Microprocessor Architecture

Lecture 1 - General architecture of digital computer, review of 8085 µp

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Course Objective

1) Understand components of the computers, microprocessors.
2) Know how to approach and undertake microprocessor development.
3) Learning role of CPU, registers, buses.
4) Know how interface memory and peripheral devices to a microprocessor.
5) Learning addressing modes (Immediate, direct, extended, indexed, indexed-indirect, and relative addressing modes).
6) Know the architecture of the 80x85-type microprocessor. Its capabilities and limitation and how it fits in with modern computers.
7) Understanding the function of each pin in 8085 microprocessor.
8) Learning interrupt vectors, interrupt process, interrupt priorities, external and advanced interrupts.
9) Learning how to write program in **assembly language using Turbo Assembler (TASM)**
10) Learning assembly-programming styles, structured assembly language programming.

Introduction of Microprocessor

- A **Microprocessor** is an important part of a computer architecture without which you will not be able to perform anything on your computer.
- It is a programmable device that takes in input performs some arithmetic and logical operations over it and produces the desired output.
- In simple words, a Microprocessor is a digital device on a chip that can fetch instructions from memory, decode and execute them and give results.

General architecture of digital computer

At present there are many types and sizes of computers available. These computers are designed and constructed based on digital and integrated circuit (**IC**) fabrication technology. A **digital computer** is a machine that can be used to solve problems for people and carrying out the tasks by following the instructions given to it. A sequence of instructions describing how to perform a certain task or job is called a program. There are two basic components of **computer system** architecture:

- **Computer Hardware**
  - Memory unit (MU)
  - Input/output unit (IOU).
  - Control Unit (CU)
  - Arithmetic and logic unit (ALU)
- **Computer Software**
  - System Software
  - Application Software

General architecture of digital computer

Computer Hardware is equipment involved in the function of a computer. Computer hardware consists of the components that can be physically handled. The function of these components is typically divided into four main categories, these are: Central Processing Unit (CPU), Memory Unit, I/O Unit and System Interconnection (Buses) that provide the communication among the CPU, main memory, and I/O. The basic components of computer hardware shown in figure (1):

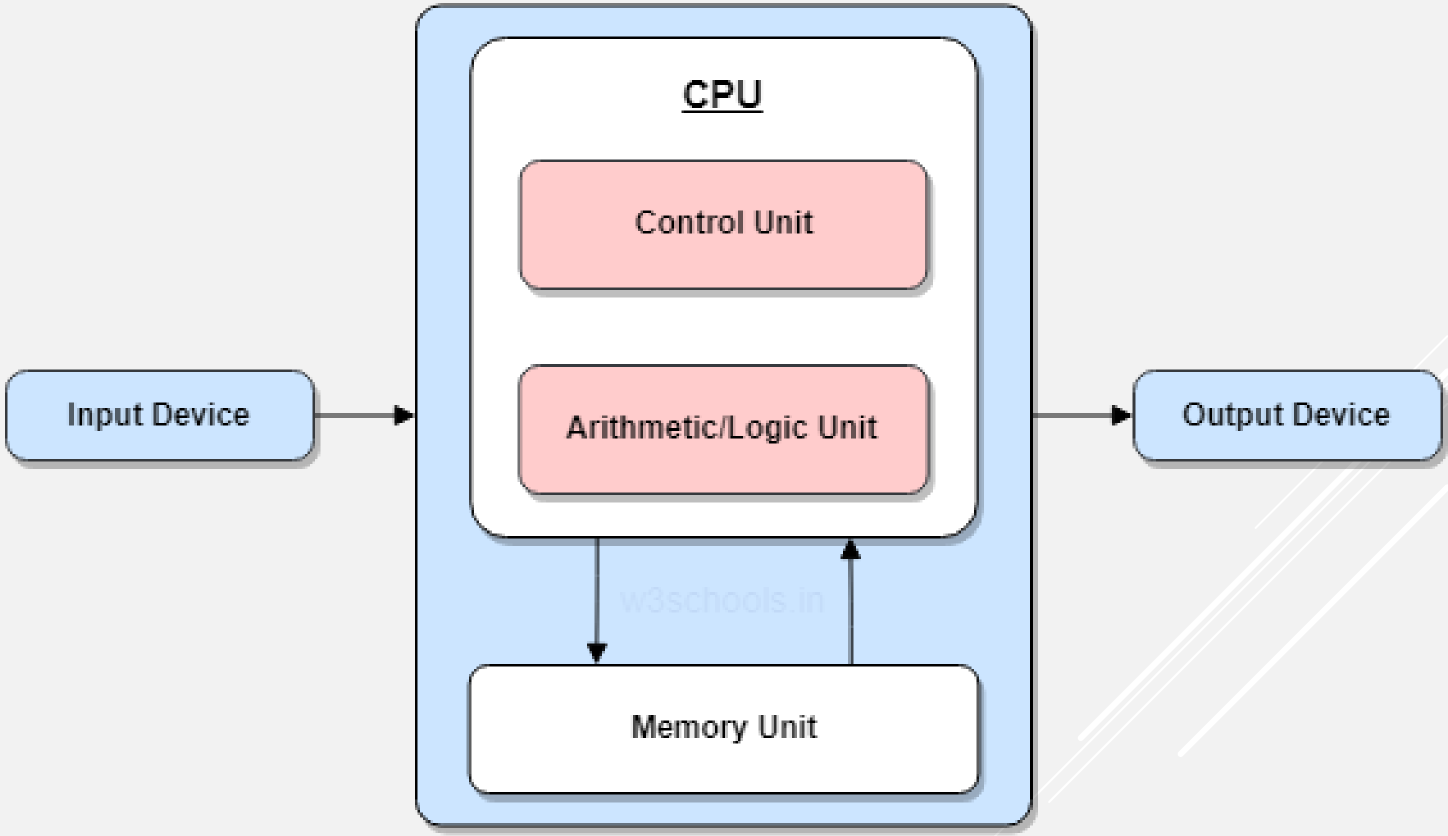


Figure 1: General Purpose Computer Organization

General architecture of digital computer

1. **CPU:** The microprocessor that makes up your personal computer's central processing unit, or CPU, is the ultimate computer brain. All the other components like RAM, disk drives, the monitor-exist only to bridge the gap between you and the processor. They take your data and turn it over to the processor to manipulate; then they display the results. A CPU consists of several units, including the Arithmetic and Logic Unit (ALU), local storage for intermediate results (registers), a control unit, and possibly a cache to speed access to memory.

- **ALU (Arithmetic /Logic Unit):** is that part of the computer that actually performs arithmetic and logical operations on data. All of the other elements of the computer system-control unit, registers, memory, I/O- are there mainly to bring data into the ALU for it to process and then to take the results back out.
- **Registers:** are temporary storage areas a computer uses to hold data or instructions during processing or after it.
- **Control Unit:** provides the necessary timing and control signals to all the operations in the computer. It controls the flow of data between the computer and its peripherals, or inside the computer itself.

General architecture of digital computer

2. Memory Unit: The computer memory is a temporary storage area. It holds the data and instructions that the Central Processing Unit (CPU) needs. Before a program can be run, the program is loaded from some storage medium into the memory. This allows the CPU direct access to the program. Memory is like the page of a notebook with space for a fixed number of binary numbers on each line.

The memory unit usually described by its size which represents the number of locations in the memory and its word-length which specify the capacity in bits for each location in the memory. The information stored in the memory as binary code in groups of bits called word. The binary is two logic levels either 0 or 1:

Bit: is binary digit (1) or (0),

Byte: is a group of eight bits, and

Word: is a group of sixteen bits.

General architecture of digital computer

Memory in general is divided into two general categories:

Read Only Memory (ROM) | **Random Access Memory (RAM)**

Read Only Memory (ROM): is a class of storage medium used in computers and other electronic devices. Data stored in ROM cannot be modified, or can be modified only slowly or with difficulty. ROM memories have gradually evolved from fixed read-only memories to memories than can be programmed and then re-programmed. There are many type of Re-Programed memory:

- ROM (Read Only Memory).
- PROM (Programmable Read Only Memory).
- EPROM (Erasable Programmable Read Only Memory).
- EEPROM (Electrically Erasable Programmable Read Only Memory).

General architecture of digital computer

Random Access Memory (RAM): is the memory that the computer uses to temporarily store the information as it is being processed.

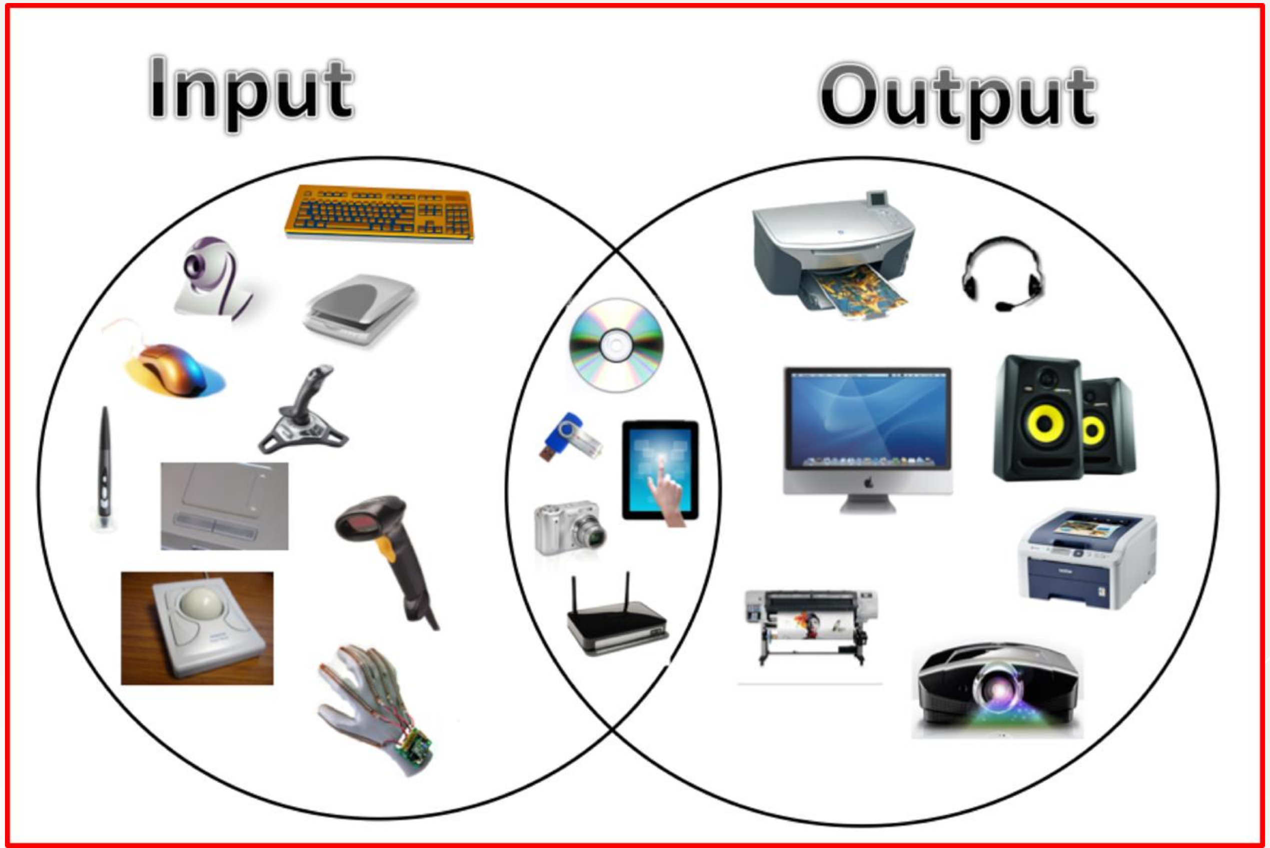
Random Access Memory (RAM)	Read Only Memory (ROM)
1. Temporary storage. 2. Store data in MBs. 3. Volatile. 4. Used in normal operation. 5. Writing data is faster	1. Permanent storage. 2. Store data in GBs. 3. Non- Volatile. 4. Used for start-up process of Computer. 5. Writing data is slower .

NOTE:

RAM is **volatile** memory, which means that the information temporarily stored in the module is erased when you restart or shut down your computer. Because the information is stored electrically on transistors

General architecture of digital computer

3. Input / Output Unit (IOU): The input unit contains the hardware devices those are used to enter the data in to computer system, Keyboard and mouse are most common devices. The output contain the hardware devices those are used to output the data from the computer system, Monitor and printer are most common output devices. Nowadays so many other I/O devices are used as shown below.



General architecture of digital computer

Computer Software: Without software, most hardware would sit there doing nothing or perform specific tasks. To make most hardware run, we need to use software, and the task here is to select the correct type of software for each job. The two main classifications of software that all programs fit under are:

- System software
- Application software

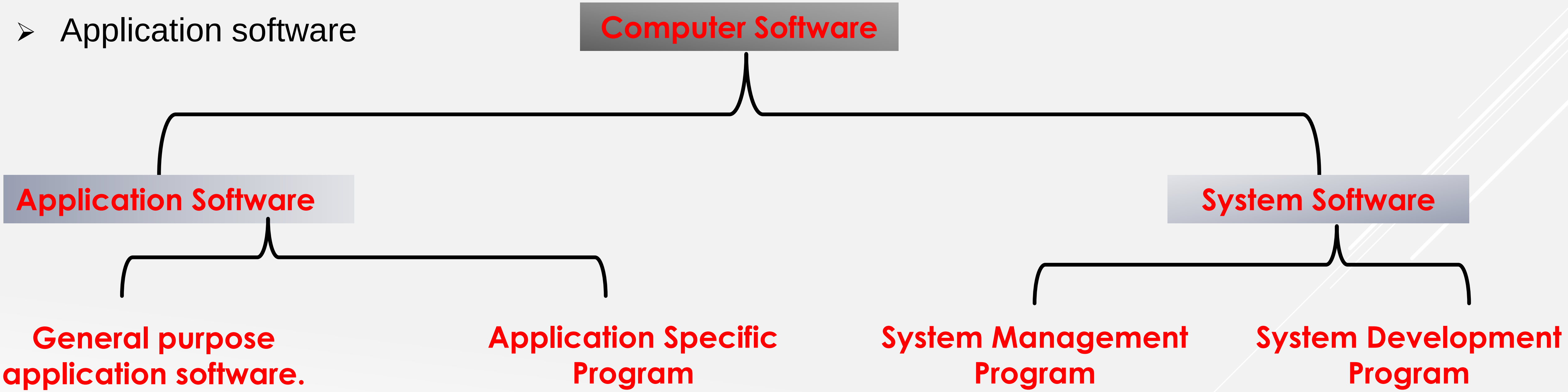


Figure 2: Basic classification of computer software

General architecture of digital computer

System software: software designed to operate the computer hardware and to provide a platform for running application software. Modern computers are complex machines involving many different parts. To keep it running well you will need system software. System software will handle the smooth running of all the components of the computer as well as providing general functionality for other programs to use, tools to speed up the computer, tools to develop new software and programs to keep you safe from attacks. There are **several different types** of system software that we will look at in more detail very shortly:

- **Operating Systems:** such as Windows 7 or Linux
- **Utility programs:** Various examples include file management, diagnosing problems and finding out information about the computer etc. Notable examples of utility programs include copy, paste, delete, file searching, disk defragmenter, disk clean-up.
- **Library programs:** are a compiled collection of subroutines (e.g. libraries make many functions and procedures available when you write a program)
- **Translator software:** (Assembler, Compiler, Interpreter):

General architecture of digital computer

- **Translator software:** (Assembler, Compiler, Interpreter):

- **Assembler** translates assembly language programs into machine code (A binary code that a machine can understand).
- **Compiler** translates high level language code into object code (which is the machine language of the target machine).
- **Interpreter** analyses and executes a high-level language program a line at a time. Execution will be slower than for the equivalent compiled code as the source code is analyzed line by line.

General architecture of digital computer

Application software: software designed to help the user to perform specific tasks

Application software is designed for people like me and you to perform tasks that we consider useful. This might be the ability of a scientist to work out statistical information using a set of results, or someone who wants to play the latest computer game. There are several categories of Application software that we'll look into shortly:

- General purpose application software.
- Special purpose application software.
- Bespoke application software

8085 Microprocessor Architecture

The microprocessor has become more essential part of many gadgets. The evolution of microprocessors was divided into five generations such as first, second, third, fourth and fifth generation.

Intel Microprocess

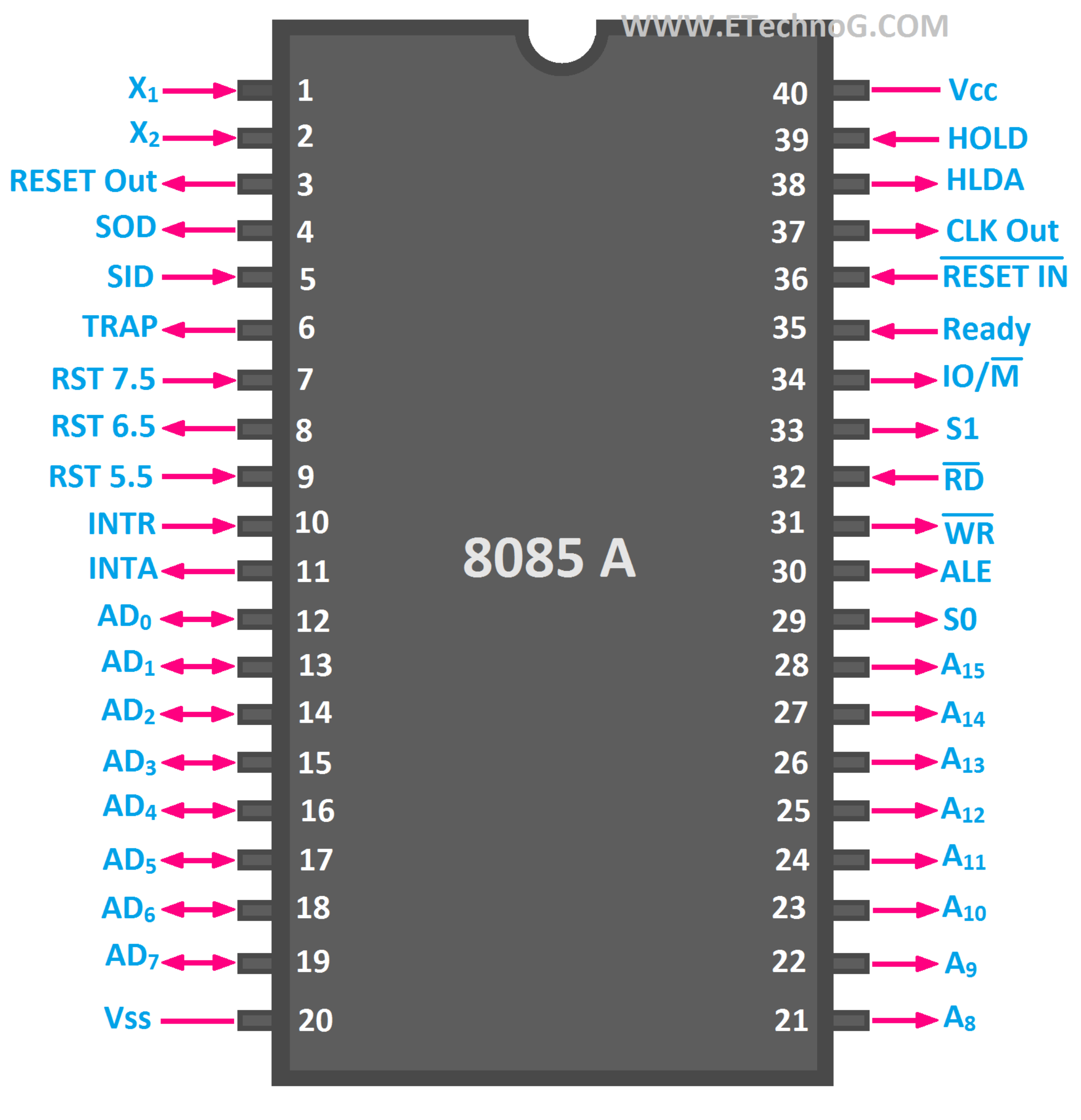
Name	Year	Transistors	Clock speed	Data width
8080	1974	6,000	2 MHz	8 bits
8085	1976	6,500	5 MHz	8 bits
8086	1978	29,000	5 MHz	16 bits
8088	1979	29,000	5 MHz	8 bits
80286	1982	134,000	6 MHz	16 bits
80386	1985	275,000	16 MHz	32 bits
80486	1989	1,200,000	25 MHz	32 bits
Pentium	1993	3,100,000	60 MHz	32/64 bits
Pentium II	1997	7,500,000	233 MHz	64 bits
Pentium III	1999	9,500,000	450 MHz	64 bits
Pentium IV	2000	42,000,000	1.5 GHz	64 bits
Pentium IV "Prescott"	2004	125,000,000	3.6 GHz	64 bits
Intel Core 2	2006	291 million	3 GHz	64 bits
Pentium Dual Core	2007	167 million	2.93 GHz	64 bits
Intel 64 Nchalem	2009	781 million	3.33 GHz	64 bits

8085 Microprocessor Architecture

Intel 8085, **an 8-bit N-channel metal-oxide semiconductor (NMOS) microprocessor is available in the form of 40 Pin** dual in line IC package. It is fabricated on a single LSI chip. **It operates on +5 V d.c. supply**. The **maximum** clock speed used in this microprocessor **is about 3 MHZ while minimum frequency is 500kHz.** General Purpose 8-bit microprocessor is capable of addressing up to **64 K** bytes (i.e. 2^{16}=65536 bytes) of memory. 8085 Microprocessor can fetch instructions from a memory, decode and execute them i.e. performs certain arithmetic and logical operations, accept data from input device, and send results to output devices.

- Year of product 1976.
- No. of transistor 6500.
- Internal Data bus 8 bit.
- External Data bus 8 bit.
- Data type 8 bit.
- Address bus 16 bit.
- Physical Memory 64 Kbyte.

8085 Microprocessor Architecture



Microprocessor 8085 Pinout Diagram

8085 Microprocessor Architecture

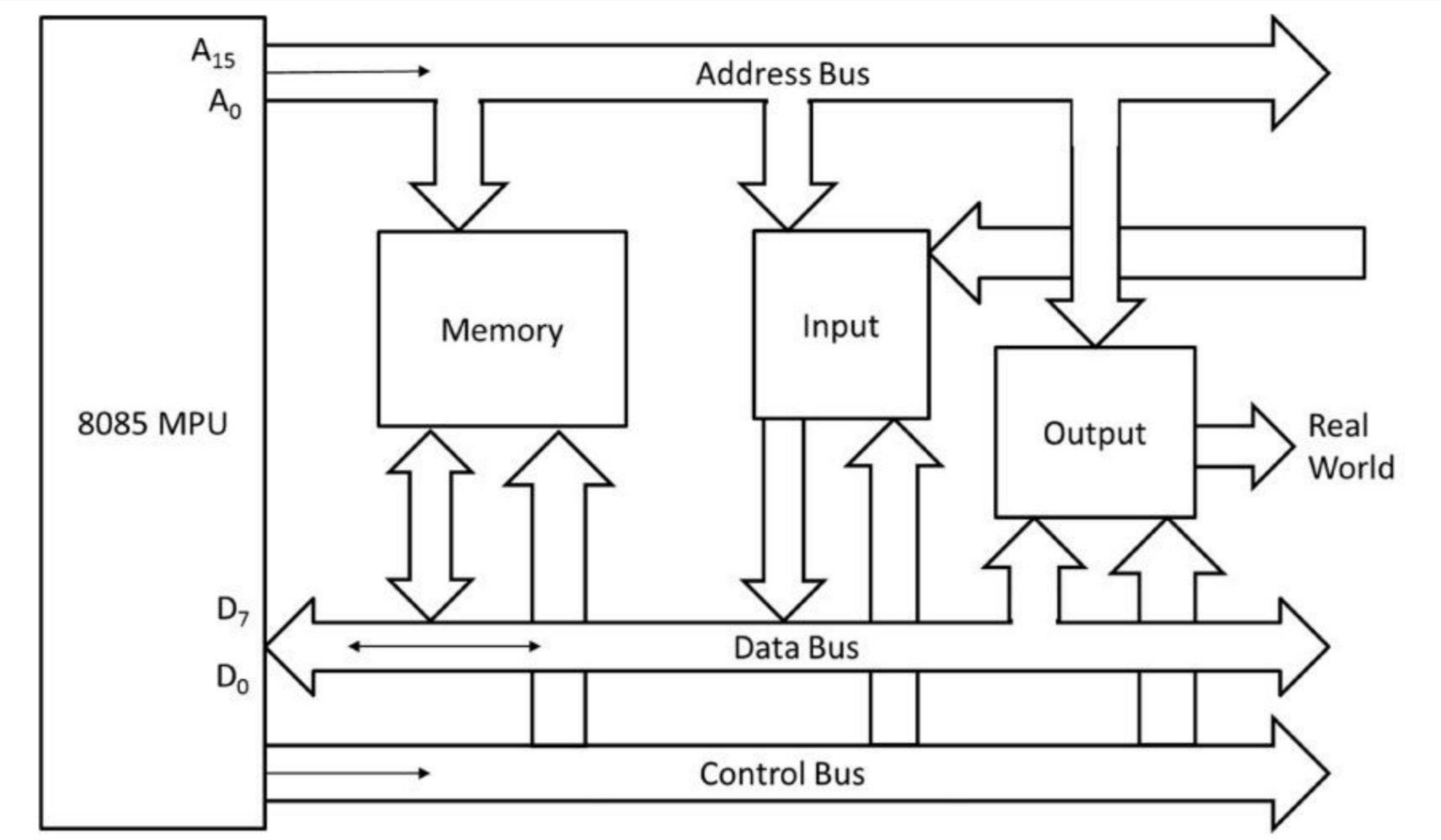
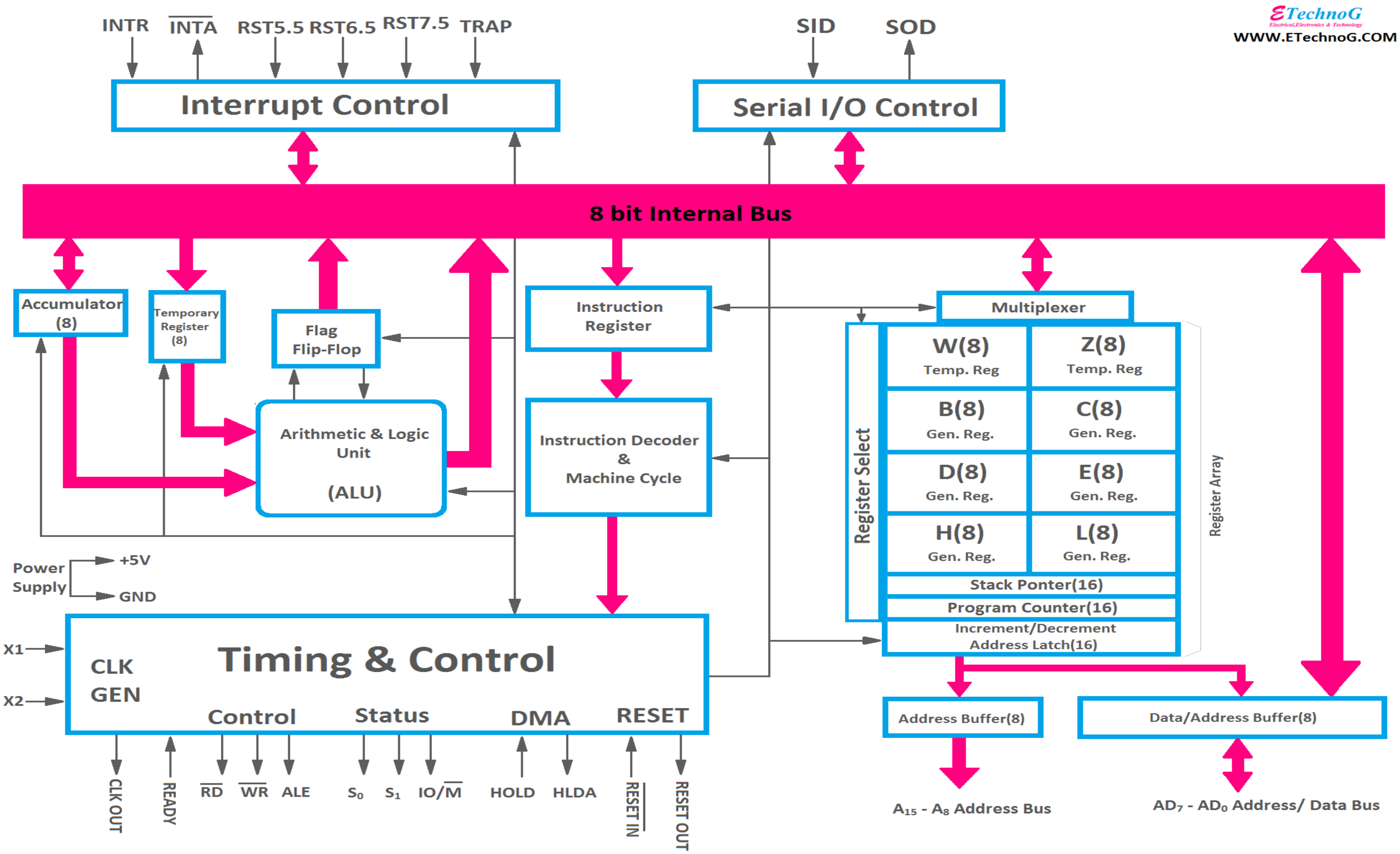


Figure 2: The 8085 Bus Structure

8085



Microprocessor 8085 Block Diagram and Architecture

Microprocessor VS Microcontroller

8085 Microprocessor Architecture

In a computer system ALU and Control Unit are combined in one unit called Central Processing Unit (CPU). The CPU is analogous to the human brain as all the decisions as per the instructions are made by this unit. All other parts are also controlled by this unit. A microprocessor is an integrated circuit designed for use as Central Processing Unit of a computer. The CPU is the primary and central player in communicating with devices such as memory, input and output. However, the timing of communication process is controlled by the group of circuits called control unit.

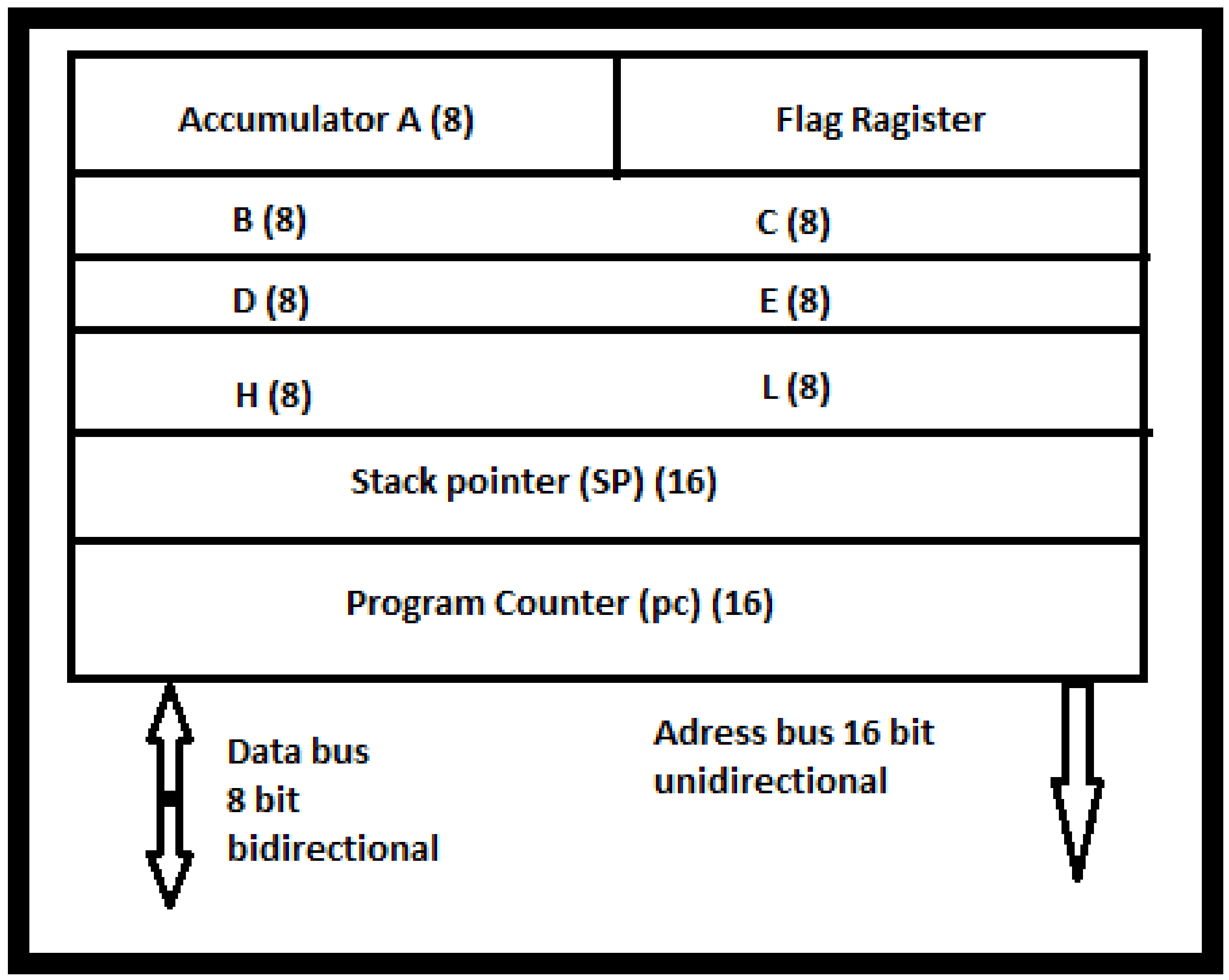
The main functional components of 8085 microprocessor are as given below:

- Register Section.
- Arithmetic and Logic Unit.
- Timing and Control Section.
- Interrupt Control.
- Serial Input / Output Control.

8085 Microprocessor Architecture

The 8085 microprocessor contains **eight addressable 8-bit registers** namely:

1. **A** (Accumulator) register
2. **F** Flag register (Flag flip-flops)
3. **B** register
4. **C** register
5. **D** register
6. **E** register
7. **H** register
8. **L** register



8085 Microprocessor Architecture

- Out of these registers **B, C, D, E, H and L** registers are 8-bit general purpose registers. These registers can either be used as single register store 8-bit data for processing or a combination of two registers as 16 bit register pair. The valid register pairs are B-C, D-E or H-L register pairs. The higher order byte of 16 bit data is stored in first register (B in B-C register pair), and low order byte in the second register (C in B C register pair).

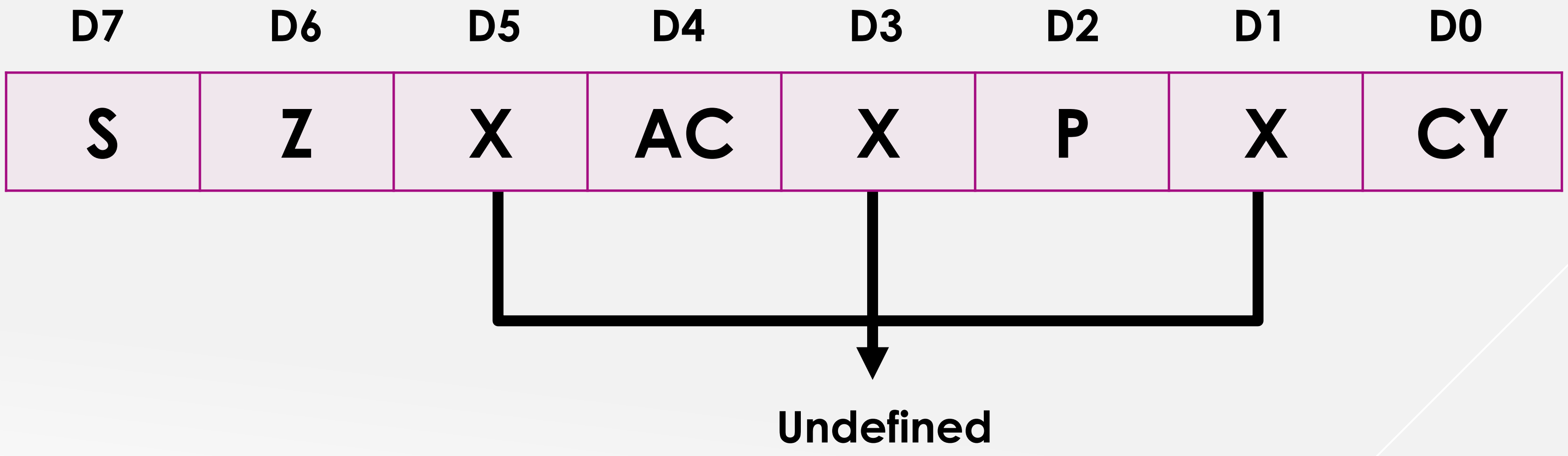
- The H-L register pair can also be used for register indirect addressing; since this register pair can also function as data pointer. The large number of general purpose registers gives more flexibility and ease in the programming. However, the general purpose registers are limited as registers occupy more space on the silicon chip.

- Beside these general purpose registers, the 8085 has remaining two 8-bit registers **Accumulator (A)** and **Flag (F)** as special purpose registers and two 16 bit registers namely Program counter (PC) and stack pointer (SP).

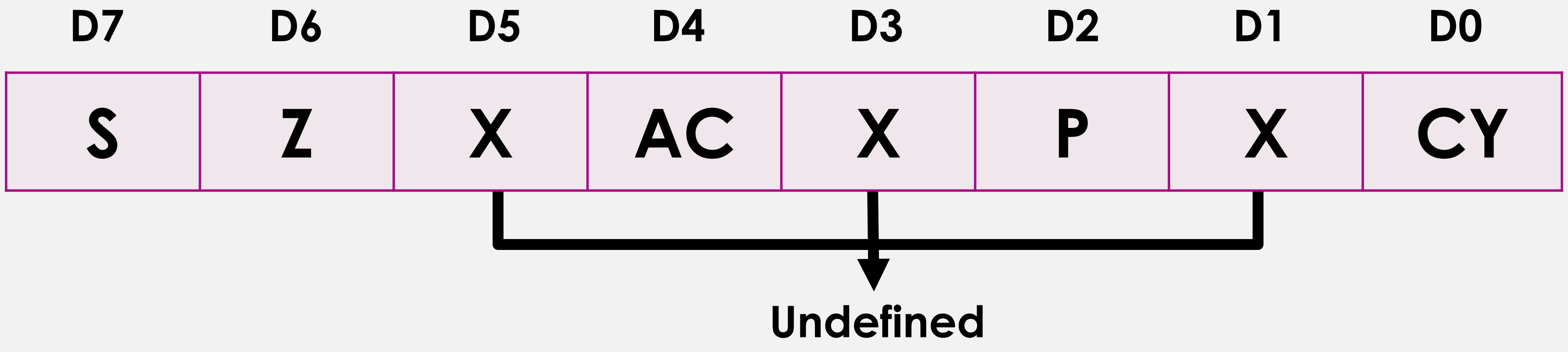
8085 Microprocessor Architecture

- **Accumulator (A)** is an 8 bit register which stores the results of arithmetical and logical operations. It is also used to receive data from input port to microprocessor and to send data to output port from microprocessor. It is referred as register A in the program.

- **Flag Register (F)** is also an 8 bit register which indicate status of the accumulator after any arithmetical or logical operation. Out of 8 bits, five are defined as flags. These flags are given below.



8085 Microprocessor Architecture



- **Sign Flag (S):** It indicates the sign of the number. If the number is negative then sign flag is set (changed to 1) and if positive then reset (changed to 0).
- **Zero Flag (Z):** If after any arithmetical or logical operation, all the bits in accumulator are zero then zero flag is set otherwise reset.
- **Auxiliary Carry Flag (AC):** If carry is generated from D3 to D4 in the accumulator after any operation then auxiliary carry flag is set otherwise reset. This flag is used internally by microprocessor for BCD operations and cannot be used by the programmer.
- **Parity Flag (P):** If after any arithmetical or logical operation number of 1’s in accumulator are even, then parity flag is set, otherwise reset.
- **Carry Flag (CY):** The size of accumulator is 8 bit. If after any operation 9th bit is generated then carry flag is set, otherwise reset.

8085 Microprocessor Architecture

- **Program counter:** is a 16 bit register which is also known as memory pointer. It stores the address of the next byte of the program to be executed. The microprocessor takes the address from program counter and executes instruction at that address. Each time the address in program counter is incremented by one.

- **Stack Pointer (SP):** It is a 16 bit register which contains the memory address of top of the stack. Stack is a part of memory which is used to store data temporarily, especially while the execution of subroutines or functions.

8085 Microprocessor Architecture

Arithmetic and Logic Unit (ALU)

The arithmetic and logical unit (ALU) **basically** consists of accumulator (A), flag register (F) and a temporary register (which is inaccessible by the programmer or user). This unit carries out the arithmetic and logic calculations of the data stored in general purpose registers or in memory locations. The arithmetic operations are ADD, SUB, compare, increments, decrements and complements etc.; while logical operations are AND, OR, XOR and Rotate. The result of these operations could be placed in the accumulator or elsewhere through the internal bus. Arithmetic operations are usually carried out in 2’s complement and for these operations the ALU receives the control signals from the timing and control unit.

8085 Microprocessor Architecture

Timing and Control Unit

This unit is responsible to synchronize Microprocessor operation as per the clock pulse and to generate the control signals which are necessary for smooth communication between Microprocessor and peripherals devices. The RD bar and WR bar signals are synchronous pulses which indicates whether data is available on the data bus or not. The control unit is responsible to control the flow of data between microprocessor, memory and peripheral devices.

8085 Microprocessor Architecture

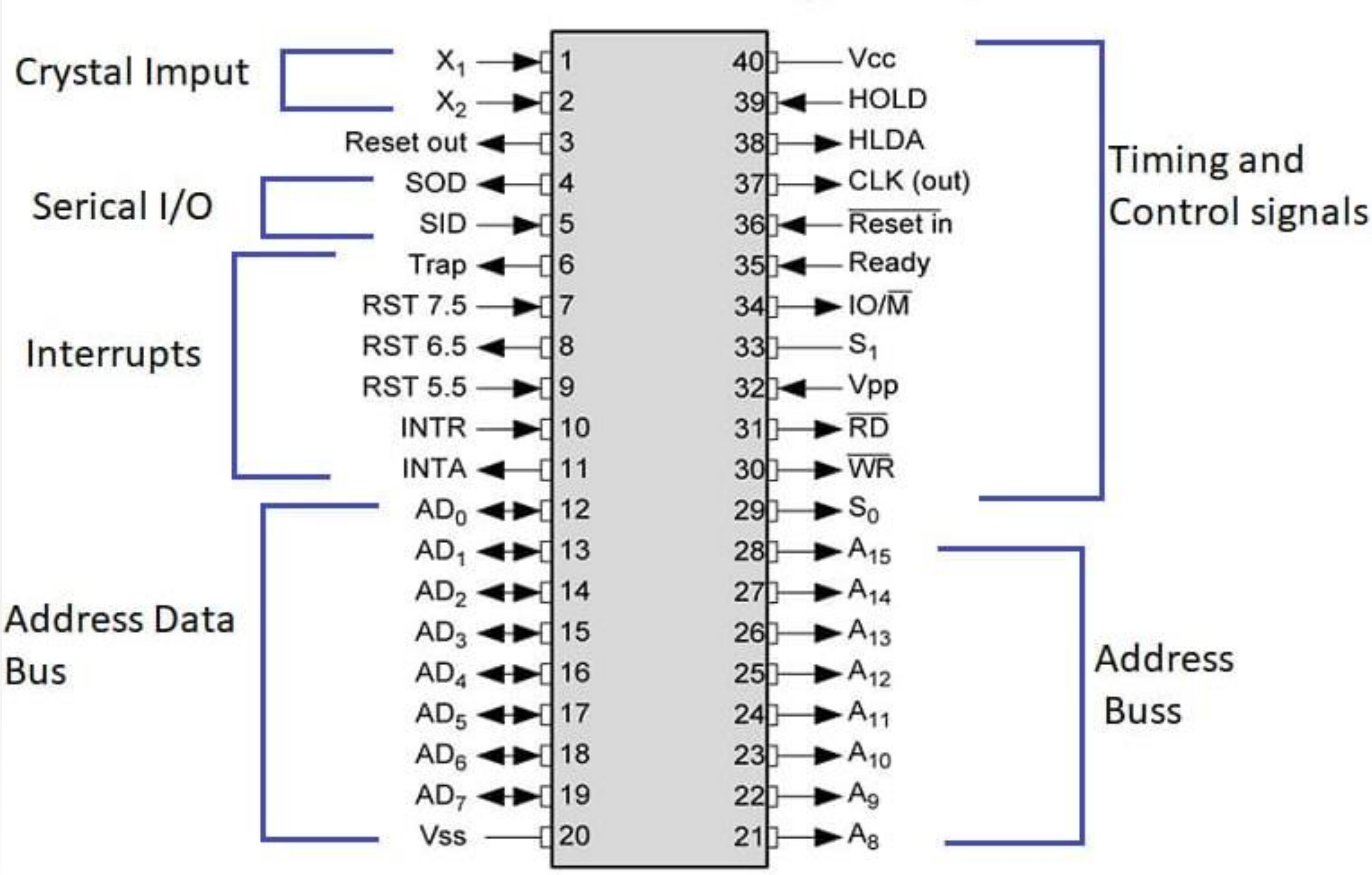


Table (1): Pins Description of 8085 µp

All the signal can be classified into six groups as explained in the following table:

NO.	Group	Description
1	**Address bus**	8085 requires 8-bit data bus and 16-bit address bus, as the memory address is of 16 bits. More number of IC pins are required if separate address and data bus are introduced. To restrict the number of pins of 8085 to only 40, lower address lines A0-A7 and data lines D0-D7 are used in multiplexed mode. The multiplexed lines are designed as Address/Data Bus (AD0-AD7). So whenever 16-bit address is transmitted by the microprocessor 8 MSBs of the address lines are sent on the Address Bus (A15-A8) and 8 LSBs of the lines are sent on the Address/Data Bus (AD7- AD0). The 8 LSBs of the address are then latched either into memory or external latch so that the complete address remains available for further operation. The 8-bit Address/Data Bus will now be free for the data transmission. The 8085 microprocessor has 8 signal line, A15 - A8 which are unidirectional and used as a high order address bus.

Table (1): Pins Description of 8085 µp

All the signal can be classified into six groups as explained in the following table:

NO.	Group	Description
2	**Data bus**	The signal line AD7 - AD0 are bi-directional for dual purpose. They are used as low order address bus as well as data bus.
3	**Control signal and Status signal**	*Control Signal* $\overline{RD}$ This is an active low signal to be connected to memory read input (output enable signal to memories) or to input / output read signal to enable input / output buffer. $\overline{WR}$ Write signal is also active low. This signal is used to write to the memory or input/ output devices. **ALE (Address Latch Enable)** When ALE is high, 8085 microprocessor use address bus. When ALE is low, 8085 microprocessor is use data bus. The 16 bit address bus is basically divided into two sets. The most significant bits A7-A15 of the address bus are used separately and the least significant bits of the address AD0-AD7 are time multiplexed with the bits of bidirectional data bus (D0-D7). The AD0-AD7 bus serves the dual purpose as they can be used as low-order address bus as well as bidirectional data bus at different times. This is used as address bus, during the first clock cycle of the machine cycle involving memory; and during the remaining clock cycle of the machine cycle, it acts as the data bus. This is accomplished by address latch enable (ALE) signal provided in the processor. During the first clock cycle of the machine cycle ALE is high which enables the lower 8-bit of the address to be latched either into the memory or external latch.

Table (1): Pins Description of 8085 µp

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<table>
<tr><th>NO.</th><th>Group</th><th>Description</th></tr>
<tr><td>3</td><td>Control signal and Status signal</td><td>
$IO/\overline{M}$ This signal $IO/\overline{M}$ distinguishes that the address and data is meant for either I/O devices or memory. Whenever this signal is high (1), microprocessor will communicate to the I/O devices and whenever it is low (0), microprocessor will communicate to the memory.
S1 and S0 The status signals (S0, S1) along with $IO/\overline{M}$ signal indicate the type of machine cycle in progress. The type of machine cycle are op code fetch, memory read, memory write, I/O read or I/O write cycles.
<table>
<tr><th>Machine Cycle</th><th>$IO/\overline{M}$</th><th>S_1</th><th>S_0</th></tr>
<tr><td>Op code fetch Cycle</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>Memory Read Cycle</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>Memory Write Cycle</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>I/O Read Cycle</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>I/O Write Cycle</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>INTR Acknowledge</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>Halt</td><td>Hi-Z</td><td>0</td><td>0</td></tr>
</table>
</td></tr>
</table>

Table (1): Pins Description of 8085 µp

All the signal can be classified into six groups as explained in the following table:

NO.	Group	Description
4	**Power supply and frequency signal**	**Vcc** – +5v power supply. **Vss** – ground reference. **X1, X2**– A crystal is connected at these two pins. The frequency is internally divided by two operate system at 3-MHz, the crystal should have a frequency of 6-MHz. **CLK out** – This signal can be used as the system clock for other devices.
5	**Externally initiated signal**	**HOLD & HLDA:**HOLD is an input signal .When µP receives HOLD signal it completes current machine cycle and stops executing next instruction. In response to HOLD µP generates HLDA that is HOLD Acknowledge signal.
6	**Serial I/O ports**	Serial input/ output control circuit incorporated in this microprocessor is used for the data transmission. For this purpose two pins SID and SOD are provided in the serial input/output control unit. The SID (Serial Input Data) terminal receives the serial data stream from an input device, the control unit converts serial data stream to parallel data before it is used by the computer. After the conversion 8-bit parallel data is stored in the accumulator. Similarly, SOD (Serial Out Data) terminal outputs the 8-bit parallel available with the accumulator into serial form to the peripheral device connected with the computer.

Reference

[1] Microprocessor architecture , programming and application with the 8085 microprocessor by Ramask S .Gonker .

[2] Microprocessor and interfacing (1st Edition),2009, by Atul p. godse

[3] The 8086 microprocessor architecture and interfacing techniques by WALTER A.TRIBEL