UNIT –I: INTRODUCTION TO MICROCONTROLLERS & MICROCONTROLLER 8051

Unit I: Introduction to Microcontrollers: *Introduction to Microcontrollers,Harvard vs Von Neumann Architectures, RISC & CISC Microcontrollers.*

Microcontroller 8051: *Overview of 8051 family, Key Features of 8051, block diagram of 8051 Microcontroller, Architecure of 8051, Pin Diagram & Memory organization of 8051*

Introduction:

A few decades ago the process and control operations were totally implemented by the Microprocessors only. But now the situation is totally changed and it is occupied by the new device called Microcontrollers. The development is so drastic that we can't find any electronic gadget without the use of a microcontroller. Any system that has a remote control, almost certainly contains a microcontroller, called an embedded system. This microcontroller changed the embedded system design so simple, cost effective and advanced.

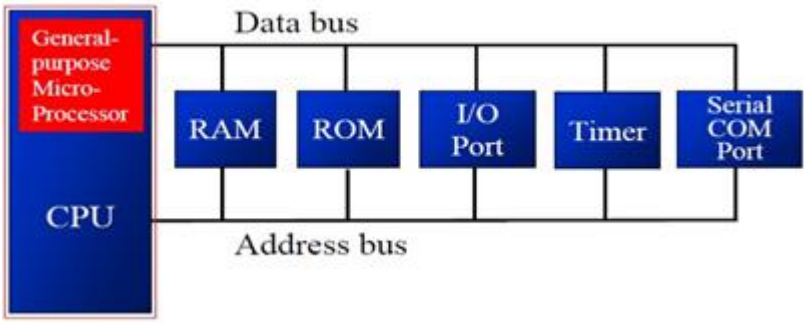
What is a Microcontroller?

A single chip computer or a CPU with all the peripherals like RAM, ROM, I/O Ports, Timers, ADCs etc.., on the same chip. For ex: Intel's 8051, PIC 16X

Comparison of Microprocessors & Microcontrollers

A Microprocessor is a general purpose microcomputer which does not have RAM, ROM and I/O ports (Fig (1)).ROM, RAM, I/O ports and Timers are added externally to a general purpose microprocessor, such as Pentium, to make it functional. This whole system is called as a computer. These additions make the system bulkier and more expensive. But microprocessor has advantages of versatility and multi-functional.

Ex: 8085, 8086 Microprocessors



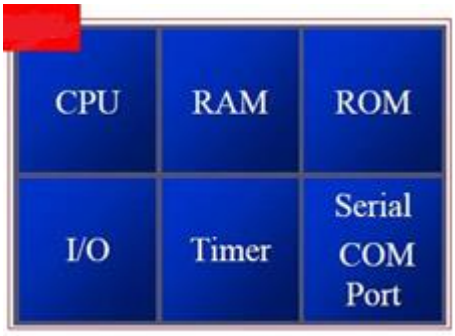


Fig (1) General-Purpose Microprocessor System **Fig (2) Microcontroller**

A Microcontroller has ROM, RAM, I/O ports, Timers and serial communication port on a single chip in addition to CPU. So there is no requirement for additional inclusions while developing an application. It is cheap, consumes very less power and the capability is very high.

Ex: Intel 8051, PIC family by Microchip, Atmel 89CXX, 89CXX51 Microcontrollers

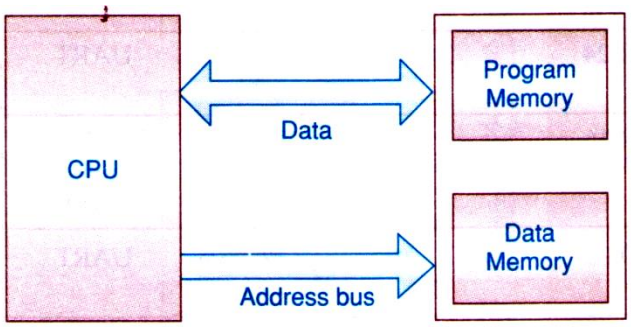
Distinguish between Microprocessor versus Microcontroller:

Microprocessor	Microcontroller
1. It is a General-purpose device. 2. It do not contain on-chip RAM, ROM, I/O ports, Timers, etc. 3. Microprocessor based system design is complex and expensive. 4. It has only byte addressable instructions. 5. It is used as a CPU of a computer system	1. It is a Single-purpose dedicated device. 2. It contains RAM, ROM, I/O ports, Timers, Including CPU on a single chip. 3. Microcontroller based system design is very simple and cost effective. 4. It has byte as well as bit addressable Instructions. 5. It is used as a controller in displays, modems, keyboards, motors etc.

Harvard and Von Neumann Architectures:

There are two major classes of Computer architectures, namely, **Harvard Architecture** and **Von Neumann (or Princeton) Architecture**

The Von-Neumann architecture is also known as Princeton architecture. This architecture consists of program memory (ROM) and data memory (RAM) on a single unit, thus they are connected by using single address and data bus as shown in Fig (1). For example Motorola 68HC11 µC and 8085 µP have Von Neumann architecture.



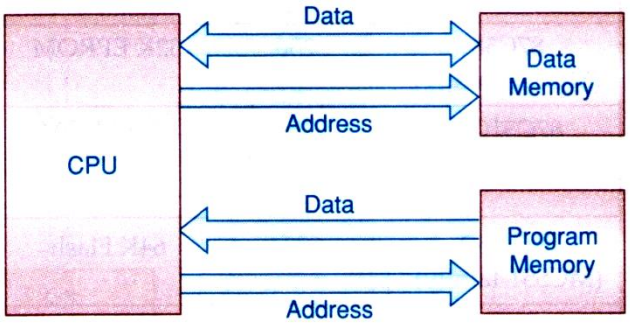


Fig (1) Von-Neumann (Princeton) Architecture **Fig (2) Harvard Architecture.**

Harvard architecture consists of Data memory (RAM) and Program memory (ROM) as separate units, thus they need to be connected using separate address and data bus to get fast execution speed as shown Fig (2). For example, the 8051 µC by Intel and PIC µC by microchip are based on Harvard architecture. Hence 8051 consists of two separate memory units, program memory as well as data memory.

RISC and CISC Microcontrollers:

The Microcontrollers with small instruction set are called **Reduced Instruction Set Computer (RISC) Machines.** Advantage of RISC is that because of the more simple instructions, hence lesser cost of production. And it is always easier to write optimized compilers, because of a smaller number of instructions. Microchip PIC 16F87X is an example of RISC machine.

The Microcontrollers with complex instruction set are called **Complex Instruction Set Computer (CISC) Machines**.. CISC Microcontrollers have large number of instructions. A larger instruction set helps assembly language programmers by providing flexibility to write effective and short programes. Intel 8051 µC is an example of CISC machine

Comparison of features of RISC and CISC machines.

RISC	CISC
1. Few instructions	1. Complex instruction set
2. Instructions executed by hardware	2.Instructions executed by micro program
3. Few addressing modes	3.Many addressing modes
4. Instruction takes one or two cycles	4. Instruction takes multiple cycles
5. Fixed format instructions	5.Variable format instructions
6. Most of them have multiple register banks	6. Single Register Bank.

Overview of 8051 family:

A brief history of the 8051:

In 1981, Intel Corporation introduced an 8-bit microcontroller called the 8051. This microcontroller had 128 bytes of RAM, 4K bytes of on-chip ROM, two timers, one serial port, and four ports (each 8-bits wide) all on a single chip. At the time it was also referred to as a "system on a chip." The 8051 is an 8-bit processor, meaning that the CPU can work on only 8 bits of data at a time. Data larger than 8 bits has to be broken into 8-bit pieces to be processed by the CPU. The

8051 has a total of four I/O ports, each 8 bits wide. Although the 8051 can have a maximum of 64K bytes of on-chip ROM, many manufacturers have put only 4K bytes on the chip.

Other members of the 8051 family

There are two other members in the 8051 family of microcontrollers. They are the 8052 and the 8031.

8052 microcontroller

The 8052 is another member of the 8051 family. The 8052 has all the standard features of the 8051 as well as an extra 128 bytes of RAM and an extra timer. In other words, the 8052 has 256 bytes of RAM and 3 timers. It also has 8K bytes of on-chip program ROM instead of 4K bytes. See Table 1

8031 microcontroller:

Another member of the 8051 family is the 8031 chip. This chip is often referred to as a ROM-less 8051 since it has OK bytes of on-chip ROM. To use this chip you must add external ROM to it. This external ROM must contain the program that the 8031 will fetch and execute.

Comparison of 8051 family members:

Feature	8051	8052	8031
ROM (on-chip program space in bytes)	4K	8K	0K
RAM (bytes)	128	256	128
Timers	2	3	2
I/O pins	32	32	32
Serial port	1	1	1
Interrupt sources	6	8	6

AT89C51 from Atmel Corporation:

The Atmel Corp. has a wide selection of 8051 chips, as shown in Table 1 For example, the AT89C51 is a popular and inexpensive chip used in many small projects. It has 4K bytes of flash ROM. Notice the AT89C51-12PC, where "C" before the 51 stands for CMOS, which has low power consumption, "12" indicates 12 MHz, "P" is for plastic DIP package, "C" is for commercial.

Table 1: **Versions of 8051 from Atmel (All ROM Flash)**

Part Number	ROM	RAM	I/O pins	Timer	Interrupt	V_{CC}	Packaging
AT89C51	4K	128	32	2	6	5V	40
AT89LV51	4K	128	32	2	6	3V	40
AT89C1051	1K	64	15	1	3	3V	20
AT89C2051	2K	128	15	2	6	3V	20
AT89C52	8K	128	32	3	8	5V	40
AT89LV52	8K	128	32	3	8	3V	40

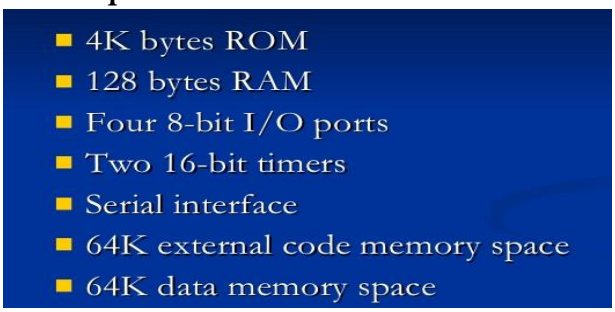
Microcontroller 8051:

The **Intel MCS-51** (commonly referred to as Microcontrollers **8051**) is single chip microcontroller (µC) which was developed by Intel in 1981 for use in embedded systems. Intel's original 8051 was developed using NMOS technology, but later versions e.g., 80C51 used CMOS technology and consume less power than their NMOS predecessors. This made them more suitable for battery-powered devices. It a 40 pin DIP IC.

Features of Intel 8051 Microcontroller:

- 8 bit CPU
- Operating frequency is 11.0592MHz
- On-chip clock oscillator
- 4K bytes of on-chip Program Memory(ROM)
- 128 bytes of on-chip Data Memory (RAM)
- 64K external Program Memory address space
- 64K external Data Memory address space

Important Features of Intel 8051



- 16 bit address bus multiplexed with port 0 and port 2 and 8-bit data bus multiplexed with port 0
- 32 bidirectional I/O line can be either used as four 8 bit ports or 32 individually addressable I/O Lines
- Two 16-bit timer/counters T_0 and T_1
- It has 21 special function registers (SFRs).
- 5-vector interrupts (2 external and 3 internal).
- 4- Ports, each of 8-bits (PORT0, PORT1, PORT2, PORT3) with a total of 32 I/O lines.
- One full duplex serial communication port.
- Bit as well as Byte addressable capabilities.

Block diagram of 8051 Microcontroller: The typical block diagram of 8051 Microcontroller is shown in fig. 1. The function of each block is explained below:

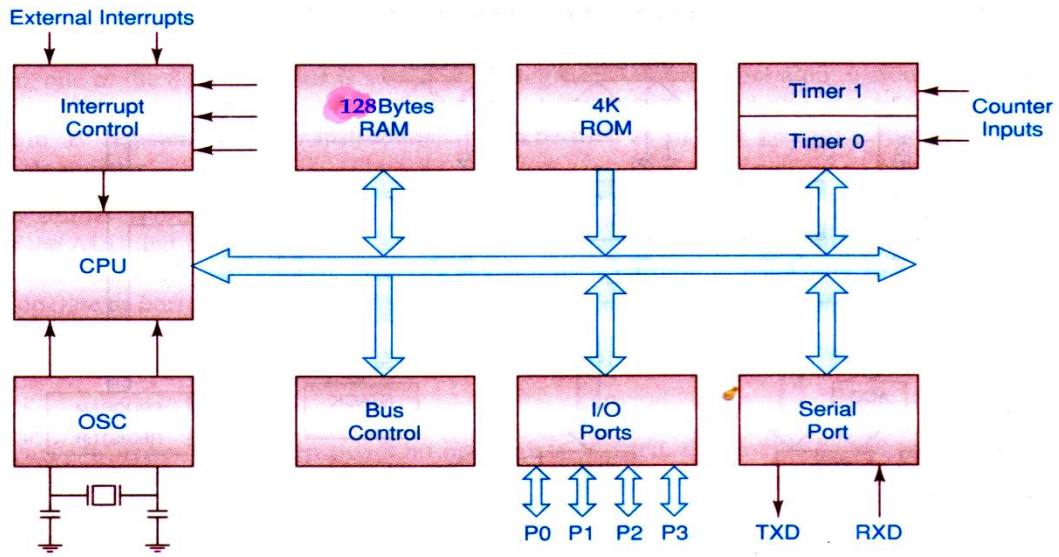


Fig (1) Block diagram of typical 8051Microcontroller

1. Central Processing Unit (CPU): It is capable of performing arithmetic and logical operations Like addition, subtraction, multiplication, division, logical AND, OR, EX-OR, rotate, clear and compliment. The CPU can do Bit as well as Byte wise manipulations.

2. Memory Units: The CPU of 8051 requires Program Codes and Data while performing a task. Thus, it has two types of internal memories called i-RAM and i-ROM.

The i-RAM is of 128 bytes. It is divided into 3 parts, such as

(i) 32 registers in 4 banks of 8 each.
(ii) 16 registers – bit addressable
(iii) 80 registers – byte addressable.

The i-ROM is of 4 KB in size ranging from 0000H to 0FFFH.

3. Timers/Counters: It has two 16-bit Timers/Counters called T0 and T1. Timers are used in maintaining time delays between the actions occurred inside the µC and Counters are used to count the external events occurred outside the µC.

4. Serial Port: It provides serial data transfer while accessing with some peripherals like Printer etc.

5. Interrupt Control: This unit alters the controller's attention from one task to some other. It may happen whenever an Interrupt input become active. Interrupts may generate inside of the 8051 or provide from the external sources.

6. I/O Ports: It has four 8-bit I/O ports called P0, P1, P2 and P3. These ports can be configured as an input or output ports. In addition port P3 performs some other functions.

Oscillator and Clock: In order to synchronize all the internal operations of the controller an on-chip oscillator is used. Since 8051 operates at 11.0592MHz. A crystal can be connected between XTAL1 and XTAL2 usually 11.0592MHz.

Architecture of 8051 Microcontroller:

The functional block of the internal operations of 8051 Microcontroller is shown in Fig (1). It includes ALU, Instruction decoder and timing generation unit, Accumulator, B-register and Program Status Word (PSW) register, Status (PSW) register, Data Pointer (DPTR), Program Counter (PC) and Stack Pointer (SP).

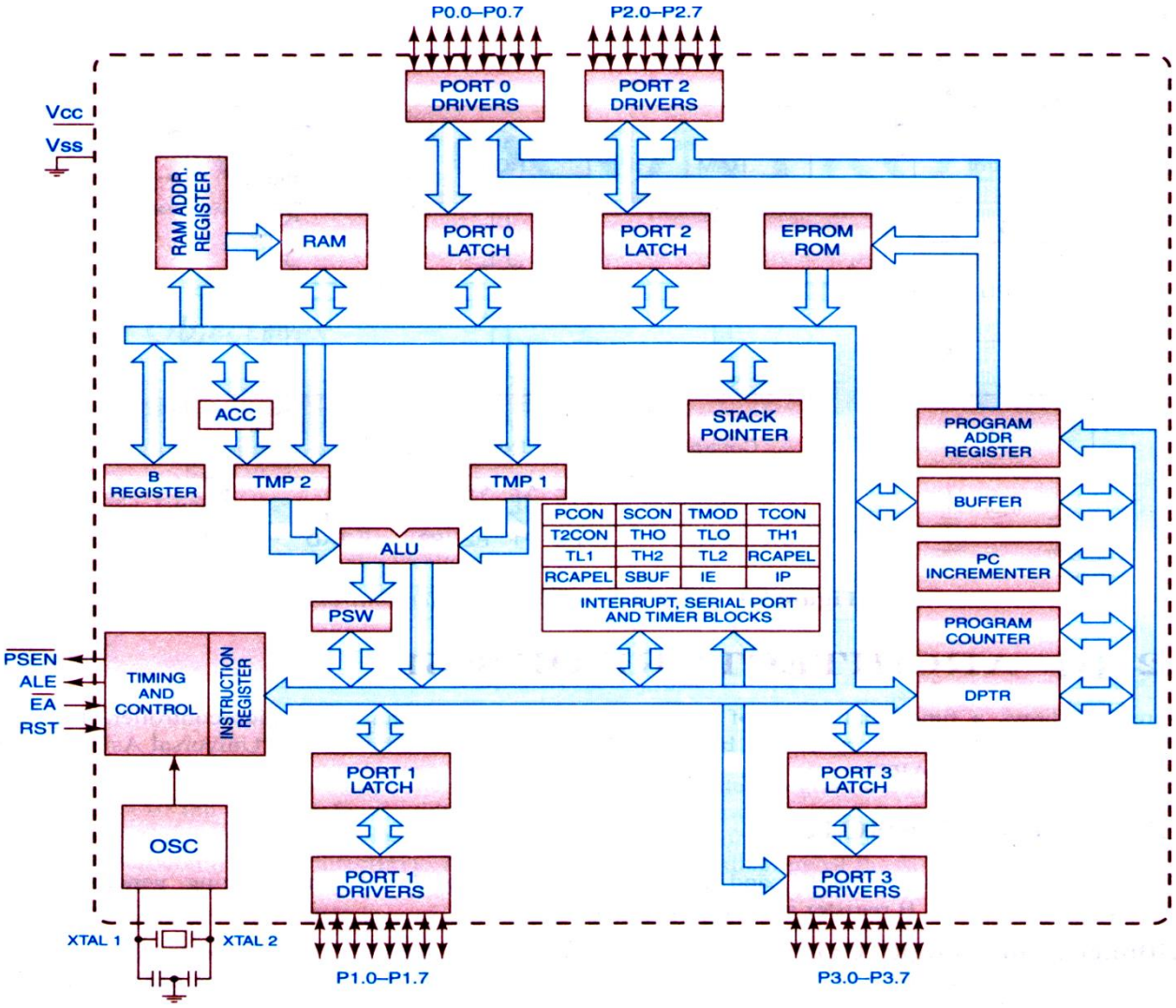


Fig (1) Architecture of 8051 Microcontroller

ALU (Arithmetic and Logic Unit): ALU of 8051 Microcontroller performs Arithmetic and Logical Operations on 8 bit operands.

Register A: It is called as Accumulator. Accumulator (A) is an 8-bit register to save an operand for an ALU and it also stores the result after an ALU operation. It is also used in data transfer between 8051 and external memory.

Register B: Register B is an 8-bit register to save a second operand for an ALU and also store the result after ALU operation for Multiplication and Division

PC (Program Counter): It is a 16 bit register. It is used to store address of the next instruction to be executed.

DPTR (Data Pointer): It is a 16 bit register. It is used to store 16 bit data. It also store 16 bit address of external memory.

Stack Pointer (SP): It is an 8-bit register. It holds the address of the data byte currently on the top of the stack. It is incremented during PUSH and CALL and decremented during POP and RET. operations.

Program Status Word (PSW): It is an 8 bit register. It contains Carry, Auxiliary carry, parity; overflow and user define flags, which are change after arithmetic and logical instruction. It also contains register bank selection bits. It is a bit addressable register.

Internal memory & External memory: Internal RAM is 128 byte and ROM is 4KB called program memory. Internal RAM divided into 3 parts: 32 bytes for register bank (four register banks, each contain 8 registers of 1 byte) (00-1FH), 16 bit addressable area where we can access individual bits (20-2FH), 80 bytes for scratch pad RAM area (30-7FH).We connect 64KB of external memory with 8051.

Special Function Registers (SFR): It has 21 SFRs. For Example SP, PSW,A, B, SCON,TCON, SMOD, SBUF,PCON, TLO,THO, TL1,TH1 are called SFRs. Some are byte addressable and some are byte as well as bit addressable. SFRs are used for control or to show the status of various functions. All SFRs have 8-bit address.

I/O Ports: It has four 8-bit I/O ports called P0, P1, P2 and P3. These ports can be configured as an input or output ports. In addition port P3 performs some other functions.

Timers/Counters: It has two 16-bit Timers/Counters called T0 and T1. Timers are used in maintaining time delays between the actions occurred inside the μC and Counters are used to count the external events occurred outside the μC.

Serial Port: It provides serial data transfer while accessing with some peripherals like Printer etc.

Interrupt Control: This unit alters the controller's attention from one task to some other. It may happen whenever an Interrupt input become active. Interrupts may generate inside of the 8051 or provide from the external sources.

Oscillator and Clock: In order to synchronize all the internal operations of the controller an on-chip oscillator is used. Since 8051 operates at 11.0592MHz. A crystal can be connected between XTAL1 and XTAL2 usually 11.0592MHz.

Pin Diagram of Intel 8051 Microcontroller

The 8051 microcontroller is available as a 40 pin DIP chip and it works at +5 volts DC. Among the 40 pins, a total of 32 pins are allotted for the four parallel ports P0, P1, P2 and P3 i.e. each port occupies 8-pins. The remaining pins are VCC, GND, XTAL1, XTAL2, RST, EA, PSEN and ALE.

Pin details of 8051:

Pins 1-8: P1.0 – P1.7: A total of 8 pins named as Port 1. These 8-pins are dedicated for Port 1 to perform input or output port operations.

Pin 9: RESET: The RESET pin is an input pin and it is an active high pin. When a high pulse is applied to this pin the microcontroller will reset and terminate all activities. Upon reset all the registers except stack will reset to 0000 and stack will reset to 07 value.

Pins10-17: P3.0 – P3.7: A total of 8 pins named as Port 3. These 8-pins are meant for Port3 operations and also for some control operations like Read, Write, Timer 0, Timer1, INT0, INT1, RxD and TxD

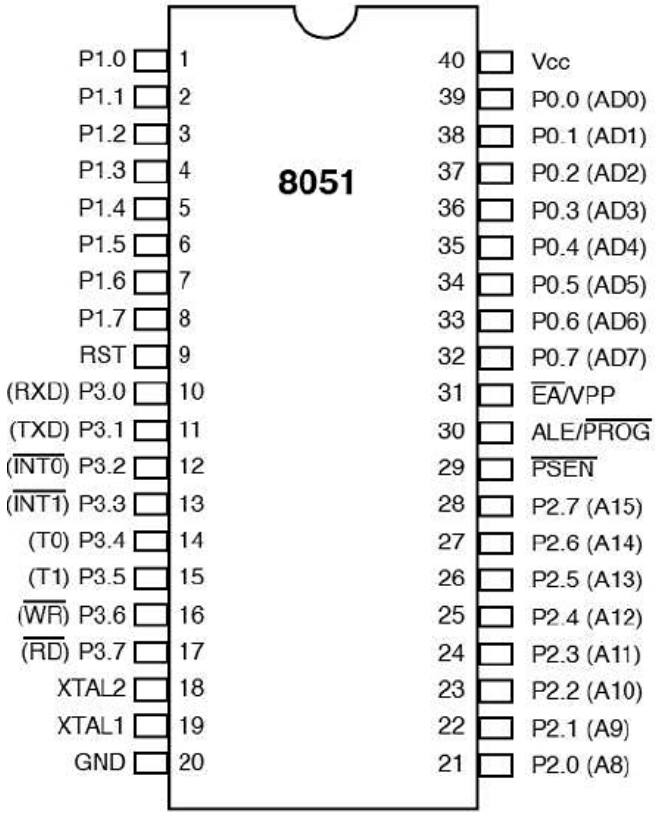


Fig.(1). Pin diagram of Intel 8051 µC

Pin 18, 19: XTAL1, XTAL2: These two pins are connected to Quartz crystal oscillator which runs the on-chip oscillator. The quartz crystal oscillator is connected to the two pins along with a capacitor of 30pF as shown in the circuit. If we use a source other than the crystal oscillator, it will be connected to XTAL1 and XTAL2 is left unconnected.

Pin 20: This is a Ground pin for the power supply.

Pin 21-28: P2.0 – P2.7: A total of 8 pins named as Port 2. The port2 pins are multiplexed with the higher order address pins (AD_8 – AD_{15}). When the microcontroller is accessing external memory these pins provide the higher order address byte otherwise they act as Port 2 pins.

Pin 29: *PSEN* (Program Store Enable): This is an output pin which is active low. When the microcontroller is accessing the program code stored in the external ROM, this pin is connected to the OE (Output Enable) pin of the ROM.

Pin 30: ALE (Address Latch Enable): This is an output pin, which is active high. When connected to external memory , port 0 provides both address and data i.e address and data are multiplexed through Port 0 .This ALE pin will de-multiplex the address and data bus .When the pin is High , the AD bus will act as address bus otherwise the AD bus will act as Data bus.

Pin 31: *EA* (External Access): This pin is **an** active low pin. This pin is connected to ground when microcontroller is accessing the program code stored in the external memory and connected to Vcc when it is accessing the program code in the On Chip memory. This pin should not be left unconnected.

Pin 32-39: A total of 8 pins named as Port 0. The port 0 pins multiplexed with Address/data pins. If the microcontroller is accessing external memory these pins will act as address/data pins otherwise they are used for Port 0 pins.

Pin 40: Vcc: This is a +5V power supply pin.

Memory Organization of 8051 Microcontroller:

The 8051 Microcontroller has 64K external data memory, 64K program memory and 256 bytes of internal data memory.

Program Memory: The program memory map of 8051 Microcontroller is shown in Fig (1). The 64K program memory space of 8051 is divided into internal and external memory.

- ✓ If the $\overline{EA}$ is high ($\overline{EA}$ = 1), then 8051 executes from the internal program memory 0000H through 0FFFH. After that, locations 1000H through FFFFH are executed from external memory.
- ✓ If the $\overline{EA}$ is Low ($\overline{EA}$ = 0), then 8051 Microcontroller executes instructions from External memory only. Table1 shows this.

Table 1: Program memory of 8051 & Program Execution

Status of $\overline{EA}$ pin	*Program execution from 0000H through 0FFFH*	*Program execution from 1000H through 0FFFFH*
High (1)	Internal program memory	External program memory
Low (0)	External program memory	External program memory

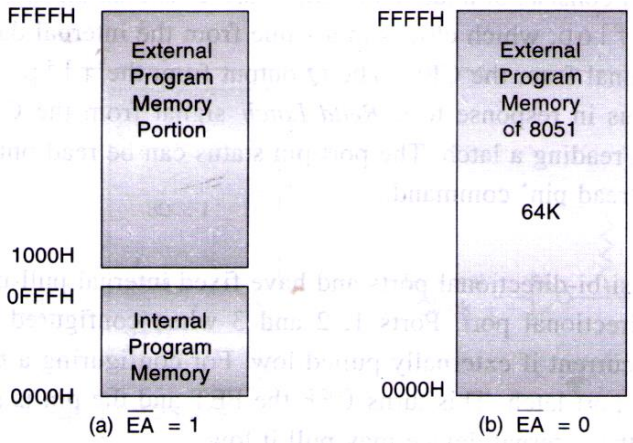


Fig (1) Program memory of 8051

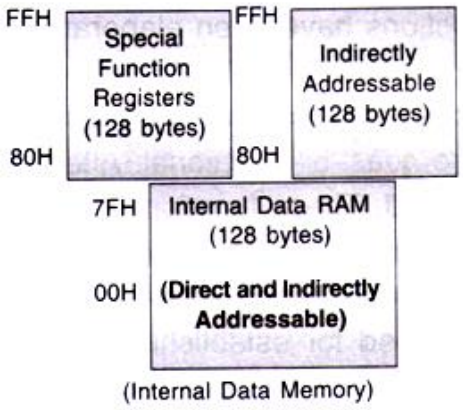
Data Memory: Fig (2) shows the internal and external data memory map of 8051 Microcontroller.

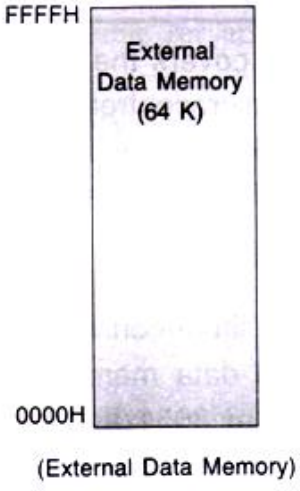
The External 64K data memory from 0000H through FFFFH can be accessed using MOVX instruction

The internal data memory of 8051 is 256 bytes, which is divided into two parts again. The lower 128 bytes between 00H and 7FH called as the internal data RAM and the upper 128 bytes between 80H and FFH consists of special function registers (SFRs).

- ✓ The internal data RAM between 00H and 7FH i.e., lower 128 bytes can be directly and indirectly addressable by an instruction.
- ✓ The internal data RAM between 00H and 1FH out of the 00H to 07FH has 32 bytes, which define 4 register sets, called Banks. Each bank (Bank 0, 1,2 & 3) is selected by first assigning the RS0 & RS1, bits B3 and B4 in the PSW. These 32 bytes are not used for the bit operations with Boolean processor and for bit transfers.

- ✓ Internal data RAM bits between 20H and 2FH out of 00H and 7FH has 16 bytes, which also define128 bytes(16 X 8 = 128 bits) with bit addresses 00H to FFH. A bit address is used in bit operations with Boolean processor and for bit transfers.
- ✓ Internal RAM between 30H and 7FH out of the 00H and 7FH has 80 bytes, which is only accessible by the address of the byte and is not used in bit operation with Boolean processor and for bit transfer.





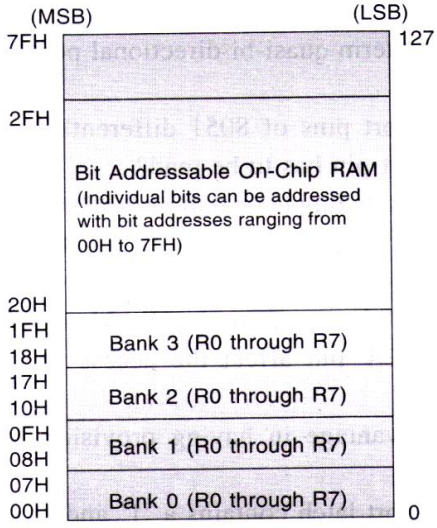


Fig (2) Internal & External Data memory of 8051 **Fig (3) On-Chip RAM (Lower 128 bytes)**

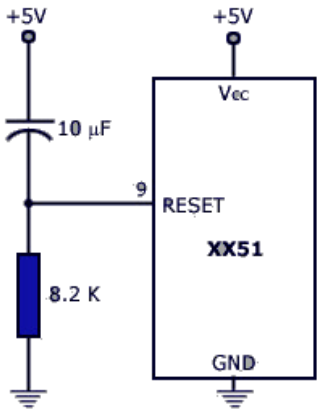
Reset Circuit of 8051 Controller:

RESET is an active High input When RESET is set to High, 8051 goes back to the power on state. The 8051 is reset by holding the **RST** high for at least **two machine cycles** and then returning it low.

There are two method of reset circuit:

1. Power on Reset. Initially charging of capacitor makes RST High. When capacitor charges fully it blocks DC.

2. Manual Reset: closing the switch momentarily will make RST High.



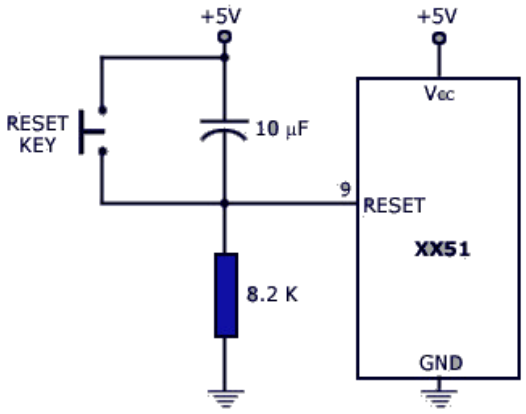


Fig (1) Power on Reset Circuit **Fig (2) Manual Reset Circuit**

After a reset, the **program counter is loaded with 0000H** but the content of on-chip RAM is not affected.

Register	Content
Program counter	0000h
Accumulator	00h
B register	00h
PSW	00h
SP	07h
DPTR	0000h
All ports	FFh

Note: content of on-chip RAM is not affected by Reset.

Oscillator Circuit of 8051 Microcontroller:

The 8051 has an on-chip oscillator. It needs an external crystal that decides the operating frequency of the 8051.

This can be achieved in two ways.

- ✓ The **crystal** is connected to pins 18 and 19 with stabilizing capacitors. 12 MHz (11.059MHz) crystal is often used and the capacitance ranges from 20pF to 40pF.
- ✓ The oscillator can also be a **TTL** clock source connected with a NOT gate as shown.