Chapter 1

The 8051 Microcontroller

1.1 INTRODUCTION

The microcontroller incorporates all the features that are found in microprocessor. The microcontroller has built in ROM, RAM, Input Output ports, Serial Port, timers, interrupts and clock circuit. A microcontroller is an entire computer manufactured on a single chip. Microcontrollers are usually dedicated devices embedded within an application. For example, microcontrollers are used as engine controllers in automobiles and as exposure and focus controllers in cameras. In order to serve these applications, they have a high concentration of on-chip facilities such as serial ports, parallel input output ports, timers, counters, interrupt control, analog-to-digital converters, random access memory, read only memory, etc. The I/O, memory, and on-chip peripherals of a microcontroller are selected depending on the specifics of the target application. Since microcontrollers are powerful digital processors, the degree of control and programmability they provide significantly enhances the effectiveness of the application. The 8051 is the first microcontroller of the MCS-51 family introduced by Intel Corporation at the end of the 1970s. The 8051 family with its many enhanced members enjoys the largest market share, estimated to be about 40%, among the various microcontroller architectures.

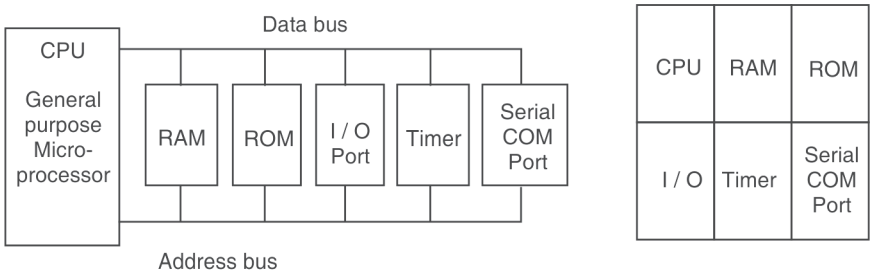
The microcontroller has on chip peripheral devices. In this unit firstly we differentiate microcontroller from microprocessor then we will discuss about Hardware details of 8051 and then introduce the Assembly level language in brief.

Microcontrollers

- Microcontroller (MC) may be called computer on chip since it has basic features of microprocessor with internal ROM, RAM, Parallel and serial ports within single chip. Or we can say microprocessor with memory and ports is called as microcontroller. This is widely used in washing machines, vcd player, microwave oven, robotics or in industries.

- Microcontroller can be classified on the basis of their bits processed like 8bit MC, 16bit MC.
- 8 bit microcontroller, means it can read, write and process 8 bit data. Ex. 8051 microcontroller. Basically 8 bit specifies the size of data bus. 8 bit microcontroller means 8 bit data can travel on the data bus or we can read, write process 8 bit data.

1.2 DIFFERENCE BETWEEN MICROCONTROLLER AND MICROPROCESSOR



(a) General-purpose microprocessor system (b) Microcontroller

Fig. 1.1 Structure of microprocessor and microcontroller

It is very clear from figure that in microprocessor we have to interface additional circuitry for providing the function of memory and ports, for example we have to interface external RAM for data storage, ROM for program storage, programmable peripheral interface (PPI) 8255 for the Input Output ports, 8253 for timers, USART for serial port. While in the microcontroller RAM, ROM, I/O ports, timers and serial communication ports are in built. Because of this it is called as "system on chip". So in micro-controller there is no necessity of additional circuitry which is interfaced in the microprocessor because memory and input output ports are inbuilt in the microcontroller. Microcontroller gives the satisfactory performance for small applications. But for large applications the memory requirement is limited because only 64 KB memory is available for program storage. So for large applications we prefer microprocessor than microcontroller due to its high processing speed.

1.3 CRITERIA FOR SELECTION OF A MICROCONTROLLER IN EMBEDDED SYSTEM

Criteria for selection of microcontroller in any embedded system is as following:

(a) Meeting the computing needs of task at hand efficiently and cost effectively
- Speed of operation
- Packing

- Power consumption
- Amount of RAM and ROM on chip
- No. of I/O pins and timers on chip
- Cost

(b) Availability of software development tools such as compiler, assembler and debugger.

1.4 MICROCONTROLLER 8051 ARCHITECTURE

It is 8-bit microcontroller, means MC 8051 can Read, Write and Process 8 bit data. This is mostly used microcontroller in the robotics, home appliances like mp3 player, washing machines, electronic iron and industries. Mostly used blocks in the architecture of 8051 are as follows:

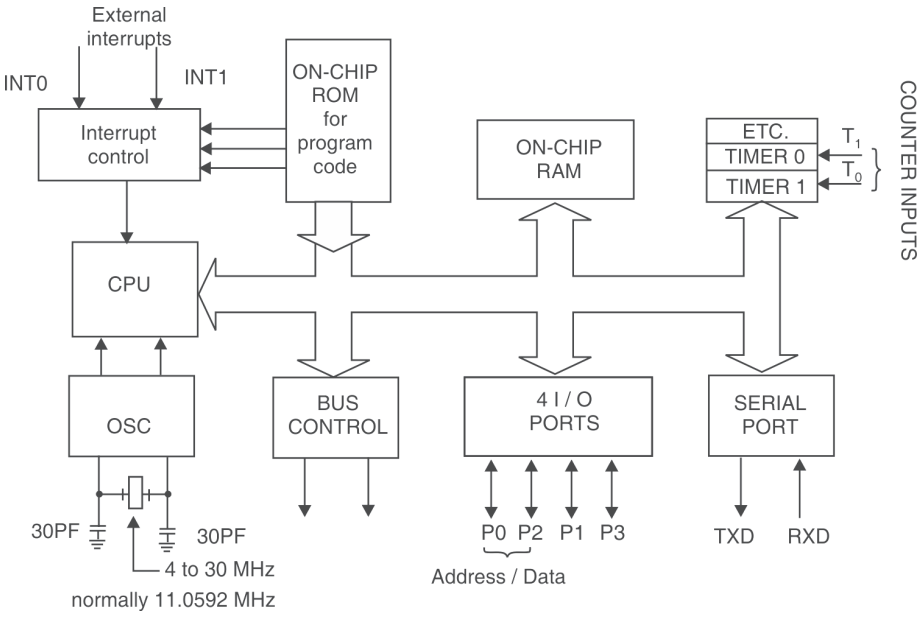


Fig. 1.2 8051 architecture

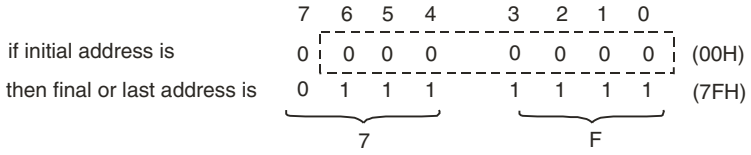
1.4.1 128 Byte RAM for Data Storage

MC 8051 has 128 byte Random Access memory for data storage. Random access memory is volatile memory. During execution for storing the data the RAM is used. RAM consists of the register banks, stack for temporary data storage. It also consists of some special function register (SFR) which are used for some specific purpose like timer, input output ports etc. Normally microcontroller has 256 byte RAM in which 128 byte is used for user space which is normally Register banks

and stack. But other 128 byte RAM which consists of SFRs. We will discuss the RAM in detail in next section.

Now what is the meaning of 128 byte RAM. What are address range which is provided for data storage. We will discuss here.

We know that 128 byte = 2^7 byte

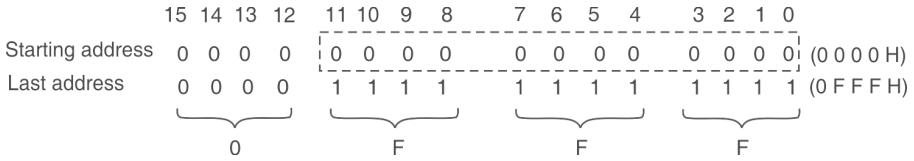


Since 2^7 bytes so last 7 bits can be changed so total locations are from 00H to 7F H. This procedure of calculating the memory address is called as **"*memory mapping*".** We can save data on memory locations from 00H to 7FH. Means total 128 byte space from 00H to 7FH is provided for data storage.

1.4.2 4KB ROM

- In 8051, 4KB read only memory (ROM) is available for program storage. This is used for permanent data storage. Or the data which is not changed during the processing like the program or algorithm for specific applications.
- This is non volatile memory; the data saved in this memory does not disappear after power failure.
- We can interface up to 64KB ROM memory externally if the application is large. These sizes are specified different by their companies.
- **Address Range of PC:** Address range of PC means program counter (which points the next instruction to be executing) can be moved between these locations or we can save the program from this location to this location. The address range can be calculated in the same way just like the RAM which is discussed in previous section.

$$4\text{KB} = 2^2 \cdot 2^{10}\,\text{B}\left(\text{since } 1\text{KB} = 2^{10}\,\text{B}\right)$$
$$= 2^{12}\,\text{Byte}$$



Address range of PC is 0000H to 0FFFH means total 4KB locations are available from 0000H to 0FFFH. At which we can save the program.

Difference between RAM and ROM

- RAM is used for data storage while ROM is used for program storage.
- Data of RAM can be changed during processing while data of ROM can't be changed during processing.
- We can take an example of calculator. If we want to perform addition of two numbers then we type the two numbers in calculator, this is saved in the RAM, but the Algorithms by which the calculation is performed is saved in the ROM. Data which is given by us to calculator can be changed but the algorithm or program by which calculation is performed can't be changed.

1.4.3 Timers and Counters

Timer means which can give the delay of particular time between some events. For example on or off the lights after every 2 sec. This delay can be provided through some assembly program but in microcontroller two hardware pins are available for delay generation. These hardware pins can be also used for counting some external events. How much times a number is repeated in the given table is calculated by the counter.

- In MC8051, two timer pins are available T0 and T1, by these timers we can give the delay of particular time if we use these in timer mode.
- We can count external pulses at these pins if we use these pins in counter mode.
- 16 bits timers are available. Means we can generate delay between 0000H to FFFFH.
- Two special function registers are available.

- If we want to load T0 with 16 bit data then we can load separate lower 8 bit in TL0 and higher 8 bit in TH0.
- In the same way for T1.
- TMOD, TCON registers are used for controlling timer operation.

1.4.4 Serial Port

- There are two pins available for serial communication TXD and RXD.
- Normally TXD is used for transmitting serial data which is in SBUF register, RXD is used for receiving the serial data.
- SCON register is used for controlling the operation.
- There are four modes of serial communication which has been discussed in next chapter.

1.4.5 Input Output Ports

- There are four input output ports available P0, P1, P2, P3.
- Each port is 8 bit wide and has special function register P0, P1, P2, P3 which are bit addressable means each bit can be set or reset by the Bit instructions (SETB for high, CLR for low) independently.
- The data at any port which is transmitting or receiving is in these registers.
- The port 0 can perform dual works. It is also used as Lower order address bus (A0 to A7) multiplexed with 8 bit data bus P0.0 to P0.7 is AD0 to AD7 respectively the address bus and data bus is demultiplex by the ALE signal and latch which is further discussed in details.
- Port 2 can be used as I/O port as well as higher order address bus A8 to A15.
- Port 3 also have dual functions it can be worked as I/O as well as each pin of P3 has specific function.

P3.0 – RXD – $\begin{cases}\text{Serial I / P for Asynchronous communication}\\ \text{Serial O / P for synchronous communication.}\end{cases}$

P3.1 – TXD – Serial data transmit.
P3.2 – INT0 – External Interrupt 0.
P3.3 – INT1 – External Interrupt 1.
P3.4 – T0 – Clock input for counter 0.
P3.5 – T1 – Clock input for counter 1.
P3.6 – WR – Signal for writing to external memory.
P3.7 – RD – Signal for reading from external memory.
When external memory is interfaced with 8051 then P0 and P2 can't be worked as I/O port they works as address bus and data bus, otherwise they can be accessed as I/O ports.

1.4.6 Oscillator

- It is used for providing the clock to MC8051 which decides the speed or baud rate of MC.
- We use crystal which frequency vary from 4MHz to 30 MHz, normally we use 11.0592 MHz frequency.

1.4.7 Interrupts

- Interrupts are defined as requests because they can be refused (masked) if they are not used, that is when an interrupt is acknowledged. A special set of events or routines are followed to handle the interrupts. These special routines are known as interrupt handler or interrupt service routines (ISR). These are located at a special location in memory.
- INT0 and INT1 are the pins for external interrupts.

1.5 PIN DIAGRAM OF 8051

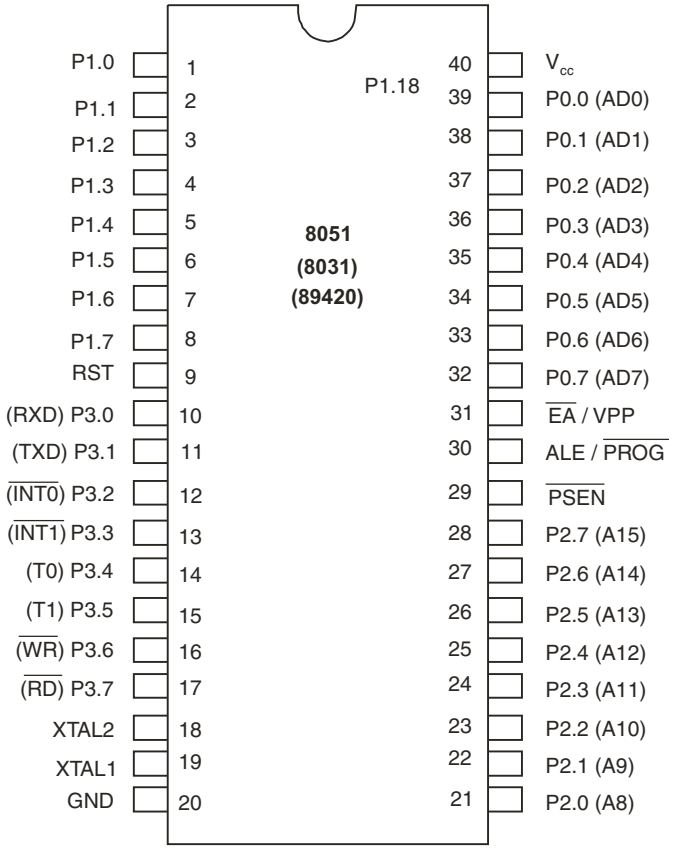


Fig. 1.3 Pin diagram of MC 8051

Description of each pin is discussed here:

- $V_{CC} \rightarrow$ 5V supply
- VSS $\rightarrow$ GND
- XTAL2/XTALI are for oscillator input
- Port 0 – 32 to 39 – AD0/AD7 and P0.0 to P0.7
- Port 1 – 1 to 8 – P1.0 to P1.7
- Port 2 – 21 to 28 – P2.0 to P2.7 and A 8 to A15
- Port 3 – 10 to 17 – P3.0 to P3.7
- P 3.0 – RXD – Serial data input – SBUF
- P 3.1 – TXD – Serial data output – SBUF
- P 3.2 – $\overline{\text{INT0}}$ – External interrupt 0 – TCON 0.1
- P 3.3 – $\overline{\text{INT1}}$ – External interrupt 1 – TCON 0.3
- P 3.4 – T0 – External timer 0 input – TMOD

- P 3.5 – T1 – External timer 1 input – TMOD
- P 3.6 – $\overline{WR}$ – External memory write cycle – Active LOW
- P 3.7 – $\overline{RD}$ – External memory read cycle – Active LOW
- RST – for Restarting 8051
- ALE – Address latch enable
  1 – Address on AD 0 to AD 7
  0 – Data on AD 0 to AD 7
- $\overline{PSEN}$ – Program store enable

1.6 ARCHITECTURE OF 8051

Figure 1.4 shows the architecture block diagram of 8051.

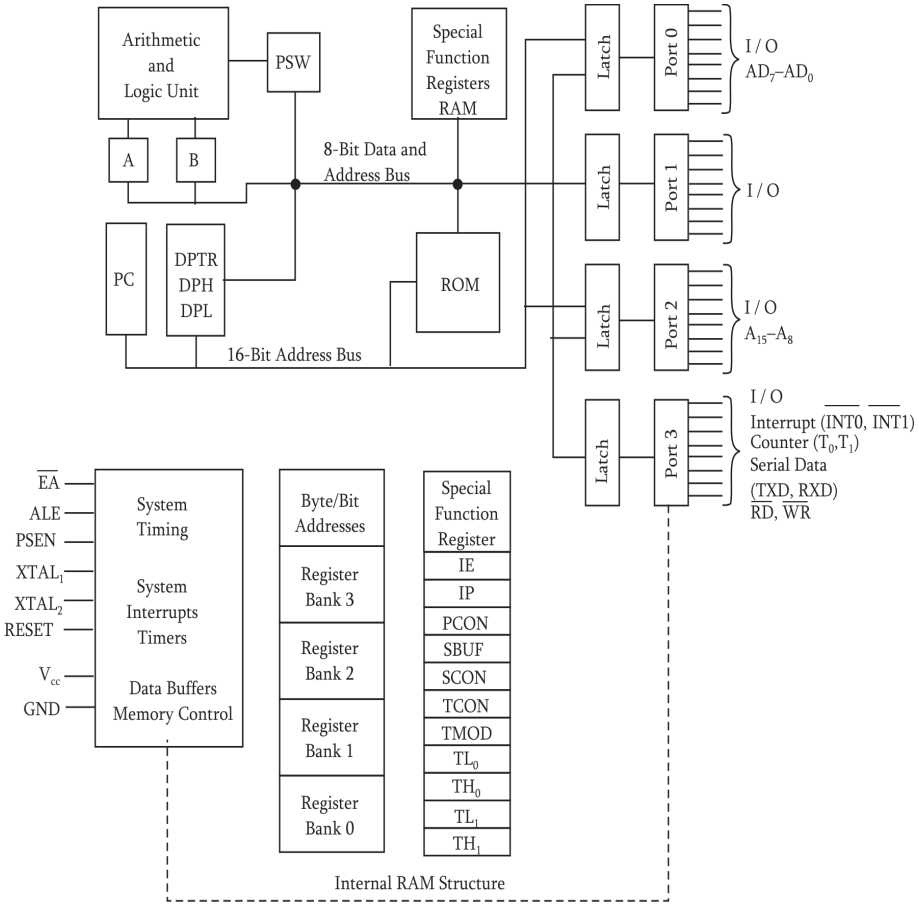


Fig. 1.4 Architectural block diagram of microcontroller 8051

Each block will be discussed step by step:

1.6.1 ALU — Arithmetic Logical Unit

This unit is used for the arithmetic calculations.

1.6.2 A-Accumulator

This register is used for arithmetic operations. This is also bit addressable and 8 bit register.

1.6.3 B-Register

This register is used in only two instructions MUL AB and DIV AB. This is also bit addressable and 8 bit register.

1.6.4 PC-Program Counter

• Points to the address of next instruction to be executed from ROM
• It is 16 bit register means the 8051 can access program address from 0000H to FFFFH. A total of 64KB of code. 16 bit register means.

Initial value	0000	0000	0000	0000	(0000H)
Final value	1111	1111	1111	1111	(FFFFH)

- Initially PC has 0000H
- ORG instruction is used to initialize the PC ORG 0000H means PC initialize by 0000H
- PC is incremented after each instruction.

Example 1:

Mnemonics	Machine codes
MOV R5, #25H	7D 25
MOV A, #00H	74 00
ADD A, R5	2D
HERE: SJMP HERE;	80 FE

- When 7D is accessed then PC locate the 0001H (next instruction to be executed)
- When 00 is accessed then PC locate the 0004H (next instruction to be executed)

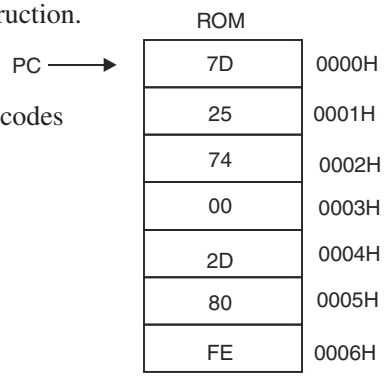


Fig. 1.5 ROM locations

1.6.5 ROM Memory Map in 8051

→ 4KB, 8KB, 16KB, 32KB, 64KB on chip ROM is available.

→ Max ROM space is 64 KB because 16 bit address line is available in 8051.

→ Starting address for ROM is 0000H (because PC which points the ROM is 16 bit wide).

Ex. For AT89C51 find the address range of ROM.
Sol.

4KB ROM = 2^2. 2^{10} = 2^{12}B
So 12 bits can be changed.

(0000H)	0000	0000	0000	0000	(Starting Address)
(0FFFH)	0000	1111	1111	1111	(Max Address)

Memory address from 0000H to 0FFFH.

1.6.6 8051 Flag Bits and PSW Register

→ Used to indicate the Arithmetic condition of ACC.
→ Flag register in 8051 is called as program status word (PSW). This special function register PSW is also bit addressable and 8 bit wide means each bit can be set or reset independently.

PSW0.7	PSW0.6	PSW0.5	PSW0.4	PSW0.3	PSW0.2	PSW0.1	PSW0.0
CY	AC	F0	RS1	RS0	OV	—	P

FLAG Register

There are four flags in 8051

- **P → Parity flag** → PSW 0.0
  1 – odd number of 1 in ACC
  0 – even number of 1 in ACC
- **OV(PSW 0.2) → overflow flag** → this is used to detect error in signed arithmetic operation. This is similar to carry flag but difference is only that carry flag is used for unsigned operation.
-

RS1(PSW0.4)	RS0(PSW0.3)	Register Bank Select
0	0	Bank 0
0	1	Bank 1
1	0	Bank 2
1	1	Bank 3

for selecting Bank 1, we use following commands
SETB PSW0.3 (means RS0=1)
CLR PSW0.4 (means RS1=0)

Initially by default always Bank 0 is selected.

- **F0** → user definable bit
- **AC → Auxiliary carry flag** → when carry is generated from D3 to D4, it is set to 1, it is used in BCD arithmetic.

```
        [1]     1
  0 0 0 0   1 1 1 0   (0EH)
+ 0 1 0 1   1 0 1 0   (5AH)
  ---------------
  0 1 1 0   1 0 0 0   (38H)
  ---------------
```