3.1 FUNCTIONAL BUILDING BLOCKS & HARDWARE ARCHITECTURE

Introduction :

A decade back the process and control operations were totally implemented by the Microprocessors only. But now a days the situation is totally changed and it is occupied by the new devices called Microcontroller. The development is so drastic that we can't find any electronic gadget without the use of a microcontroller. This microcontroller changed the embedded system design so simple and advanced that the embedded market has become one of the most sought after for not only entrepreneurs but for design engineers also.

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: Motorola's 6811, Intel's 8051, Zilog's Z8 and PIC 16X etc…

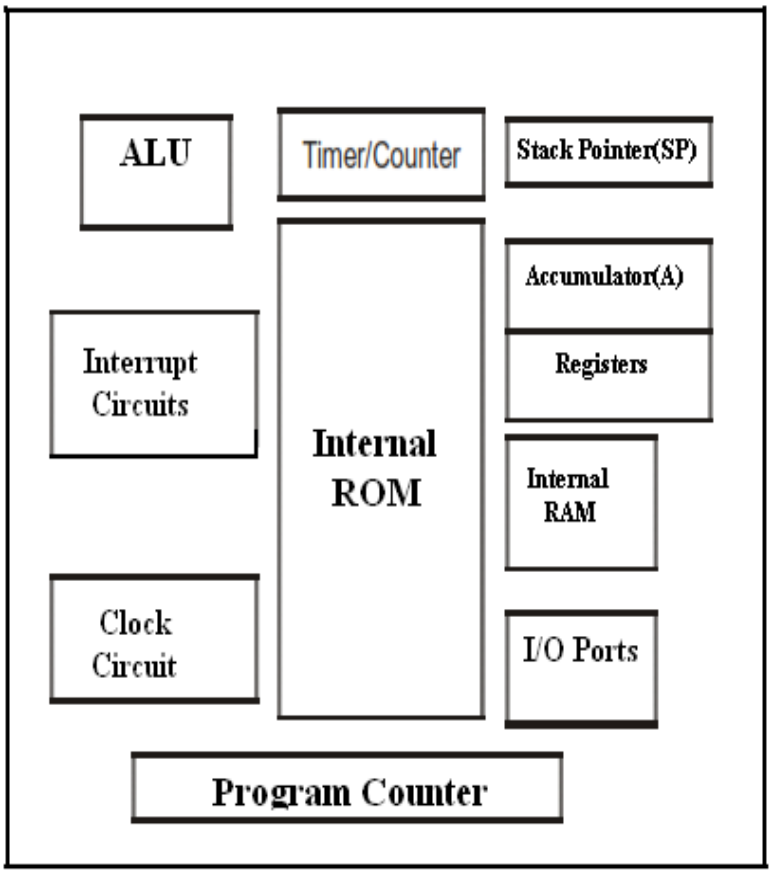

Figure 3.1.1 Block Diagram of a Microcontroller

[Source: "Microprocessor Architecture Programming and Application" by R.S. Gaonkar, page-]

S.No	Microprocessor	Microcontroller
1	A microprocessor is a general purpose device which is called a CPU	A microcontroller is a dedicated chip which is also called single chip computer.
2	A microprocessor do not contain onchip I/Ports, Timers, Memories etc..	A microcontroller includes RAM, ROM, serial and parallel interface, timers, interrupt circuitry (in addition to CPU) in a single chip.
3	Microprocessors are most commonly used as the CPU in microcomputer systems	Microcontrollers are used in small, minimum component designs performing control-oriented applications.
4	Microprocessor instructions are mainly nibble or byte addressable	Microcontroller instructions are both bit addressable as well as byte addressable.
5	Microprocessor instruction sets are mainly intended for catering to large volumes of data.	Microcontrollers have instruction sets catering to the control of inputs and outputs.
6	Microprocessor based system design is complex and expensive	Microcontroller based system design is rather simple and cost effective
7	The Instruction set of microprocessor is complex with large number of instructions.	The instruction set of a Microcontroller is very simple with less number of instructions. For, ex:

		PIC microcontrollers have only 35 instructions.
8	A microprocessor has zero status flag	A microcontroller has no zero flag.

Evolution of Microcontrollers :

The first microcontroller TMS1000 was introduced by Texas Instrumentsin the year 1974. In the year 1976, Motorola designed a Microprocessor chip called 6801 which replaced its earlier chip 6800 with certain add-on chips to make a computer. This paved the way for the new revolution in the history of chip design and gave birth to a new entity called "Microcontroller". Later the Intel company produced its first Microcontroller 8048 with a CPU and 1K bytes of EPROM, 64 Bytes of RAM an 8-Bit Timer and 27 I/O pins in 1976. Then followed the most popular controller 8051 in the year 1980 with 4K bytes of ROM,128 Bytes of RAM , a serial port, two 16-bit Timers , and 32 I/O pins. The 8051 family has many additions and improvements over the years and remains a most acclaimed tool for today's circuit designers. INTEL introduced a 16 bit microcontroller 8096 in the year 1982 . Later INTEL introduced 80c196 series of 16-bit Microcontrollers for mainly industrial applications. Microchip, another company has introduced an 8-bit Microcontroller PIC 16C64 in the year 1985.The 32-bit microcontrollers have been developed by IBM and Motorola. MPC 505 is a 32-bit RISC controller of Motorola. The 403 GA is a 32 -bit RISC embedded controller of IBM.
In recent times ARM company (Advanced RISC machines) has developed and introduced 32 bit controllers for high-end application devices like mobiles , Ipods .

Microcontroller Development Tools:

To develop an assembly language program we need certain program development tools. An assembly language program consists of Mnemonics which are nothing but short abbreviated English instructions given to the controller.The various development tools required for Microcontroller programming are explained below.

1. Editor :

An Editor is a program which allows us to create a file containing the assembly language statements for the program. Examples of some editors are PC write Wordstar.

As we type the program the editor stores the ACSII codes for the letters and numbers in successive RAM locations. If any typing mistake is done editor will alert us to correct it. If we leave out a program statement an editor will let you move everything down and insert a line. After typing all the program we have to save the program . This we call it as source file. The next step is to process the source file with an assembler.

Ex: Sample. asm

2.Assembler :

An Assembler is used to translate the assembly language mnemonics into machine language(i.e binary codes). When you run the assembler it reads the source file of your program from where you have saved it. The assembler generates a filee with the extension .hex. This file consists of hexadecimal values encoding a sequence of data and their starting offset or absolute address.

3.Compiler : A compiler is a program which converts the high level language program like "C" into binary or machine code. Using high level languages it is easy to manage complex data structures which are often required for data manipulation. Because of its ease , flexibility and debug options now a days the compilers have become very popular in the market. Compilers like Keil ,Ride and IAR workbench are very popular.

3. Debugger/Simulator :

A debugger is a program which allows execute the program, and troubleshoot or debug it. The debugger allows to look into the contents of registers and memory locations after the program runs. We can also change the contents of registers and memory locations and rerun the program. Some debuggers allows to stop the program after each instruction so that you can check or alter memory and register contents. This is called single step debug. A debugger also allows to set a breakpoint at any point in the program. If we insert a break point , the debugger will run the program up to the instruction where the breakpoint is put and then stop the execution.

A simulator is a software program which virtually executes the instructions similar to a microcontroller and shows the results. This will help in evaluating the results without committing any errors. By doing so we can detect the possible logic errors.

INTEL 8051 Micrcontroller :

The 8051 microcontroller is a very popular 8-bit microcontroller introduced by Intel in the year 1981 and it has become almost the academic standard now a days. The 8051 is based on an 8-bit CISC core with Harvard architecture. Its 8-bit architecture is optimized for control applications with extensive Boolean processing. It is available as a 40-pin DIP chip and works at +5 Volts DC. The salient features of 8051 controller are given below.

Salient Features :

The salient features of 8051 Microcontroller are

i. 4 KB on chip program memory (ROM or EPROM)).

ii. 128 bytes on chip data memory(RAM).

iii. 8-bit data bus

iv. 16-bit address bus

v. 32 general purpose registers each of 8 bits

vi. Two -16 bit timers T0 and T1

vii. Five Interrupts (3 internal and 2 external).

ix. Four Parallel ports each of 8-bits (PORT0, PORT1,PORT2,PORT3) with a total of 32 I/O lines.

x. One 16-bit program counter and One 16-bit DPTR (data pointer)

xi. One 8-bit stack pointer

xii. One Microsecond instruction cycle with 12 MHz Crystal.

xiii. One full duplex serial communication port.

Architecture & Block Diagram of 8051 Microcontroller:

The architecture of the 8051 microcontroller can be understood from the block diagram. It has Harward architecture with RISC (Reduced Instruction Set Computer) concept. The block diagram of 8051 microcontroller is shown in Fig 3. below1.It consists of an 8-bit ALU, one 8-bit PSW(Program Status Register), A and B registers , one 16-bit Program counter , one 16-bit Data pointer register(DPTR),128 bytes of RAM and 4kB of ROM and four parallel I/O ports each of 8-bit width. 8051 has 8-bit ALU which can perform all the 8-bit arithmetic and logical operations in one machine cycle. The ALU is associated with two registers A & B

A and B Registers:

The A and B registers are special function registers which hold the results of many arithmetic and logical operations of 8051.The A register is also called the Accumulator and as it's name suggests, is used as a general register to accumulate the results of a large number of instructions. By default it is used for all mathematical operations and also data transfer operations between CPU and any external memory.

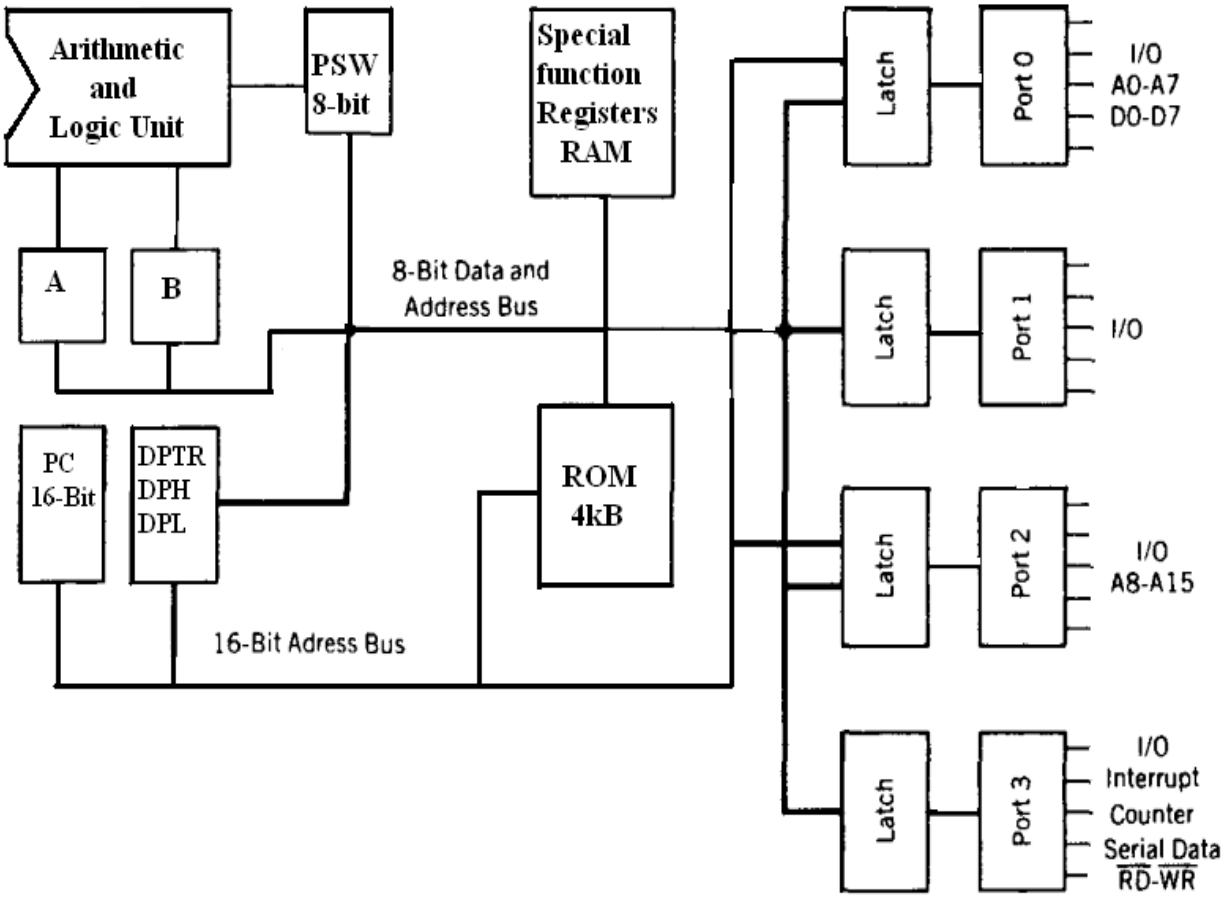

Figure 3.1.2 Block Diagram of 8051 Microcontroller

[Source: "Microprocessor Architecture Programming and Application" by R.S. Gaonkar, page-]

The R registers:

The "R" registers are a set of eight registers that are named R0, R1, etc. up to and including R7. These registers are used as auxiliary registers in many operations. The "R" registers are also used to temporarily store values.

Program Counter(PC):

8051 has a 16-bit program counter. The program counter always points to the address of the next instruction to be executed. After execution of one instruction the program counter is incremented to point to the address of the next instruction to be

executed. It is the contents of the PC that are placed on the address bus to find and fetch the desired instruction. Since the PC is 16-bit width ,8051 can access program addresses from 0000H to FFFFH, a total of 6kB of code.

Stack Pointer Register (SP) : It is an 8-bit register which stores the address of the stack top. i.e the Stack Pointer is used to indicate where the next value to be removed from the stack should be taken from. When a value is pushed onto the stack, the 8051 first increments the value of SP and then stores the value at the resulting memory location. Similarly, when a value is popped off the stack, the 8051 returns the value from the memory location indicated by SP, and then decrements the value of SP. Since the SP is only 8-bit wide it is incremented or decremented by two. SP is modified directly by the 8051 by six instructions: PUSH, POP, ACALL, LCALL, RET, and RETI. It is also used intrinsically whenever an interrupt is triggered.

STACK in 8051 Microcontroller:

The stack is a part of RAM used by the CPU to store information temporarily. This information may be either data or an address. The CPU needs this storage area as there are only limited number of registers. The register used to access the stack is called the Stack pointer which is an 8-bit register. So, it can take values of 00 to FF When the8051 is powered up, the SP register contains the value 07.i.e the RAM location value 08 is the first location being used for the stack by the 8051 controller

There are two important instructions to handle this stack.One is the PUSH and the Other is the POP. The loading of data from CPU registers to the stack is done by PUSH and the loading of the contents of the stack back into aCPU register is done by POP.

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EX:  MOV R6 ,#35 H
     MOV R1 ,#21 H
     PUSH 6
     PUSH 1
```

In the above instructions the contents of the Registers R6 and R1 are moved to stack and they occupy the 08 and 09 locations of the stack. Now the contents of the SP are incremented by two and it is 0A

Similarly, POP 3 instruction pops the contents of stack into R3 register. Now the contents of the SP is decremented by 1

In 8051 the RAM locations 08 to 1F (24 bytes) can be used for the Stack.In any program if we need more than 24 bytes of stack ,we can change the SP point to RAM locations 30-7F H.this can be done with the instruction MOV SP,# XX.

Data Pointer Register(DPTR):

It is a 16-bit register which is the only user-accessible. DPTR, as the name suggests, is used to point to data. It is used by a number of commands which allow the 8051 to access external memory. When the 8051 accesses external memory it will access external memory at the address indicated by DPTR. This DPTR can also be used as two 8-registers DPH and DPL.

Program Status Register (PSW):

The 8051 has a 8-bit PSW register which is also known as Flag register. In the 8-bit register only 6-bits are used by 8051.The two unused bits are user definable bits. In the 6-bits four of them are conditional flags. They are Carry –CY, Auxiliary Carry-AC, Parity-P, and Overflow-OV. These flag bits indicate some conditions that resulted after an instruction was executed.

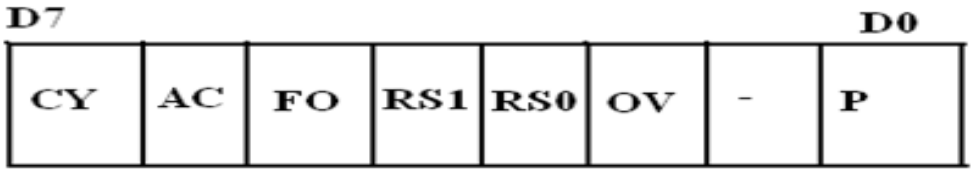

Figure 3.1.2 Program Status Word of 8051 Microcontroller

[Source: "Microprocessor Architecture Programming and Application" by R.S. Gaonkar, page-]

The bits PSW3 and PSW4 are denoted as RS0 and RS1 and these bits are used th select the bank registers of the RAM location. The meaning of various bits of PSW register is shown below.

CY	PSW.7	Carry Flag
AC	PSW.6	Auxiliary Carry Flag
FO	PSW.5	Flag 0 available for general purpose .
RS1	PSW.4	Register Bank select bit 1
RS0	PSW.3	Register bank select bit 0
OV	PSW.2	Overflow flag
---	PSW.1	User difinable flag
P	PSW.0	Parity flag .set/cleared by hardware.

The selection of the register Banks and their addresses are given below.

RS1	RS0	Register Bank	Address
0	0	0	00H-07H
0	1	1	08H-0FH
1	0	2	10H-17H
1	1	3	18H-1FH