

MICROPROCESSOR BASICS AND RELATED TERMS

Microprocessor:

Programmable integrated device that has computing ability and decision making capacity.

It is the CPU of computer.

A multipurpose, programmable, clock driver, register based electronic device that reads binary instruction from memory, accepts binary data, processes the data according to the instruction and provides the results as output.

A controlled intelligent processor.

Human analog of computer:

CPU =brain

Bus =berves

Input device =Eyes and ears

Output device =Mouth and hands

Backup storage=notebook

Bit – Binary Digits(0 and 1)

Word byte –combination of 8 bits

Nibble-combination of 4 bits

System-Set of devices used to perform a task

Hardware-Physical components of a system

Software-set of program.

Program-set of instruction used to perform a task.

Instruction-command to the microprocessor to perform a task.

Mnemonics-abbreviation for each binary instruction word.

Bus-communication path.

Word length:

The number of bits that can be processed by a microprocessor is termed as word length of the microprocessor.

Word length of 8085-8 bits

Assembly Language - low level language.

Machine Language - very low level programming language

- Combination of 0's and 1's.
- Only m/c understandable.

Assembler and Interpreter:

(i.e) Source Program → one to one → object programming machine tools

COMPILER- Converts whole program at a time into Machine code
SSI, MSI, LSI, VLSI, UVLSI, Gaint Large Scale (GLSI)

GENERAL 8 BIT MICROPROCESSOR-ARCHITECTURE

8 Bit Microprocessors having the ability to process 8 Bits at a time and it may have 8 Bit data bus.

Eg: 8085, Z-80, M6800, etc.

Main elements of Microprocessor are

Register array- (1) GPRS

(2) SPRS

Timing and Control Unit

Arithmetic and Logic Unit (ALU)

Bus such as address bus, data bus and control bus

ARCHITECTURE - Study of internal logic circuitry.

THE GENERAL MP ARCHITECTURE

Architecture-Internal logic design of the MP

Microprocessor is a clock driven semiconductor device manufactured by LSI or VLSI technology

The MP architecture also can be explained with and the elements can be explained

The 4 main elements or logic circuits are

- (i) ALU,
- (ii) Register array
- (iii) Timing and control or control unit
- (iv) System bus.

ALU:

Arithmetic and Logic unit used to perform various computation such as arithmetic function (add, sub, inc., dec.) and Logical function (AND, OR, EXOR) with the data.

For holding the data during the processing time, temp. register are used. The result of the operation is stored in the register.

Sometimes the results may be reflected or shown through a register termed as Flag register.

REGISTER ARRAY:

Collection of registers present in this.

The register may be either General Purpose Register (GPRs) or Special Purpose Register (SPRs).

GPRs are used for general purpose-holding of data(or storing the data during processing time).

SPRs are very much useful for specific functions

Eg: Stack Pointer is used to point the top location of the STACK (Special Memory)

In 8085 GPRs - B,C,D,E,H and L

SPRs – SP, program counter PC.

CONTROL UNIT:

Provides necessary timing and control signals to all the operation of the microprocessor and microprocessor system.

Controls the flow of data.

Unit used to synchronize the operation

SYSTEM BUS:

Communication path between Microprocessor and peripherals (or) group of wires used to carry the information bits.

There are address bus, data bus and control bus.

Address bus ---carries the address

Data bus ----carries the data

Control bus-----carries the control information

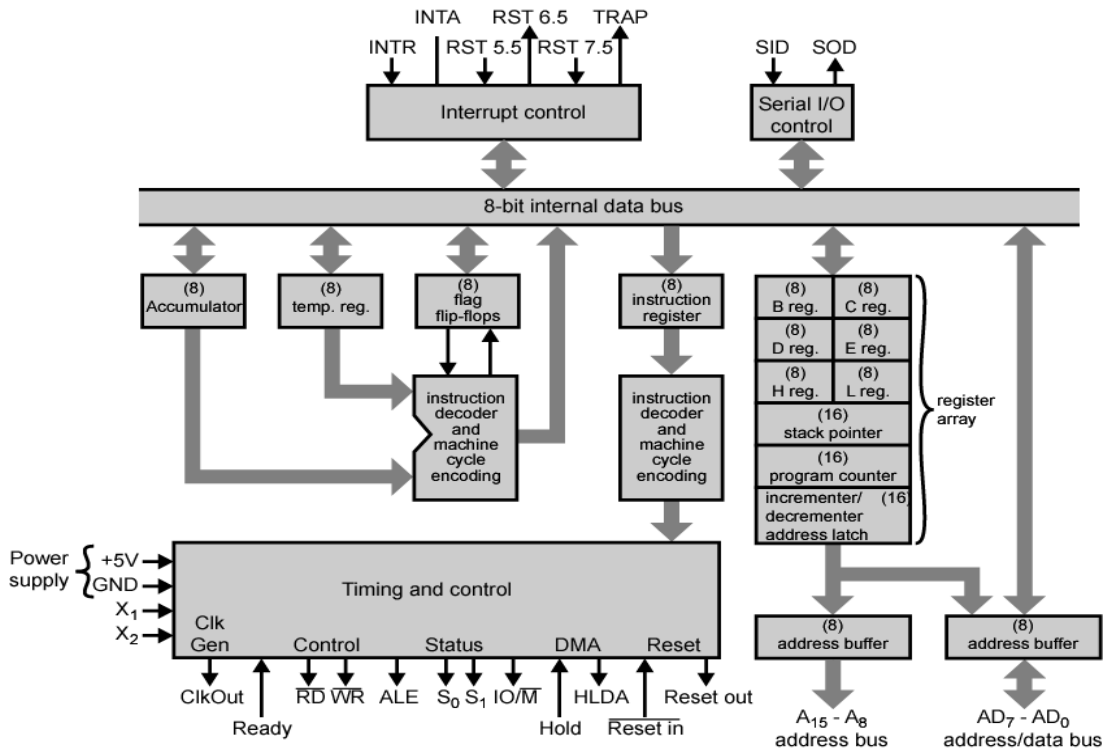
All peripherals (I/O devices) share the bus (ie) communication with only one peripheral at a time. Timing is provided by control unit through control bus.

MICROPROCESSORS AND MICROCONTROLLERS

UNIT I

8085 ARCHITECTURE AND PROGRAMMING

1.1. Internal Architecture of 8085 Microprocessor



Control Unit

Generates signals within uP to carry out the instruction, which has been decoded. In reality causes certain connections between blocks of the uP to be opened or closed, so that data goes where it is required, and so that ALU operations occur.

Arithmetic Logic Unit

The ALU performs the actual numerical and logic operation such as 'add', 'subtract', 'AND', 'OR', etc. Uses data from memory and from Accumulator to perform arithmetic. Always stores result of operation in Accumulator.

Registers

The 8085/8080A-programming model includes six registers, one accumulator, and one flag register, as shown in Figure. In addition, it has two 16-bit registers: the stack pointer and the program counter. They are described briefly as follows.

The 8085/8080A has six general-purpose registers to store 8-bit data; these are identified as B,C,D,E,H, and L as shown in the figure. They can be combined as register pairs - BC, DE, and HL - to perform some 16-bit operations. The programmer can use these registers to store or copy data into the registers by using data copy instructions.

Accumulator

The accumulator is an 8-bit register that is a part of arithmetic/logic unit (ALU). This register is used to store 8-bit data and to perform arithmetic and logical operations. The result of an operation is stored in the accumulator. The accumulator is also identified as register A.

Flags

The ALU includes five flip-flops, which are set or reset after an operation according to data conditions of the result in the accumulator and other registers. They are called Zero(Z), Carry (CY), Sign (S), Parity (P), and Auxiliary Carry (AC) flags; they are listed in the Table and their bit positions in the flag register are shown in the Figure below. The most commonly used flags are Zero, Carry, and Sign. The microprocessor uses these flags to test data conditions.

For example, after an addition of two numbers, if the sum in the accumulator is larger than eight bits, the flip-flop used to indicate a carry -- called the Carry flag (CY) -- is set to one. When an arithmetic operation results in zero, the flip-flop called the Zero(Z) flag is set to one. The first Figure shows an 8-bit register, called the flag register, adjacent to the accumulator. However, it is not used as a register; five bit positions out of eight are used to store the outputs of the five flip-flops. The flags are stored in the 8-bit register so that the programmer can examine these flags (data conditions) by accessing the register through an instruction.

These flags have critical importance in the decision-making process of the microprocessor.

The conditions (set or reset) of the flags are tested through the software instructions. For example, the instruction JC (Jump on Carry) is implemented to change the sequence of a program when CY flag is set. The thorough understanding of flag is essential in writing assembly language programs.

Program Counter (PC)

This 16-bit register deals with sequencing the execution of instructions. This register is a memory pointer. Memory locations have 16-bit addresses, and that is why this is a 16-bit register.

The microprocessor uses this register to sequence the execution of the instructions. The function of the program counter is to point to the memory address from which the next byte is to be fetched. When a byte (machine code) is being fetched, the program counter is incremented by one to point to the next memory location

Stack Pointer (SP)

The stack pointer is also a 16-bit register used as a memory pointer. It points to a memory location in R/W memory, called the stack. The beginning of the stack is defined by loading 16-bit address in the stack pointer.

Instruction Register/Decoder

Temporary store for the current instruction of a program. Latest instruction sent here from memory prior to execution. Decoder then takes instruction and 'decodes' or interprets the instruction. Decoded instruction then passed to next stage.

Memory Address Register

Holds address, received from PC, of next program instruction. Feeds the address bus with addresses of location of the program under execution.

Control Generator

Generates signals within uP to carry out the instruction which has been decoded. In reality causes certain connections between blocks of the uP to be opened or closed, so that data goes where it is required, and so that ALU operations occur.

Register Selector

This block controls the use of the register stack in the example. Just a logic circuit which switches between different registers in the set will receive instructions from Control Unit.

General Purpose Registers

uP requires extra registers for versatility. Can be used to store additional data during a program. More complex processors may have a variety of differently named registers.

2. 8085 System Bus

Typical system uses a number of busses, collection of wires, which transmit binary numbers, one bit per wire. A typical microprocessor communicates with memory and other devices (input and output) using three busses: Address Bus, Data Bus and Control Bus.

Address Bus

One wire for each bit, therefore 16 bits = 16 wires. Binary number carried alerts memory to 'open' the designated box. Data (binary) can then be put in or taken out. The Address Bus consists of 16 wires, therefore 16 bits. Its "width" is 16 bits. A 16 bit binary number allows 2^{16} different numbers, or 32000 different numbers, ie 0000000000000000 up to 1111111111111111. Because memory consists of boxes, each with a unique address, the size of the address bus determines the size of memory, which can be used. To communicate with memory the microprocessor sends an address on the address bus, eg 0000000000000011 (3 in decimal), to the memory. The memory then selects box number 3 for reading or writing data. Address bus is unidirectional, ie numbers only sent from microprocessor to memory, not other way.

Data Bus

Data Bus carries 'data', in binary form, between μ P and other external units, such as memory. Typical size is 8 or 16 bits. Size determined by size of boxes in memory and μ P size helps determine performance of μ P. The Data Bus typically consists of 8 wires. Therefore, 256 combinations of binary digits. Data bus used to transmit "data", ie information, results of arithmetic, etc, between memory and the microprocessor. Bus is bi-directional. Size of the data bus determines what arithmetic can be done. If only 8 bits wide then largest number is 11111111 (255 in decimal). Therefore, larger numbers have to be broken down into chunks of 255. This slows microprocessor. Data Bus also carries instructions from memory to the microprocessor. Size of the bus therefore limits the number of possible instructions to 256, each specified by a separate number.

Control Bus

Control Bus are various lines which have specific functions for coordinating and controlling uP operations. Eg: Read/NotWrite line, single binary digit. Control whether memory is being 'written to' (data stored in mem) or 'read from' (data taken out of mem) 1 = Read, 0 = Write. May also include clock line(s) for timing/synchronising, 'interrupts', 'reset' etc. Typically μ P has 10 control lines. The Control Bus carries control signals partly unidirectional, partly bi-directional.

Control signals are things like "read or write". This tells memory that we are either **reading from** a location, specified on the address bus, or **writing to** a location specified. Various other signals to control and coordinate the operation of the system. Modern day microprocessors, like 80386, 80486 have much larger busses. Typically 16 or 32 bit busses, which allow larger number of instructions, more memory location, and faster arithmetic. Microcontrollers organized along same lines, except: because microcontrollers have memory etc inside the chip, the busses may all be internal. In the microprocessor the three busses are external to the chip (except for the internal data bus). In case of external busses, the chip connects to the busses via buffers, which are simply an electronic connection between external bus and the internal data bus.

1.2. 8085 Pin description.

Properties

Single + 5V Supply

4 Vectored Interrupts (One is Non Maskable)

Serial In/Serial Out Port

Decimal, Binary, and Double Precision Arithmetic

Direct Addressing Capability to 64K bytes of memory

The Intel 8085A is a new generation, complete 8 bit parallel central processing unit (CPU). The 8085A uses a multiplexed data bus. The address is split between the 8bit address bus and the 8bit data bus. Figures are at the end of the document.

Pin Description

The following describes the function of each pin:

A6 - A1s (Output 3 State)

Address Bus; The most significant 8 bits of the memory address or the 8 bits of the I/O address, 3 stated during Hold and Halt modes.

AD0 - 7 (Input/Output 3state)

Multiplexed Address/Data Bus; Lower 8 bits of the memory address (or I/O address) appear on the bus during the first clock cycle of a machine state. It then becomes the data bus during the second and third clock cycles. 3 stated during Hold and Halt modes.

ALE (Output)

Address Latch Enable: It occurs during the first clock cycle of a machine state and enables the address to get latched into the on chip latch of peripherals. The falling edge of ALE is set to guarantee setup and hold times for the address information. ALE can also be used to strobe the status information. ALE is never 3stated.

SO, S1 (Output)

Data Bus Status. Encoded status of the bus cycle:

S1	S0	
0	0	HALT
0	1	WRITE
1	0	READ
1	1	FETCH

S1 can be used as an advanced R/W status.

RD (Output 3state)

READ indicates the selected memory or I/O device is to be read and that the Data Bus is available for the data transfer.

WR (Output 3state)

WRITE indicates the data on the Data Bus is to be written into the selected memory or I/O location. Data is set up at the trailing edge of WR. 3stated during Hold and Halt modes.

READY (Input)

If Ready is high during a read or write cycle, it indicates that the memory or peripheral is ready to send or receive data. If Ready is low, the CPU will wait for Ready to go high before completing the read or write cycle.

HOLD (Input)

HOLD indicates that another Master is requesting the use of the Address and Data Buses. The CPU, upon receiving the Hold request, will relinquish the use of buses as soon as the completion of the current machine cycle. Internal processing can continue. The processor can regain the buses only after the Hold is removed. When the Hold is acknowledged, the Address, Data, RD, WR, and IO/M lines are 3stated.

HLDA (Output)

HOLD ACKNOWLEDGE indicates that the CPU has received the Hold request and that it will relinquish the buses in the next clock cycle. HLDA goes low after the Hold request is removed. The CPU takes the buses one half clock cycle after HLDA goes low.

INTR (Input)

INTERRUPT REQUEST is used as a general purpose interrupt. It is sampled only during the next to the last clock cycle of the instruction. If it is active, the Program Counter (PC) will be inhibited from incrementing and an INTA will be issued. During this cycle a RESTART or CALL instruction can be inserted to jump to the interrupt service routine. The INTR is enabled and disabled by software. It is disabled by Reset and immediately after an interrupt is accepted.

INTA (Output)

INTERRUPT ACKNOWLEDGE is used instead of (and has the same timing as) RD during the Instruction cycle after an INTR is accepted. It can be used to activate the 8259 Interrupt chip or some other interrupt port.

RST 5.5**RST 6.5 - (Inputs)****RST 7.5**

RESTART INTERRUPTS These three inputs have the same timing as I NTR except they cause an internal RESTART to be automatically inserted.

RST 7.5 ~ Highest Priority

RST 6.5

RST 5.5 o Lowest Priority

The priority of these interrupts is ordered as shown above. These interrupts have a higher priority than the INTR.

TRAP (Input)

Trap interrupt is a nonmaskable restart interrupt. It is recognized at the same time as INTR. It is unaffected by any mask or Interrupt Enable. It has the highest priority of any interrupt.

RESET IN (Input)

Reset sets the Program Counter to zero and resets the Interrupt Enable and HLDA flipflops. None of the other flags or registers (except the instruction register) are affected. The CPU is held in the reset condition as long as Reset is applied.

RESET OUT (Output)

Indicates CPIJ is being reset. Can be used as a system RESET. The signal is synchronized to the processor clock.

X1, X2 (Input)

Crystal or R/C network connections to set the internal clock generator X1 can also be an external clock input instead of a crystal. The input frequency is divided by 2 to give the internal operating frequency.

CLK (Output)

Clock Output for use as a system clock when a crystal or R/ C network is used as an input to the CPU. The period of CLK is twice the X1, X2 input period.

IO/M (Output)

IO/M indicates whether the Read/Write is to memory or I/O Tristated during Hold and Halt modes.

SID (Input)

Serial input data line The data on this line is loaded into accumulator bit 7 whenever a RIM instruction is executed.

SOD (output)

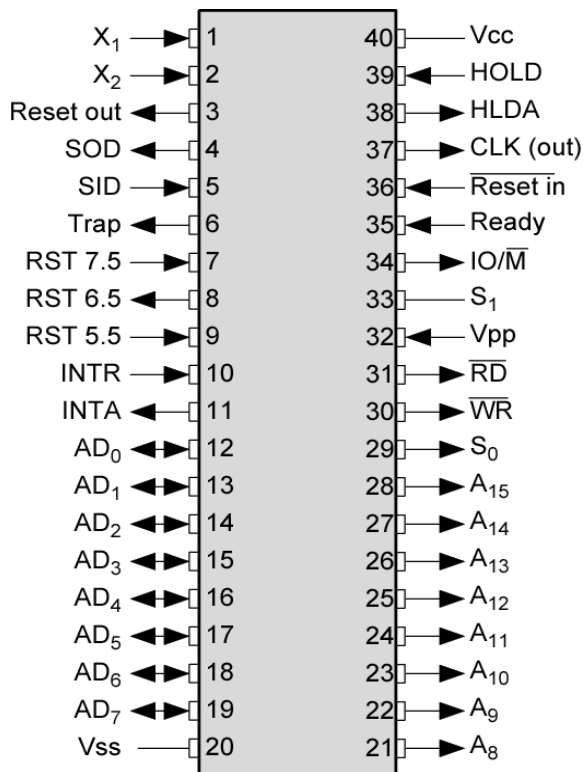
Serial output data line. The output SOD is set or reset as specified by the SIM instruction.

Vcc

+5 volt supply.

Vss

Ground Reference.



The salient features of 8085 μ p are:

- It is a 8 bit microprocessor.
- It is manufactured with N-MOS technology.
- It has 16-bit address bus and hence can address up to $2^{16} = 65536$ bytes (64KB) memory locations through A₀-A₁₅.
- The first 8 lines of address bus and 8 lines of data bus are multiplexed AD₀ – AD₇.
- Data bus is a group of 8 lines D₀ – D₇.
- It supports external interrupt request.
- A 16 bit program counter (PC)
- A 16 bit stack pointer (SP)
- Six 8-bit general purpose register arranged in pairs: BC, DE, HL.
- It requires a signal +5V power supply and operates at 3.2 MHZ single phase clock.
- It is enclosed with 40 pins DIP (Dual in line package).

1.3. 8085 Functional Description

The 8085A is a complete 8 bit parallel central processor. It requires a single +5 volt supply. Its basic clock speed is 3 MHz thus improving on the present 8080's performance with higher system speed. Also it is designed to fit into a minimum system of three IC's: The CPU, a RAM/ IO, and a ROM or PROM/IO chip.

The 8085A uses a multiplexed Data Bus. The address is split between the higher 8bit Address Bus and the lower 8bit Address/Data Bus. During the first cycle the address is sent out. The lower 8bits are latched into the peripherals by the Address Latch Enable (ALE). During the rest of the machine cycle the Data Bus is used for memory or I/O data. The 8085A provides RD, WR, and IO/Memory signals for bus control. An Interrupt Acknowledge signal (INTA) is also provided. Hold, Ready, and all Interrupts are synchronized. The 8085A also provides serial input data (SID) and serial output data (SOD) lines for simple serial interface.

In addition to these features, the 8085A has three maskable, restart interrupts and one non-maskable trap interrupt. The 8085A provides RD, WR and IO/M signals for Buscontrol.

Status Information

Status information is directly available from the 8085A. ALE serves as a status strobe. The status is partially encoded, and provides the user with advanced timing of the type of bus transfer being done. IO/M cycle status signal is provided directly also. Decoded So, S1 Carries the following status information:

HALT, WRITE, READ, FETCH

S1 can be interpreted as R/W in all bus transfers. In the 8085A the 8 LSB of address are multiplexed with the data instead of status. The ALE line is used as a strobe to enter the lower half of the address into the memory or peripheral address latch. This also frees extra pins for expanded interrupt capability.

Interrupt and Serial I/O

The 8085A has 5 interrupt inputs: INTR, RST5.5, RST6.5, RST 7.5, and TRAP. INTR is identical in function to the 8080 INT. Each of the three RESTART inputs, 5.5, 6.5, 7.5, has a programmable mask. TRAP is also a RESTART interrupt except it is nonmaskable.

The three RESTART interrupts cause the internal execution of RST (saving the program counter in the stack and branching to the RESTART address) if the interrupts are enabled and if the interrupt mask is not set. The non-maskable TRAP causes the internal execution of a RST independent of the state of the interrupt enable or masks. The interrupts are arranged in a fixed priority that determines which interrupt is to be recognized if more than one is pending as follows: TRAP highest priority, RST 7.5, RST 6.5, RST 5.5, INTR lowest priority. This priority scheme does not take into account the priority of a routine that was started by a higher priority interrupt. RST 5.5 can interrupt a RST 7.5 routine if the interrupts were re-enabled before the end of the RST 7.5 routine. The TRAP interrupt is useful for catastrophic errors such as power failure or bus error. The TRAP input is recognized just as any other interrupt but has the highest priority. It is not affected by any flag or mask. The TRAP input is both edge and level sensitive.

Basic System Timing

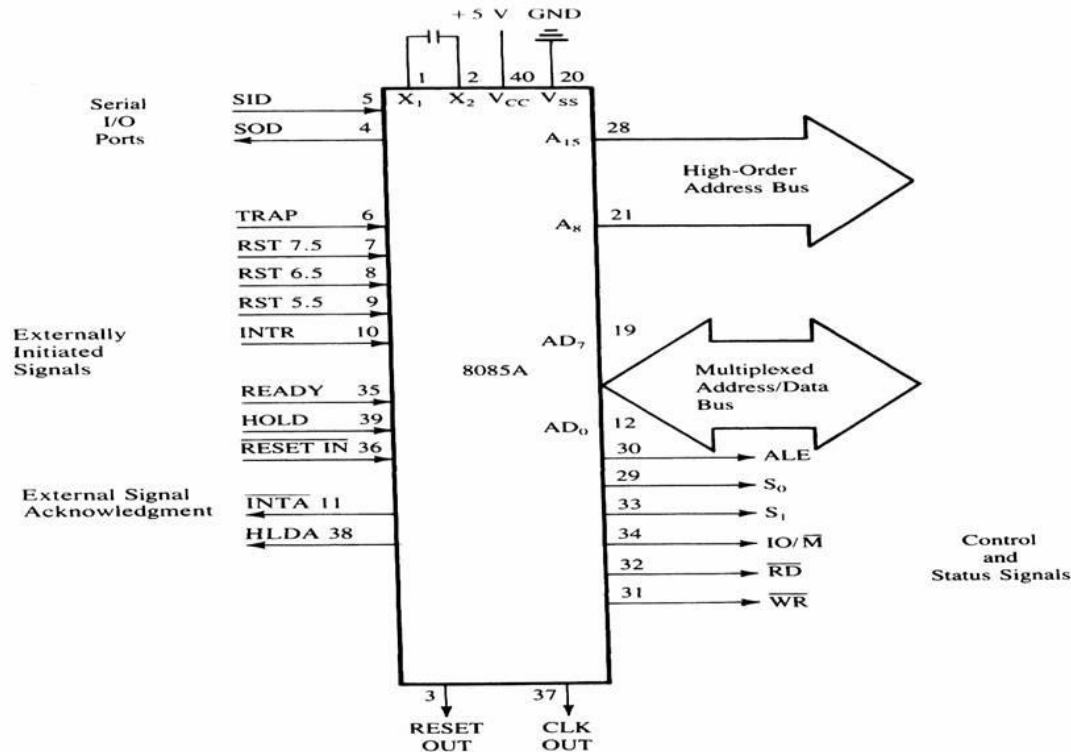
The 8085A has a multiplexed Data Bus. ALE is used as a strobe to sample the lower 8bits of address on the Data Bus. Figure 2 shows an instruction fetch, memory read and I/ O write cycle (OUT). Note that during the I/O write and read cycle that the I/O port address is copied on both the upper and lower half of the address. As in the 8080, the READY line is used to extend the read and write pulse lengths so that the 8085A can be used with slow memory. Hold causes the CPU to relinquish the bus when it is through with it by floating the Address and Data Buses.

System Interface

8085A family includes memory components, which are directly compatible to the 8085A CPU. For example, a system consisting of the three chips, 8085A, 8156, and 8355 will have the following features:

- 2K Bytes ROM
- 256 Bytes RAM
- 1 Timer/Counter
- 4 8bit I/O Ports
- 1 6bit I/O Port
- 4 Interrupt Levels
- Serial In/Serial Out Ports

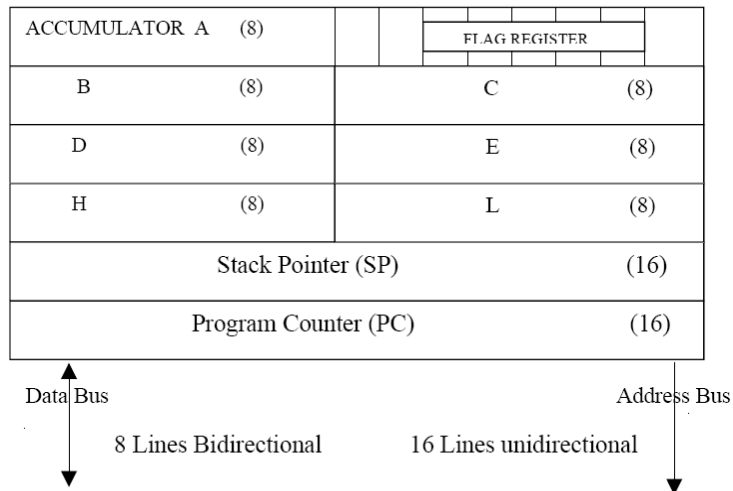
In addition to standard I/O, the memory mapped I/O offers an efficient I/O addressing technique. With this technique, an area of memory address space is assigned for I/O address, thereby, using the memory address for I/O manipulation. The 8085A CPU can also interface with the standard memory that does not have the multiplexed address/data bus.



1.4. The 8085 Programming Model

In the previous tutorial we described the 8085 microprocessor registers in reference to the internal data operations. The same information is repeated here briefly to provide the continuity and the context to the instruction set and to enable the readers who prefer to focus initially on the programming aspect of the microprocessor.

The 8085 programming model includes six registers, one accumulator, and one flag register, as shown in Figure. In addition, it has two 16-bit registers: the stack pointer and the program counter. They are described briefly as follows.



Registers

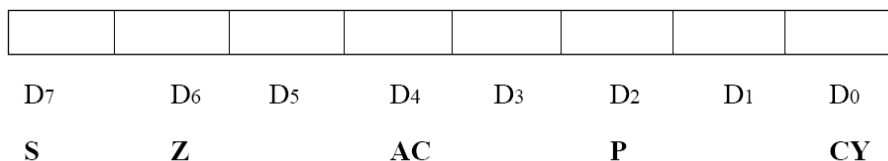
The 8085 has six general-purpose registers to store 8-bit data; these are identified as B,C,D,E,H, and L as shown in the figure. They can be combined as register pairs - BC, DE, and HL - to perform some 16-bit operations. The programmer can use these registers to store or copy data into the registers by using data copy instructions.

Accumulator

The accumulator is an 8-bit register that is a part of arithmetic/logic unit (ALU). This register is used to store 8-bit data and to perform arithmetic and logical operations. The result of an operation is stored in the accumulator. The accumulator is also identified as register A.

Flags

The ALU includes five flip-flops, which are set or reset after an operation according to data conditions of the result in the accumulator and other registers. They are called Zero(Z), Carry (CY), Sign (S), Parity (P), and Auxiliary Carry (AC) flags; their bit positions in the flag register are shown in the Figure below. The most commonly used flags are Zero, Carry, and Sign. The microprocessor uses these flags to test data conditions.



For example, after an addition of two numbers, if the sum in the accumulator is larger than eight bits, the flip-flop used to indicate a carry -- called the Carry flag (CY) -- is set to one. When an arithmetic operation results in zero, the flip-flop called the Zero(Z) flag is set to one. The first Figure shows an 8-bit register, called the flag register, adjacent to the accumulator. However, it is not used as a register; five bit positions out of eight are used to store the outputs of the five flip-flops. The flags are stored in the 8-bit register so that the programmer can examine these flags (data conditions) by accessing the register through an instruction.

These flags have critical importance in the decision-making process of the microprocessor.

The conditions (set or reset) of the flags are tested through the software instructions. For example, the instruction JC (Jump on Carry) is implemented to change the sequence of a program when CY flag is set. The thorough understanding of flag is essential in writing assembly language programs.

Program Counter (PC)

This 16-bit register deals with sequencing the execution of instructions. This register is a memory pointer. Memory locations have 16-bit addresses, and that is why this is a 16-bit register.

The microprocessor uses this register to sequence the execution of the instructions. The function of the program counter is to point to the memory address from which the next byte is to be fetched. When a byte (machine code) is being fetched, the program counter is incremented by one to point to the next memory location.

Stack Pointer (SP)

The stack pointer is also a 16-bit register used as a memory pointer. It points to a memory location in R/W memory, called the stack. The beginning of the stack is defined by loading 16-bit address in the stack pointer.

This programming model will be used in subsequent tutorials to examine how these registers are affected after the execution of an instruction.

1.5. The 8085 Addressing Modes

The instructions MOV B, A or MVI A, 82H are to copy data from a source into a destination. In these instructions the source can be a register, an input port, or an 8-bit number (00H to FFH). Similarly, a destination can be a register or an output port. The sources and destination are operands. The various formats for specifying operands are called the ADDRESSING MODES. For 8085, they are:

1. Immediate addressing.
2. Register addressing.
3. Direct addressing.
4. Indirect addressing.

Immediate addressing

Data is present in the instruction. Load the immediate data to the destination provided.

Example: MVI R,data

Register addressing

Data is provided through the registers.

Example: MOV Rd, Rs

Direct addressing

Used to accept data from outside devices to store in the accumulator or send the data stored in the accumulator to the outside device. Accept the data from the port 00H and store them into the accumulator or Send the data from the accumulator to the port 01H.

Example: IN 00H or OUT 01H

Indirect Addressing

This means that the Effective Address is calculated by the processor. And the contents of the address (and the one following) is used to form a second address. The second address is where the data is stored. Note that this requires several memory accesses; two accesses to retrieve the 16-bit address and a further access (or accesses) to retrieve the data which is to be loaded into the register.

1.6. Instruction Set Classification

An **instruction** is a binary pattern designed inside a microprocessor to perform a specific function. The entire group of instructions, called the **instruction set**, determines what

functions the microprocessor can perform. These instructions can be classified into the following five functional categories: data transfer (copy) operations, arithmetic operations, logical operations, branching operations, and machine-control operations.

Data Transfer (Copy) Operations

This group of instructions copy data from a location called a source to another location called a destination, without modifying the contents of the source. In technical manuals, the term *data transfer* is used for this copying function. However, the term *transfer* is misleading; it creates the impression that the contents of the source are destroyed when, in fact, the contents are retained without any modification. The various types of data transfer (copy) are listed below together with examples of each type:

Types	Examples
1. Between Registers.	1. Copy the contents of the register B into register D.
2. Specific data byte to a register or a memory location.	2. Load register B with the data byte 32H.
3. Between a memory location and a register.	3. From a memory location 2000H to register B.
4. Between an I/O device and the accumulator.	4. From an input keyboard to the accumulator.

Arithmetic Operations

These instructions perform arithmetic operations such as addition, subtraction, increment, and decrement.

Addition - Any 8-bit number, or the contents of a register or the contents of a memory location can be added to the contents of the accumulator and the sum is stored in the accumulator. No two other 8-bit registers can be added directly (e.g., the contents of register B cannot be added directly to the contents of the register C). The instruction DAD is an exception; it adds 16-bit data directly in register pairs.

Subtraction - Any 8-bit number, or the contents of a register, or the contents of a memory location can be subtracted from the contents of the accumulator and the results stored in the accumulator. The subtraction is performed in 2's complement, and the results

if negative, are expressed in 2's complement. No two other registers can be subtracted directly.

Increment/Decrement - The 8-bit contents of a register or a memory location can be incremented or decremented by 1. Similarly, the 16-bit contents of a register pair (such as BC) can be incremented or decremented by 1. These increment and decrement operations differ from addition and subtraction in an important way; i.e., they can be performed in any one of the registers or in a memory location.

Logical Operations

These instructions perform various logical operations with the contents of the accumulator.

AND, OR Exclusive-OR - Any 8-bit number, or the contents of a register, or of a memory location can be logically ANDed, Ored, or Exclusive-ORed with the contents of the accumulator. The results are stored in the accumulator.

Rotate- Each bit in the accumulator can be shifted either left or right to the next position.

Compare- Any 8-bit number, or the contents of a register, or a memory location can be compared for equality, greater than, or less than, with the contents of the accumulator.

Complement - The contents of the accumulator can be complemented. All 0s are replaced by 1s and all 1s are replaced by 0s.

Branching Operations

This group of instructions alters the sequence of program execution either conditionally or unconditionally.

Jump - Conditional jumps are an important aspect of the decision-making process in the programming. These instructions test for a certain conditions (e.g., Zero or Carry flag) and alter the program sequence when the condition is met. In addition, the instruction set includes an instruction called *unconditional jump*.

Call, Return, and Restart - These instructions change the sequence of a program either by calling a subroutine or returning from a subroutine. The conditional Call and Return instructions also can test condition flags.

Machine Control Operations

These instructions control machine functions such as Halt, Interrupt, or do nothing. The microprocessor operations related to data manipulation can be summarized in four functions:

1. Copying data
2. Performing arithmetic operations
3. Performing logical operations
4. Testing for a given condition and alerting the program sequence

Some important aspects of the instruction set are noted below:

1. In data transfer, the contents of the source are not destroyed; only the contents of the destination are changed. The data copy instructions do not affect the flags.
2. Arithmetic and Logical operations are performed with the contents of the accumulator, and the results are stored in the accumulator (with some exceptions). The flags are affected according to the results.
3. Any register including the memory can be used for increment and decrement.
4. A program sequence can be changed either conditionally or by testing for a given data condition.

1.7. Instruction Format

An **instruction** is a command to the microprocessor to perform a given task on a specified data. Each instruction has two parts: one is task to be performed, called the **operation code** (opcode), and the second is the data to be operated on, called the **operand**. The operand (or data) can be specified in various ways. It may include 8-bit (or 16-bit) data, an internal register, a memory location, or 8-bit (or 16-bit) address. In some instructions, the operand is implicit.

Instruction word size

The 8085 instruction set is classified into the following three groups according to word size:

1. One-word or 1-byte instructions
2. Two-word or 2-byte instructions
3. Three-word or 3-byte instructions

In the 8085, "byte" and "word" are synonymous because it is an 8-bit microprocessor. However, instructions are commonly referred to in terms of bytes rather than words.

One-Byte Instructions

A 1-byte instruction includes the opcode and operand in the same byte. Operand(s) are internal register and are coded into the instruction.

For example:

Task	Op code	Operand	Binary Code	Hex Code
Copy the contents of the accumulator in the register C.	MOV	C,A	0100 1111	4FH
Add the contents of register B to the contents of the accumulator.	ADD	B	1000 0000	80H
Invert (compliment) each bit in the accumulator.	CMA		0010 1111	2FH

These instructions are 1-byte instructions performing three different tasks. In the first instruction, both operand registers are specified. In the second instruction, the operand B is specified and the accumulator is assumed. Similarly, in the third instruction, the accumulator is assumed to be the implicit operand. These instructions are stored in 8-bit binary format in memory; each requires one memory location.

MOV rd, rs

rd \leftarrow rs copies contents of rs into rd.

Coded as 01 ddd sss where ddd is a code for one of the 7 general registers which is the destination of the data, sss is the code of the source register.

Example: MOV A,B

Coded as 01111000 = 78H = 170 octal (octal was used extensively in instruction design of such processors).

ADD r

A \leftarrow A + r

Two-Byte Instructions

In a two-byte instruction, the first byte specifies the operation code and the second byte specifies the operand. Source operand is a data byte immediately following the opcode.

For example:

Task	Opcode	Operand	Binary Code	Hex Code	
Load an 8-bit data byte in the accumulator.	MVI	A, Data	0011 1110	3E	First Byte
			DATA	Data	Second Byte

Assume that the data byte is 32H. The assembly language instruction is written as

Mnemonics	Hex code
MVI A, 32H	3E 32H

The instruction would require two memory locations to store in memory.

MVI r,data

$r \leftarrow \text{data}$

Example: MVI A,30H coded as 3EH 30H as two contiguous bytes. This is an example of immediate addressing.

ADI data

$A \leftarrow A + \text{data}$

OUT port

0011 1110

DATA

where port is an 8-bit device address. $(\text{Port}) \leftarrow A$. Since the byte is not the data but points directly to where it is located this is called direct addressing.

Three-Byte Instructions

In a three-byte instruction, the first byte specifies the opcode, and the following two bytes specify the 16-bit address. Note that the second byte is the low-order address and the third byte is the high-order address.

opcode + data byte + data byte

For example:

Task	Opcode	Operand	Binary code	Hex Code	
Transfer the program sequence to the memory location 2085H.	JMP	2085H	1100 0011	C3	First byte
			1000 0101	85	Second Byte
			0010 0000	20	Third Byte

This instruction would require three memory locations to store in memory.

Three byte instructions - opcode + data byte + data byte

LXI rp, data16

rp is one of the pairs of registers BC, DE, HL used as 16-bit registers. The two data bytes are 16-bit data in L H order of significance.

rp <-- data16

Example:

LXI H,0520H coded as 21H 20H 50H in three bytes. This is also immediate addressing.

LDA addr

A <-- (addr) Addr is a 16-bit address in L H order. Example: **LDA 2134H** coded as 3AH 34H 21H. This is also an example of direct addressing.

1.8. INSTRUCTION CYCLE:

An instruction is a command given to the computer to perform a specified operation on the given data. Sequence of instructions written for a computer to perform a particular task is called program. Program & data are stored in the memory. The microprocessor fetches one instruction from the memory at a time & executes it. It executes all the instructions of the program one by one to produce the final result. The necessary steps that a microprocessor carries out to fetch an instruction & necessary data from the memory & to execute it constitute an instruction cycle.

In other words, an instruction cycle is defined as the time required completing the execution of an instruction.

An instruction cycle consists of a fetch cycle & an execute cycle. The time required to fetch an opcode (fetch cycle) is a fixed slot of time while the time required to execute an

instruction (execute cycle) is variable which depends on the type of instruction to be executed.

FETCH OPERATION:

The first byte of an instruction is its opcode. An instruction may be more than one byte long. The other bytes are data of operand address. The program counter (PC) keeps the memory address of the next instruction to be executed. In the beginning of a fetch cycle the content of the program counter, which is the address of the memory location where opcode is available, is sent to the memory. The memory places the opcode on the data bus so as to transfer it to the microprocessor. The entire operation of fetching an opcode takes three clock cycles.

EXECUTE OPERATION:

The opcode fetched from the memory goes to the instruction register (IR). From the instruction register it goes to the decoder circuitry which decodes the instruction. After the instruction is decoded, execution begins. If the operand is in general purpose registers execution is immediately performed.

The time taken for decoding and execution is one clock cycle. If an instruction contains data or operand and address which are still in the memory, the microprocessor has to perform some read operations to get the desired data. After receiving the data it performs execute operation. A read cycle is similar to a fetch cycle. In case of a read cycle the quantity received from the memory are data or operand address instead of an opcode. In some instructions write operation is performed. In write cycle data are sent from the microprocessor to the memory or an output device. Thus we see that in some cases an execute cycle may involve one or more read or write cycles or both.

MACHINE CYCLE:

Machine cycle is defined as the time required completing the operation of accessing either memory or I/O. In the 8085, the machine cycle may consist of three to six T states.

T-State:

T-State is defined as one sub-division of the operation performed in one clock period. These sub-divisions are internal states synchronized with the system clock.

1.9. TIME DELAYS:

Counters are constructed using software instructions to keep track of the events. Since the counting is performed at such high speed, only the last count can be observed. To observe all the counts, there must be an appropriate time delay between counts.

Designing a delay is very simple. A register is loaded with a number, depending on the delay required, and then the register is decremented until it reaches zero by setting up a loop with a conditional JUMP instruction. The loop causes the delay, depending upon the clock period of the system.

Single Register Delay:

A count is loaded in a register and the loop is executed until the count reaches zero. The set of instructions necessary to set up a delay loop are:

LOOPMVI B, FF

DCR B

JNZ LOOP

To calculate the time delay we must consider the T-states required for each instruction, and for the number of times the instruction are executed in the loop. The clock frequency of 8085 is **3MHZ**.

Clock period $T = 1/f = 1/3 \times 10^6 = 0.33 \times 10^{-6}$

Register B is loaded with FFH (255_{10}) therefore the loop is repeated 255 times.

The time delay can be calculated as follows:

$T_L = (T \times \text{Loop T states} \times N_{10})$

Where:

T_L = Time Delay in loop

T = System Clock Period.

N_{10} = Equivalent decimal number of Hexadecimal count loaded in the delay register.

DCR & JNZ forms a 0 loop with a total of 14 (4+10) T- states.

Therefore:

$T_L = (0.33 \times 10^{-6} \times 14 \times 255)$

$T_L = 1.1781 \times 10^{-3}$

Eg:

Write an ALP to display FF and 00 alternatively with a delay:

MVI A, FF

BACK PUSH PSW

STA 8FF1

CALL UPDDT

CALL DELAY

POP PSW

CMA

JMP **BACK**

HLT