Lecture Notes

for

Microprocessors & Microcontrollers

(PHYS4008: Electronics)

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MICROPROCESSOR

Unit of data Size

Bit : a binary digit that can have the value 0 or 1.

Byte : 8 bits

Nibble : half of a byte, or 4 bits

word : two byte (or 16 bits); But it may vary (32, 64, ----)

Kilobyte : 2^{10} bytes = 1024 bytes

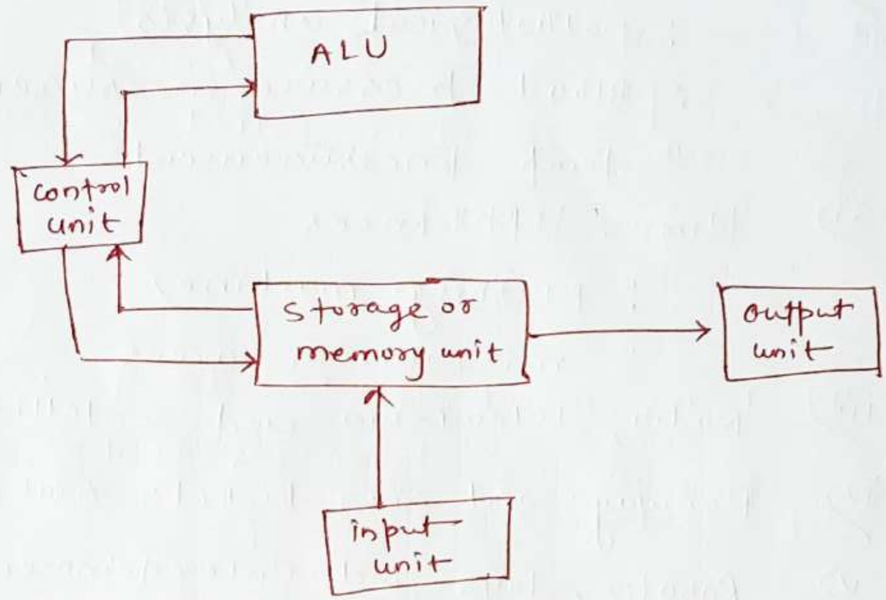
Megabyte : 2^{20} bytes, over 1 million

Gigabyte : 2^{30} bytes, over 1 billion

Terabyte : 2^{40} bytes, over 1 trillion

* Basic architecture of a digital computer is based on Von-Neumann model.
* The first microprocessor was developed by The BUSICOM of Japan and INTEL of USA in the year 1971.
* NMOS technology is used in microprocessors.
* CPU is another name of microprocessor.
* Microprocessor may be thought of as silicon chip around which a microcomputer is built.
* Three main units of a digital computer
    i) central processing unit (CPU)
    ii) memory unit
    iii) input/output devices
* What are main jobs that the CPU is expected to do at any given point of time?
    i) memory read or write operation
    ii) I/O read or write operation
    iii) internal activity

Block diagram of a digital computer.



The diagram consist of five major blocks or functional units.

1) input
2) storage or memory
3) arithmatic logic
4) control
5) output unit

* The control & arithmatic-logic unit (ALU) are generally combined physically into a single unit and is termed as central processing unit (CPU).

* A CPU built on a single semiconductor chip serves as a microprocessor.

* Hence, a microprocessor is a VLSI chip which can be programmed to execute arithmatic and logic operations and other functions in a prescribed manner for movement and processing of digital data.

* Instruments can be made intelligent by making them microprocessor-controlled because they can be programmed.

Microprocessors are applied in following applications.

* i) Medical instruments
  : pathological analysis
  : Blood pressure measurement
  : temp measurement
* ii) Home appliances
  : washing machines
  : microwave ovens
* iii) Radio, television and satellite communication.
* iv) Railway and air ticket booking
* v) Robots, toys and entertainment equipment

* Three basic segments of microprocessor
  i) arithmatic and logic unit
  ii) Register unit
  iii) control unit

i) Arithmatic and logic unit (ALU) : In this section, computing operations are performed on data. Arithmetic operations like addition & substraction, and logic operations like AND, OR and XOR are performed in the ALU. The results can be stored in registers or in memory, or transferred to output devices.

ii) Register unit : This section containing array of registers, is mainly used for a temporary storage of data, instructions and data addresses during execution of program.

iii) Control unit : This unit gives the required timing and control signals to coordinate the different operations.

* Many manufacturers have produced microprocessors of which the widely used type is Intel 8085.

* It is an 8-bit general-purpose microprocessor capable of addressing a 64K memory. It has 40 pins, operates with a +5V single power supply and a 3MHz single phase clock.

* Intel Corporation released 8085 μP in 1977.

* The 16-bit 8086 μP and 32-bit 80386 μP were introduced by Intel in 1978 and 1986 respectively.

Q* How does the microprocessor communicate with the memory and input/output devices?

Ans: Via three buses

i) data bus
ii) address bus
iii) control bus

Q List different generation languages:

i) 1st generation language : Machine Language
ii) 2nd " " : Assembly Language
iii) 3rd " " : FORTRAN, BASIC, COBOL, PASCAL, C, C++, JAVA
iv) 4th " " : LISP, APL, PROLOG, etc.

Q What is machine language?

Ans: Programming a computer by utilising hex or binary code is known as machine language programming.

Q: What is meant by assembly language programming?

Ans: Programming a microcomputer by writing mnemonics is known as assembly language programming.

Q What is <u>mnemonic</u> ?

Ans: It is very difficult to understand a program if it is written in either binary or hex code. Thus the manufacturers has devised a symbolic code for each instruction, called a mnemonic.

e.g. ADD M,
MOV A,

Q What are meant by low level and high level languages?

Ans: Programming languages that are machine dependent are called <u>low level</u> languages.

e.g: assembly language

Programming languages that machine independent are called <u>high level</u> languages.

e.g.: BASIC, FORTRAN, C, COBOL etc.

Q What is meant by <u>'word length'</u> of a computer?

Ans: The number of bits that a computer recognises and can process at a time is known as its 'word length'.

Q What is meant by <u>instruction</u> ?

Ans: It is a command which asks the microprocessor to perform a specific task or Job.

* 8085 microprocessor has a total of <u>74</u> different instructions for performing different operations.

Q What an <u>instruction</u> consists of ?

Ans: An instruction consists of an operation code (called <u>'opcode'</u>) and the address of the data (called <u>'operand'</u>), on which the opcode operates.

Operation code (or opcode)	Address of data (or operand)
Field 1	Field 2

Q What language a microprocessor understands?

Ans: Microprocessor understand only binary language.

Q How the mnemonics written in assembly language are translated into binary?

Ans: The translation from assembly language (i.e, mnemonics) into binary is done either manually (known as hand (or manual) assembly) or by a program called an assembler.

Q How the high level languages are converted into binary?

Ans: by using a program called <u>compiler</u> or <u>interpreter</u>.

Q what are <u>source codes</u> and <u>object codes</u>?

Ans: High level languages are called <u>Source codes</u>. Whereas binary languages are called <u>object codes</u>.

Q What are names given to instructions written in high and low level languages?

Ans: The instructions in high level languages : <u>statements</u>

" " " low " " : <u>mnemonics</u>

***Q** What is a **bus**?

Ans: A bunch of wires through which <u>data</u> or <u>address</u> or <u>control signals</u> flow.

* 8085 MP operates at a frequency of <u>3 MHz</u> and the minm frequency of operation is <u>500 KHz</u>.

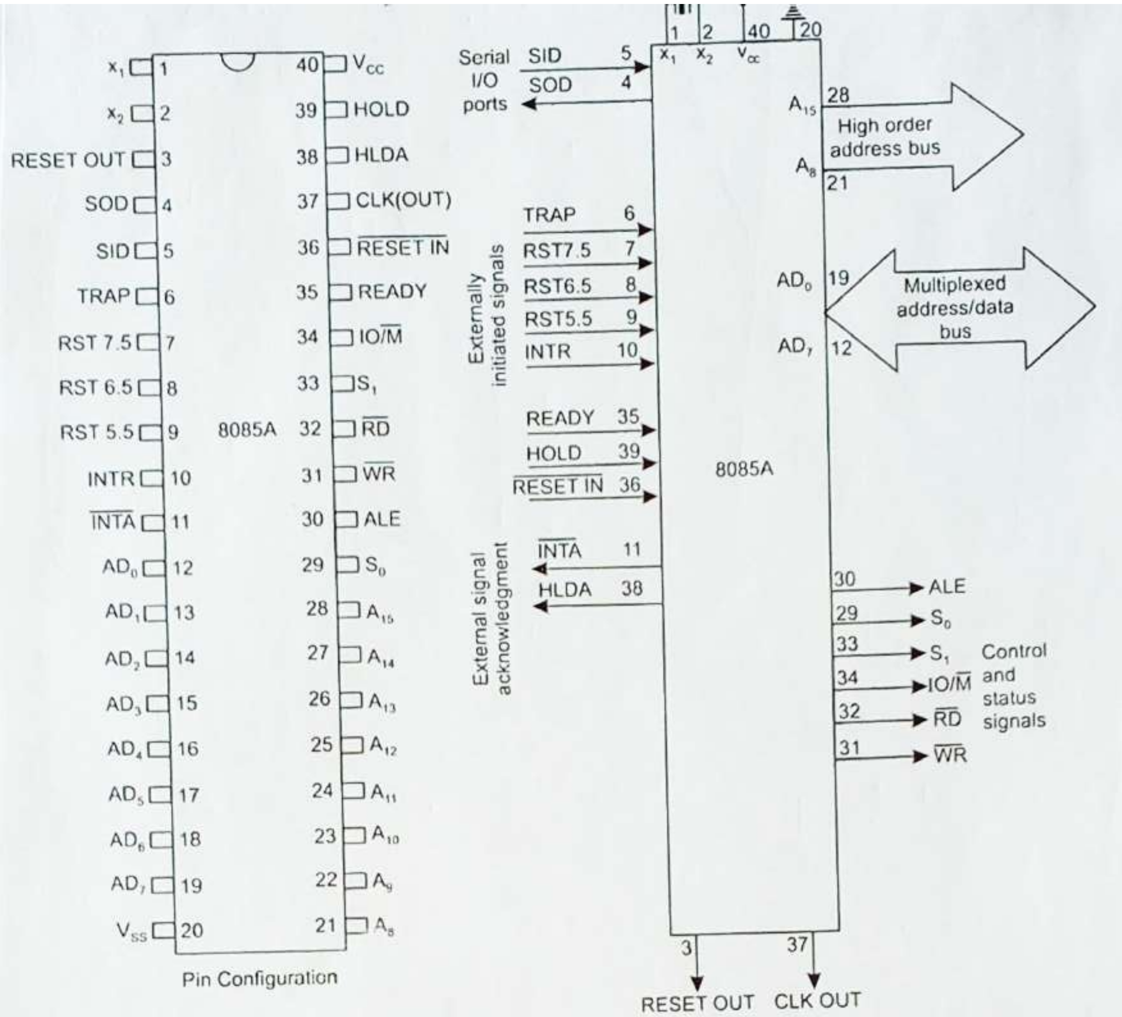


Fig. 2.1: Functional pin diagram

* The signals of 8085 μP can be classified into seven groups according to their function.

    i) power supply and frequency signals
    ii) Data and Address buses
    iii) control bus
    iv) Interrupt signals
    v) Serial I/O signals
    vi) DMA signals
    vii) Reset signals

* CLK (out) signals obtained from pin 37 of 8085 μP is used for synchronizing external devices.

* Architecture of µP 8085 is shown below.

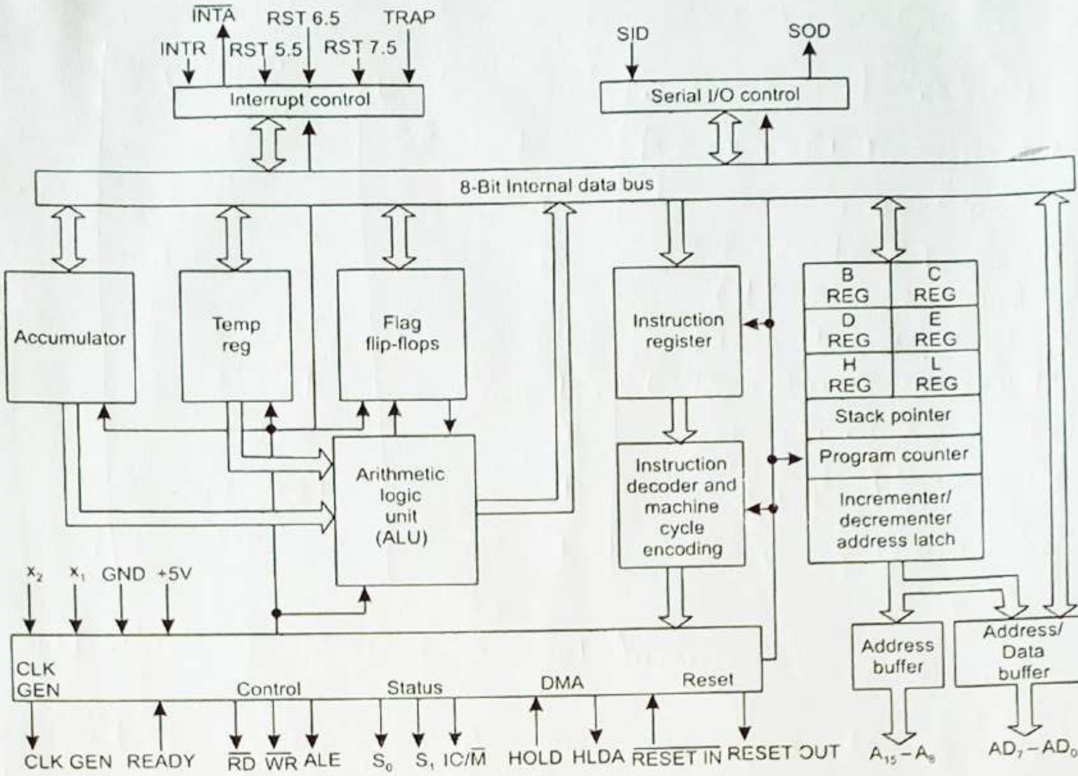


Fig. 2.2: Architecture of 8085

The various functional blocks of 8085 are as follows:

- Registers
- Arithmetic logic unit
- Address buffer
- Incrementer/decrementer address latch
- Interrupt control
- Serial I/O control
- Timing and control circuitry
- Instructions decoder and machine cycle encoder.

* Addressing modes of 8085 µP.

i) Immediate
ii) Register
iii) Direct
iv) Indirect
v) Implied

Q* How many hardware interrupts 8085 supports?

Ans: It supports 5 hardware interrupts

i) TRAP
ii) RST 7.5
iii) RST 6.5
iv) RST 5.5
v) INTR

These are available on interrupt pins of 8085 µP : pin 6 to pin 10

Q List the various registers of 8085.

S. No.	Name of register	Quantity	Capacity
01	→ Accumulator register A	1	8-bit
02	→ Temporary resister	1	8-bit
03	→ General purpose registers (B, C, D, E, H and L)	6	8-bit each
04	→ Stack point (SP)	1	16-bit
05	→ Program counter (PC)	1	16-bit
06	→ Instruction register	1	8-bit
07	→ Increment/decrement address latch	1	16-bit
08	→ Status flag register	1	8-bit

Q Describe the accumulator register of 8085 MP.

Ans: It is 8 bit register which is most important one amongst all registers of 8085. Any data input/output to/from the microprocessor takes place via the accumulator (register). It is generally used for temporary storage of data and for the placement of final result of arithmatic or logical operations.

Q Describe the (status) flag register of 8085 MP.

Ans: It is an 8 bit register in which five bit positions contain the status of five condition flags which are zero (Z), Sign (S), Carry (CY), Parity (P) and Auxiliary carry (AC). Each of these five flags is a 1 bit F/F. The flag register format is shown below.

D7	D6	D5	D4	D3	D2	D1	D0
S	Z	X	AC	X	P	X	CY

- Sign (S) flag: If the MSB of the result of an operation is 1, this flag is set, otherwise it is reset.
- Zero (Z) flag: If the result of an instruction is zero, this flag is set, otherwise reset.

* Auxiliary Carry (AC) flag : If there is carry out of bit 3 and into bit 4 resulting from the execution of an arithmatic operation, it is set otherwise reset.

* Carry (CY) flag : If an instruction results in a carry (for addition operation) or borrow (for substraction or comparison) out of bit D_7, then this flag is set, otherwise reset.

* Parity (P) flag : This flag is set when the result of an operation contains an even number of 1's and is reset otherwise.

Q Describe the instruction register of 8085 μP.

Ans: Program written by the programmer resides in the R/W memory. When an instruction is being executed by the system, the opcode of the instruction is fetched from the memory and stored in instruction register during opcode feetch cycle. It is then sent to the instruction decoder.

Q Explain maskable and non-maskable interrupts.

Ans: An interrupt which can be disabled by software means, is called a maskable interrupts. Thus, an interrupt which cannot be masked is an unmaskable interrupt.

* TRAP interrupt is the non-maskable interrupt.

Q* Do the interrupt of 8085 μP have priority?

Ans: yes, the interrupts of 8085 μP have their priorities fixed - TRAP interrupt has the highest priority, followed by RST 7.5, RST6.5, RST 5.5 and lastly INTR.

Q The process of interrupt is asynchronous in nature. Why?

Ans: It may come and be acknowledged (provided masking of any interrupt is not done) by the microprocessor without any reference to the system clock. That is why interrupts are asynchronous in nature.

Q For what purpose TRAP interrupt is normally used?

Ans: TRAP interrupt is a non-maskable one i.e. if an interrupt comes via the TRAP input, the system will have to acknowledge that. That is why it is used for vital purposes which require immediate attention like power failure.

If the microprocessor based system loses power, the filter capacitors hold the supply voltage for several mili second.

During this time, data in the RAM can be written in disk or E^2PROM for future use.

* A program consists of a set of instructions written in a logical way to direct a microprocessor to perform the specific operation in a given sequence.

The set of instructions can be classified into five groups.

i) data transfer operations
ii) arithmatic operations
iii) logic operations
iv) Branching operations
v) Stack, I/O, and machine control operations.

* Data transfer operations:

e.g. MOV B, C : data movement from register C to register B

MOV : opcode

B, C : operand

* Arithmatic operations:

eg. ADD E : the content of the register E is added to the contents of accumulator (A register) accumulator. The result is stored in the accumulator and the flags are changed.

ADI means Add Immediate. It is two byte instruction. Let the initial contents of the accumula be 00100001. The execution of ADI 75H is illustrated below.

	CY	D7	D6	D5	D4	D3	D2	D1	D0
A:		0	0	1	0	0	0	0	1
Data (75H):	+	0	1	1	1	0	1	0	1
	0	1	0	0	1	0	1	1	0

The sum is 10010110, i.e. 96H. The carry flag (CY) is reset to 0 as there is no carry in the result. The sign flag (S) is set to 1 since the D_7 bit of the result is 1. The parity flag (P) is also made 1 as the number of 1s in the result is four i.e. ev

Microcontroller

* → A system designer using a general purpose microprocessor such as the pentium must add RAM, ROM, I/O ports and timers externally to make them functional. Although the addition of external RAM, ROM, I/O ports make these system bulkier and much more expensive, they have the advantage of versatility, enabling the designer to decide on the amount of RAM, ROM and I/O ports needed to fit task at hand.
  But this is not case with microcontroller.

→ Microcontroller: Processor, RAM, ROM, I/O ports and timers are all embedded together on one chip. Hence, designer cannot add any external memory, I/O, or timer to it.

→ The fixed amount of on-chip ROM, RAM, and number of I/O ports in a micocontroller makes them ideal for many applications in which cost and space are critical.
  e.g. TV remote control

* In an embedded system, the microcontroller's ROM is burned with a purpose for specific function needed for the system.
  e.g. printer

* An x86 PC contains or is connected to various embedded products such as the keyboard, printer, modem, disk controller, sound card, CD-ROM driver, mouse & so on. each one of these peripherals has a microcontroller inside it that performs only one task.

  e.g. A microcontroller inside a mouse performs the task of finding the mouse's position and sending it to the PC.

Criteria for choosing a microcontroller.

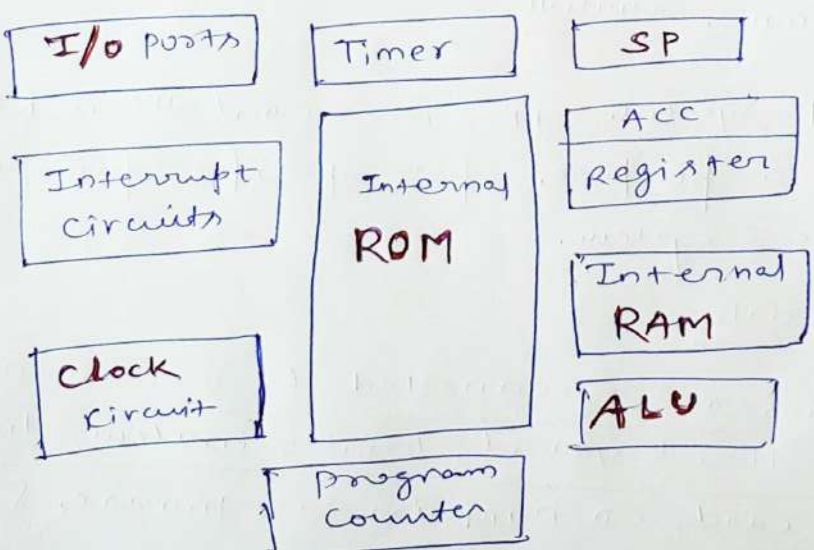
1. It must meet the task at hand efficiently and cost effectively.

e.g (a) Speed
(b) packaging
(c) power consumption
(d) Amount of RAM and ROM
(e) The no of I/O ports and timer
(f) ease of upgradation
(g) Cost per unit

2. The second criterion is how easy it is to develop products around it.

3. The third criterion is its ready availability in needed quantities both now and in the future.

* Intel **8051** is a 8-bit microcontroller and Intel **8096** is 16-bit microcontroller.



Block diagram of microcontroller

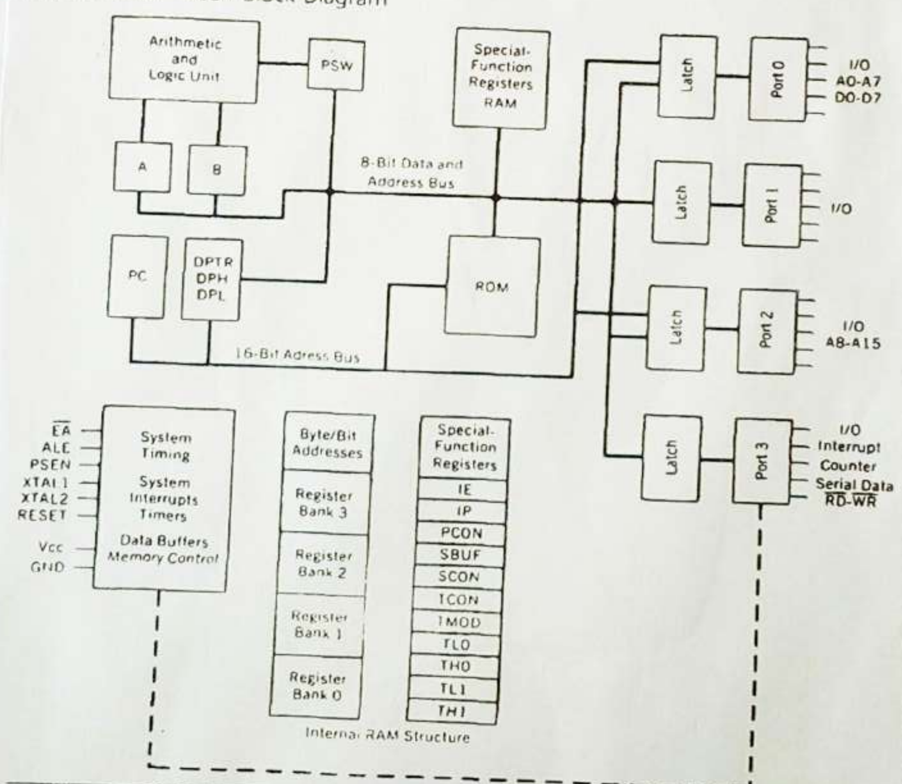
8051 : Pin Configurations

Total pins :	40
Address pins :	16
Data pins :	8
Interrupt pins :	2
I/O pins :	32

Architecture of 8051

8 bit registers : 34
16 bit registers : 2
Stack size : 128
Internal ROM : 4K bytes
Internal RAM : 128 bytes
External memory : 128 Kbytes
Flags : 4
Timers : 2
parallel ports : 4
serial ports : 1

FIGURE 2.1a 8051 Block Diagram



package types. An enhanced version of the 8051, the 8052, also exists with its own family of variations and even includes one member that can be programmed in BASIC. This galaxy of parts, the result of desires by the manufacturers to leave no market niche unfilled, would require many chapters to cover. In this chapter, we will study a "generic" 8051, housed in a 40-pin DIP, and direct the investigation of a particular type to the data books. The block diagram of the 8051 in Figure 2.1a shows all of the features unique to microcontrollers:

Internal ROM and RAM
I/O ports with programmable pins
Timers and counters
Serial data communication

8051 DIP Pin Assignments

Port 1 Bit 0	1	P1.0	Vcc	40	+5V
Port 1 Bit 1	2	P1.1	(AD0)P0.0	39	Port 0 Bit 0 (Address/Data 0)
Port 1 Bit 2	3	P1.2	(AD1)P0.1	38	Port 0 Bit 1 (Address/Data 1)
Port 1 Bit 3	4	P1.3	(AD2)P0.2	37	Port 0 Bit 2 (Address/Data 2)
Port 1 Bit 4	5	P1.4	(AD3)P0.3	36	Port 0 Bit 3 (Address/Data 3)
Port 1 Bit 5	6	P1.5	(AD4)P0.4	35	Port 0 Bit 4 (Address/Data 4)
Port 1 Bit 6	7	P1.6	(AD5)P0.5	34	Port 0 Bit 5 (Address/Data 5)
Port 1 Bit 7	8	P1.7	(AD6)P0.6	33	Port 0 Bit 6 (Address/Data 6)
Reset Input	9	RST	(AD7)P0.7	32	Port 0 Bit 7 (Address/Data 7)
Port 3 Bit 0 (Receive Data)	10	P3.0(RXD)	(Vpp)/EA	31	External Enable (EPROM Programming Voltage)
Port 3 Bit 1 (XMIT Data)	11	P3.1(TXD)	(PROG)ALE	30	Address Latch Enable (EPROM Program Pulse)
Port 3 Bit 2 (Interrupt 0)	12	P3.2($\overline{\text{INT0}}$)	$\overline{\text{PSEN}}$	29	Program Store Enable
Port 3 Bit 3 (Interrupt 1)	13	P3.3($\overline{\text{INT1}}$)	(A15)P2.7	28	Port 2 Bit 7 (Address 15)
Port 3 Bit 4 (Timer 0 Input)	14	P3.4(T0)	(A14)P2.6	27	Port 2 Bit 6 (Address 14)
Port 3 Bit 5 (Timer 1 Input)	15	P3.5(T1)	(A13)P2.5	26	Port 2 Bit 5 (Address 13)
Port 3 Bit 6 (Write Strobe)	16	P3.6($\overline{\text{WR}}$)	(A12)P2.4	25	Port 2 Bit 4 (Address 12)
Port 3 Bit 7 (Read Strobe)	17	P3.7($\overline{\text{RD}}$)	(A11)P2.3	24	Port 2 Bit 3 (Address 11)
Crystal Input 2	18	XTAL2	(A10)P2.2	23	Port 2 Bit 2 (Address 10)
Crystal Input 1	19	XTAL1	(A9)P2.1	22	Port 2 Bit 1 (Address 9)
Ground	20	Vss	(A8)P2.0	21	Port 2 Bit 0 (Address 8)

Note: Alternate functions are shown below the port name (in parentheses). Pin numbers and pin names are shown inside the DIP package.

References:

1. Fundamentals of Microprocessors and Microcontrollers by B. Ram

2. Microprocessor Architecture, Programming and Applications with the 8085 by R. Gaonkar