence; 8051 has 32 input/output lines

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**Functions of I/O Ports**

Ports are used for:

- Receiving input signals
- Sending output signals
- Interfacing external devices

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**Examples of Interfaced Devices**

Input devices:

- Switches
- Sensors
- Keypads

Output devices:

- LEDs
- Motors
- LCD displays
- Relays

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### 2.7 Timers and Counters

8051 contains:

- Timer 0
- Timer 1

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**Functions of Timers**

Timers are used for:

- Generating delays
- Measuring time
- Controlling timing operations

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**Functions of Counters**

Counters are used for:

- Counting external events
- Pulse counting

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**Example Applications**

- Digital clocks
- Traffic light timing
- Frequency measurement

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### 2.8 Interrupt System

**Definition**

An interrupt is a signal that temporarily stops normal program execution to handle an urgent task.

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**Importance of Interrupts**

Interrupts improve:

- Speed
- Efficiency
- Real-time operation

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**Types of Interrupts in 8051**

| Interrupt | Function |
|---|---|
| External Interrupt | External event handling |
| Timer Interrupt | Timer overflow handling |
| Serial Interrupt | Communication handling |

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**Example of Interrupt Use**

When a fire alarm sensor detects smoke:

- Interrupt signal generated
- Controller immediately activates alarm system

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**2.9 Serial Communication**

**Definition**

Serial communication transfers data one bit at a time between devices.

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**Importance**

Used for communication between:

- Computers
- Microcontrollers
- Communication systems

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**Applications**

- Data transmission
- Network communication
- Device interfacing

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**2.10 Oscillator and Clock Circuit**

The oscillator generates clock pulses for synchronization.

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**Importance of Clock Signal**

Clock signals control:

- Instruction execution speed
- Timing operations
- Synchronization

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**Crystal Oscillator**

8051 commonly uses:

- Crystal oscillator circuit to generate stable frequency.

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**2.11 Pin Configuration of 8051**

The 8051 usually has:

- 40 pins

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**Important Pins**

| Pin | Function |
|---|---|
| VCC | Power supply |
| GND | Ground |
| XTAL1 & XTAL2 | Oscillator connection |
| RST | Reset pin |

| Pin | Function |
|---|---|
| RXD | Receive data |
| TXD | Transmit data |

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**Reset Pin**

Used to restart microcontroller operation.

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**2.12 Introduction to 8051 Programming**

The 8051 can be programmed using:

1. Assembly Language
2. Embedded C

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**What is Assembly Language?**

Assembly language is a low-level programming language that uses symbolic instructions.

Example:

MOV A, #25H

Meaning:

- Move value 25H into accumulator.

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**What is Embedded C?**

Embedded C is a programming language used for embedded systems and microcontrollers.

It is based on the C language but designed for:

- Hardware control
- Real-time applications
- Embedded programming

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**Advantages of Embedded C**

- Easier to write
- Easier to debug
- Faster development
- More readable programs

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**2.13 Interfacing Techniques**

**Definition**

Interfacing means connecting external devices to a microcontroller system.

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**Common Interfaced Devices**

| Device | Purpose |
|---|---|
| LED | Indication |
| Motor | Movement |
| Sensor | Input detection |
| Relay | Switching control |
| LCD | Display output |

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**Example: LED Interfacing**

Microcontroller sends signal to LED:

- Logic 1 → LED ON
- Logic 0 → LED OFF

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**2.14 Applications of 8051 Microcontroller**

8051 is used in:

- Traffic light systems
- Industrial automation
- Robotics

- Home automation
- Security systems
- Medical devices
- Communication systems

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**Advantages of 8051**

1. Low cost
2. Easy programming
3. Reliable operation
4. Compact size
5. Built-in peripherals

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**Disadvantages of 8051**

1. Limited memory
2. Lower processing speed
3. Limited modern features

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**Summary**

In this unit, we studied:

- Introduction to microcontrollers
- 8051 architecture
- CPU and registers
- Memory organization
- I/O ports
- Timers and counters
- Interrupt systems
- Serial communication
- Oscillator circuits

- 8051 programming
- Interfacing techniques

The 8051 microcontroller is very important in:

- Embedded systems
- Automation
- Robotics
- Industrial control systems

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