



SCHOOL OF ELECTRICAL AND ELECTRONICS
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

UNIT – I – MICROPROCESSORS AND MICROCONTROLLERS– SEC1201

UNIT 1 INTRODUCTION TO MICROPROCESSORS

Introduction, 8085 Architecture, Pin Diagram and signals, Addressing Modes, Timing Diagram, Memory read, Memory write, I/O cycle, Interrupts and its types, Introduction to 8086 microprocessors and its operation.

History of microprocessor:-

The invention of the transistor in 1947 was a significant development in the world of technology. It could perform the function of a large component used in a computer in the early years. Shockley, Brattain and Bardeen are credited with this invention and were awarded the Nobel prize for the same. Soon it was found that the function this large component was easily performed by a group of transistors arranged on a single platform. This platform, known as the integrated chip (IC), turned out to be a very crucial achievement and brought along a revolution in the use of computers. A person named Jack Kilby of Texas Instruments was honored with the Nobel Prize for the invention of IC, which laid the foundation on which microprocessors were developed. At the same time, Robert Noyce of Fairchild made a parallel development in IC technology for which he was awarded the patent.

ICs proved beyond doubt that complex functions could be integrated on a single chip with a highly developed speed and storage capacity. Both Fairchild and Texas Instruments began the manufacture of commercial ICs in 1961. Later, complex developments in the IC led to the addition of more complex functions on a single chip. The stage was set for a single controlling circuit for all the computer functions. Finally, Intel corporation's Ted Hoff and Frederico Fagin were credited with the design of the first microprocessor.

The work on this project began with an order from a Japanese calculator company Busicom to Intel, for building some chips for it. Hoff felt that the design could integrate a number of functions on a single chip making it feasible for providing the required functionality. This led to the design of Intel 4004, the world's first microprocessor. The next in line was the 8 bit 8008 microprocessor. It was developed by Intel in 1972 to perform complex functions in harmony with the 4004.

This was the beginning of a new era in computer applications. The use of mainframes and huge computers was scaled down to a much smaller device that was affordable to many. Earlier, their use was limited to large organizations and universities. With the advent of microprocessors, the use of computers trickled down to the common man. The next processor in line was Intel's 8080 with an 8 bit data bus and a 16 bit address bus. This was amongst the most popular microprocessors of all time.

Very soon, the Motorola corporation developed its own 6800 in competition with the Intel's 8080. Fagin left Intel and formed his own firm Zilog. It launched a new microprocessor Z80 in 1980 that was far superior to the previous two versions. Similarly, a break off from Motorola prompted the design of 6502, a derivative of the 6800. Such attempts continued with some modifications in the base structure.

The use of microprocessors was limited to task-based operations specifically required for company projects such as the automobile sector. The concept of a 'personal computer' was still a distant dream for the world and microprocessors were yet to come into personal use. The 16 bit microprocessors started becoming a commercial sell-out in the 1980s with the first popular one being the TMS9900 of Texas Instruments.

Intel developed the 8086 which still serves as the base model for all latest advancements in the microprocessor family. It was largely a complete processor integrating all the required features in it. 68000 by Motorola was one of the first microprocessors to develop the concept of microcoding in its instruction set. They were further developed to 32 bit architectures. Similarly, many players like Zilog, IBM and Apple were successful in getting their own products in the market. However, Intel had a commanding position in the market right through the microprocessorers.

The 1990s saw a large scale application of microprocessors in the personal computer applications developed by the newly formed Apple, IBM and Microsoft corporation. It witnessed a revolution in the use of

computers, which by then was a household entity.

This growth was complemented by a highly sophisticated development in the commercial use of microprocessors. In 1993, Intel brought out its 'Pentium Processor' which is one of the most popular processors in use till date. It was followed by a series of excellent processors of the Pentium family, leading into the 21st century. The latest one in commercial use is the Pentium Dual Core technology and the Xeon processor. They have opened up a whole new world of diverse applications. Supercomputers have become common, owing to this amazing development in microprocessors.

1.2 INTRODUCTION TO MICROPROCESSOR AND MICROCOMPUTER ARCHITECTURE:

A microprocessor is a programmable electronics chip that has computing and decision making capabilities similar to central processing unit of a computer. Any microprocessor-based systems having limited number of resources are called microcomputers. Nowadays, microprocessor can be seen in almost all types of electronics devices like mobile phones, printers, washing machines etc. Microprocessors are also used in advanced applications like radars, satellites and flights. Due to the rapid advancements in electronic industry and large scale integration of devices results in a significant cost reduction and increase application of microprocessors and their derivatives.

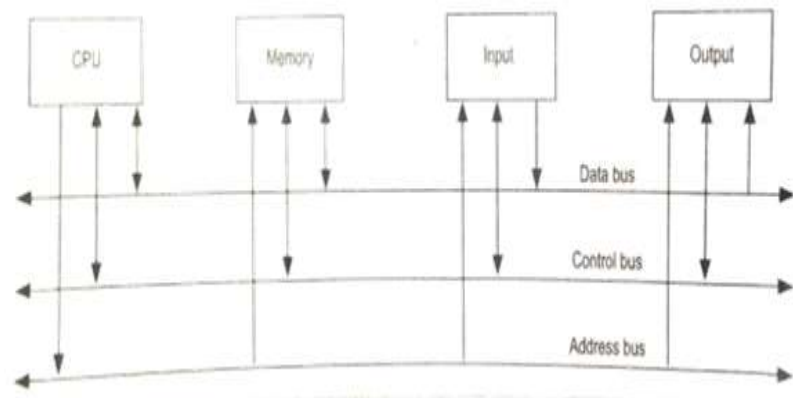


Fig.1.1 Microprocessor-based system

Bit: A bit is a single binary digit.

Word: A word refers to the basic data size or bit size that can be processed by the arithmetic and logic unit of the processor. A 16-bit binary number is called a word in a 16-bit processor.

Bus: A bus is a group of wires/lines that carry similar information.

System Bus: The system bus is a group of wires/lines used for communication between the microprocessor and peripherals.

Memory Word: The number of bits that can be stored in a register or memory element is called a memory word.

Address Bus: It carries the address, which is a unique binary pattern used to identify a memory location or an I/O port. For example, an eight bit address bus has eight lines and thus it can address $2^8 = 256$ different locations. The locations in hexadecimal format can be written as 00H – FFH.

Data Bus: The data bus is used to transfer data between memory and processor or between I/O device and processor. For example, an 8-bit processor will generally have an 8-bit data bus and a 16-bit processor will have 16-bit data bus.

Control Bus: The control bus carry control signals, which consists of signals for selection of memory or I/O device from the given address, direction of data transfer and synchronization of data transfer in case of slow devices.

A typical microprocessor consists of arithmetic and logic unit (ALU) in association with control unit to process the instruction execution. Almost all the microprocessors are based on the principle of store-program concept. In store-program concept, programs or instructions are sequentially stored in the memory locations that are to be executed. To do any task using a microprocessor, it is to be programmed by the user. So the programmer must have idea about its internal resources, features and supported instructions. Each microprocessor has a set of instructions, a list which is provided by the microprocessor manufacturer. The instruction set of a microprocessor is provided in two forms: binary machine code and mnemonics.

Microprocessor communicates and operates in binary numbers 0 and 1. The set of instructions in the form of binary patterns is called a machine language and it is difficult for us to understand. Therefore, the binary patterns are given abbreviated names, called mnemonics, which forms the assembly language. The conversion of assembly-level language into binary machine-level language is done by using an application called assembler.

Technology Used:

The semiconductor manufacturing technologies used for chips are:

- Transistor-Transistor Logic (TTL)
- Emitter Coupled Logic (ECL)
- Complementary Metal-Oxide Semiconductor (CMOS)

Classification of Microprocessors:

Based on their specification, application and architecture microprocessors are classified.

Based on size of data bus:

- 4-bit microprocessor
- 8-bit microprocessor
- 16-bit microprocessor
- 32-bit microprocessor

Based on application:

- General-purpose microprocessor- used in general computer system and can be used by programmer for any application. Examples, 8085 to Intel Pentium.
- Microcontroller- microprocessor with built-in memory and ports and can be programmed for any generic

control application. Example, 8051.

- Special-purpose processors- designed to handle special functions required for an application. Examples, digital signal processors and application-specific integrated circuit (ASIC) chips.

Based on architecture:

- Reduced Instruction Set Computer (RISC) processors
- Complex Instruction Set Computer (CISC) processors

2. 8085 MICROPROCESSOR ARCHITECTURE

The 8085 microprocessor is an 8-bit processor available as a 40-pin IC package and uses +5 V for power. It can run at a maximum frequency of 3 MHz. Its data bus width is 8-bit and address bus width is 16-bit, thus it can address $2^{16} = 64$ KB of memory. The internal architecture of 8085 is shown in Fig. 1.2.

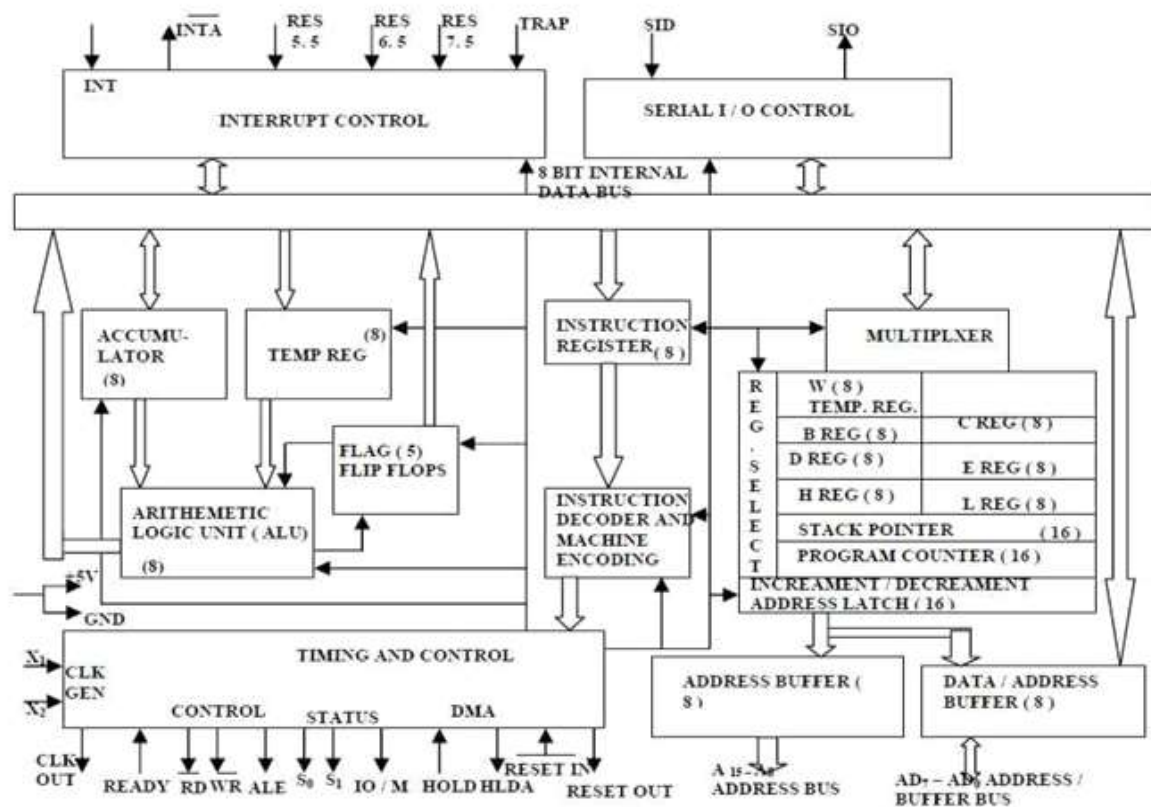


Fig 1.2: 8085 Architecture

Arithmetic and Logic Unit

The ALU performs the actual numerical and logical operations such as Addition (ADD), Subtraction (SUB), AND, OR etc. It uses data from memory and from Accumulator to perform operations. The results of the arithmetic and logical operations are stored in the accumulator.

Registers

The 8085 includes six registers, one accumulator and one flag register, as shown in Fig. 1.3. In addition, it has two 16-bit registers: stack pointer and program counter. They are briefly described as follows.

The 8085 has six general-purpose registers to store 8-bit data; these are identified as B, C, D, E, H and L. 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 register by using data copy instructions.

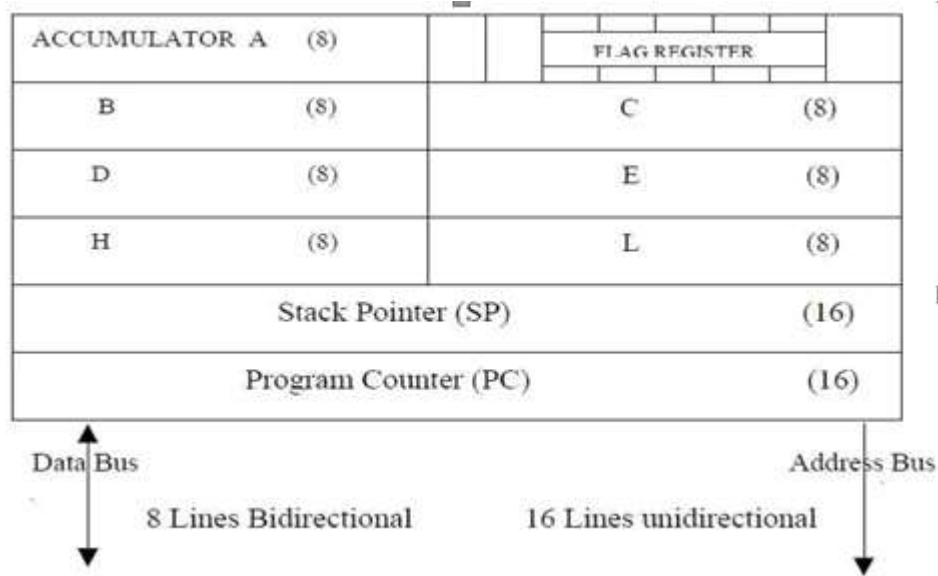


Fig 1.3: Register Organization

Accumulator

The accumulator is an 8-bit register that is a part of 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.

Flag register

The ALU includes five flip-flops, which are set or reset after an operation according to data condition 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 Fig. 4. The microprocessor uses these flags to test data conditions.

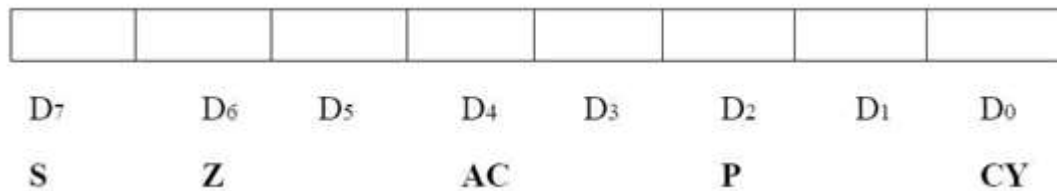


Fig 1.5: PSW

For example, after an addition of two numbers, if the result in the accumulator is larger than 8-bit, the flip-flop uses to indicate a carry by setting CY flag to 1. When an arithmetic operation results in zero, Z flag is set to 1. The S flag is just a copy of the bit D7 of the accumulator. A negative number has a 1 in bit D7 and a positive number has a 0 in 2's complement representation. The AC flag is set to 1, when a carry result from bit D3 and passes to bit D4. The P flag is set to 1, when the result in accumulator contains even number of 1s.

Program Counter (PC)

This 16-bit register deals with sequencing the execution of instructions. This register is a memory pointer. 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 is being fetched, the program counter is automatically 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 stack. The beginning of the stack is defined by loading 16-bit address in the stack pointer.

Instruction Register/Decoder

It is an 8-bit register that temporarily stores 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.

Control Unit

Generates signals on data bus, address bus and control bus within microprocessor to carry out the instruction, which has been decoded. Typical buses and their timing are described as follows:

- **Data Bus:** Data bus carries data in binary form between microprocessor and other external units such as memory.

It is used to transmit data i.e. information, results of

arithmetic etc between memory and the microprocessor. Data bus is bidirectional in nature. The data bus width of 8085 microprocessor is 8-bit i.e. 28 combination of binary digits and are typically identified as D0 – D7. Thus

size of the data bus determines what arithmetic can be done. If only 8-bit wide then largest number is 11111111 (255 in decimal). Therefore, larger numbers have to be broken down into chunks of 255. This slows microprocessor.

- **Address Bus:** The address bus carries addresses and is one way bus from microprocessor to the memory or other devices. 8085 microprocessor contain 16-bit address bus and are generally identified as A0 - A15. The higher

order address lines (A8 – A15) are unidirectional and the lower order lines (A0 – A7) are multiplexed (time-shared) with the eight data bits (D0 – D7) and hence, they are bidirectional.

- **Control Bus:** Control bus are various lines which have specific functions for coordinating and controlling

microprocessor operations. The control bus carries control signals partly unidirectional and partly bidirectional. The following control and status signals are used by 8085 processor:

- I. **ALE (output):** Address Latch Enable is a pulse that is provided when an address appears on the AD0 – AD7 lines, after which it becomes 0.
- II. **RD (active low output):** The Read signal indicates that data are being read from the selected I/O or memory device and that they are available on the data bus.
- III. **WR (active low output):** The Write signal indicates that data on the data bus are to be written into a selected memory or I/O location.
- IV. **IO/M (output):** It is a signal that distinguished between a memory operation and an I/O operation. When IO/M = 0 it is a memory operation and IO/M = 1 it is an I/O operation.
- V. **S1 and S0 (output):** These are status signals used to specify the type of operation being performed; they are listed in Table 1.1

Table 1.1: Status signals and associated operations

S1	S0	States
0	0	Halt
0	1	Write
1	0	Read
1	1	Fetch

The schematic representation of the 8085 bus structure is as shown in Fig. 1.5. The microprocessor performs primarily four operations:

- 1.Memory Read: Reads data (or instruction) from memory.
- 2.Memory Write: Writes data (or instruction) into memory.
- 3.I/O Read: Accepts data from input device.
- 4.I/O Write: Sends data to output device.

The 8085 processor performs these functions using address bus, data bus and control bus as shown in Fig. 1.5.

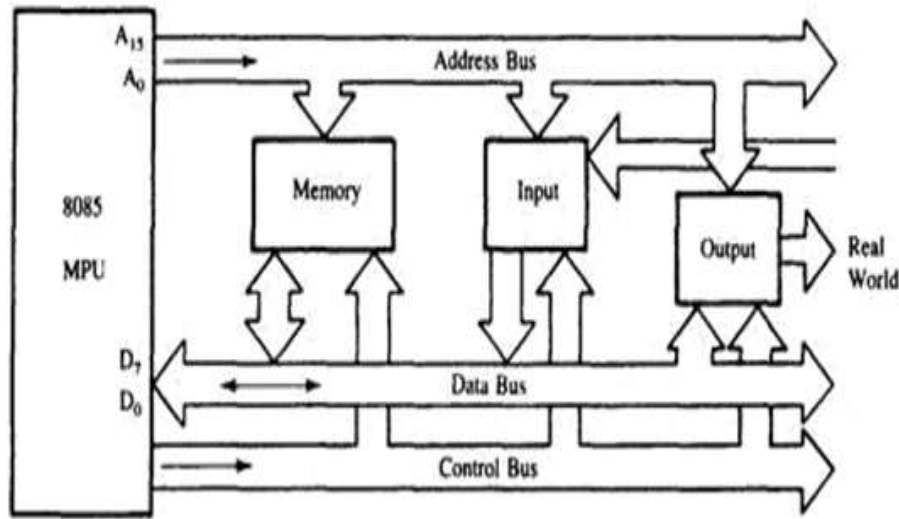


Fig 1.5: 8085 Bus structure

3. 8085 PIN DESCRIPTION

Properties:

- It is a 8-bit microprocessor
- Manufactured with N-MOS technology
- 40 pin IC package
- It has 16-bit address bus and thus has $2^{16} = 64$ KB addressing capability.
- Operate with 3 MHz single-phase clock
- +5 V single power supply

The logic pin layout and signal groups of the 8085nmicroprocessor are shown in Fig. 1.6. All the signals

are classified into six groups:

- Address bus
- Data bus
- Control & status signals
- Power supply and frequency signals
- Externally initiated signals
- Serial I/O signals

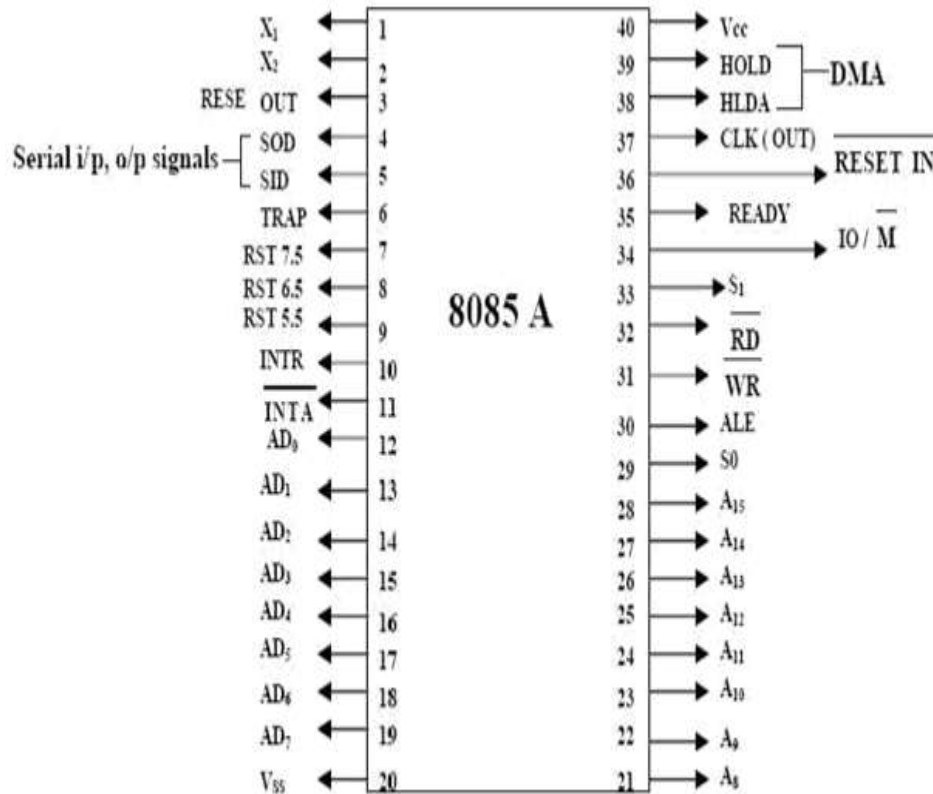


Fig 1.6: 8085-Pin Diagram

Address and Data Buses:

- **A8 – A15 (output, 3-state):** Most significant eight bits of memory addresses and the eight bits of the I/O addresses. These lines enter into tri-state high impedance state during HOLD and HALT modes.
- **AD0 – AD7 (input/output, 3-state):** Lower significant bits of memory addresses and the eight bits of the I/O addresses during first clock cycle. Behaves as data bus during third and fourth clock cycle. These lines enter into tri-state high impedance state during HOLD and HALT modes.

Control & Status Signals:

- **ALE:** Address latch enable
- **RD :** Read control signal.

- **WR : Write control signal**
- **IO/M , S1 and S0 : Status signals. Power**

Supply & Clock Frequency:

- **Vcc: +5 V power supply**
- **Vss: Ground reference**
- **X1, X2: A crystal having frequency of 6 MHz is connected at these two pins**
- **CLK: Clock output**

Externally Initiated and Interrupt Signals:

- **RESET IN :** When the signal on this pin is low, the PC is set to 0, the buses are tri-stated and the processor is reset.
- **RESET OUT:** This signal indicates that the processor is being reset. The signal can be used to reset other devices.
- **READY:** When this signal is low, the processor waits for an integral number of clock cycles until it goes high.
- **HOLD:** This signal indicates that a peripheral like DMA (direct memory access) controller is requesting the use of address and data bus.
- **HLDA:** This signal acknowledges the HOLD request.
- **INTR:** Interrupt request is a general-purpose interrupt.
- **INTA :** This is used to acknowledge an interrupt.
- **RST 7.5, RST 6.5, RST 5.5 – restart interrupt:** These are vectored interrupts and have highest priority than INTR interrupt.
- **TRAP:** This is a non-maskable interrupt and has the highest priority.

Serial I/O Signals:

- **SID:** Serial input signal. Bit on this line is loaded to D7 bit of register A using RIM instruction.
- **SOD:** Serial output signal. Output SOD is set or reset by using SIM instruction.

4. INSTRUCTION SET AND EXECUTION IN 8085

Based on the design of the ALU provides and decoding unit, the microprocessor manufacturer

microprocessor. The instruction set for every machine code and instruction set consists of both

mnemonics.

An instruction is a binary pattern designed inside a microprocessor to perform a specific function. The entire group of instructions that a microprocessor supports is called instruction set. Microprocessor instructions can be classified based on the parameters such functionality, length and operand addressing.

Classification based on functionality:

- I. **Data transfer operations:** This group of instructions copies data from source to destination. The content of the source is not altered.
- II. **Arithmetic operations:** Instructions of this group perform operations like addition, subtraction, increment & decrement. One of the data used in arithmetic operation is stored in accumulator and the result is also stored in accumulator.
- III. **Logical operations:** Logical operations include AND, OR, EXOR, NOT. The operations like AND, OR and EXOR uses two operands, one is stored in accumulator and other can be any register or memory location. The result is stored in accumulator. NOT operation requires single operand, which is stored in accumulator.
- IV. **Branching operations:** Instructions in this group can be used to transfer program sequence from one memory location to another either conditionally or unconditionally.
- V. **Machine control operations:** Instruction in this group control execution of other instructions and control operations like interrupt, halt etc.

Classification based on length:

- I. **One-byte instructions:** Instruction having one byte in machine code. Examples are depicted in Table 1.2.
- I. **Two-byte instructions:** Instruction having two byte in machine code. Examples are depicted in Table 1.3
- II. **Three-byte instructions:** Instruction having three byte in machine code. Examples are depicted in Table 1.4.

Table 1.2: Example of one byte instruction

Opcode	Operand	Machine code/Hex code
MOV	A, B	78
ADD	M	86

Table 1.3 Examples of two byte instructions

Opcode	Operand	Machine code/Hex code	Byte description
MVI	A, 7FH	3E	First byte
		7F	Second byte
ADI	0FH	C6	First byte
		0F	Second byte

Table 1.4 Examples of three byte instructions

Opcode	Operand	Machine code/Hex code	Byte description
JMP	9050H	C3	First byte
		50	Second byte
		90	Third byte
LDA	8850H	3A	First byte
		50	Second byte
		88	Third byte

Addressing Modes in Instructions:

The process of specifying the data to be operated on by the instruction is called addressing. The various formats for specifying operands are called addressing modes. The 8085 has the following five types of addressing:

1. **Immediate addressing**
2. **Memory direct addressing**
3. **Register direct addressing**
4. **Indirect addressing**
5. **Implicit addressing**

Immediate Addressing:

In this mode, the operand given in the instruction - a byte or word – transfers to the destination register or memory location.

Ex: MVI A, 9AH

- The operand is a part of the instruction.
- The operand is stored in the register mentioned in the instruction.

Memory Direct Addressing:

Memory direct addressing moves a byte or word between a memory location and register. The memory location address is given in the instruction.

Ex: LDA 850FH

This instruction is used to load the content of memory address 850FH in the accumulator.

Register Direct Addressing:

Register direct addressing transfer a copy of a byte or word from source register to destination register.

Ex: MOV B, C

It copies the content of register C to register B.

Indirect Addressing:

Indirect addressing transfers a byte or word between a register and a memory location.

Ex: MOV A, M

Here the data is in the memory location pointed to by the contents of HL pair. The data is moved to the accumulator.

Implicit Addressing

In this addressing mode the data itself specifies the data to be operated upon.

Ex: CMA

The instruction complements the content of the accumulator. No specific data or operand is mentioned in the instruction

INSTRUCTION EXECUTION AND TIMING DIAGRAM

Each instruction in 8085 microprocessor consists of two part- operation code (opcode) and operand. The opcode is a command such as ADD and the operand is an object to be operated on, such as a byte or the content of a register.

Instruction Cycle: The time taken by the processor to complete the execution of an instruction. An instruction cycle consists of one to six machine cycles.

Machine Cycle: The time required to complete one operation; accessing either the memory or I/O device. A machine cycle consists of three to six T-states.

T-State: Time corresponding to one clock period. It is the basic unit to calculate execution of instructions or programs in a processor.

To execute a program, 8085 performs various operations as:

- **Opcode fetch**
- **Operand fetch**

- **Memory read/write**
- **I/O read/write**

External communication functions are:

- **Memory read/write**
- **I/O read/write**

- **Interrupt request acknowledge**

Opcode Fetch Machine Cycle:

It is the first step in the execution of any instruction. The timing diagram of this cycle is given in Fig. 1.7.

The following points explain the various operations that take place and the signals that are changed during the execution of opcode fetch machine cycle:

T1 clock cycle

- i. The content of PC is placed in the address bus; AD0 - AD7 lines contains lower bit address and A8 - A15 contains higher bit address.
- ii. IO/M signal is low indicating that a memory location is being accessed. S1 and S0 also changed to the levels as indicated in Table 1.
- iii. ALE is high, indicates that multiplexed AD0 - AD7 act as lower order bus.

T2 clock cycle

- i. Multiplexed address bus is now changed to data bus.
- ii. The RD signal is made low by the processor. This signal makes the memory device load the data bus with the contents of the location addressed by the processor.

T3 clock cycle

- i. The opcode available on the data bus is read by the processor and moved to the instruction register.
- ii. The RD signal is deactivated by making it logic 1.

T4 clock cycle

- i. The processor decode the instruction in the instruction register and generate the necessary control signals to execute the instruction. Based on the instruction further operations such as fetching, writing into memory etc takes place.

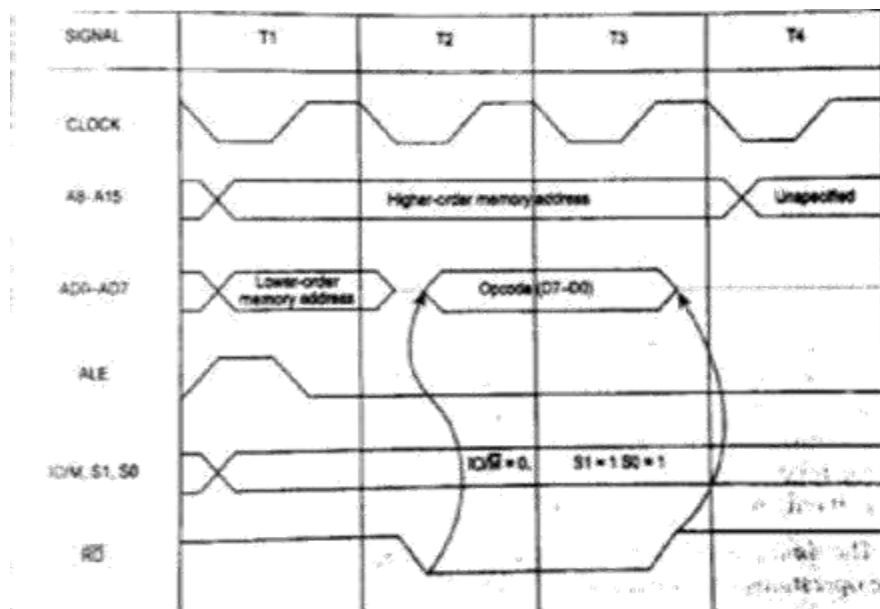


Fig. 1.7 Timing diagram for opcode fetch cycle

Memory Read Machine Cycle:

The memory read cycle is executed by the processor to read a data byte from memory. The machine cycle is exactly same to opcode fetch except: a) It has three T-states b) The S0 signal is set to 0. The timing diagram of this cycle is given in Fig. 1.8.

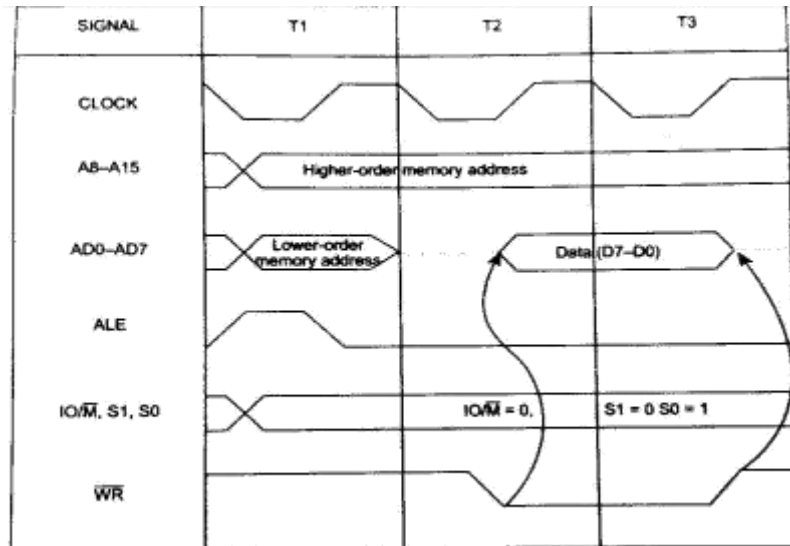


Fig. 1.8 Timing diagram for memory write machine cycle

Memory Write Machine Cycle:

The memory write cycle is executed by the processor to write a data byte in a memory location. The processor takes three T-states and WR signal is made low. The timing diagram of this cycle is given in Fig.1.8.

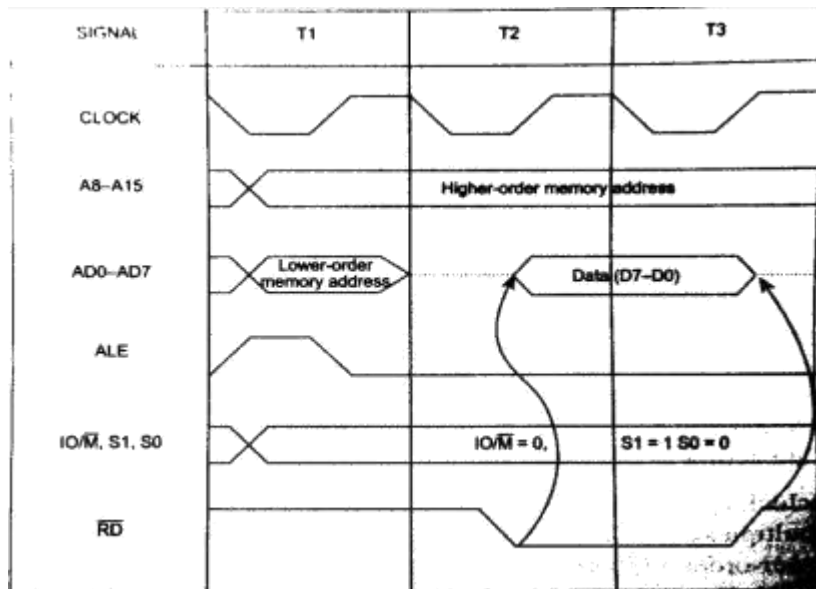


Fig. 1.9 Timing diagram for memory read machine cycle

I/O Read Cycle:

The I/O read cycle is executed by the processor to read a data byte from I/O port or from peripheral, which is I/O mapped in the system. The 8-bit port address is placed both in the lower and higher order address bus. The processor takes three T-states to execute this machine cycle. The timing diagram of this cycle is given in Fig. 1.10.

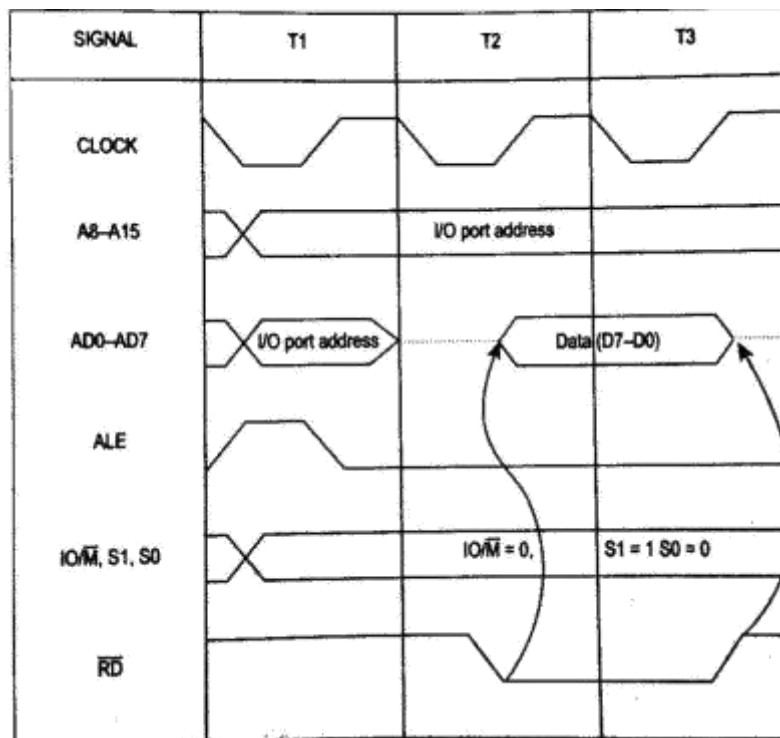


Fig.1. 10 Timing diagram I/O read machine cycle

I/O Write Cycle:

The I/O write cycle is executed by the processor to write a data byte to I/O port or to a peripheral, which is I/O mapped in the system. The processor takes three T-states to execute this machine cycle. The timing diagram of this cycle is given in Fig. 1.11.

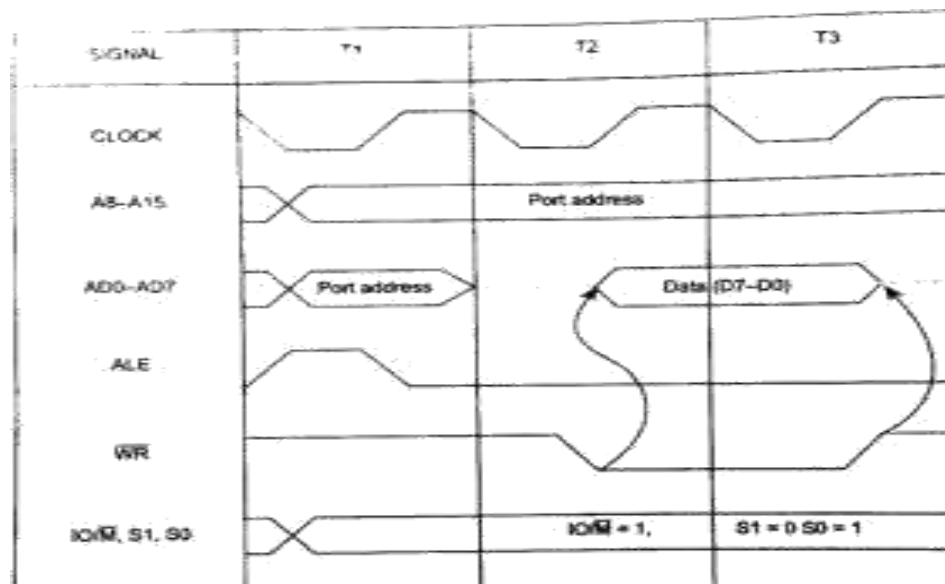


Fig.1. 11 Timing diagram I/O write machine cycle

Ex: Timing diagram for IN 80H.

The instruction and the corresponding codes and memory locations are given in Table 5.

Table 5 IN instruction

Address	Mnemonics	Opcode
800F	IN 80H	DB
8010		80

i. During the first machine cycle, the opcode DB is fetched from the memory, placed in the instruction register and decoded.

ii. During second machine cycle, the port address 80H is read from the next memory location.

iii. During the third machine cycle, the address 80H is placed in the address bus and the data read from that port address is placed in the accumulator.

The timing diagram is shown in Fig. 1.12.

Timing diagram for INR M

Algorithm –

The instruction INR M is of 1 byte; therefore the complete instruction will be stored in a single memory address.

For example:

2000: INR M

The opcode fetch will be same as for other instructions in first 4 T states.

Only the Memory read and Memory Write need to be added in the successive T states.

For the opcode fetch the IO/M (low active) = 0, S1 = 1 and S0 = 1.

For the memory read the IO/M (low active) = 0, S1 = 1 and S0 = 0. Also, only 3 T states will be required.

For the memory write the IO/M (low active) = 0, S1 = 0 and S0 = 1 and 3 T states will be required.

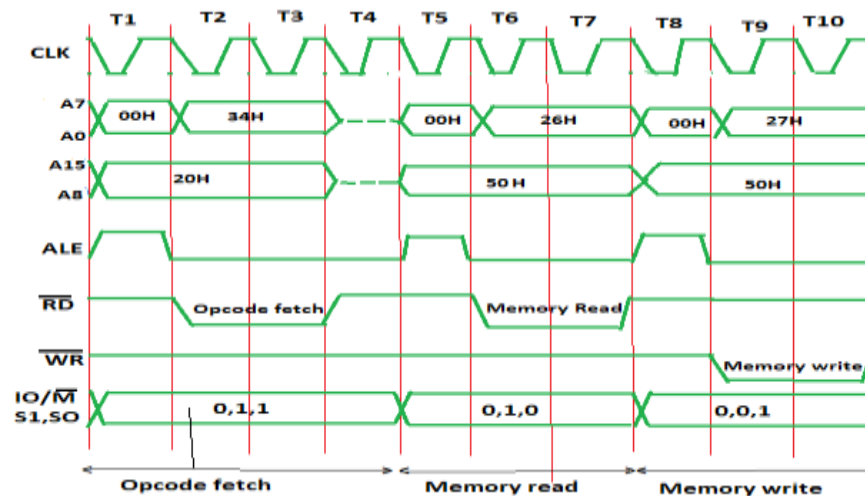


Fig 1.12 Timing diagram for INR M

In Opcode fetch (t1-t4 T states) –

- 00: lower bit of address where opcode is stored, i.e., 00
- 20: higher bit of address where opcode is stored, i.e., 20.
- ALE: provides signal for multiplexed address and data bus. Only in t1 it used as address bus to fetch lower bit of address otherwise it will be used as data bus.
- RD (low active): signal is 1 in t1 & t4 as no data is read by microprocessor. Signal is 0 in t2 & t3 because here the data is read by microprocessor.
- WR (low active): Signal is 1 throughout, no data is written by microprocessor.
- IO/M (low active): Signal is 0 in throughout because the operation is performing on memory.
- S0 and S1: both are 1 in case of opcode fetching.

In Memory read (t5-t7 T states) –

- 00: lower bit of address where opcode is stored, i.e., 00
- 50: higher bit of address where opcode is stored, i.e., 50.
- ALE: provides signal for multiplexed address and data bus. Only in t5 it used as address bus to fetch lower bit of address otherwise it will be used as data bus.
- RD (low active): signal is 1 in t5, no data is read by microprocessor. Signal is 0 in t6 & t7, data is read by microprocessor.
- WR (low active): signal is 1 throughout, no data is written by microprocessor.
- IO/M (low active): signal is 0 in throughout, operation is performing on memory.
- S0 and S1 – S1=1 and S0=0 for Read operation.

In Memory write (t8-t10 T states) –

- 00: lower bit of address where opcode is stored, i.e., 00
- 50: higher bit of address where opcode is stored, i.e., 50.
- ALE: provides signal for multiplexed address and data bus. Only in t8 it used as address bus to fetch lower bit of address otherwise it will be used as data bus.
- RD (low active): signal is 1 throughout, no data is read by microprocessor.
- WR (low active): signal is 1 in t8, no data is written by microprocessor. Signal is 0 in t9 & t10, data is written by microprocessor.
- IO/M (low active): signal is 0 in throughout, operation is performing on memory.
- S0 and S1 – S1=0 and S0=1 for write operation.

Timing diagram of MVI instruction

Problem – Draw the timing diagram of the following code,

MVI B, 45

Explanation of the command – It stores the immediate 8 bit data to a register or memory location.

Example: MVI B, 45

Opcode: MVI

Operand: B is the destination register and 45 is the source data which needs to be transferred to the register.

'45' data is stored in the B register.

Algorithm –

- Decide what is the opcode and what is the data. Here, opcode is 'MVI B' and data is 45.
- Assume the memory address of the opcode and the data. For example:

MVI B, 45

2000: Opcode

2001: 45

- The opcode fetch will be same in all the instructions.
- Only the read instruction of the opcode needs to be added in the successive T states.
- For the opcode read the IO/M (low active) = 0, S1 = 1 and S0 = 0. Also, only 3 T states will be required.

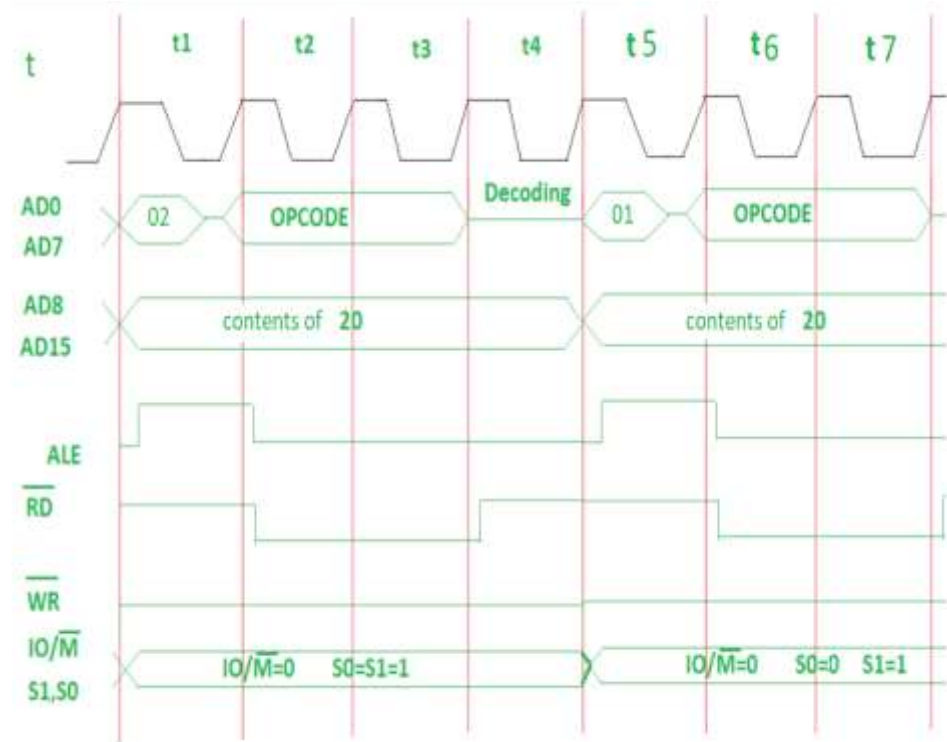


Fig 1.13: timing diagram for MOV B,45

Timing diagram of MOV Instruction in Microprocessor

Problem – Draw the timing diagram of the given instruction in 8085,
MOV B, C

Given instruction copies the contents of the source register into the destination register and the contents of the source register are not altered

OV B, C

Opcode: MOV

Operand: B and C

B is the destination register and C is the source register whose contents need to be transferred to the destination register.

Algorithm –

The instruction MOV B, C is of 1 byte; therefore the complete instruction will be stored in a single memory address. For example:

2000: MOV B, C

Only opcode fetching is required for this instruction and thus we need 4 T states for the timing diagram. For the opcode fetch the IO/M (low active) = 0, S1 = 1 and S0 = 1.

The timing diagram of MOV instruction is shown below:

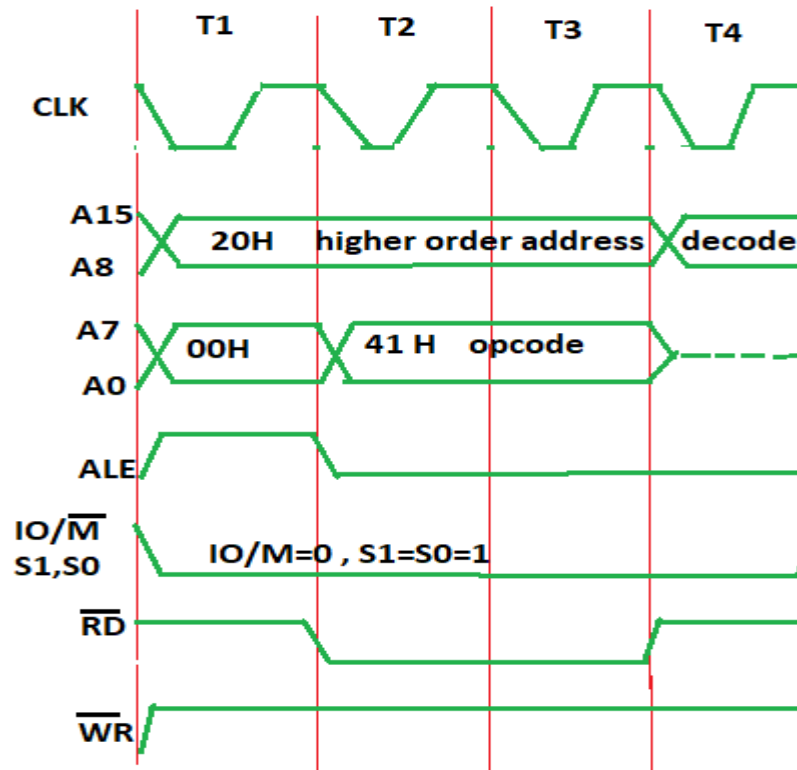


Fig 1.14:Timing diagram for MOV B,C

Timing diagram for STA 526AH

STA means Store Accumulator -The contents of the accumulator is stored in the specified address(526A).

The opcode of the STA instruction is said to be 32H. It is fetched from the memory 41FFH(see fig). - OF machine cycle Then the lower order memory address is read(6A). - Memory Read Machine Cycle Read the higher order memory address (52).- Memory Read Machine Cycle The combination of both the addresses are considered and the content from accumulator is written in 526A. - Memory Write Machine Cycle Assume the memory address for the instruction and let the content of accumulator is C7H. So, C7H from accumulator is now stored in 526A

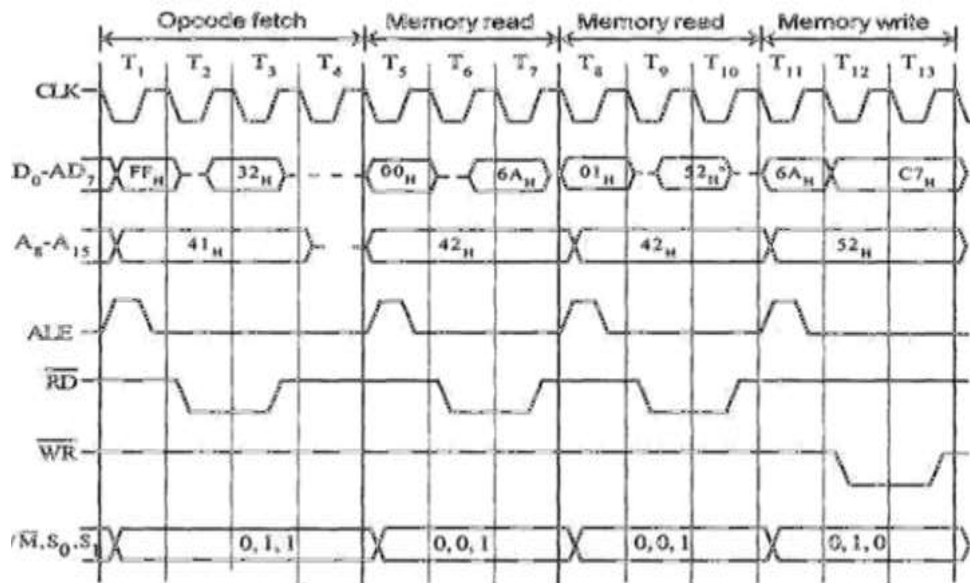


Fig 1.15:Timing diagram for STA 526A

Timing Diagram for Call instruction

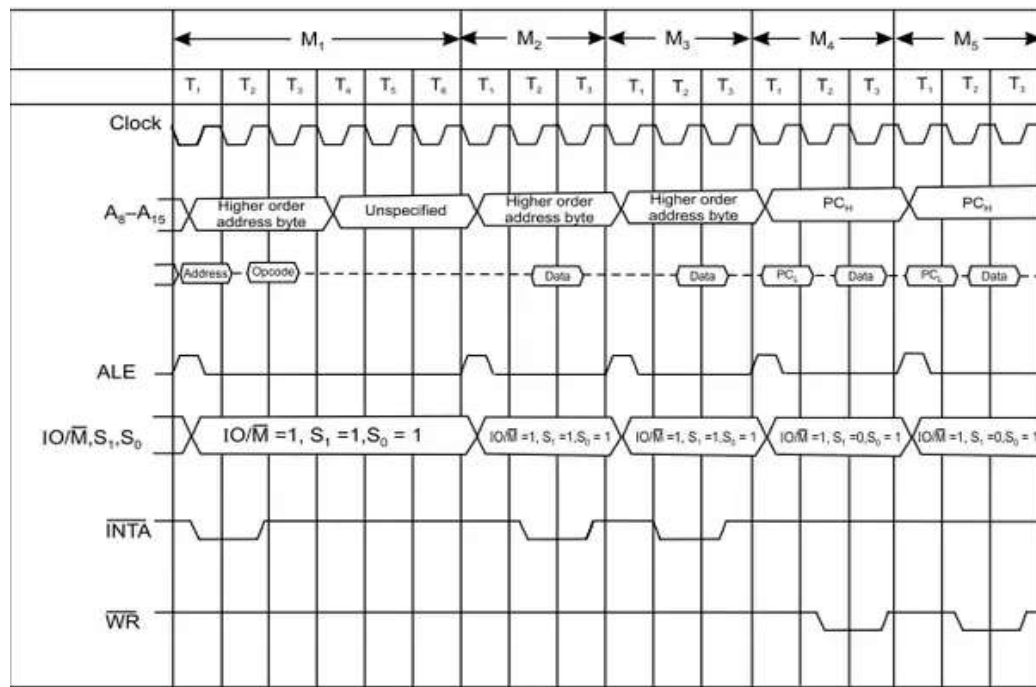


Fig 1.16:Timing diagram for CALL instruction

Note : The instruction, which involves stack mostly will take 6T states in opcode fetch.

8085 INTERRUPTS

Interrupt Structure:

Interrupt is the mechanism by which the processor is made to transfer control from its current program execution to another program having higher priority. The interrupt signal may be given to the processor by any external peripheral device.

The program or the routine that is executed upon interrupt is called interrupt service routine (ISR). After execution of ISR, the processor must return to the interrupted program. Key features in the interrupt structure of any microprocessor are as follows:

- i. Number and types of interrupt signals available.
- ii. The address of the memory where the ISR is located for a particular interrupt signal. This address is called interrupt vector address (IVA).
- iii. Masking and unmasking feature of the interrupt signals.
- iv. Priority among the interrupts.
- v. Timing of the interrupt signals.
- vi. Handling and storing of information about the interrupt program (status information).

Types of Interrupts:

Interrupts are classified based on their maskability, IVA and source. They are classified as:

i. Vectored and Non-Vectored Interrupts

Vectored interrupts require the IVA to be supplied by the external device that gives the interrupt signal. This technique is vectoring, is implemented in number of ways.

Non-vectored interrupts have fixed IVA for ISRs of different interrupt signals.

ii. Maskable and Non-Maskable Interrupts

Maskable interrupts are interrupts that can be blocked. Masking can be done by software or hardware means.

Non-maskable interrupts are interrupts that are always recognized; the corresponding ISRs are executed.

iii. Software and Hardware Interrupts

Software interrupts are special instructions, after execution transfer the control to predefined ISR.

Hardware interrupts are signals given to the processor, for recognition as an interrupt and execution of the corresponding ISR.

Interrupt Handling Procedure:

The following sequence of operations takes place when an interrupt signal is recognized:

- i. Save the PC content and information about current state (flags, registers etc) in the stack.
- ii. Load PC with the beginning address of an ISR and start to execute it.
- iii. Finish ISR when the return instruction is executed.
- iv. Return to the point in the interrupted program where execution was interrupted.

Interrupt Sources and Vector Addresses in 8085:

Software Interrupts:

8085 instruction set includes eight software interrupt instructions called Restart (RST) instructions. These are one byte instructions that make the processor execute a subroutine at predefined locations. Instructions and their vector addresses are given in Table 1.6

Table 1.6 Vector address

Instruction	Machine hex code	Interrupt Vector Address
RST 0	C7	0000H
RST 1	CF	0008H
RST 2	D7	0010H
RST 3	DF	0018H
RST 4	E7	0020H
RST 5	EF	0028H
RST 6	F7	0030H
RST 7	FF	0032H

The software interrupts can be treated as CALL instructions with default call locations. The concept of priority does not apply to software interrupts as they are inserted into the program as instructions by the programmer and executed by the processor when the respective program lines are read.

Hardware Interrupts and Priorities:

8085 have five hardware interrupts – INTR, RST 5.5, RST 6.5, RST 7.5 and TRAP. Their IVA and priorities are given in Table 1.7.

Table 1.7 Hardware interrupts of 8085

Interrupt	Interrupt vector address	Maskable or non-maskable	Edge or level Triggered	priority
TRAP	0024H	Non-maskable	Level	1
RST 7.5	003CH	Maskable	Rising edge	2
RST 6.5	0034H	Maskable	Level	3
RST 5.5	002CH	Maskable	Level	4
INTR	Decided by hardware	Maskable	Level	5

Masking of Interrupts:

Masking can be done for four hardware interrupts INTR, RST 5.5, RST 6.5, and RST 7.5. The masking of 8085 interrupts is done at different levels. Fig. 13 shows the organization of hardware interrupts in the 8085.

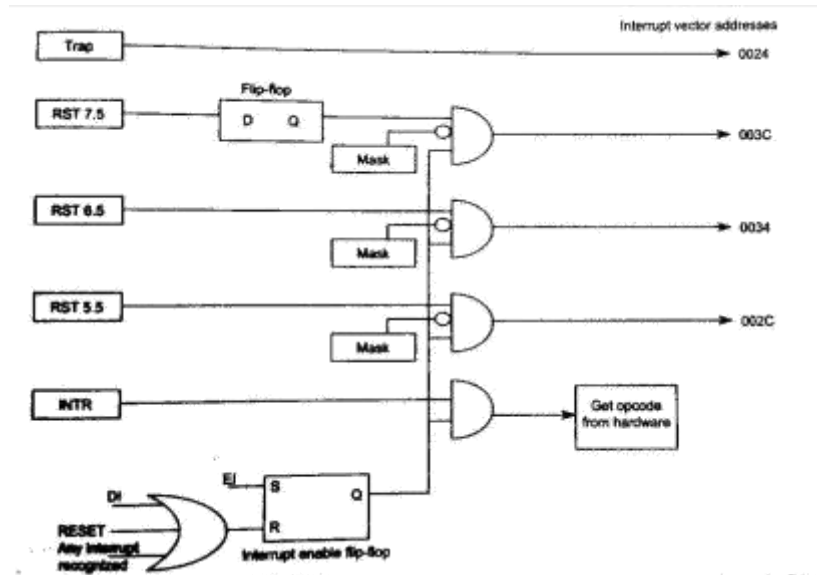


Fig 1.17: Interrupt diagram

The Fig. 1.17 is explained by the following five points:

- i. The maskable interrupts are by default masked by the Reset signal. So no interrupt is recognized by the hardware reset.
- ii. The interrupts can be enabled by the EI instruction.
- iii. The three RST interrupts can be selectively masked by loading the appropriate word in the accumulator and executing SIM instruction. This is called software masking.
- iv. All maskable interrupts are disabled whenever an interrupt is recognized.
- v. All maskable interrupts can be disabled by executing the DI instruction.

RST 7.5 alone has a flip-flop to recognize edge transition. The DI instruction reset interrupt enable flip-flop in the processor and the interrupts are disabled. To enable interrupts, EI instruction has to be executed.

SIM Instruction:

The SIM instruction is used to mask or unmask RST hardware interrupts. When executed, the SIM instruction reads the content of accumulator and accordingly mask or unmask the interrupts. The format of control word to be stored in the accumulator before executing SIM instruction is as shown in Fig. 1.18.

Bit position	D7	D6	D5	D4	D3	D2	D1	D0
Name	SOD	SDE	X	R7.5	MSE	M7.5	M6.5	M5.5
Explanation	Serial data to be sent	Serial data enable—set to 1 for sending	Not used	Reset RST 7.5 flip-flop	Mask set enable—Set to 1 to mask interrupts	Set to 1 to mask RST 7.5	Set to 1 to mask RST 6.5	Set to 1 to mask RST 5.5

Fig 1.18:SIM instruction

Fig. 1.18 Accumulator bit pattern for SIM instruction

In addition to masking interrupts, SIM instruction can be used to send serial data on the SOD line of the processor. The data to be send is placed in the MSB bit of the accumulator and the serial data output is enabled by making D6 bit to 1.

RIM Instruction:

RIM instruction is used to read the status of the interrupt mask bits. When RIM instruction is executed, the accumulator is loaded with the current status of the interrupt masks and the pending interrupts. The format and the meaning of the data stored in the accumulator after execution of RIM instruction is shown in Fig. 15.

In addition RIM instruction is also used to read the serial data on the SID pin of the processor. The data on the SID pin is stored in the MSB of the accumulator after the execution of the RIM instruction.

Bit position	D7	D6	D5	D4	D3	D2	D1	D0
Name	SID	I7.5	I6.5	I5.5	IE	M7.5	M6.5	M5.5
Explanation	Serial input data in the SID pin	Set to 1 if RST 7.5 is pending	Set to 1 if RST 6.5 is pending	Set to 1 if RST 5.5 is pending	Set to 1 if interrupts are enabled	Set to 1 if RST 7.5 is masked	Set to 1 if RST 6.5 is masked	Set to 1 if RST 5.5 is masked

Fig. 1.19 Accumulator bit pattern after execution of RIM instruction

Ex: Write an assembly language program to enables all the interrupts in 8085 after reset.

EI : Enable interrupts

MVI A, 08H : Unmask the interrupts

SIM : Set the mask and unmask using SIM instruction

Timing of Interrupts:

The interrupts are sensed by the processor one cycle before the end of execution of each instruction. An interrupts signal must be applied long enough for it to be recognized. The longest instruction of the 8085 takes 18 clock periods. So, the interrupt signal must be applied for at least 17.5 clock periods. This decides the minimum pulse width for the interrupt signal.

The maximum pulse width for the interrupt signal is decided by the condition that the interrupt signal must not be recognized once again. This is under the control of the programmer.

8086 Microprocessor Architecture and Operation:

It is a 16 bit μ p. 8086 has a 20 bit address bus can access upto 220 memory locations (1 MB) . It can support upto 64K I/O ports. It provides 14, 16-bit registers. It has multiplexed address and data bus AD0- AD15 and A16 – A19. It requires single phase clock with 33% duty cycle to provide internal timing. 8086 is designed to operate in two modes, Minimum and Maximum. It can prefetches upto 6 instruction bytes from memory and queues them in order to speed up instruction execution. It requires +5V power supply. A 40 pin dual in line package.

The minimum mode is selected by applying logic 1 to the MN / MX# input pin. This is a

single microprocessor configuration. The maximum mode is selected by applying logic 0 to the MN / MX# input pin. This is a multi micro processors configuration.

Block diagram of 8086

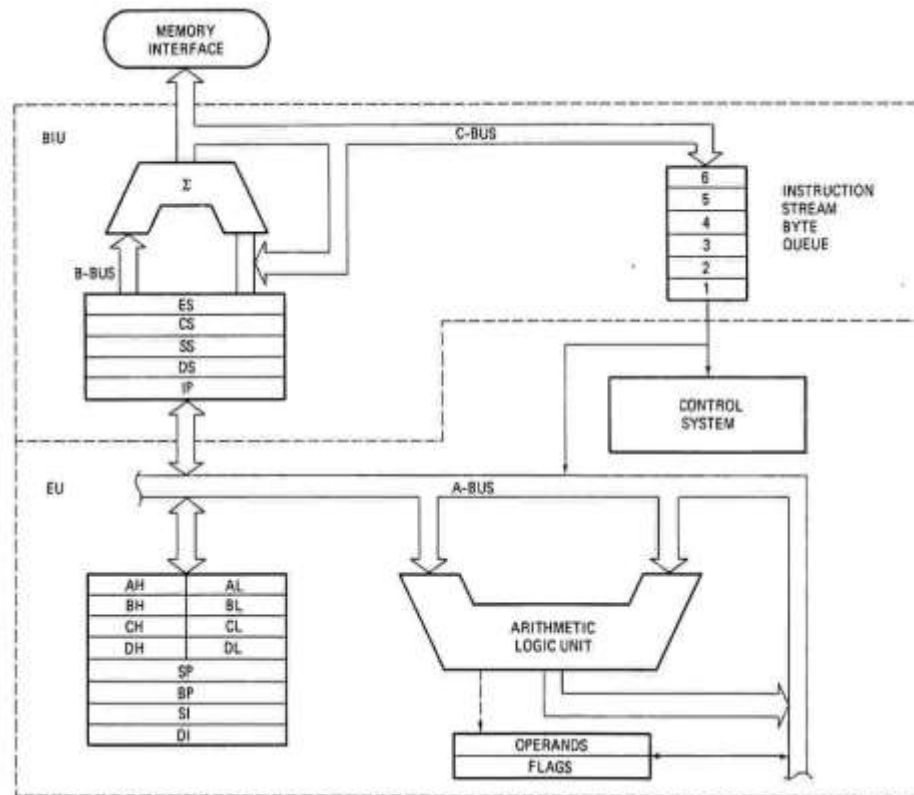


Fig 1.20 Block diagram of 8086 microprocessor

Software model of 8086

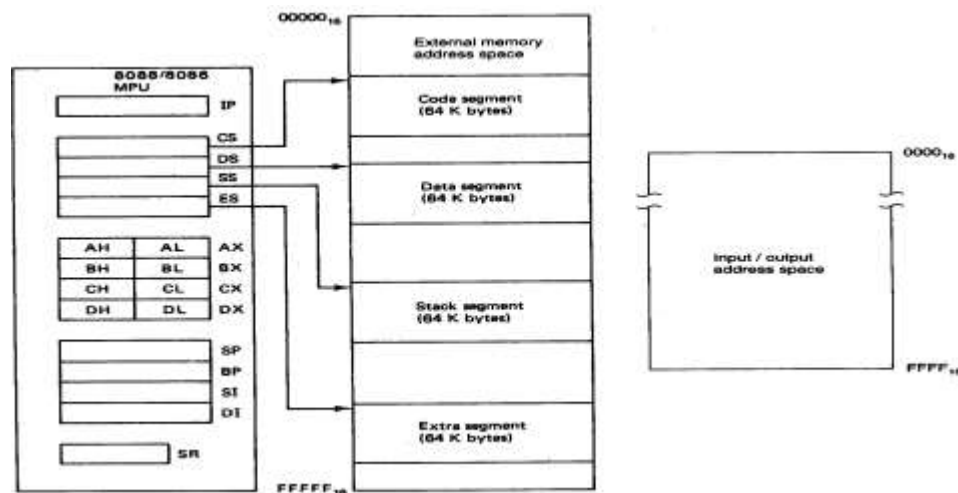


Fig 1.21 Software model-8086

15	H	8	7	L	0
AX (Accumulator)					
AH			AL		
BX (Base Register)					
BH			BL		
CX (Used as a counter)					
CH			CL		
DX (Used to point to data in I/O operations)					
DH			DL		

Fig 1.22: General purpose registers

Internal Architecture of 8086

8086 has two blocks BIU and EU. The BIU performs all bus operations such as instruction fetching, reading and writing operands for memory and calculating the addresses of the memory operands. The instruction bytes are transferred to the instruction queue. EU executes instructions from the instruction system byte queue. Both units operate asynchronously to give the 8086 an overlapping instruction fetch and execution mechanism which is called as Pipelining. This results in efficient use of the system bus and system performance. BIU contains Instruction queue, Segment registers, Instruction pointer, Address adder. EU contains Control circuitry, Instruction decoder, ALU, Pointer and Index register, Flag register.

Bus Interfacr Unit:

It provides a full 16 bit bidirectional data bus and 20 bit address bus. The bus interface unit is responsible for performing all external bus operations.

Specifically it has the following functions:

Instruction fetch, Instruction queuing, Operand fetch and storage, Address relocation and Bus control. The BIU uses a mechanism known as an instruction stream queue to implement a *pipeline architecture*.

This queue permits prefetch of up to six bytes of instruction code. When ever the queue of the BIU is not full, it has room for at least two more bytes and at the same time the EU is not requesting it to read or write operands from memory, the BIU is free to look ahead in the program by prefetching the next sequential instruction. These prefetching instructions are held in its FIFO queue. With its 16 bit data bus, the BIU fetches two instruction bytes in a single memory cycle. After a byte is loaded at the input end of the queue, it automatically shifts up through the FIFO to the empty location nearest the output.

The EU accesses the queue from the output end. It reads one instruction byte after the other from the output of the queue. If the queue is full and the EU is not requesting access to operand in memory. These intervals of no bus activity, which may occur between bus cycles are known as *Idle state*. If the BIU is already in the process of fetching an instruction when the EU request it to read or write operands from memory or I/O, the BIU first completes the instruction fetch bus cycle before initiating the operand read / write cycle. The BIU also contains a dedicated adder which is used to generate the 20 bit physical address that is output on the address bus. This address is formed by adding an appended 16 bit segment address and a 16 bit offset address. For example, the physical address of the next instruction to be fetched is formed by combining the current contents of the code segment CS register and the current contents of the instruction pointer IP register. The BIU is also responsible for generating bus control signals such as those for memory read or write and I/O read or write.

EXECUTION UNIT : The Execution unit is responsible for decoding and executing all instructions. The EU extracts instructions from the top of the queue in the BIU, decodes them, generates operands if necessary, passes them to the BIU and requests it to perform the read or write bus cycles to memory or I/O and perform the operation specified by the instruction on the operands. During the execution of the instruction, the EU tests the status and control flags and updates them based on the results of executing the instruction. If the queue is empty, the EU waits for the next instruction byte to be fetched and shifted to top of the queue. When the EU executes a branch or jump instruction, it transfers control to a location corresponding to another set of sequential instructions. Whenever this happens, the BIU automatically resets the queue and then begins to fetch instructions from this new location to refill the queue.

Maximum mode signals (MN / \overline{MX} = GND)		
Name	Function	Type
$\overline{RQ} / \overline{GT1}, 0$	Request / Grant Bus Access Control	Bidirectional
\overline{LOCK}	Bus Priority Lock Control	Output, 3- State
$\overline{S_2} - \overline{S_0}$	Bus Cycle Status	Output, 3- State
QS1, QS0	Instruction Queue Status	Output

Internal Registers of 8086

The 8086 has four groups of the user accessible internal registers. They are the instruction pointer, four data registers, four pointer and index register, four segment registers.

The 8086 has a total of fourteen 16-bit registers including a 16 bit register called the *status register*, with 9 of bits implemented for status and control flags. Most of the registers contain data/instruction offsets within 64 KB memory segment. There are four different 64 KB segments for instructions, stack, data and extra data. To specify where in 1 MB of processor memory these 4 segments are located the processor uses four segment registers:

Code segment (CS) is a 16-bit register containing address of 64 KB segment with processor instructions. The processor uses CS segment for all accesses to instructions referenced by instruction pointer (IP) register. CS register cannot be changed directly. The CS register is automatically updated during far jump, far call and far return instructions.

Stack segment (SS) is a 16-bit register containing address of 64KB segment with program stack. By default, the processor assumes that all data referenced by the stack pointer (SP) and base pointer (BP) registers is located in the stack segment. SS register can be changed directly using POP instruction.

Data segment (DS) is a 16-bit register containing address of 64KB segment with program data. By default, the processor assumes that all data referenced by general registers (AX, BX, CX, DX) and index register (SI, DI) is located in the data segment. DS register can be changed directly using POP and LDS instructions.

Extra segment (ES) is a 16-bit register containing address of 64KB segment, usually with program data. By default, the processor assumes that the DI register references the ES

segment in string manipulation instructions. ES register can be changed directly using POP and LES instructions. It is possible to change default segments used by general and index registers by prefixing instructions with a CS, SS, DS or ES prefix.

All general registers of the 8086 microprocessor can be used for arithmetic and logic operations. The general registers are:

Accumulator register consists of two 8-bit registers AL and AH, which can be combined together and used as a 16-bit register AX. AL in this case contains the low-order byte of the word, and AH contains the high-order byte. Accumulator can be used for I/O operations and string manipulation.

Base register consists of two 8-bit registers BL and BH, which can be combined together and used as a 16-bit register BX. BL in this case contains the low-order byte of the word, and BH contains the high-order byte. BX register usually contains a data pointer used for based, based indexed or register indirect addressing.

Count register consists of two 8-bit registers CL and CH, which can be combined together and used as a 16-bit register CX. When combined, CL register contains the low-order byte of the word, and CH contains the high-order byte. Count register can be used in Loop, shift/rotate instructions and as a counter in string manipulation,.

Data register consists of two 8-bit registers DL and DH, which can be combined together and used as a 16-bit register DX. When combined, DL register contains the low-order byte of the word, and DH contains the high-order byte. Data register can be used as a port number in I/O operations. In integer 32-bit multiply and divide instruction the DX register contains high-order word of the initial or resulting number.

The following registers are both general and index registers:

Stack Pointer (SP) is a 16-bit register pointing to program stack.

Base Pointer (BP) is a 16-bit register pointing to data in stack segment. BP register is usually used for based, based indexed or register indirect addressing.

Source Index (SI) is a 16-bit register. SI is used for indexed, based indexed and register indirect addressing, as well as a source data address in string manipulation instructions.

Destination Index (DI) is a 16-bit register. DI is used for indexed, based indexed and register indirect addressing, as well as a destination data address in string manipulation instructions.

Other registers:

Instruction Pointer (IP) is a 16-bit register. **Flags** is a 16-bit register containing 9 one bit flags.

Overflow Flag (OF) - set if the result is too large positive number, or is too small negative number to fit into destination operand.

Direction Flag (DF) - if set then string manipulation instructions will auto-decrement index registers. If cleared then the index registers will be auto-incremented.

Interrupt-enable Flag (IF) - setting this bit enables maskable interrupts.

Single-step Flag (TF) - if set then single-step interrupt will occur after the next instruction.

Sign Flag (SF) - set if the most significant bit of the result is set.

Zero Flag (ZF) - set if the result is zero

Auxiliary carry Flag (AF) - set if there was a carry from or borrow to bits 0-3 in the AL register.

Parity Flag (PF) - set if parity (the number of "1" bits) in the low-order byte of the result is even.

Carry Flag (CF) - set if there was a carry from or borrow to the most significant bit during last result calculation.

Addressing Modes

Implied - the data value/data address is implicitly associated with the instruction.

Register - references the data in a register or in a register pair.

Immediate - the data is provided in the instruction.

Direct - the instruction operand specifies the memory address where data is located.

Register indirect - instruction specifies a register containing an address, where data is located. This addressing mode works with SI, DI, BX and BP registers.

Based :- 8-bit or 16-bit instruction operand is added to the contents of a base register (BX or BP), the resulting value is a pointer to location where data resides.

Indexed :- 8-bit or 16-bit instruction operand is added to the contents of an index register (SI or DI), the resulting value is a pointer to location where data resides.

Based Indexed :- the contents of a base register (BX or BP) is added to the contents of an index register (SI or DI), the resulting value is a pointer to location where data resides.

Based Indexed with displacement :- 8-bit or 16-bit instruction operand is added to the contents of a base register (BX or BP) and index register (SI or DI), the resulting value is a pointer to location where data resides.

Interrupts

The processor has the following interrupts:

INTR is a maskable hardware interrupt. The interrupt can be enabled/disabled using STI/CLI instructions or using more complicated method of updating the FLAGS register with the help of the POPF instruction.

When an interrupt occurs, the processor stores FLAGS register into stack, disables further interrupts, fetches from the bus one byte representing interrupt type, and jumps to interrupt processing routine address of which is stored in location $4 * \text{<interrupt type>}$. Interrupt processing routine should return with the IRET instruction.

NMI is a non-maskable interrupt. Interrupt is processed in the same way as the INTR interrupt. Interrupt type of the NMI is 2, i.e. the address of the NMI processing routine is stored in location 0008h. This interrupt has higher priority than the maskable interrupt.

Software interrupts can be caused by:

INT instruction - breakpoint interrupt. This is a type 3 interrupt.

INT <interrupt number> instruction - any one interrupt from available 256

interrupts. INTO instruction - interrupt on overflow

Single-step interrupt - generated if the TF flag is set. This is a type 1 interrupt. When the CPU processes this interrupt it clears TF flag before calling the interrupt processing routine.

Processor exceptions: Divide Error (Type 0), Unused

Opcode (type 6) and Escape opcode (type 7).

Software interrupt processing is the same as for the hardware interrupts.

The figure below shows the 256 interrupt vectors arranged in the interrupt vector table in the memory.

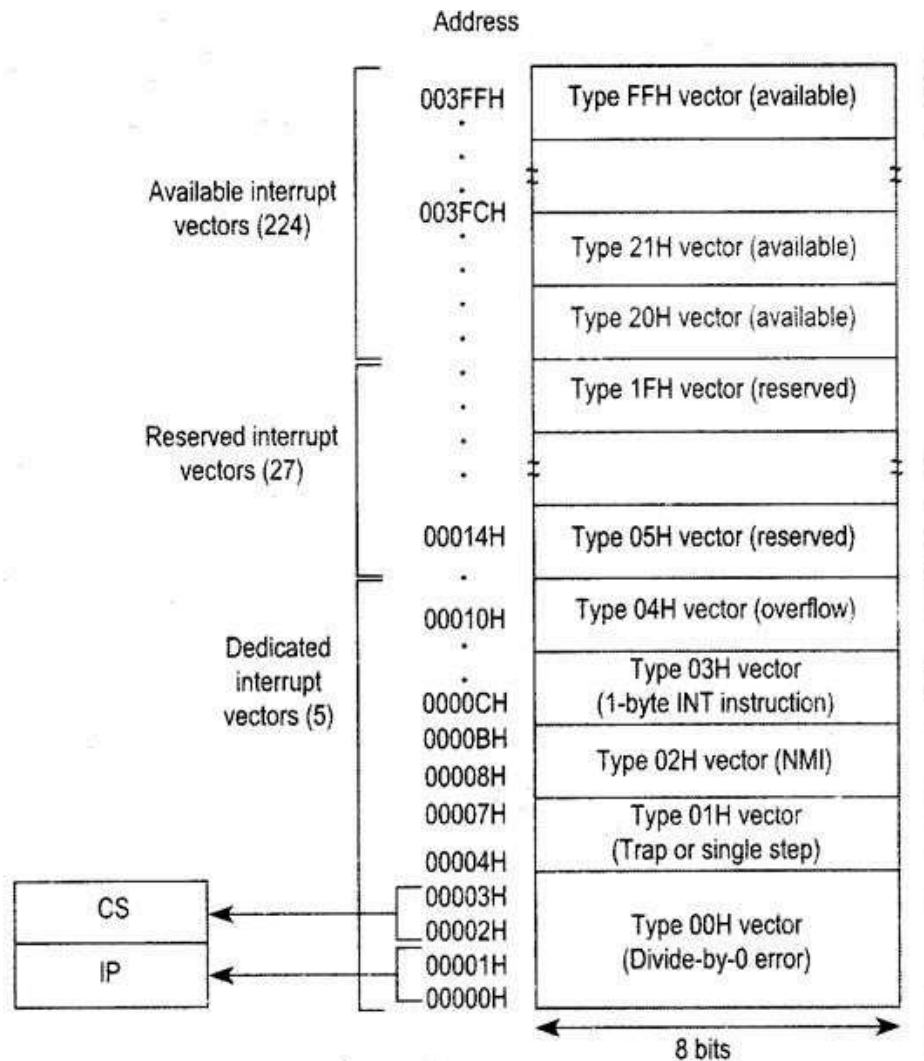


Fig 1.23 Interrupt Vector Table in the 8086

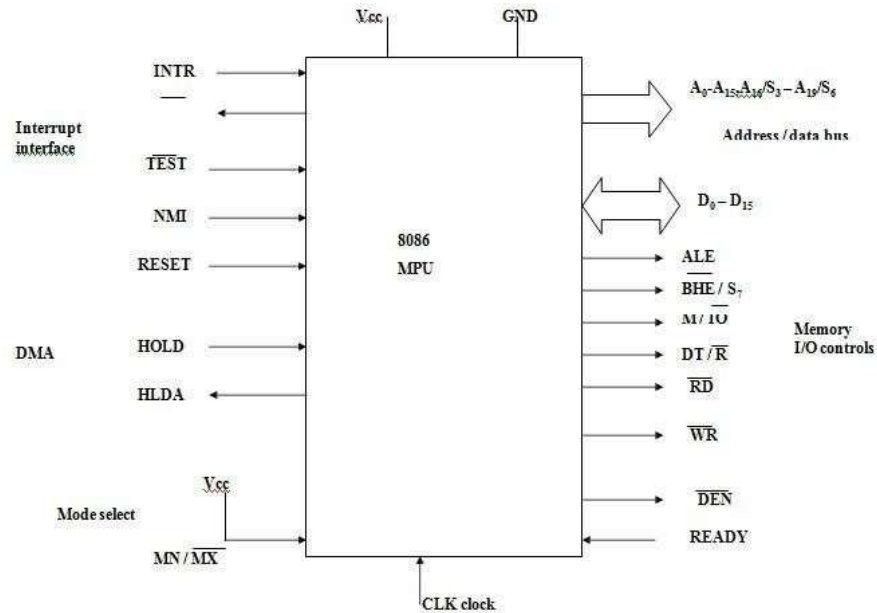
Minimum Mode Interface

When the Minimum mode operation is selected, the 8086 provides all control signals needed to implement the memory and I/O interface. The minimum mode signal can be divided into the following basic groups : address/data bus, status, control, interrupt and DMA.

Address/Data Bus : these lines serve two functions. As an address bus is 20 bits long and consists of signal lines A0 through A19. A19 represents the MSB and A0 LSB. A 20bit address gives the 8086 a 1Mbyte memory address space. More over it has an independent I/O address space which is 64K bytes in length.

The 16 data bus lines D0 through D15 are actually multiplexed with address lines A0

through A15 respectively. By multiplexed we mean that the bus work as an address bus during first machine cycle and as a data bus during next machine cycles. D15 is the MSB and D0 LSB. When acting as a data bus, they carry read/write data for memory, input/output data for I/O devices, and interrupt type codes from an interrupt controller.



Block Diagram of the Minimum Mode 8086 MPU

Fig 1.24: Block diagram of Minimum mode

Status signal : The four most significant address lines A19 through A16 are also multiplexed but in this case with status signals S6 through S3. These status bits are output on the bus at the same time that data are transferred over the other bus lines. Bit S4 and S3 together form a 2 bit binary code that identifies which of the 8086 internal segment registers are used to generate the physical address that was output on the address bus during the current bus cycle. Code S4S3 = 00 identifies a register known as *extra segment register* as the source of the segment address.

S ₄	S ₃	Segment Register
0	0	Extra
0	1	Stack
1	0	Code / none
1	1	Data

Fig 1.25:Memory segment status code

Status line S5 reflects the status of another internal characteristic of the 8086. It is the logic level of the internal enable flag. The last status bit S6 is always at the logic 0 level.

Control Signals : The control signals are provided to support the 8086 memory I/O interfaces. They control functions such as when the bus is to carry a valid address in which direction data are to be transferred over the bus, when valid write data are on the bus and when to put read data on the system bus.

ALE is a pulse to logic 1 that signals external circuitry when a valid address word is on the bus. This address must be latched in external circuitry on the 1-to-0 edge of the pulse at ALE.

Another control signal that is produced during the bus cycle is BHE bank high enable. Logic 0 on this used as a memory enable signal for the most significant byte half of the data bus D8 through D1. These lines also serves a second function, which is as the S7 status line.

Using the M/I/O and DT/R lines, the 8086 signals which type of bus cycle is in progress and in which direction data are to be transferred over the bus.

The logic level of M/I/O tells external circuitry whether a memory or I/O transfer is taking place over the bus. Logic 1 at this output signals a memory operation and logic 0 an

I/O operation.

The direction of data transfer over the bus is signalled by the logic level output at DT/R. When this line is logic 1 during the data transfer part of a bus cycle, the bus is in the transmit mode. Therefore, data are either written into memory or output to an I/O device.

On the other hand, logic 0 at DT/R signals that the bus is in the receive mode. This corresponds to reading data from memory or input of data from an input port.

The signal read RD and write WR indicates that a read bus cycle or a write bus cycle is in progress. The 8086 switches WR to logic 0 to signal external device that valid write or output data are on the bus.

On the other hand, RD indicates that the 8086 is performing a read of data of the bus. During read operations, one other control signal is also supplied. This is DEN (data enable) and it signals external devices when they should put data on the bus.

There is one other control signal that is involved with the memory and I/O interface. This is the READY signal.

READY signal is used to insert wait states into the bus cycle such that it is extended by a number of clock periods. This signal is provided by an external clock generator device and can be supplied by the memory or I/O sub- system to signal the 8086 when they are ready to permit the data transfer to be completed.

Maximum Mode Interface (cont..)

Status Inputs			CPU Cycles	8288 Command
\overline{S}_2	\overline{S}_1	\overline{S}_0		
0	0	0	Interrupt Acknowledge	INTA
0	0	1	Read I/O Port	IORC
0	1	0	Write I/O Port	IOWC, AIOWC
0	1	1	Halt	None
1	0	0	Instruction Fetch	MRDC
1	0	1	Read Memory	MRDC
1	1	0	Write Memory	MWTC, AMWC
1	1	1	Passive	None

Bus Status Codes

Fig 1.26: Maximum mode

Maximum Mode Interface

When the 8086 is set for the maximum-mode configuration, it provides signals for implementing a multiprocessor / coprocessor system environment. By multiprocessor environment we mean that one microprocessor exists in the system and that each processor is executing its own program. Usually in this type of system environment, there are some system resources that are common to all processors. They are called as *global resources*. There are also other resources that are assigned to specific processors. These are known as *local or private resources*. Coprocessor also means that there is a second processor in the system. In this two processor does not access the bus at the same time. One passes the control of the system bus to the other and then may suspend its operation. In the maximum-mode 8086 system, facilities are provided for implementing allocation of global resources and passing bus control to other microprocessor or coprocessor.

8288 Bus Controller – Bus Command and Control Signals: 8086 does not directly provide all the signals that are required to control the memory, I/O and interrupt interfaces. Specially the WR, M/IO, DT/R, DEN, ALE and INTA, signals are no longer produced by the 8086. Instead it outputs three status signals \overline{S}_0 , \overline{S}_1 , \overline{S}_2 prior to the initiation of each bus cycle. This 3- bit bus status code identifies which type of bus cycle is to follow. $\overline{S}_2\overline{S}_1\overline{S}_0$ are input to the external bus controller device, the bus controller generates the appropriately timed command and control signals. The 8288 produces one or two of these eight command signals for each bus cycles. For instance, when the 8086 outputs the code $\overline{S}_2\overline{S}_1\overline{S}_0$ equals 001, it indicates that an *I/O read cycle* is to be performed. In the code 111 is output by the 8086, it is signalling that no bus

activity is to take place.

The control outputs produced by the 8288 are DEN, DT/R and ALE. These 3 signals provide the same functions as those described for the minimum system mode. This set of bus commands and control signals is compatible with the Multibus and industry standard for interfacing microprocessor systems.

8289 Bus Arbiter – Bus Arbitration and Lock Signals:

This device permits processors to reside on the system bus. It does this by implementing the Multibus arbitration protocol in an 8086-based system. Addition of the 8288 bus controller and 8289 bus arbiter frees a number of the 8086 pins for use to produce control signals that are needed to support multiple processors. Bus priority lock (LOCK) is one of these signals. It is input to the bus arbiter together with status signals S0 through S2.

Queue Status Signals: Two new signals that are produced by the 8086 in the maximum-mode system are queue status outputs QS0 and QS1. Together they form a 2-bit queue status code, QS1QS0. Following table shows the four different queue status.

Table 1.8: Queue status code

QS ₁	QS ₀	Queue Status
0 (low)	0	No Operation. During the last clock cycle, nothing was taken from the queue.
0	1	First Byte. The byte taken from the queue was the first byte of the instruction.
1 (high)	0	Queue Empty. The queue has been reinitialized as a result of the execution of a transfer instruction.
1	1	Subsequent Byte. The byte taken from the queue was a subsequent byte of the instruction.

Queue status codes

AX - the Accumulator **BX** - the Base Register **CX** - the Count Register **DX** - the Data Register
Normally used for storing temporary results. Each of the registers is 16 bits wide (AX, BX, CX, DX). Can be accessed as either 16 or 8 bits AX, AH, AL

AX-Accumulator Register. Preferred register to use in arithmetic, logic and data transfer instructions because it generates the shortest Machine Language Code. Must be used in multiplication and division operations. Must also be used in I/O operations.

BX-Base Register. Also serves as an address register

CX- Count register. Used as a loop counter. Used in shift and rotate operations

DX- Data register. Used in multiplication and division. Also used in I/O operations

Pointer and Index Registers

SP	Stack Pointer
BP	Base Pointer
SI	Source Index
DI	Destination Index
IP	Instruction Pointer

Fig 1.27 Pointers and index registers

- All 16 bits wide, L/H bytes are not accessible. Used as memory pointers
- Example: MOV AH,[SI]
- *Move the byte stored in memory location whose address is contained in register SI to register AH.*
IP is not under direct control of the programmer

The Stack

The stack is used for temporary storage of information such as data or addresses. When a CALL is executed, the 8086 automatically PUSH es the current value of CS and IP onto the stack. Other registers can also be pushed. Before return from the subroutine, POP instructions can be used to pop values back from the stack into the corresponding registers.

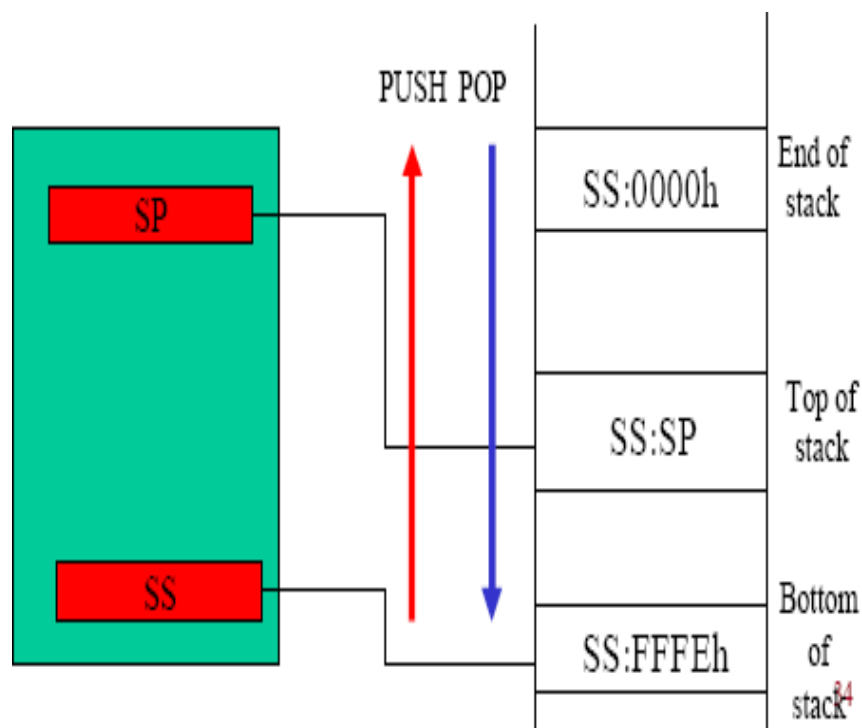


Fig 1.28 stack operation

Test signals in 8086

TEST is an input pin and is only used by the wait instruction. The 8086 enters a wait state after execution of the wait instruction until a low is seen on the test pin. Used in conjunction with the WAIT instruction in multiprocessing environments. This is input from the 8087 coprocessor. During execution of a wait instruction, the CPU checks this signal. If it is low, execution of the signal will continue; if not, it will stop executing.

Coprocessor Execution

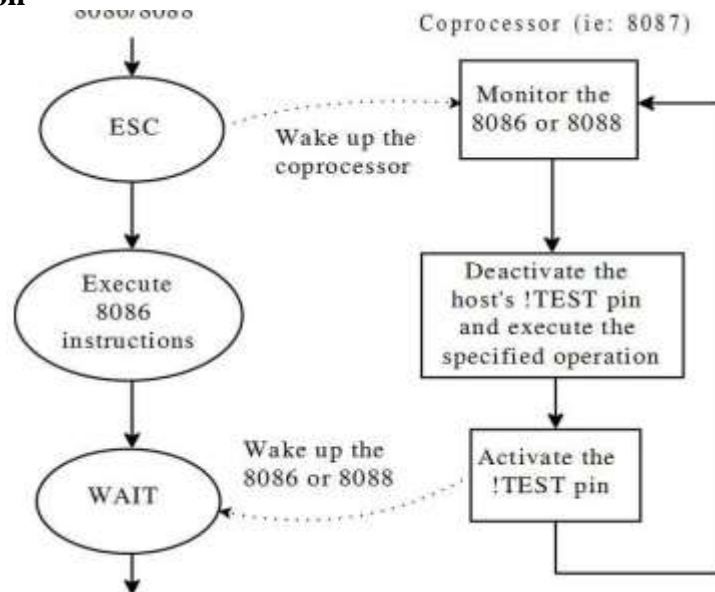


Fig 1.29. Coprocessor execution

Multiprocessor configuration Advantages

High system throughput can be achieved by having more than one CPU. The system can be expanded in modular form. Each bus master module is an independent unit and normally resides on a separate PC board. One can be added or removed without affecting the others in the system. A failure in one module normally does not affect the breakdown of the entire system and the faulty module can be easily detected and replaced. Each bus master has its own local bus to access dedicated memory or IO devices. So a greater degree of parallel processing can be achieved.

Question Bank

Part A

1. Define microprocessor
2. In how many groups can the signals of 8085 be classified?
3. What is the technology used in the manufacture of 8085?
4. Draw the block diagram of the built-in clock generator of 8085
5. What is the purpose of CLK signal of 8085?
6. What are the widths of data bus (DB) and address bus (AB) of 8085?
7. The address capability of 8085 is 64 KB. Explain.
8. Does 8085 have serial I/O control
9. What jobs ALU of 8085 can perform?
10. How many hardware interrupts 8085 supports?
11. How many I/O ports can 8085 access?
12. Why the lower byte address bus (A0 – A7) and data bus (D0 – D7) are multiplexed?

13. Why the lower byte address bus (A0 – A7) and data bus (D0 – D7) are multiplexed?
14. List the interrupts of 8085
15. List the flag bits of 8086

PART B

1. Explain the architecture of 8085
2. Discuss the addressing modes of 8085
3. Draw the timing diagram for the given instructions
 - a. STA
 - b. CALL
 - c. LDA
 - d. MOV A,M
4. Explain the 8086 architecture with neat diagram
5. Explain the interrupts of 8085

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SCHOOL OF ELECTRICAL AND ELECTRONICS

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

UNIT – II– MICROPROCESSORS AND MICROCONTROLLERS– SEC1201

UNIT 2 PROGRAMMING 8085 MICROPROCESSOR

8085 assembly language programming, addressing modes, 8085 instruction set, Instruction formats, Instruction Classification: data transfer, arithmetic operations, logical operations, branching operations, machine control —Stack and subroutines, Example Programs

Instruction Set of 8085

- An instruction is a binary pattern designed inside a microprocessor to perform a specific function.
- The entire group of instructions that a microprocessor supports is called Instruction Set.
- 8085 has 246 instructions.
- Each instruction is represented by an 8-bit binary value.
- These 8-bits of binary value is called Op-Code or Instruction Byte.

Classification of Instruction Set

- Data Transfer Instruction
- Arithmetic Instructions
- Logical Instructions
- Branching Instructions
- Control Instructions

Data Transfer Instructions • These instructions move data between registers, or between memory and registers. • These instructions copy data from source to destination. • While copying, the contents of source are not modified.

Arithmetic Instructions • These instructions perform the operations like: • Addition • Subtract • Increment • Decrement

Logical Instructions • These instructions perform logical operations on data stored in registers, memory and status flags. • The logical operations are: • AND • OR • XOR • Rotate • Compare • Complement

Branching Instructions • The branching instruction alter the normal sequential flow. • These instructions alter either unconditionally or conditionally

Control Instructions • The control instructions control the operation of microprocessor.

DATA TRANSFER INSTRUCTIONS

Copy of data

- **MOV** Moves data from register to register / memory
- **MVI** Moves immediate data to register / memory

Load Instructions

- **LDA** Load accumulator direct
- **LDAX** Load accumulator indirect
- **LHLD** Load H&L registers direct
- **LXI** Load register pair immediate

Store Instructions

- **STA** Store accumulator direct
- **SPHL** Copy H&L registers to stack pointer.
- **STAX** Store accumulator indirect

Opcode	Operand	Meaning	Explanation
MOV	Rd, Sc M, Sc Dt, M	Copy from the source (Sc) to the destination(Dt)	This instruction copies the contents of the source register into the destination register without any alteration. Example – MOV A, L
MVI	Rd, data M, data	Move immediate 8-bit	The 8-bit data is stored in the destination register or memory. Example – MVI H, 55H
LDA	16-bit address	Load the accumulator	The contents of a memory location, specified by a 16-bit address in the operand, are copied to the accumulator. Example – LDA 2034H
LDAX	B/D Reg. pair	Load the accumulator indirect	The contents of the designated register pair point to a memory location. This instruction copies the contents of that memory location into the accumulator. Example – LDAX B
LXI	Reg. pair, 16-bit data	Load the register pair immediate	The instruction loads 16-bit data in the register pair designated in the register or the memory. Example – LXI H, 3225H
LHLD	16-bit address	Load H and L registers direct	The instruction copies the contents of the memory location pointed out by the address into register L and copies the contents of the next memory location into register H.

			Example – LHLD 3225H
STA	16-bit address	16-bit address	<p>The contents of the accumulator are copied into the memory location specified by the operand.</p> <p>This is a 3-byte instruction, the second byte specifies the low-order address and the third byte specifies the high-order address.</p> <p>Example – STA 3257H</p>
STAX	16-bit address	Store the accumulator indirect	<p>The contents of the accumulator are copied into the memory location specified by the contents of the operand.</p> <p>Example – STAX D</p>
SHLD	16-bit address	Store H and L registers direct	<p>The contents of register L are stored in the memory location specified by the 16-bit address in the operand and the contents of H register are stored into the next memory location by incrementing the operand.</p> <p>This is a 3-byte instruction, the second byte specifies the low-order address and the third byte specifies the high-order address.</p> <p>Example – SHLD 3225H</p>
XCHG	None	Exchange H and L with D and E	<p>The contents of register H are exchanged with the contents of register D, and the contents of register L are exchanged with the contents of register E.</p> <p>Example – XCHG</p>

SPHL	None	Copy H and L registers to the stack pointer	<p>The instruction loads the contents of the H and L registers into the stack pointer register. The contents of the H register provide the high-order address and the contents of the L register provide the low-order address.</p> <p>Example – SPHL</p>
XTHL	None	Exchange H and L with top of stack	<p>The contents of the L register are exchanged with the stack location pointed out by the contents of the stack pointer register.</p> <p>The contents of the H register are exchanged with the next stack location (SP+1).</p> <p>Example – XTHL</p>
PUSH	Reg. pair	Push the register pair onto the stack	<p>The contents of the register pair designated in the operand are copied onto the stack in the following sequence.</p> <p>The stack pointer register is decremented and the contents of the high order register (B, D, H, A) are copied into that location.</p> <p>The stack pointer register is decremented again and the contents of the low-order register (C, E, L, flags) are copied to that location.</p> <p>Example – PUSH PSW</p>
POP	Reg. pair	Pop off stack to the register pair	<p>The contents of the memory location pointed out by the stack pointer register are copied to the low-order register (C, E, L, status flags) of the operand.</p>

			<p>The stack pointer is incremented by 1 and the contents of that memory location are copied to the high-order register (B, D, H, A) of the operand.</p> <p>The stack pointer register is again incremented by 1.</p> <p>Example – POP D</p>
OUT	8-bit port address	Output the data from the accumulator to a port with 8bit address	<p>The contents of the accumulator are copied into the I/O port specified by the operand.</p> <p>Example – OUT 12H</p>
IN	8-bit port address	Input data to accumulator from a port with 8-bit address	<p>The contents of the input port designated in the operand are read and loaded into the accumulator.</p> <p>Example – IN 55H</p>

Store accumulator direct
STA 16-bit address

The contents of the accumulator are copied into the memory location specified by the operand. This is a 3-byte instruction, the second byte specifies the low-order address and the third byte specifies the high-order address.

Example: STA 4350 or STA XYZ

Store accumulator indirect
STAX Reg. pair

The contents of the accumulator are copied into the memory location specified by the contents of the operand (register pair). The contents of the accumulator are not altered.

Example: STAX B

Store H and L registers direct
SHLD 16-bit address

The contents of register L are stored into the memory location specified by the 16-bit address in the operand and the contents of H register are stored into the next memory location by incrementing the operand. The contents of registers HL are not altered. This is a 3-byte instruction, the second byte specifies the low-order address and the third byte specifies the high-order address.

Example: SHLD 2470

Exchange H and L with D and E
XCHG none

The contents of register H are exchanged with the contents of register D, and the contents of register L are exchanged with the contents of register E.

Example: XCHG

Copy H and L registers to the stack pointer
SPHL none

The instruction loads the contents of the H and L registers into the stack pointer register, the contents of the H register provide the high-order address and the contents of the L register provide the low-order address. The contents of the H and L registers are not altered.

Example: SPHL

Exchange H and L with top of stack
XTHL none

The contents of the L register are exchanged with the stack location pointed out by the contents of the stack pointer register. The contents of the H register are exchanged with the next stack location (SP+1); however, the contents of the stack pointer register are not altered.

Example: XTHL

Push register pair onto stack
PUSH Reg. pair

The contents of the register pair designated in the operand are copied onto the stack in the following sequence. The stack pointer register is decremented and the contents of the high-order register (B, D, H, A) are copied into that location. The stack pointer register is decremented again and the contents of the low-order register (C, E, L, flags) are copied to that location.
 Example: **PUSH B** or **PUSH A**

Pop off stack to register pair
POP Reg. pair

The contents of the memory location pointed out by the stack pointer register are copied to the low-order register (C, E, L, status flags) of the operand. The stack pointer is incremented by 1 and the contents of that memory location are copied to the high-order register (B, D, H, A) of the operand. The stack pointer register is again incremented by 1.
 Example: **POP H** or **POP A**

Output data from accumulator to a port with 8-bit address
OUT 8-bit port address

The contents of the accumulator are copied into the I/O port specified by the operand.
 Example: **OUT 87**

Input data to accumulator from a port with 8-bit address
IN 8-bit port address

The contents of the input port designated in the operand are read and loaded into the accumulator.
 Example: **IN 82**

ARITHMETIC INSTRUCTIONS:

Opcode	Operand	Description
--------	---------	-------------

Add register or memory to accumulator

ADD	R M
------------	--------

The contents of the operand (register or memory) are added to the contents of the accumulator and the result is stored in the accumulator. If the operand is a memory location, its location is specified by the contents of the HL registers. All flags are modified to reflect the result of the addition.
 Example: **ADD B** or **ADD M**

Add register to accumulator with carry

ADC	R M
------------	--------

The contents of the operand (register or memory) and the Carry flag are added to the contents of the accumulator and the result is stored in the accumulator. If the operand is a memory location, its location is specified by the contents of the HL registers. All flags are modified to reflect the result of the addition.
 Example: **ADC B** or **ADC M**

Add immediate to accumulator

ADI	8-bit data
------------	------------

The 8-bit data (operand) is added to the contents of the accumulator and the result is stored in the accumulator. All flags are modified to reflect the result of the addition.
 Example: **ADI 45**

Add immediate to accumulator with carry

ACI	8-bit data
------------	------------

The 8-bit data (operand) and the Carry flag are added to the contents of the accumulator and the result is stored in the accumulator. All flags are modified to reflect the result of the addition.
 Example: **ACI 45**

Add register pair to H and L registers

DAD	Reg. pair
------------	-----------

The 16-bit contents of the specified register pair are added to the contents of the HL register and the sum is stored in the HL register. The contents of the source register pair are not altered. If the result is larger than 16 bits, the CY flag is set. No other flags are affected.
 Example: **DAD H**

Subtract register or memory from accumulator

SUB	R	The contents of the operand (register or memory) are subtracted from the contents of the accumulator, and the result is stored in the accumulator. If the operand is a memory location, its location is specified by the contents of the HL registers. All flags are modified to reflect the result of the subtraction. Example: SUB B or SUB M
	M	

Subtract source and borrow from accumulator

SBB	R	The contents of the operand (register or memory) and the Borrow flag are subtracted from the contents of the accumulator and the result is placed in the accumulator. If the operand is a memory location, its location is specified by the contents of the HL registers. All flags are modified to reflect the result of the subtraction. Example: SBB B or SBB M
	M	

Subtract immediate from accumulator

SUI	8-bit data	The 8-bit data (operand) is subtracted from the contents of the accumulator and the result is stored in the accumulator. All flags are modified to reflect the result of the subtraction. Example: SUI 45
-----	------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Subtract immediate from accumulator with borrow

SBI	8-bit data	The 8-bit data (operand) and the Borrow flag are subtracted from the contents of the accumulator and the result is stored in the accumulator. All flags are modified to reflect the result of the subtraction. Example: SBI 45
-----	------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Increment register or memory by 1

INR	R	The contents of the designated register or memory) are incremented by 1 and the result is stored in the same place. If the operand is a memory location, its location is specified by the contents of the HL registers. Example: INR B or INR M
	M	

Increment register pair by 1

INX	R	The contents of the designated register pair are incremented by 1 and the result is stored in the same place. Example: INX H
-----	---	---------------------------------------------------------------------------------------------------------------------------------

Decrement register or memory by 1

DCR R
 M

The contents of the designated register or memory are decremented by 1 and the result is stored in the same place. If the operand is a memory location, its location is specified by the contents of the HL registers.
Example: DCR B or DCR M

Decrement register pair by 1

DCX R

The contents of the designated register pair are decremented by 1 and the result is stored in the same place.
Example: DCX H

Decimal adjust accumulator

DAA none

The contents of the accumulator are changed from a binary value to two 4-bit binary coded decimal (BCD) digits. This is the only instruction that uses the auxiliary flag to perform the binary to BCD conversion, and the conversion procedure is described below. S, Z, AC, P, CY flags are altered to reflect the results of the operation.

If the value of the low-order 4-bits in the accumulator is greater than 9 or if AC flag is set, the instruction adds 6 to the low-order four bits.

If the value of the high-order 4-bits in the accumulator is greater than 9 or if the Carry flag is set, the instruction adds 6 to the high-order four bits.

Example: DAA

BRANCHING INSTRUCTIONS

Opcode Operand

Description

Jump unconditionally

JMP 16-bit address

The program sequence is transferred to the memory location specified by the 16-bit address given in the operand.
Example: JMP 2034 or JMP XYZ

Jump conditionally

Operand: 16-bit address

The program sequence is transferred to the memory location specified by the 16-bit address given in the operand based on the specified flag of the PSW as described below.
Example: JZ 2034 or JZ XYZ

Opcode	Description	Flag Status
JC	Jump on Carry	CY = 1
JNC	Jump on no Carry	CY = 0
JP	Jump on positive	S = 0
JM	Jump on minus	S = 1
JZ	Jump on zero	Z = 1
JNZ	Jump on no zero	Z = 0
JPE	Jump on parity even	P = 1
JPO	Jump on parity odd	P = 0

Unconditional subroutine call

CALL 16-bit address

The program sequence is transferred to the memory location specified by the 16-bit address given in the operand. Before the transfer, the address of the next instruction after CALL (the contents of the program counter) is pushed onto the stack.
Example: CALL 2034 or CALL XYZ

Call conditionally

Operand: 16-bit address

The program sequence is transferred to the memory location specified by the 16-bit address given in the operand based on the specified flag of the PSW as described below. Before the transfer, the address of the next instruction after the call (the contents of the program counter) is pushed onto the stack.
Example: CZ 2034 or CZ XYZ

Opcode	Description	Flag Status
CC	Call on Carry	CY = 1
CNC	Call on no Carry	CY = 0
CP	Call on positive	S = 0
CM	Call on minus	S = 1
CZ	Call on zero	Z = 1
CNZ	Call on no zero	Z = 0
CPE	Call on parity even	P = 1
CPO	Call on parity odd	P = 0

Return from subroutine unconditionally

RET none

The program sequence is transferred from the subroutine to the calling program. The two bytes from the top of the stack are copied into the program counter, and program execution begins at the new address.
Example: RET

Return from subroutine conditionally

Operand: none

The program sequence is transferred from the subroutine to the calling program based on the specified flag of the PSW as described below. The two bytes from the top of the stack are copied into the program counter, and program execution begins at the new address.
Example: RZ

Opcode	Description	Flag Status
RC	Return on Carry	CY = 1
RNC	Return on no Carry	CY = 0
RP	Return on positive	S = 0
RM	Return on minus	S = 1
RZ	Return on zero	Z = 1
RNZ	Return on no zero	Z = 0
RPE	Return on parity even	P = 1
RPO	Return on parity odd	P = 0

Load program counter with HL contents

PCHL none

The contents of registers H and L are copied into the program counter. The contents of H are placed as the high-order byte and the contents of L as the low-order byte.
Example: PCHL

Restart

RST 0-7

The RST instruction is equivalent to a 1-byte call instruction to one of eight memory locations depending upon the number. The instructions are generally used in conjunction with interrupts and inserted using external hardware. However these can be used as software instructions in a program to transfer program execution to one of the eight locations. The addresses are:

Instruction	Restart Address
RST 0	0000H
RST 1	0008H
RST 2	0010H
RST 3	0018H
RST 4	0020H
RST 5	0028H
RST 6	0030H
RST 7	0038H

The 8085 has four additional interrupts and these interrupts generate RST instructions internally and thus do not require any external hardware. These instructions and their Restart addresses are:

Interrupt	Restart Address
TRAP	0024H
RST 5.5	002CH
RST 6.5	0034H
RST 7.5	003CH

LOGICAL INSTRUCTIONS

Opcode Operand Description

Compare register or memory with accumulator

CMP R
M

The contents of the operand (register or memory) are compared with the contents of the accumulator. Both contents are preserved. The result of the comparison is shown by setting the flags of the PSW as follows:
if (A) < (reg/mem): carry flag is set, s=1
if (A) = (reg/mem): zero flag is set, s=0
if (A) > (reg/mem): carry and zero flags are reset, s=0
Example: CMP B or CMP M

Compare immediate with accumulator

CPI 8-bit data

The second byte (8-bit data) is compared with the contents of the accumulator. The values being compared remain unchanged. The result of the comparison is shown by setting the flags of the PSW as follows:
if (A) < data: carry flag is set, s=1
if (A) = data: zero flag is set, s=0
if (A) > data: carry and zero flags are reset, s=0
Example: CPI 89

Logical AND register or memory with accumulator

ANA R
M

The contents of the accumulator are logically ANDed with the contents of the operand (register or memory), and the result is placed in the accumulator. If the operand is a memory location, its address is specified by the contents of HL registers. S, Z, P are modified to reflect the result of the operation. CY is reset. AC is set.
Example: ANA B or ANA M

Logical AND immediate with accumulator

ANI 8-bit data

The contents of the accumulator are logically ANDed with the 8-bit data (operand) and the result is placed in the accumulator. S, Z, P are modified to reflect the result of the operation. CY is reset. AC is set.
Example: ANI 86

Exclusive OR register or memory with accumulator

XRA R
 M

The contents of the accumulator are Exclusive ORed with the contents of the operand (register or memory), and the result is placed in the accumulator. If the operand is a memory location, its address is specified by the contents of HL registers. S, Z, P are modified to reflect the result of the operation. CY and AC are reset.
Example: XRA B or XRA M

Exclusive OR immediate with accumulator

XRI 8-bit data

The contents of the accumulator are Exclusive ORed with the 8-bit data (operand) and the result is placed in the accumulator. S, Z, P are modified to reflect the result of the operation. CY and AC are reset.
Example: XRI 86

Logical OR register or memory with accumulator

ORA R
 M

The contents of the accumulator are logically ORed with the contents of the operand (register or memory), and the result is placed in the accumulator. If the operand is a memory location, its address is specified by the contents of HL registers. S, Z, P are modified to reflect the result of the operation. CY and AC are reset.
Example: ORA B or ORA M

Logical OR immediate with accumulator

ORI 8-bit data

The contents of the accumulator are logically ORed with the 8-bit data (operand) and the result is placed in the accumulator. S, Z, P are modified to reflect the result of the operation. CY and AC are reset.
Example: ORI 86

Rotate accumulator left

RLC none

Each binary bit of the accumulator is rotated left by one position. Bit D7 is placed in the position of D0 as well as in the Carry flag. CY is modified according to bit D7. S, Z, P, AC are not affected.
Example: RLC

Rotate accumulator right

RRC none

Each binary bit of the accumulator is rotated right by one position. Bit D0 is placed in the position of D7 as well as in the Carry flag. CY is modified according to bit D0. S, Z, P, AC are not affected.
Example: RRC

Rotate accumulator left through carry

RAL none

Each binary bit of the accumulator is rotated left by one position through the Carry flag. Bit D7 is placed in the Carry flag, and the Carry flag is placed in the least significant position D0. CY is modified according to bit D7. S, Z, P, AC are not affected.

Example: RAL

Rotate accumulator right through carry

RAR none

Each binary bit of the accumulator is rotated right by one position through the Carry flag. Bit D0 is placed in the Carry flag, and the Carry flag is placed in the most significant position D7. CY is modified according to bit D0. S, Z, P, AC are not affected.

Example: RAR

Complement accumulator

CMA none

The contents of the accumulator are complemented. No flags are affected.

Example: CMA

Complement carry

CMC none

The Carry flag is complemented. No other flags are affected.

Example: CMC

Set Carry

STC none

The Carry flag is set to 1. No other flags are affected.

Example: STC

CONTROL INSTRUCTIONS

Opcode Operand

Description

No operation

NOP none

No operation is performed. The instruction is fetched and decoded. However no operation is executed.

Example: NOP

Halt and enter wait state

HLT none

The CPU finishes executing the current instruction and halts any further execution. An interrupt or reset is necessary to exit from the halt state.

Example: HLT

Disable interrupts

DI none

The interrupt enable flip-flop is reset and all the interrupts except the TRAP are disabled. No flags are affected.

Example: DI

Enable interrupts

EI none

The interrupt enable flip-flop is set and all interrupts are enabled. No flags are affected. After a system reset or the acknowledgement of an interrupt, the interrupt enable flip-flop is reset, thus disabling the interrupts. This instruction is necessary to reenable the interrupts (except TRAP).

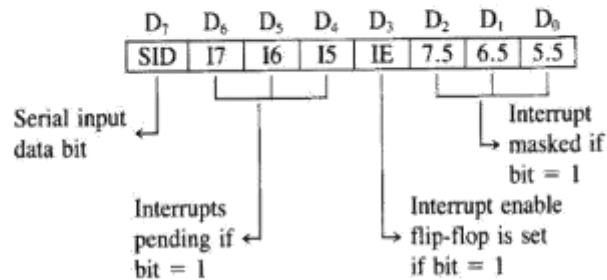
Example: EI

Read interrupt mask

RIM none

This is a multipurpose instruction used to read the status of interrupts 7.5, 6.5, 5.5 and read serial data input bit. The instruction loads eight bits in the accumulator with the following interpretations.

Example: RIM

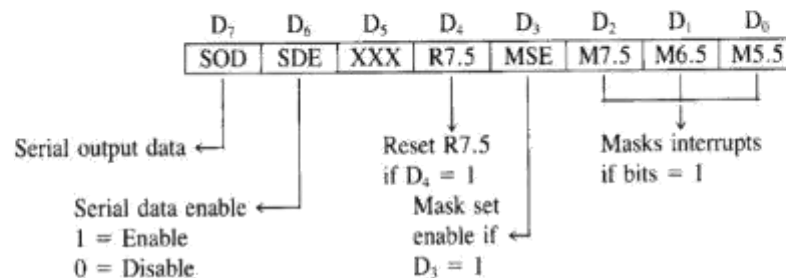


Set interrupt mask

SIM none

This is a multipurpose instruction and used to implement the 8085 interrupts 7.5, 6.5, 5.5, and serial data output. The instruction interprets the accumulator contents as follows.

Example: SIM



- SOD—Serial Output Data: Bit D7 of the accumulator is latched into the SOD output line and made available to a serial peripheral if bit D6 = 1.
- SDE—Serial Data Enable: If this bit = 1, it enables the serial output. To implement serial output, this bit needs to be enabled.
- XXX—Don't Care
- R7.5—Reset RST 7.5: If this bit = 1, RST 7.5 flip-flop is reset. This is an additional control to reset RST 7.5.
- MSE—Mask Set Enable: If this bit is high, it enables the functions of bits D2, D1, D0. This is a master control over all the interrupt masking bits. If this bit is low, bits D2, D1, and D0 do not have any effect on the masks.
- M7.5—D2 = 0, RST 7.5 is enabled.
 = 1, RST 7.5 is masked or disabled.
- M6.5—D1 = 0, RST 6.5 is enabled.
 = 1, RST 6.5 is masked or disabled.
- M5.5—D0 = 0, RST 5.5 is enabled.
 = 1, RST 5.5 is masked or disabled.

8085 Assembly Language Programs & Explanations

1. Statement: Store the data byte 32H into memory location 4000H.

Program 1:

```
MVI A, 32H      : Store 32H in the accumulator
STA 4000H       : Copy accumulator contents at address 4000H
HLT            : Terminate program execution
```

Program 2:

```
LXI H          : Load HL with 4000H
MVI M          : Store 32H in memory location pointed by HL register pair
(4000H)
HLT           : Terminate program execution
```

2. Statement: Exchange the contents of memory locations 2000H and 4000H

Program 1:

```
LDA 2000H      : Get the contents of memory location 2000H into
accumulator
MOV B, A       : Save the contents into B register
LDA 4000H      : Get the contents of memory location 4000H into
accumulator
STA 2000H      : Store the contents of accumulator at address 2000H
MOV A, B       : Get the saved contents back into A register
STA 4000H      : Store the contents of accumulator at address 4000H
```

Program 2:

```
LXI H 2000H    : Initialize HL register pair as a pointer to
memory location 2000H.
LXI D 4000H    : Initialize DE register pair as a pointer to
memory location 4000H.
MOV B, M       : Get the contents of memory location 2000H into B
register.
LDAX D         : Get the contents of memory location 4000H into A
register.
MOV M, A       : Store the contents of A register into memory
location 2000H.
MOV A, B       : Copy the contents of B register into accumulator.
STAX D        : Store the contents of A register into memory location
4000H.
```


HLT
: Terminate program execution.

3. Sample problem

$(4000H) = 14H$
 $(4001H) = 89H$
 $Result = 14H + 89H = 9DH$ Source program

<i>LXI H 4000H</i>	: HL points 4000H
<i>MOV A, M</i>	: Get first operand
<i>INX H</i>	: HL points 4001H
<i>ADD M</i>	: Add second operand
<i>INX H</i>	: HL points 4002H
<i>MOV M, A</i>	: Store result at 4002H
<i>HLT</i>	: Terminate program execution

4. Statement: Subtract the contents of memory location 4001H from the memory location 2000H and place the result in memory location 4002H.

Program - 4: Subtract two 8-bit numbers

Sample problem:

$(4000H) = 51H$
 $(4001H) = 19H$
 $Result = 51H - 19H = 38H$

Source program:

<i>LXI H, 4000H</i>	: HL points 4000H
<i>MOV A, M</i>	: Get first operand
<i>INX H</i>	: HL points 4001H
<i>SUB M</i>	: Subtract second operand
<i>INX H</i>	: HL points 4002H
<i>MOV M, A</i>	: Store result at 4002H.
<i>HLT</i>	: Terminate program execution

5. Statement: Add the 16-bit number in memory locations 4000H and 4001H to the 16-bit number in memory locations 4002H and 4003H. The most significant eight bits of the two numbers to be added are in memory locations 4001H and 4003H. Store the result in memory locations 4004H and 4005H with the most significant byte in memory location 4005H.

Program - 5.a: Add two 16-bit numbers - Source Program 1

Sample problem:

(4000H) = 15H
(4001H) = 1CH
(4002H) = B7H
(4003H) = 5AH
Result = 1C15 + 5AB7H = 76CCH (4004H) =
CCH
(4005H) = 76H

Source Program 1:

LHLD 4000H	: Get first 16-bit number in HL
XCHG	: Save first 16-bit number in DE
LHLD 4002H	: Get second 16-bit number in HL
MOV A, E	: Get lower byte of the first number
ADD L	: Add lower byte of the second number
MOV L, A	: Store result in L register
MOV A, D	: Get higher byte of the first number
ADC H	: Add higher byte of the second number with CARRY
MOV H, A	: Store result in H register
SHLD 4004H	: Store 16-bit result in memory locations 4004H and 4005H.
HLT	: Terminate program execution

6.Statement: Add the contents of memory locations 40001H and 4001H and place the result in the memory locations 4002H and 4003H.

Sample problem:

(4000H) = 7FH
(4001H) = 89H
Result = 7FH + 89H = 108H (4002H) =
08H (4003H) = 01H

Source program:

LXI H, 4000H	:HL Points 4000H
MOV A, M	:Get first operand
INX H	:HL Points 4001H
ADD M	:Add second operand
INX H	:HL Points 4002H
MOV M, A	:Store the lower byte of result at 4002H
MVIA, 00	:Initialize higher byte result with 00H

ADC A	:Add carry in the high byte result
INX H	:HL Points 4003H
MOV M, A	:Store the higher byte of result at 4003H
HLT	:Terminate program execution

7.Statement: Subtract the 16-bit number in memory locations 4002H and 4003H from the 16-bit number in memory locations 4000H and 4001H. The most significant eight bits of the two numbers are in memory locations 4001H and 4003H. Store the result in memory locations 4004H and 4005H with the most significant byte in memory location 4005H.

Sample problem

(4000H) = 19H
 (4001H) = 6AH
 (4004H) = 15H (4003H) = 5CH Result = 6A19H -
 5C15H = 0E04H (4004H) = 04H
 (4005H) = 0EH

Source program:

LHLD 4000H	: Get first 16-bit number in HL
XCHG	: Save first 16-bit number in DE
LHLD 4002H	: Get second 16-bit number in HL
MOV A, E	: Get lower byte of the first number
SUB L	: Subtract lower byte of the second number
MOV L, A	: Store the result in L register
MOV A, D	: Get higher byte of the first number
SBB H	: Subtract higher byte of second number with borrow
MOV H, A	: Store 16-bit result in memory locations 4004H and
4005H.	
SHLD 4004H	: Store 16-bit result in memory locations 4004H and
4005H.	
HLT	: Terminate program execution

8.Statement: Find the 1's complement of the number stored at memory location 4400H and store the complemented number at memory location 4300H.

Sample problem:

(4400H) = 55H

$Result = (4300B) = AAB$

Source program:

<i>LDA 4400B</i>	<i>: Get the number</i>
<i>CMA</i>	<i>: Complement number</i>
<i>STA 4300H</i>	<i>: Store the result</i>
<i>HLT</i>	<i>: Terminate program execution</i>

9.Statement: Find the 2's complement of the number stored at memory location 4200H and store the complemented number at memory location 4300H.

Sample problem:

$(4200H) = 55H$
 $Result = (4300H) = AAH + 1 = ABH$

Source program:

<i>LDA 4200H</i>	<i>: Get the number</i>
<i>CMA</i>	<i>: Complement the number</i>
<i>ADI, 01 H</i>	<i>: Add one in the number</i>
<i>STA 4300H</i>	<i>: Store the result</i>
<i>HLT</i>	<i>: Terminate program execution</i>

10.Statement: Pack the two unpacked BCD numbers stored in memory locations 4200H and 4201H and store result in memory location 4300H. Assume the least significant digit is stored at 4200H.

Sample problem: (4200H)
= 04 (4201H) = 09
Result = (4300H) = 94

Source program

<i>LDA 4201H</i>	<i>: Get the Most significant BCD digit</i>
<i>RLC</i>	
<i>RLC</i>	
<i>RLC</i>	
<i>RLC</i>	<i>: Adjust the position of the second digit (09 is changed to 90)</i>

<i>ANI FOH</i>	<i>: Make least significant BCD digit zero</i>
<i>MOV C, A</i>	<i>: store the partial result</i>
<i>LDA 4200H</i>	<i>: Get the lower BCD digit</i>
<i>ADD C</i>	<i>: Add lower BCD digit</i>
<i>STA 4300H</i>	<i>: Store the result</i>
<i>HLT</i>	<i>: Terminate program execution</i>

11.Statement: Two digit BCD number is stored in memory location 4200H. Unpack the BCD number and store the two digits in memory locations 4300H and 4301H such that memory location 4300H will have lower BCD digit.

Sample problem

$(4200H) = 58$

$Result = (4300H) = 08 \text{ and } (4301H) = 05$

Source program

<i>LDA 4200H</i>	<i>: Get the packed BCD number</i>
<i>ANI FOH</i>	<i>: Mask lower nibble</i>
<i>RRC</i>	
<i>RRC</i>	
<i>RRC</i>	
<i>RRC</i>	<i>: Adjust higher BCD digit as a lower digit</i>
<i>STA 4301H</i>	<i>: Store the partial result</i>
<i>LDA 4200H</i>	<i>: .Get the original BCD number</i>
<i>ANI OFH</i>	<i>: Mask higher nibble</i>
<i>STA 4201H</i>	<i>: Store the result</i>
<i>HLT</i>	<i>: Terminate program execution</i>

12.Statement:Read the program given below and state the contents of all registers after the execution of each instruction in sequence.

Main program:

<i>4000H</i>	<i>LXI SP, 27FFH</i>
<i>4003H</i>	<i>LXI H, 2000H</i>
<i>4006H</i>	<i>LXI B, 1020H</i>
<i>4009H</i>	<i>CALL SUB</i>
<i>400CH</i>	<i>HLT</i>

Subroutine program:

4100H	SUB: PUSH B
4101H	PUSH H
4102H	LXI B, 4080H
4105H	LXI H, 4090H
4108H	SHLD 2200H
4109H	DAD B
410CH	POP H
410DH	POP B
410EH	RET

13.Statement: Write a program to shift an eight bit data four bits right. Assume that data is in register C.

Source program:

```
MOV A, C
RAR
RAR
RAR
RAR
MOV C, A
HLT
```

14.Statement: Program to shift a 16-bit data 1 bit left. Assume data is in the HL register pair

Source program:

DAD H : Adds HL data with HL data

15.Statement: Write a set of instructions to alter the contents of flag register in 8085.

PUSH PSW	: Save flags on stack
POP H	: Retrieve flags in 'L'
MOV A, L	: Flags in accumulator
CMA	: Complement accumulator
MOV L, A	: Accumulator in 'L'

PUSH H : Save on stack
POP PSW : Back to flag register
HLT : Terminate program execution

16.Statement: Calculate the sum of series of numbers. The length of the series is in memory location 4200H and the series begins from memory location 4201H.

1. Consider the sum to be 8 bit number. So, ignore carries. Store the sum at memory location 4300H.
2. Consider the sum to be 16 bit number. Store the sum at memory locations 4300H and 4301H

a. Sample problem

4200H = 04H
 4201H = 10H
 4202H = 45H
 4203H = 33H
 4204H = 22H
 Result = 10 + 41 + 30 + 12 = H
 4300H = H

Source program:

LDA 4200H
 MOV C, A : Initialize counter
 SUB A : sum = 0
 LXI H, 4201H : Initialize pointer
 BACK: ADD M : SUM = SUM + data
 INX H : increment pointer
 DCR C : Decrement counter
 JNZ BACK : if counter 0 repeat
 STA 4300H : Store sum
 HLT : Terminate program execution

b. Sample problem

4200H = 04H 4201H
 = 9AH 4202H = 52H
 4203H = 89H 4204H
 = 3EH
 Result = 9AH + 52H + 89H + 3EH = H 4300H = B3H
 Lower byte
 4301H = 01H Higher byte

Source program:

```

LDA 4200H
MOV C, A           : Initialize counter
LXI H, 4201H       : Initialize pointer
SUB A              : Sum low = 0
MOV B, A           : Sum high = 0
BACK: ADD M         : Sum = sum + data
JNC SKIP
INR B              : Add carry to MSB of SUM
SKIP: INX H         : Increment pointer
DCR C              : Decrement counter
JNZ BACK           : Check if counter 0 repeat
STA 4300H          : Store lower byte

MOV A, B
STA 4301H          : Store higher byte
HLT               : Terminate program execution

```

17.Statement: Multiply two 8-bit numbers stored in memory locations 2200H and 2201H by repetitive addition and store the result in memory locations 2300H and 2301H.

Sample problem:

```

(2200H) = 03H
(2201H) = B2H
Result = B2H + B2H + B2H = 216H = 216H
(2300H) = 16H
(2301H) = 02H

```

Source program

```

LDA 2200H
MOV E, A
MVI D, 00          : Get the first number in DE register pair
LDA 2201H
MOV C, A           : Initialize counter
LXI H, 0000 H      : Result = 0
BACK: DAD D         : Result = result + first number
DCR C              : Decrement count
JNZ BACK           : If count 0 repeat
SHLD 2300H         : Store result
HLT               : Terminate program execution

```


18.Statement: Divide 16 bit number stored in memory locations 2200H and 2201H by the 8 bit number stored at memory location 2202H. Store the quotient in memory locations 2300H and 2301H and remainder in memory locations 2302H and 2303H.

Sample problem (2200H) =

60H (2201H) = A0H

(2202H) = 12H

Result = A060H/12H = 8E8H Quotient and 10H remainder (2300H) =

E8H (2301H) = 08H

(2302H) = 10H (2303H)

00H

Source program

```

LHLD 2200H          : Get the dividend
LDA 2202H            : Get the divisor

MOV C, A
LXI D, 0000H         : Quotient = 0
BACK: MOV A, L
SUB C                : Subtract divisor
MOV L, A             : Save partial result
JNC SKIP             : if CY 1 jump
DCR H                : Subtract borrow of previous subtraction
SKIP: INX D           : Increment quotient

MOV A, H
CPI, 00              : Check if dividend < divisor
JNZ BACK             : if no repeat
MOV A, L
CMP C
JNC BACK
SHLD 2302H           : Store the remainder
XCHG
SHLD 2300H           : Store the quotient
HLT                  : Terminate program execution

```

19.Statement: Find the number of negative elements (most significant bit 1) in a block of data. The length of the block is in memory location 2200H and the block itself begins in memory location 2201H. Store the number of negative elements in memory location 2300H

Sample problem

(2200H) = 04H

(2201H) = 56H
 (2202H) = A9H
 (2203H) = 73H
 (2204H) = 82H

Result = 02 since 2202H and 2204H contain numbers with a MSB of 1.

Source program

```

    LDA 2200H
    MOV C, A           : Initialize count
    MVI B, 00          : Negative number = 0
    LXI H, 2201H       : Initialize pointer
BACK: MOV A, M         : Get the number
    ANI 80H            : Check for MSB
    JZ SKIP            : If MSB = 1
    INR B              : Increment negative number count
SKIP: INX H            : Increment pointer
    DCR C              : Decrement count
    JNZ BACK           : If count 0 repeat

    MOV A, B
    STA 2300H          : Store the result
    HLT                : Terminate program execution
  
```

20.Statement:Find the largest number in a block of data. The length of the block is in memory location 2200H and the block itself starts from memory location 2201H. Store the maximum number in memory location 2300H. Assume that the numbers in the block are all 8 bit unsigned binary numbers.

Sample problem

(2200H) = 04
 (2201H) = 34H
 (2202H) = A9H
 (2203H) = 78H
 (2204H) = 56H
Result = (2202H) = A9H

Source program

```

    LDA 2200H
    MOV C, A           : Initialize counter
    XRA A              : Maximum = Minimum possible value = 0
    LXI H, 2201H       : Initialize pointer
BACK: CMP M            : Is number > maximum
    JNC SKIP           : Yes, replace maximum
  
```

```

MOV A, M
SKIP: INX H
DCR C
JNZ BACK
STA 2300H          : Store maximum number
HLT                : Terminate program execution

```

21.Statement:Write a program to count number of 1's in the contents of D register and store the count in the B register.

Source program:

```

MVI B, 00H
MVI C, 08H
MOV A, D
BACK: RAR
JNC SKIP
INR B
SKIP: DCR C
JNZ BACK
HLT

```

22.Statement:Write a program to sort given 10 numbers from memory location 2200H in the ascending order.

Source program:

```

MVI B, 09          : Initialize counter
START              : LXI H, 2200H: Initialize memory pointer
MVI C, 09H         : Initialize counter 2
BACK: MOV A, M     : Get the number
INX H              : Increment memory pointer
CMP M              : Compare number with next number
JC SKIP            : If less, don't interchange
JZ SKIP            : If equal, don't interchange

MOV D, M
MOV M, A
DCX H
MOV M, D
INX H              : Interchange two numbers
SKIP:DCR C         : Decrement counter 2
JNZ BACK           : If not zero, repeat
DCR B              : Decrement counter 1
JNZ START
HLT                : Terminate program execution

```

23.Statement:Calculate the sum of series of even numbers from the list of numbers. The length of the list is in memory location 2200H and the series itself begins from memory location 2201H. Assume the sum to be 8 bit number so you can ignore carries and store the sum at memory location 2210H. *Sample problem:*

2200H= 4H
 2201H= 20H
 2202H= 15H
 2203H= 13H
 2204H= 22H
 Result 2210H= 20 + 22 = 42H = 42H

Source program:

```

    LDA 2200H
    MOV C, A
    MVI B, 00H
    LXI H, 2201H
BACK: MOV A, M
    ANI 01H
    JNZ SKIP
    MOV A, B
    ADD M
    MOV B, A
SKIP: INX H
    DCR C
    JNZ BACK
    STA 2210H
    HLT
  
```

24.Statement:Calculate the sum of series of odd numbers from the list of numbers. The length of the list is in memory location 2200H and the series itself begins from memory location 2201H. Assume the sum to be 16-bit. Store the sum at memory locations 2300H and 2301H.

Sample problem:

2200H = 4H
 2201H= 9AH
 2202H= 52H
 2203H= 89H
 2204H= 3FH
 Result = 89H + 3FH = C8H 2300H= H
 Lower byte 2301H = H Higher byte

Source program

```
LDA 2200H
MOV C, A           : Initialize counter
LXI H, 2201H       : Initialize pointer
MVI E, 00          : Sum low = 0
MOV D, E           : Sum high = 0
BACK: MOV A, M      : Get the number
ANI 01H            : Mask Bit 1 to Bit7
JZ SKIP            : Don't add if number is even
MOV A, E           : Get the lower byte of sum
ADD M              : Sum = sum + data
MOV E, A           : Store result in E register
JNC SKIP
INR D              : Add carry to MSB of SUM
SKIP: INX H         : Increment pointer
DCR C              : Decrement
```

25.Statement:Find the square of the given numbers from memory location 6100H and store the result from memory location 7000H

Source Program:

```
LXI H, 6200H       : Initialize lookup table pointer
LXI D, 6100H       : Initialize source memory pointer
LXI B, 7000H       : Initialize destination memory pointer
BACK: LDAX D        : Get the number
MOV L, A           : A point to the square
MOV A, M           : Get the square
STAX B             : Store the result at destination memory location
INX D              : Increment source memory pointer
INX B              : Increment destination memory pointer

MOV A, C
CPI 05H            : Check for last number
JNZ BACK           : If not repeat
HLT               : Terminate program execution
```

26.Statement: Search the given byte in the list of 50 numbers stored in the consecutive memory locations and store the address of memory location in the memory locations 2200H and 2201H. Assume byte is in the C register and starting address of the list is 2000H. If byte is not found store 00 at 2200H and 2201H.

Source program:

<i>LXI H, 2000H</i>	<i>: Initialize memory pointer 52H</i>
<i>MVI B, 52H</i>	<i>: Initialize counter</i>
<i>BACK: MOV A, M</i>	<i>: Get the number</i>
<i>CMP C</i>	<i>: Compare with the given byte</i>
<i>JZ LAST</i>	<i>: Go last if match occurs</i>
<i>INX H</i>	<i>: Increment memory pointer</i>
<i>DCR B</i>	<i>: Decrement counter</i>
<i>JNZ B</i>	<i>: If not zero, repeat</i>
<i>LXI H, 0000H</i>	
<i>SHLD 2200H</i>	
<i>JMP END</i>	<i>: Store 00 at 2200H and 2201H</i>
<i>LAST: SHLD 2200H</i>	<i>: Store memory address</i>
<i>END: HLT</i>	<i>: Stop</i>

27.Statement: Two decimal numbers six digits each, are stored in BCD package form. Each number occupies a sequence of byte in the memory. The starting address of first number is 6000H Write an assembly language program that adds these two numbers and stores the sum in the same format starting from memory location 6200H

Source Program:

<i>LXI H, 6000H</i>	<i>: Initialize pointer 1 to first number</i>
<i>LXI D, 6100H</i>	<i>: Initialize pointer2 to second number</i>
<i>LXI B, 6200H</i>	<i>: Initialize pointer3 to result</i>
<i>STC</i>	
<i>CMC</i>	<i>: Carry = 0</i>
<i>BACK: LDAX D</i>	<i>: Get the digit</i>
<i>ADD M</i>	<i>: Add two digits</i>
<i>DAA</i>	<i>: Adjust for decimal</i>
<i>STAX B</i>	<i>: Store the result</i>
<i>INX H</i>	<i>: Increment pointer 1</i>
<i>INX D</i>	<i>: Increment pointer2</i>
<i>INX B</i>	<i>: Increment result pointer</i>
<i>MOV A, L</i>	
<i>CPI 06H</i>	<i>: Check for last digit</i>
<i>JNZ BACK</i>	<i>: If not last digit repeat</i>
<i>HLT</i>	<i>: Terminate program execution</i>

28.Statement: Add 2 arrays having ten 8-bit numbers each and generate a third array of result. It is necessary to add the first element of array 1 with the first

element of array-2 and so on. The starting addresses of array 1, array2 and array3 are 2200H, 2300H and 2400H, respectively.

Source Program:

```

        LXI H, 2200H           : Initialize memory pointer 1
        LXI B, 2300H           : Initialize memory pointer 2
        LXI D, 2400H           : Initialize result pointer
BACK: LDAX B                   : Get the number from array 2
        ADD M                   : Add it with number in array 1
        STAX D                   : Store the addition in array 3
        INX H                   : Increment pointer 1
        INX B                   : Increment pointer2
        INX D                   : Increment result pointer

        MOV A, L
        CPI 0AH                 : Check pointer 1 for last number
        JNZ BACK               : If not, repeat
        HLT                     : Stop

```

29.Statement: Write an assembly language program to separate even numbers from the given list of 50 numbers and store them in the another list starting from 2300H. Assume starting address of 50 number list is 2200H

Source Program:

```

        LXI H, 2200H           : Initialize memory pointer 1
        LXI D, 2300H           : Initialize memory pointer2
        MVI C, 32H             : Initialize counter
BACK: MOV A, M                 : Get the number
        ANI 01H                : Check for even number
        JNZ SKIP               : If ODD, don't store
        MOV A, M                : Get the number
        STAX D                 : Store the number in result list
        INX D                   : Increment pointer 2
SKIP: INX H                    : Increment pointer 1
        DCR C                  : Decrement counter
        JNZ BACK               : If not zero, repeat
        HLT                     : Stop

```

30.Statement: Write assembly language program with proper comments for the following:

A block of data consisting of 256 bytes is stored in memory starting at 3000H. This block is to be shifted (relocated) in memory from 3050H onwards. Do not shift the block or part of the block anywhere else in the memory.

Source Program:

Two blocks (3000 - 30FF and 3050 - 314F) are overlapping. Therefore it is necessary to transfer last byte first and first byte last.

MVI C, FFH	: Initialize counter
LXI H, 30FFH	: Initialize source memory pointer 30FFH
LXI D, 314FH	: Initialize destination memory pointer
BACK: MOV A, M	: Get byte from source memory block
STAX D	: Store byte in the destination memory block
DCX H	: Decrement source memory pointer
DCX	: Decrement destination memory pointer
DCR C	: Decrement counter
JNZ BACK	: If counter 0 repeat
HLT	: Stop execution

31.Statement: Add even parity to a string of 7-bit ASCII characters. The length of the string is in memory location 2040H and the string itself begins in memory location 2041H. Place even parity in the most significant bit of each character.

Source Program:

LXI H, 2040H	
MOV C, M	: Counter for character
REPEAT: INX H	: Memory pointer to character
MOV A, M	: Character in accumulator
ORA A	: ORing with itself to check parity.
JPO PAREVEN	: If odd parity place
ORI 80H	even parity in D7 (80).
PAREVEN: MOV M, A	: Store converted even parity character.
DCR C	: Decrement counter.
JNZ REPEAT	: If not zero go for next character.
HLT	

32.Statement: A list of 50 numbers is stored in memory, starting at 6000H. Find number of negative, zero and positive numbers from this list and store these results in memory locations 7000H, 7001H, and 7002H respectively

Source Program:

```
LXI H, 6000H           : Initialize memory pointer
MVI C, 00H             : Initialize number counter
MVI B, 00H             : Initialize negative number counter
MVI E, 00H             : Initialize zero number counter
BEGIN:MOV A, M         : Get the number
CPI 00H                : If number = 0
JZ ZERONUM             : Goto zeronum
ANI 80H                : If MSB of number = 1 i.e. if
JNZ NEGNUM             : number is negative goto NEGNUM
INR D                  : otherwise increment positive number counter
JMP LAST
ZERONUM:INR E          : Increment zero number counter
JMP LAST
NEGNUM:INR B           : Increment negative number counter
LAST:INX H             : Increment memory pointer
INR C                  : Increment number counter
MOVA, C
CPI 32H                : If number counter = 5010 then
JNZ BEGIN              : Store otherwise check next number
LXI H, 7000            : Initialize memory pointer.
MOV M, B               : Store negative number.
INX H
MOV M, E               : Store zero number.
INX H
MOV M, D               : Store positive number.
HLT                    : Terminate execution
```

33.Statement: Write an 8085 assembly language program to insert a string of four characters from the tenth location in the given array of 50 characters

Solution:

Step 1: Move bytes from location 10 till the end of array by four bytes downwards.
Step 2: Insert four bytes at locations 10, 11, 12 and 13.

Source Program:

```
LXI H, 2131H           : Initialize pointer at the last location of array.
LXI D, 2135H           : Initialize another pointer to point the last
location of array after insertion.
AGAIN: MOV A, M         : Get the character
```

<i>STAX D</i>	<i>: Store at the new location</i>
<i>DCX D</i>	<i>: Decrement destination pointer</i>
<i>DCX H</i>	<i>: Decrement source pointer</i>
<i>MOV A, L</i>	<i>: [check whether desired</i>
<i>CPI 05H</i>	<i>bytes are shifted or not]</i>
<i>JNZ AGAIN</i>	<i>: if not repeat the process</i>
<i>INX H</i>	<i>: adjust the memory pointer</i>
<i>LXI D, 2200H</i>	<i>: Initialize the memory pointer to point the string to</i>

be inserted

<i>REPE: LDAX D</i>	<i>: Get the character</i>
<i>MOV M, A</i>	<i>: Store it in the array</i>
<i>INX D</i>	<i>: Increment source pointer</i>
<i>INX H</i>	<i>: Increment destination pointer</i>
<i>MOV A, E</i>	<i>: [Check whether the 4 bytes</i>
<i>CPI 04</i>	<i>are inserted]</i>
<i>JNZ REPE</i>	<i>: if not repeat the process</i>
<i>HLT</i>	<i>: stop</i>

34.Statement:Write an 8085 assembly language program to delete a string of 4 characters from the tenth location in the given array of 50 characters.

Solution: Shift bytes from location 14 till the end of array upwards by 4 characters i.e. from location 10 onwards.

Source Program:

<i>LXI H, 210DH</i>	<i>:Initialize source memory pointer at the 14thlocation</i>
---------------------	--------------------------------------------------------------

of the array.

<i>LXI D, 2109H</i>	<i>: Initialize destn memory pointer at the 10th location</i>
---------------------	---------------------------------------------------------------

of the array.

<i>MOV A, M</i>	<i>: Get the character</i>
<i>STAX D</i>	<i>: Store character at new location</i>
<i>INX D</i>	<i>: Increment destination pointer</i>
<i>INX H</i>	<i>: Increment source pointer</i>
<i>MOV A, L</i>	<i>: [check whether desired</i>
<i>CPI 32H</i>	<i>bytes are shifted or not]</i>
<i>JNZ REPE</i>	<i>: if not repeat the process</i>
<i>HLT</i>	<i>: stop</i>

35.Statement:Multiply the 8-bit unsigned number in memory location 2200H by the 8-bit unsigned number in memory location 2201H. Store the 8 least significant bits of the result in memory location 2300H and the 8 most significant bits in memory location 2301H.

Sample problem:

(2200)	= 1100 (0CH)
(2201)	= 0101 (05H)
Multiplicand	= 1100 (1210)
Multiplier	= 0101 (510)
Result	= 12 x 5 = (6010)

Source program

LXI H, 2200	: Initialize the memory pointer
MOV E, M	: Get multiplicand
MVI D, 00H	: Extend to 16-bits
INX H	: Increment memory pointer
MOV A, M	: Get multiplier
LXI H, 0000	: Product = 0
MVI B, 08H	: Initialize counter with count 8
MULT: DAD H	: Product = product x 2
RAL	
JNC SKIP	: Is carry from multiplier 1 ?
DAD D	: Yes, Product = Product + Multiplicand
SKIP: DCR B	: Is counter = zero
JNZ MULT	: no, repeat
SHLD 2300H	: Store the result
HLT	: End of program

36.Statement: Divide the 16-bit unsigned number in memory locations 2200H and 2201H (most significant bits in 2201H) by the B-bit unsigned number in memory location 2300H store the quotient in memory location 2400H and remainder in 2401H

Assumption: The most significant bits of both the divisor and dividend are zero.

Source program

MVI E, 00	: Quotient = 0
LHLD 2200H	: Get dividend
LDA 2300	: Get divisor
MOV B, A	: Store divisor
MVI C, 08	: Count = 8
NEXT: DAD H	: Dividend = Dividend x 2
MOV A, E	
RLC	
MOV E, A	: Quotient = Quotient x 2

<i>MOV A, H</i>	
<i>SUB B</i>	: Is most significant byte of Dividend > divisor
<i>JC SKIP</i>	: No, go to Next step
<i>MOV H, A</i>	: Yes, subtract divisor
<i>INR E</i>	: and Quotient = Quotient + 1
<i>SKIP: DCR C</i>	: Count = Count - 1
<i>JNZ NEXT</i>	: Is count = 0 repeat
<i>MOV A, E</i>	
<i>STA 2401H</i>	: Store Quotient
<i>Mov A, H</i>	
<i>STA 2410H</i>	: Store remainder
<i>HLT</i>	: End of program

37.DAA instruction is not present. Write a sub routine which will perform the same task as DAA.

Sample Problem:

Execution of DAA instruction:

- ☐ If the value of the low order four bits (03-00) in the accumulator is greater than 9 or if auxiliary carry flag is set, the instruction adds 6 (06) to the low-order four bits.
- ☐ If the value of the high-order four bits (07-04) in the accumulator is greater than 9 or if carry flag is set, the instruction adds 6(06) to the high-order four bits.

Source Program:

<i>LXI SP, 27FFH</i>	: Initialize stack pointer
<i>MOV E, A</i>	: Store the contents of accumulator
<i>ANI 0FH</i>	: Mask upper nibble
<i>CPI 0AH</i>	: Check if number is greater than 9
<i>JC SKIP</i>	: if no go to skip
<i>MOV A, E</i>	: Get the number
<i>ADI 06H</i>	: Add 6 in the number
<i>JMP SECOND</i>	: Go for second check
<i>SKIP: PUSH PSW</i>	: Store accumulator and flag contents in stack
<i>POP B</i>	: Get the contents of accumulator in B register and

flag register contents in

C register

<i>MOV A, C</i>	: Get flag register contents in accumulator
<i>ANI 10H</i>	: Check for bit 4
<i>JZ SECOND</i>	: if zero, go for second check
<i>MOV A, E</i>	: Get the number
<i>ADI 06</i>	: Add 6 in the number
<i>SECOND: MOV E, A</i>	: Store the contents of accumulator
<i>ANI FOH</i>	: Mask lower nibble
<i>RRC</i>	
<i>RRC</i>	
<i>RRC</i>	

<i>RRC</i>	<i>: Rotate number 4 bit right</i>
<i>CPI 0AH</i>	<i>: Check if number is greater than 9</i>
<i>JC SKIP1</i>	<i>: if no go to skip 1</i>
<i>MOV A, E</i>	<i>: Get the number</i>
<i>ADI 60 H</i>	<i>: Add 60 H in the number</i>
<i>JMP LAST</i>	<i>: Go to last</i>
<i>SKIP1: JNC LAST</i>	<i>: if carry flag = 0 go to last</i>
<i>MOV A, E</i>	<i>: Get the number</i>
<i>ADI 60 H</i>	<i>: Add 60 H in the number</i>
<i>LAST: HLT</i>	


38.Statement:To test RAM by writing '1' and reading it back and later writing '0' (zero) and reading it back. RAM addresses to be checked are 40FFH to 40FFH. In case of any error, it is indicated by writing 01H at port 10H

Source Program:

<i>LXI H, 4000H</i>	<i>: Initialize memory pointer</i>
<i>BACK: MVI M, FFH</i>	<i>: Writing '1' into RAM</i>
<i>MOV A, M</i>	<i>: Reading data from RAM</i>
<i>CPI FFH</i>	<i>: Check for ERROR</i>
<i>JNZ ERROR</i>	<i>: If yes go to ERROR</i>
<i>INX H</i>	<i>: Increment memory pointer</i>
<i>MOV A, H</i>	
<i>CPI 00H</i>	<i>: Check for last check</i>
<i>JNZ BACK</i>	<i>: If not last, repeat</i>
<i>LXI H, 4000H</i>	<i>: Initialize memory pointer</i>
<i>BACK1: MVI M, 00H</i>	<i>: Writing '0' into RAM</i>
<i>MOV A, M</i>	<i>: Reading data from RAM</i>
<i>CPI 00H</i>	<i>: Check for ERROR</i>
<i>INX H</i>	<i>: Increment memory pointer</i>
<i>MOV A, H</i>	
<i>CPI 00H</i>	<i>: Check for last check</i>
<i>JNZ BACK1</i>	<i>: If not last, repeat</i>
<i>HLT</i>	<i>: Stop Execution</i>

39.Statement:Write an assembly language program to generate fibonacci number

Source Program:

<i>MVI D, COUNT</i>	 <i>Initialize counter</i>
<i>MVI B, 00</i>	<i>Initialize variable to store previous number</i>
<i>MVI C, 01</i>	<i>Initialize variable to store current number</i>

```

MOV A, B           ;[Add two numbers]
BACK: ADD C         ;[Add two numbers]
MOV B, C           : Current number is now previous number
MOV C, A           : Save result as a new current number
DCR D              : Decrement count
JNZ BACK           : if count 0 go to BACK
HLT                : Stop

```

40.Statement: Write a program to generate a delay of 0.4 sec if the crystal frequency is 5 MHz

Calculation: In 8085, the operating frequency is half of the crystal frequency,

ie. Operating frequency Time = $5/2 = 2.5 \text{ MHz}$

for one T-state =

Number of T-states required =
= 1×106

Source Program:

```

LXI B, count       : 16 - bit count
BACK: DCX B         : Decrement count
MOV A, C
ORA B               : Logically OR Band C
JNZ BACK            : If result is not zero repeat

```

41.Statement: Arrange an array of 8 bit unsigned no in descending order

Source Program:

```

START: MVI B, 00    ; Flag = 0
      LXI H, 4150    ; Count = length of array

      MOV C, M
      DCR C          ; No. of pair = count - 1
      INX H          ; Point to start of array
LOOP: MOV A, M       ; Get kth element
      INX H
      CMP M          ; Compare to (K+1) th element
      JNC LOOP 1     ; No interchange if kth >= (k+1) th
      MOV D, M       ; Interchange if out of order
      MOV M, A
      DCR H
      MOV M, D
      INX H
      MVI B, 01H    ; Flag=1
LOOP 1: DCR C        ; count down
      JNZ LOOP
      DCR B          ; is flag = 1?

```

```

JZ START          ; do another sort, if yes
HLT               ; If flag = 0, step execution

```

42.Statement: Transfer ten bytes of data from one memory to another memory block. Source memory block starts from memory location 2200H where as destination memory block starts from memory location 2300H

Source Program:

```

LXI H, 4150        : Initialize memory pointer
MVI B, 08          : count for 8-bit

MVI A, 54
LOOP : RRC
JC LOOP1
MVI M, 00          : store zero if no carry
JMP COMMON
LOOP2: MVI M, 01    : store one if there is a carry
COMMON: INX H
DCR B              : check for carry
JNZ LOOP
HLT                : Terminate the program

```

43.Statement: Program to calculate the factorial of a number between 0 to 8

Source program

```

LXI SP, 27FFH      ; Initialize stack pointer
LDA 2200H           ; Get the number
CPI 02H            ; Check if number is greater than 1
JC LAST
MVI D, 00H         ; Load number as a result
MOV E, A
DCR A
MOV C, A           ; Load counter one less than number
CALL FACTO         ; Call subroutine FACTO
XCHG               ; Get the result in HL
SHLD 2201H         ; Store result in the memory
JMP END
LAST: LXI H, 0001H  ; Store result = 01
END: SHLD 2201H
HLT

```

44.Statement:Write a program to find the Square Root of an 8 bit binary number. The binary number is stored in memory location 4200H and store the square root in 4201H.

Source Program:

```

LDA 4200H          : Get the given data(Y) in A register
MOV B,A            : Save the data in B register
MVI C,02H          : Call the divisor(02H) in C register
CALL DIV           : Call division subroutine to get initial value(X)

in D-reg
REP: MOV E,D        : Save the initial value in E-reg
    MOV A,B         : Get the dividend(Y) in A-reg
    MOV C,D         : Get the divisor(X) in C-reg
    CALL DIV        : Call division subroutine to get initial
value(Y/X) in D-reg
    MOV A, D        : Move Y/X in A-reg
    ADD E           : Get the((Y/X) + X) in A-reg
    MVI C, 02H      : Get the divisor(02H) in C-reg
    CALL DIV        : Call division subroutine to get ((Y/X) + X)/2

in D-reg.This is XNEW
MOV A, E           : Get Xin A-reg
CMP D              : Compare X and XNEW
JNZ REP            : If XNEW is not equal to X, then repeat
STA 4201H          : Save the square root in memory
HLT                : Terminate program execution

```

45.Statement:Write a simple program to Split a HEX data into two nibbles and store it in memory

Source Program:

```

LXI H, 4200H       : Set pointer data for array
MOV B,M            : Get the data in B-reg
MOV A,B            : Copy the data to A-reg
ANI 0FH           : Mask the upper nibble
INX H              : Increment address as 4201
MOV M,A            : Store the lower nibble in memory
MOV A,B            : Get the data in A-reg
ANI 0FH           : Bring the upper nibble to lower nibble position

RRC
RRC
RRC
RRC
INX H
MOV M,A            : Store the upper nibble in memory
HLT                : Terminate program execution

```


46.Statement: Add two 4 digit BCD numbers in HL and DE register pairs and store result in memory locations, 2300H and 2301H. Ignore carry after 16 bit.

Sample Problem:

(HL) = 3629 (DE)
 = 4738
 Step 1 : $29 + 38 = 61$ and auxiliary carry flag = 1
 ∴ add 06
 $61 + 06 = 67$
 Step 2 : $36 + 47 + 0$ (carry of LSB) = 7D

Lower nibble of addition is greater than 9, so add 6. $7D + 06 = 83$
 Result = 8367

Source program

MOV A, L	: Get lower 2 digits of no. 1
ADD E	: Add two lower digits
DAA	: Adjust result to valid BCD
STA 2300H	: Store partial result
MOV A, H	: Get most significant 2 digits of number
ADC D	: Add two most significant digits
DAA	: Adjust result to valid BCD
STA 2301H	: Store partial result
HLT	: Terminate program execution

47.Subtract the BCD number stored in E register from the number stored in the D register.

Source Program:

MVI A, 99H	
SUB E	: Find the 99's complement of subtrahend
INR A	: Find 100's complement of subtrahend
ADD D	: Add minuend to 100's complement of subtrahend
DAA	: Adjust for BCD
HLT	: Terminate program execution

48.Statement: Write an assembly language program to multiply 2 BCD numbers

Source Program:

<i>MVI C, Multiplier</i>	<i>: Load BCD multiplier</i>
<i>MVI B, 00</i>	<i>: Initialize counter</i>
<i>LXI H, 0000H</i>	<i>: Result = 0000</i>
<i>MVI E, multiplicand</i>	<i>: Load multiplicand</i>
<i>MVI D, 00H</i>	<i>: Extend to 16-bits</i>
<i>BACK: DAD D</i>	<i>: Result Result + Multiplicand</i>
<i>MOV A, L</i>	<i>: Get the lower byte of the result</i>
 <i>ADI, 00H</i>	
<i>DAA</i>	<i>: Adjust the lower byte of result to BCD.</i>
<i>MOV L, A</i>	<i>: Store the lower byte of result</i>
<i>MOV A, H</i>	<i>: Get the higher byte of the result</i>
<i>ACI, 00H</i>	
<i>DAA</i>	
<i>MOV H, A</i>	
<i>MOV A, B</i>	
<i>ADI 01H</i>	
<i>DAA</i>	
<i>MOV B, A</i>	
<i>CMP C</i>	
<i>JNZ BACK</i>	
<i>HLT</i>	

QUESTION BANK -UNIT II

PART A

1. Identify the addressing modes of LDA and LDAXB instruction
2. Identify the no of bytes of XTHL and LXI H,16bit
3. Define addressing modes
4. Classify the instruction sets of 8085
5. Explain SPHL instruction with example
6. What is the difference between CMP and SUB instruction
7. When the parity flag will set
8. What determines the number of bytes to be fetched from memory to execute an instruction?
9. What are the different instruction word sizes in 8085?
10. Give one example each of 1-byte, 2-byte and 3-byte instructions.
11. Mention the different types of operations possible with arithmetic, logical, branch and machine control operations
12. What is an instruction?
13. What are the different types of data transfer operations possible?
14. What is the output in 9100 after executing the following instructions

```
MVI A, 09
MVI B, 04
ADD B
DAA
STA 9100
HLT
```

15. What is the content in DE register?

```
MVI A,09
ADI 77
PUSH PSW
POP D
HLT
```

PART B

1. Classify the instruction set based on the operations performed and explain with examples
2. Classify the instruction set based on the size of the instructions and explain with examples
3. Explain a. XTHL b.SPHL c.PCHL d.RAR e.SIM
4. Explain with example a.LDAX B b.PUSH PSW c.RLC d.JNC 16bit e.XRA A
5. Write an ALP to sort a given array in ascending order
6. Write an ALP to find a factorial of a number
7. Write an ALP to add two multibyte data
8. Write an ALP to generate fibonacci series

Note: Study all the programs

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SCHOOL OF ELECTRICAL AND ELECTRONICS

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

UNIT – III– MICROPROCESSORS AND MICROCONTROLLERS– SEC1201

UNIT 3 PERIPHERALS AND INTERFACING

Introduction, memory and I/O interfacing, data transfer schemes, Interface ICs'- USART (8251), programmable peripheral interface (8255), programmable interrupt controller (8259), programmable counter/interval timer (8254), Analog to Digital Converter (ADC), and Digital to Analog Converter (DAC).

8255 - PROGRAMMABLE PERIPHERAL INTERFACE (PPI)

The Intel 8255 (or i8255) Programmable Peripheral Interface (PPI) chip is a peripheral chip, is used to give the CPU access to programmable parallel I/O. It can be programmable to transfer data under various conditions from simple I/O to interrupt I/O. it is flexible versatile

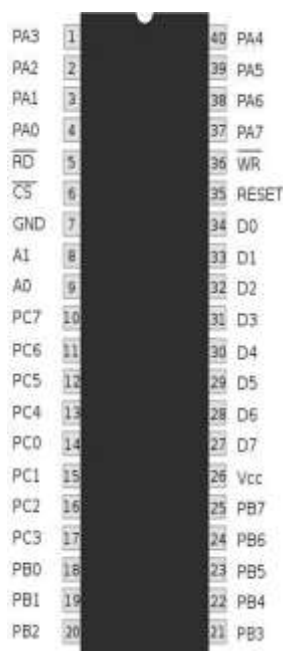


Fig 3.1: Pin diagram

and economical (when multiple I/O ports are required) but some what complex. It is an important general purpose I/O device that can be used with almost any microprocessor. Functional block of 8255 – Programmable Peripheral Interface (PPI)

The 8255A has 24 I/O pins that can be grouped primarily in two 8-bit parallel ports: A and B with the remaining eight bits as port C. The eight bits of port C can be used as individual bits or be grouped in to 4-bit ports: CUpper (Cu) and CLower (CL) as in Figure 2. The function of these ports is defined by writing a control word in the control register as shown in Figure 3.3

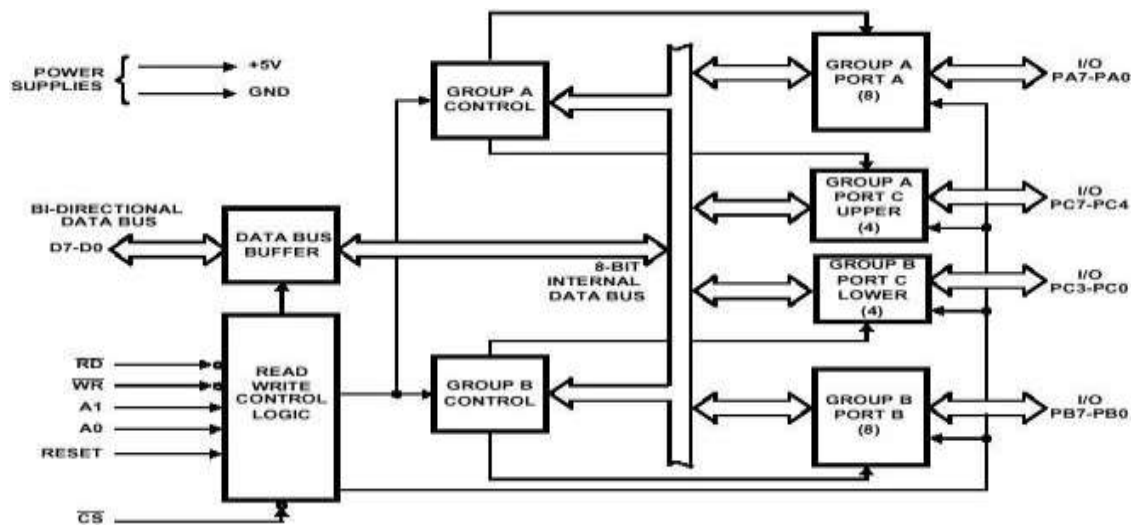


Fig 3.2 : Block diagram of 8255

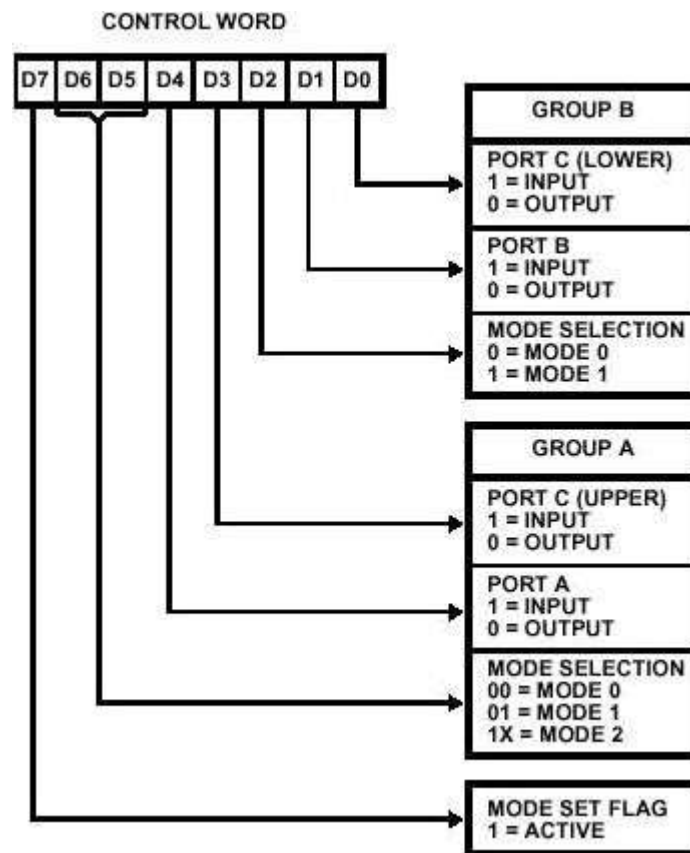


Fig 3.3. Control word Register format

Data Bus Buffer

This three-state bi-directional 8-bit buffer is used to interface the 8255 to the system data bus. Data is transmitted or received by the buffer upon execution of input or output instructions by the CPU. Control words and status information are also transferred through the data bus buffer.

Read/Write and Control Logic

The function of this block is to manage all of the internal and external transfers of both Data and Control or Status words. It accepts inputs from the CPU Address and Control busses and in turn, issues commands to both of the Control Groups.

(CS) Chip Select. A "low" on this input pin enables the communication between the 8255 and the CPU.

(RD) Read. A "low" on this input pin enables 8255 to send the data or status information to the CPU on the data bus. In essence, it allows the CPU to "read from" the 8255.

(WR) Write. A "low" on this input pin enables the CPU to write data or control words into the 8255.

(A0 and A1) Port Select 0 and Port Select 1. These input signals, in conjunction with the RD and WR inputs, control the selection of one of the three ports or the control word register. They are normally connected to the least significant bits of the address bus (A0 and A1).

A1	A0	SELECTION
0	0	PORT A
0	1	PORT B
1	0	PORT C
1	1	CONTROL

Fig 3.4 selection of Ports and Control reg

(RESET) Reset. A "high" on this input initializes the control register to 9Bh and all ports (A, B,C) are set to the input mode.

Group A and Group B Controls

The functional configuration of each port is programmed by the systems software. In essence, the CPU "outputs" a control word to the 8255. The control word contains information such as "mode", "bit set", "bit reset", etc., that initializes the functional configuration of the 8255. Each of the Control blocks (Group A and Group B) accepts "commands" from the Read/Write Control logic, receives "control words" from the internal data bus and issues the proper commands to its associated ports.

Ports A, B, and C

The 8255 contains three 8-bit ports (A, B, and C). All can be configured to a wide variety of functional characteristics by the system software but each has its own special features or "personality" to further enhance the power and flexibility of the 8255.

Port A One 8-bit data output latch/buffer and one 8-bit data input latch. Both "pull-up" and "pull-down" bus-hold devices are present on Port A.

Port B One 8-bit data input/output latch/buffer and one 8-bit data input buffer.

Port C One 8-bit data output latch/buffer and one 8-bit data input buffer (no latch for input). This port can be divided into two 4-bit ports under the mode control. Each 4-bit port contains a 4-bit latch and it can be used for the control signal output and status signal inputs in conjunction with ports A and B.

I. Operational modes of 8255

There are two basic operational modes of 8255:

1. Bit set/reset Mode (BSR Mode).
2. Input/Output Mode (I/O Mode).

The two modes are selected on the basis of the value present at the D₇ bit of the Control Word

Register. When $D_7 = 1$, 8255 operates in I/O mode and when $D_7 = 0$, it operates in the BSR mode.

1. Bit set/reset (BSR) mode

The Bit Set/Reset (BSR) mode is applicable to port C only. Each line of port C ($PC_0 - PC_7$) can be set/reset by suitably loading the control word register as shown in Figure 4. BSR mode and I/O mode are independent and selection of BSR mode does not affect the operation of other ports in I/O mode.

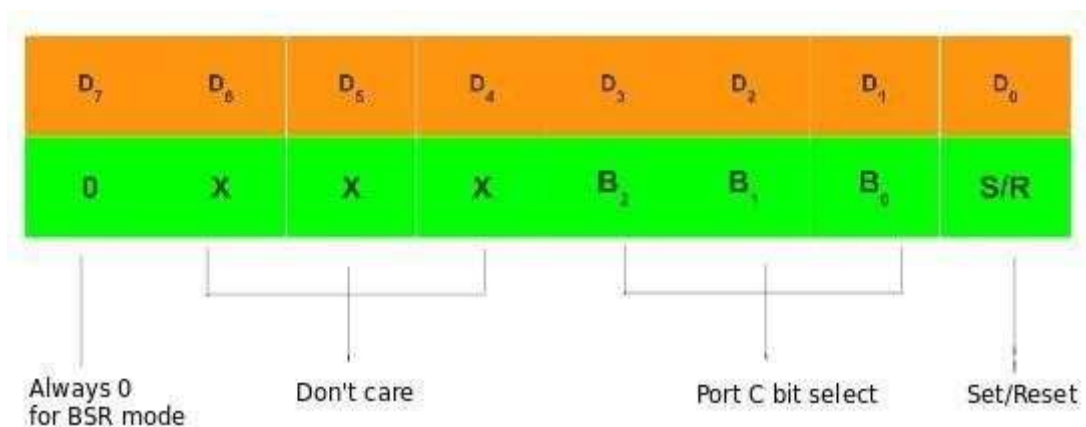


Fig 3.5: 8255 Control register format for BSR mode

- ☐ D₇ bit is always 0 for BSR mode.
- ☐ Bits D₆, D₅ and D₄ are don't care bits.
- ☐

Bits D₃, D₂ and D₁ are used to select the pin of Port C.
 Bit D₀ is used to set/reset the selected pin of Port C.

Selection of port C pin is determined as follows:

B3	B2	B1	Bit/pin of port C selected
0	0	0	PC ₀
0	0	1	PC ₁
0	1	0	PC ₂
0	1	1	PC ₃
1	0	0	PC ₄
1	0	1	PC ₅
1	1	0	PC ₆
1	1	1	PC ₇

As an example, if it is needed that PC₅ be set, then in the control word,

1. Since it is BSR mode, **D₇ = '0'**.
2. Since D₄, D₅, D₆ are not used, assume them to be '0'.
3. PC₅ has to be selected, hence, **D₃ = '1', D₂ = '0', D₁ = '1'**.
4. PC₅ has to be set, hence, **D₀ = '1'**.

Thus, as per the above values, 0B (Hex) will be loaded into the Control Word Register (CWR).

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	1	0	1	1

2. Input/Output mode

This mode is selected when D₇ bit of the Control Word Register is 1. There are three I/O modes:

1. Mode 0 - Simple I/O
2. Mode 1 - Strobed I/O
3. Mode 2 - Strobed Bi-directional I/O

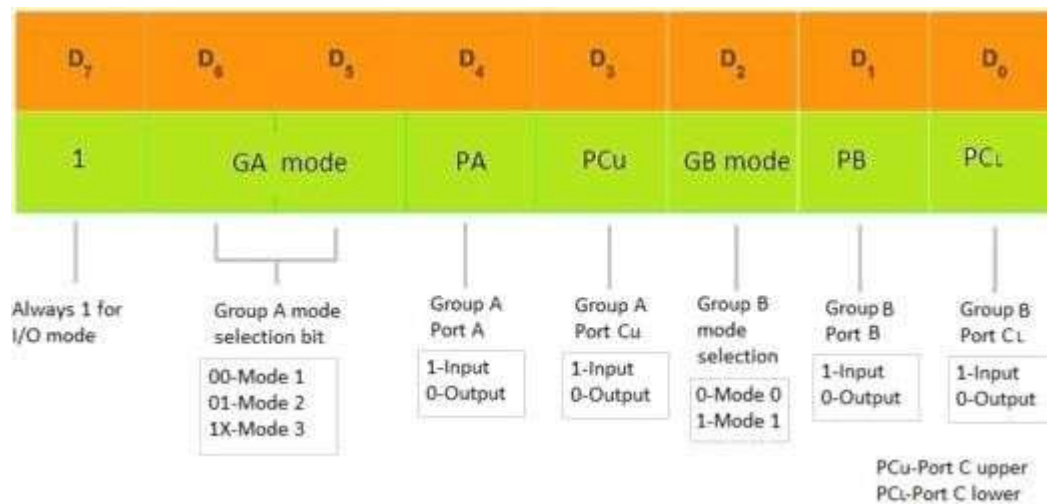


Figure 3.6: 8255 Control word for I/O mode

- ⌈ D₀, D₁, D₃, D₄ are assigned for lower port C, port B, upper port C and port A respectively. When these bits are 1, the corresponding port acts as an input port. For e.g., if D₀ = D₄ = 1, then lower port C and port A act as input ports. If these bits are 0, then the corresponding port acts as an output port. For e.g., if D₁ = D₃ = 0, then port B and upper port C act as output ports as shown in Figure 5.
- ⌈ D₂ is used for mode selection of Group B (port B and lower port C). When D₂ = 0, mode 0 is selected and when D₂ = 1, mode 1 is selected.
- ⌈ D₅ & D₆ are used for mode selection of Group A (port A and upper port C). The selection is done as follows:

D ₆	D ₅	Mode
0	0	0
0	1	1
1	X	2

┌ As it is I/O mode, D₇ = 1.

For example, if port B and upper port C have to be initialized as input ports and lower port C and port A as output ports (all in mode 0):

1. Since it is an I/O mode, D₇ = 1.
2. Mode selection bits, D₂, D₅, D₆ are all 0 for mode 0 operation.
3. Port B and upper port C should operate as Input ports, hence, D₁ = D₃ = 1.
4. Port A and lower port C should operate as Output ports, hence, D₄ = D₀ = 0.

Hence, for the desired operation, the control word register will have to be loaded with "10001010" = 8A (hex).

┌ **Mode 0 - simple I/O**

In this mode, the ports can be used for simple I/O operations without handshaking signals. Port A, port B provide simple I/O operation. The two halves of port C can be either used together as an additional 8-bit port, or they can be used as individual 4-bit ports. Since the two halves of port C are independent, they may be used such that one-half is initialized as an input port while the other half is initialized as an output port.

The input/output features in mode 0 are as follows:

1. Output ports are latched.

2. Input ports are buffered, not latched.
3. Ports do not have handshake or interrupt capability.
4. With 4 ports, 16 different combinations of I/O are possible.

┌ Mode 0 - input mode

- ┌ In the input mode, the 8255 gets data from the external peripheral ports and the CPU reads the received data via its data bus.
- ┌ The CPU first selects the 8255 chip by making \overline{CS} low. Then it selects the desired port using A_0 and A_1 lines.
- ┌ The CPU then issues an \overline{RD} signal to read the data from the external peripheral device via the system data bus.

┌ Mode 0 - output mode

- ┌ In the output mode, the CPU sends data to 8255 via system data bus and then the external peripheral ports receive this data via 8255 port.
- ┌ CPU first selects the 8255 chip by making \overline{CS} low. It then selects the desired port using A_0 and A_1 lines.
- ┌ CPU then issues a \overline{WR} signal to write data to the selected port via the system data bus. This data is then received by the external peripheral device connected to the selected port.

┌ Mode 1

When we wish to use port A or port B for handshake (strobed) input or output operation, we initialise that port in mode 1 (port A and port B can be initialised to operate in different modes, i.e., for e.g., port A can operate in mode 0 and port B in mode 1). Some of the pins of port C function as handshake lines.

For port B in this mode (irrespective of whether is acting as an input port or output port), PC_0 , PC_1 and PC_2 pins function as handshake lines.

If port A is initialised as mode 1 input port, then, PC3, PC4 and PC5 function as handshake signals. Pins PC6 and PC7 are available for use as input/output lines.

The mode 1 which supports handshaking has following features:

1. Two ports i.e. port A and B can be used as 8-bit i/o ports.
2. Each port uses three lines of port c as handshake signal and remaining two signals can be used as i/o ports.
3. Interrupt logic is supported.
4. Input and Output data are latched.

Input Handshaking signals

1. IBF (Input Buffer Full) - It is an output indicating that the input latch contains information.
2. STB (Strobed Input) - The strobe input loads data into the port latch, which holds the information until it is input to the microprocessor via the IN instruction.
3. INTR (Interrupt request) - It is an output that requests an interrupt. The INTR pin becomes a logic 1 when the STB input returns to a logic 1, and is cleared when the data are input from the port by the microprocessor.
4. INTE (Interrupt enable) - It is neither an input nor an output; it is an internal bit programmed via the port PC4(port A) or PC2(port B) bit position.

Output Handshaking signals

1. OBF (Output Buffer Full) - It is an output that goes low whenever data are output(OUT) to the port A or port B latch. This signal is set to a logic 1 whenever the ACK pulse returns from the external device.

2. ACK (Acknowledge)-It causes the OBF pin to return to a logic 1 level. The ACK signal is a response from an external device, indicating that it has received the data from the 82C55 port.

3. INTR (Interrupt request) - It is a signal that often interrupts the microprocessor when the external device receives the data via the signal. this pin is qualified by the internal INTE(interrupt enable) bit.

4. INTE (Interrupt enable) - It is neither an input nor an output; it is an internal bit programmed to enable or disable the INTR pin. The INTE A bit is programmed using the PC6 bit and INTE B is programmed using the PC2 bit.

▮ Mode 2

Only group A can be initialized in this mode. Port A can be used for bidirectional handshake data transfer. This means that data can be input or output on the same eight lines (PA0 - PA7). Pins PC3 - PC7 are used as handshake lines for port A. The remaining pins of port C (PC0 - PC2) can be used as input/output lines if group B is initialized in mode 0 or as handshaking for port B if group B is initialized in mode 1. In this mode, the 8255 may be used to extend the system bus to a slave microprocessor or to transfer data bytes to and from a floppy disk controller. Acknowledgement and handshaking signals are provided to maintain proper data flow and synchronisation between the data transmitter and receiver.

II. Interfacing 8255 with 8085 processor

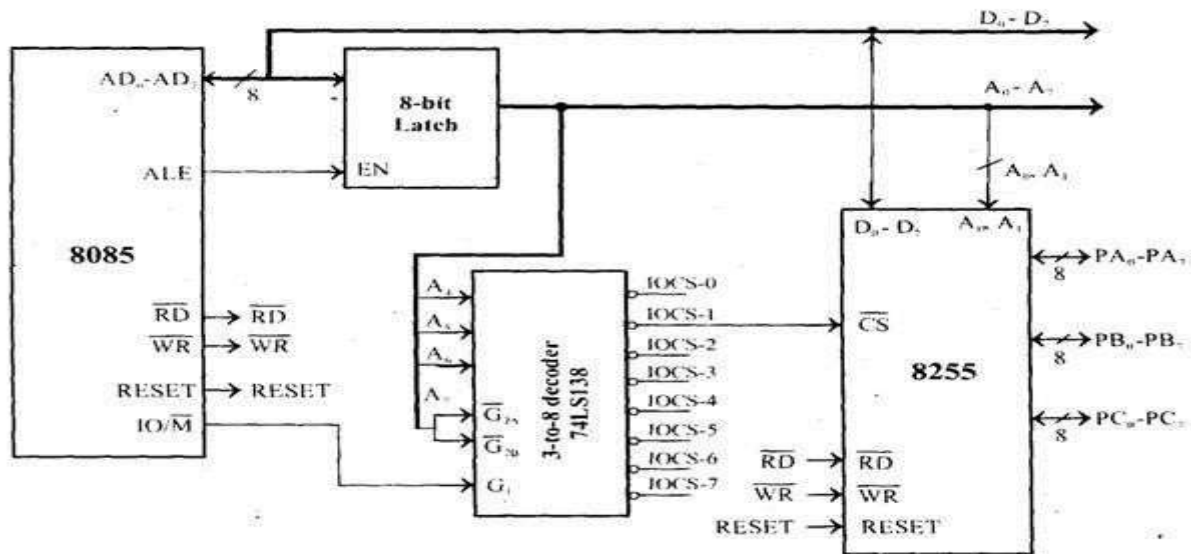


Fig 3.7. Interfacing 8255 with 8085 processor

- ▮ The 8255 can be either memory mapped or I/O mapped in the system. In the schematic shown in above is I/O mapped in the system.

Using a 3-to-8 decoder generates the chip select signals for I/O mapped devices.

- ▮ The address lines A4, A5 and A6 are decoded to generate eight chip select signals (IOCS-0 to IOCS-7) and in this, the chip select IOCS- 1 is used to select 8255 as shown in Figure 3.7.
- ▮ The address line A7 and the control signal IO/M (low) are used as enable for the decoder.
- ▮ The address line A0 of 8085 is connected to A0 of 8255 and A1 of 8085 is connected to A1 of 8255 to provide the internal addresses.
- ▮ The data lines D0-D7 are connected to D0-D7 of the processor to achieve parallel data transfer.
- ▮ The I/O addresses allotted to the internal devices of 8255 are listed in table.

Internal Device	Binary Address								Hexa Address
	Decoder input and enable				Input to address pins of 8255				
	A ₇	A ₆	A ₅	A ₄	A ₃	A ₂	A ₁	A ₀	
Port-A	0	0	0	1	x	x	0	0	10
Port-B	0	0	0	1	x	x	0	1	11
Port-C	0	0	0	1	x	x	1	0	12
Control Register	0	0	0	1	x	x	1	1	13

Note : Don't care "x" is considered as zero.

USART 8251 (Universal Synchronous/ Asynchronous Receiver Transmitter)

The 8251 is a USART (Universal Synchronous Asynchronous Receiver Transmitter) for serial data communication. As a peripheral device of a microcomputer system, the 8251 receives parallel data from the CPU and transmits serial data after conversion. This device also receives serial data from the outside and transmits parallel data to the CPU after conversion as shown in Figure 3.8.

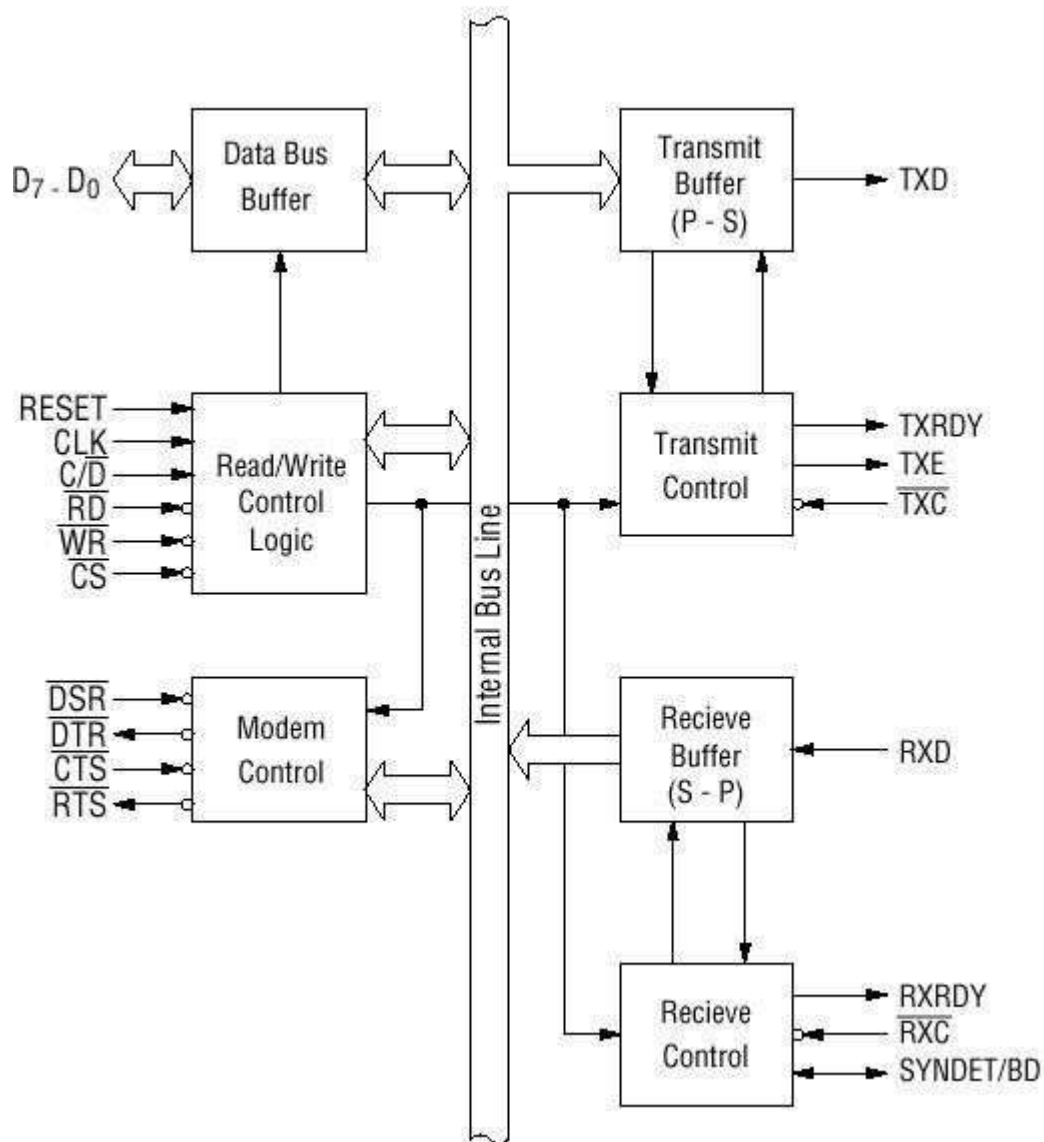


Figure 3.8 : Architecture of 8251

Transmitter Section

The transmitter section consists of three blocks—transmitter buffer register, output register and the transmitter control logic block. The CPU deposits (when TXRDY = 1, meaning that the transmitter buffer register is empty) data into the transmitter buffer register, which is subsequently put into the output register (when TXE = 1, meaning that the output buffer is empty). In the output register, the eight bit data is converted into serial form and comes out

via TXD pin. The serial data bits are preceded by START bit and succeeded by STOP bit, which are known as framing bits. But this happens only if transmitter is enabled and the CTS is low. TxC signal is the transmitter clock signal which controls the bit rate on the TXD line (output line). This clock frequency can be 1, 16 or 64 times the baud.

Receiver Section

The receiver section consists of three blocks — receiver buffer register, input register and the receiver control logic block. Serial data from outside world is delivered to the input register via RXD line, which is subsequently put into parallel form and placed in the receiver buffer register. When this register is full, the RXRDY (receiver ready) line becomes high. This line is then used either to interrupt the MPU or to indicate its own status. MPU then accepts the data from the register. RXC line stands for receiver clock. This clock signal controls the rate at which bits are received by the input register. The clock can be set to 1, 16 or 64 times the baud in the asynchronous mode.

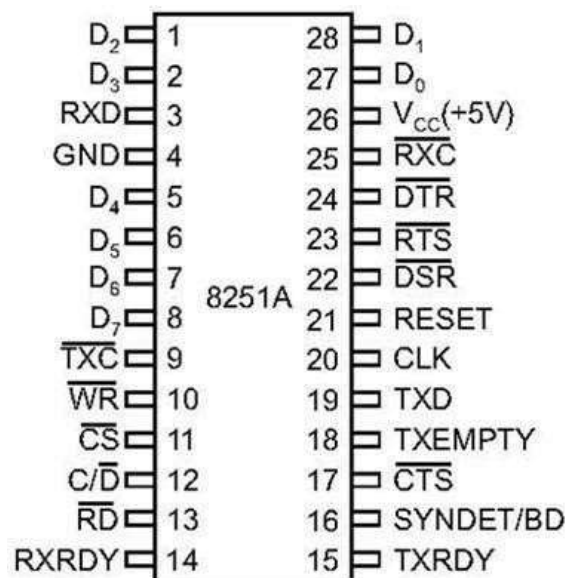


Fig 3.9 : Pin Configuration of 8251

Pin Configuration of 8251 is shown in figure

11. D 0 to D 7 (I/O terminal)

This is bidirectional data bus which receive control words and transmits data from the CPU and sends status words and received data to CPU.

RESET (Input terminal)

A "High" on this input forces the 8251 into "reset status." The device waits for the writing of "mode instruction." The min. reset width is six clock inputs during the operating status of CLK.

CLK (Input terminal)

CLK signal is used to generate internal device timing. CLK signal is independent of RXC or TXC. However, the frequency of CLK must be greater than 30 times the RXC and TXC at Synchronous mode and Asynchronous "x1" mode, and must be greater than 5 times at Asynchronous "x16" and "x64" mode.

WR (Input terminal)

This is the "active low" input terminal which receives a signal for writing transmit data and control words from the CPU into the 8251.

RD (Input terminal)

This is the "active low" input terminal which receives a signal for reading receive data and status words from the 8251.

C/D (Input terminal)

This is an input terminal which receives a signal for selecting data or command words and status words when the 8251 is accessed by the CPU. If C/D = low, data will be accessed. If

C/D

= high, command word or status word will be

accessed. CS (Input terminal)

This is the "active low" input terminal which selects the 8251 at low level when the CPU

accesses. Note: The device won't be in "standby status"; only setting CS = High.

TXD (output terminal)

This is an output terminal for transmitting data from which serial-converted data is sent out. The device is in "mark status" (high level) after resetting or during a status when transmit is disabled. It is also possible to set the device in "break status" (low level) by a command.

TXRDY (output terminal)

This is an output terminal which indicates that the 8251 is ready to accept a transmitted data character. But the terminal is always at low level if CTS = high or the device was set in "TX disable status" by a command. Note: TXRDY status word indicates that transmit data character is receivable, regardless of CTS or command. If the CPU writes a data character, TXRDY will be reset by the leading edge of WR signal.

TXEMPTY (Output terminal)

This is an output terminal which indicates that the 8251 has transmitted all the characters and had no data character. In "synchronous mode," the terminal is at high level, if transmit data characters are no longer remaining and sync characters are automatically transmitted. If the CPU writes a data character, TXEMPTY will be reset by the leading edge of WR signal. Note : As the transmitter is disabled by setting CTS "High" or command, data written before disable will be sent out. Then TXD and TXEMPTY will be "High". Even if a data is written after disable, that data is not sent out and TXE will be "High". After the transmitter is enabled, it sent out. (Refer to Timing Chart of Transmitter Control and Flag Timing)

TXC (Input terminal)

This is a clock input signal which determines the transfer speed of transmitted data. In "synchronous mode," the baud rate will be the same as the frequency of TXC. In "asynchronous mode", it is possible to select the baud rate factor by mode instruction. It can be 1, 1/16 or 1/64 the TXC. The falling edge of TXC sifts the serial data out of the 8251.

RXD (input terminal)

This is a terminal which receives serial

data. RXRDY (Output terminal)

This is a terminal which indicates that the 8251 contains a character that is ready to READ. If the CPU reads a data character, RXRDY will be reset by the leading edge of RD signal.

Unless the CPU reads a data character before the next one is received completely, the preceding data will be lost. In such a case, an overrun error flag status word will be set.

RXC (Input terminal)

This is a clock input signal which determines the transfer speed of received data. In "synchronous mode," the baud rate is the same as the frequency of RXC. In "asynchronous mode," it is possible to select the baud rate factor by mode instruction. It can be 1, 1/16, 1/64 the RXC.

SYNDET/BD (Input or output terminal)

This is a terminal whose function changes according to mode. In "internal synchronous mode," this terminal is at high level, if sync characters are received and synchronized. If a status word is read, the terminal will be reset. In "external synchronous mode," this is an input terminal. A "High" on this input forces the 8251 to start receiving data characters.

In "asynchronous mode," this is an output terminal which generates "high level" output upon the detection of a "break" character if receiver data contains a "low-level" space between the stopbits of two continuous characters. The terminal will be reset, if RXD is at high level. After Reset is active, the terminal will be output at low level.

DSR (Input terminal)

This is an input port for MODEM interface. The input status of the terminal can be recognized by the CPU reading status words.

DTR (Output terminal)

This is an output port for MODEM interface. It is possible to set the status of DTR by a command.

CTS (Input terminal)

This is an input terminal for MODEM interface which is used for controlling a transmit circuit. The terminal controls data transmission if the device is set in "TX Enable" status by a command.

Data is transmittable if the terminal is at low level.

RTS (Output terminal)

This is an output port for MODEM interface. It is possible to set the status RTS by a command. The 8251 functional configuration is programmed by software. Operation between the 8251 and CPU is executed by program control. Table 1 shows the operation between a CPU and the device.

Summary of Control Signals for 8251

\overline{CS}	$\overline{C/D}$	\overline{RD}	\overline{WR}	Function
0	1	1	0	MPU writes instructions in the control register
0	1	0	1	MPU reads status from the status register
0	0	1	0	MPU outputs data to the Data Buffer
0	0	0	1	MPU accepts data from the Data Buffer
1	X	X	X	USART is not selected

Control Words

There are two types of control word.

1. Mode instruction (setting of function)
2. Command (setting of operation)

1) Mode Instruction

Mode instruction is used for setting the function of the 8251. Mode instruction will be in "wait for write" at either internal reset or external reset. That is, the writing of a control word after resetting will be recognized as a "mode instruction."

Items set by mode instruction are as follows:

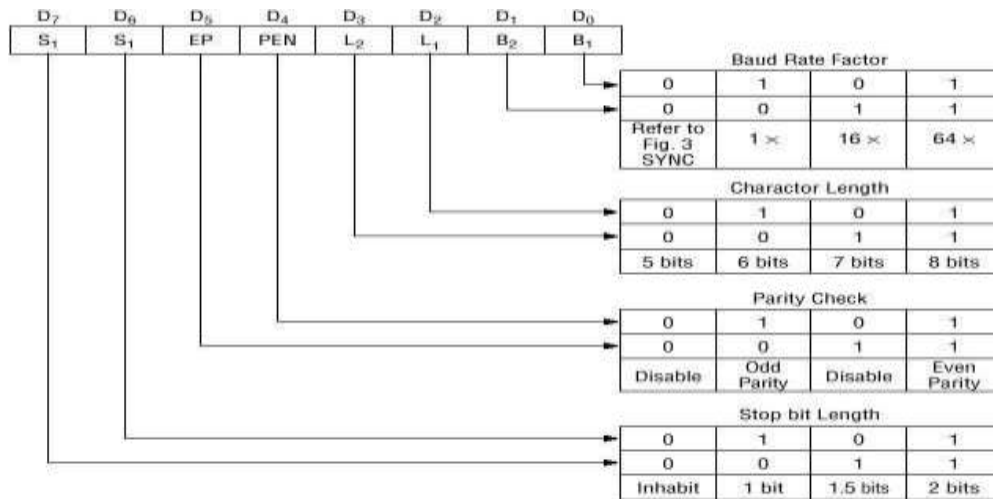


Fig. 2 Bit Configuration of Mode Instruction (Asynchronous)

Fig 3.10: Bit configuration of Mode instruction (Asynchronous)

- Synchronous/asynchronous mode
- Stop bit length (asynchronous mode)
- Character length
- Parity bit
- Baud rate factor (asynchronous mode)
- Internal/external synchronization (synchronous mode)
- Number of synchronous characters (Synchronous mode)

The bit configuration of mode instruction is shown in Figures 12 and 13. In the case of synchronous mode, it is necessary to write one-or two byte sync characters. If sync characters were written, a function will be set because the writing of sync characters constitutes part of mode instruction.

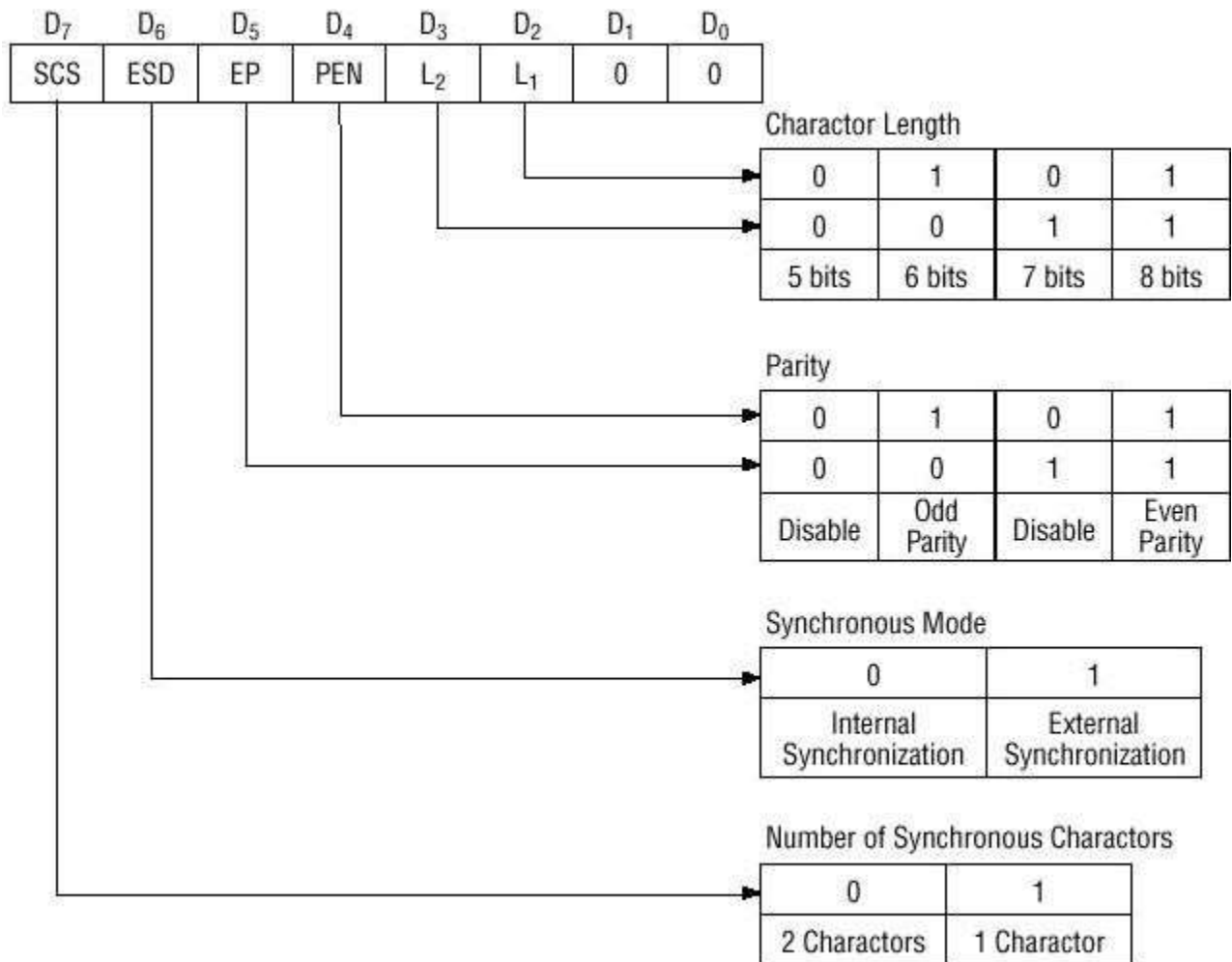


Fig. 3 Bit Configuration of Mode Instruction (Synchronous)

Fig 3.11: Bit configuration of mode instruction(synchronous)

2) Command

Command is used for setting the operation of the 8251. It is possible to write a command whenever necessary after writing a mode instruction and sync characters as shown in figure 14.

Items to be set by command are as follows:

- Transmit Enable/Disable
- Receive Enable/Disable
- DTR, RTS Output of data.
- Resetting of error flag.
- Sending to break characters
- Internal resetting
- Hunt mode (synchronous mode)

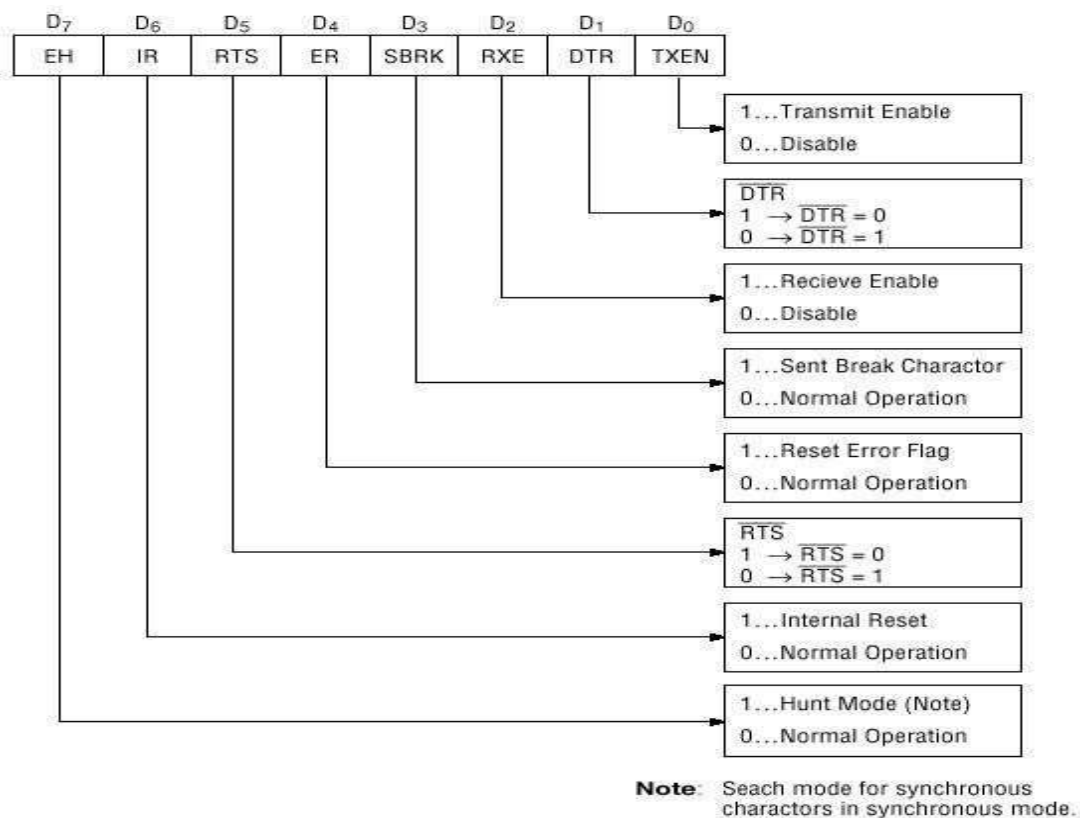


Fig. 4 Bit Configuration of Command

Fig 3.12: Bit configuration of command

Status Word

It is possible to see the internal status of the 8251 by reading a status word. The bit configuration of status word is shown in Fig.15.

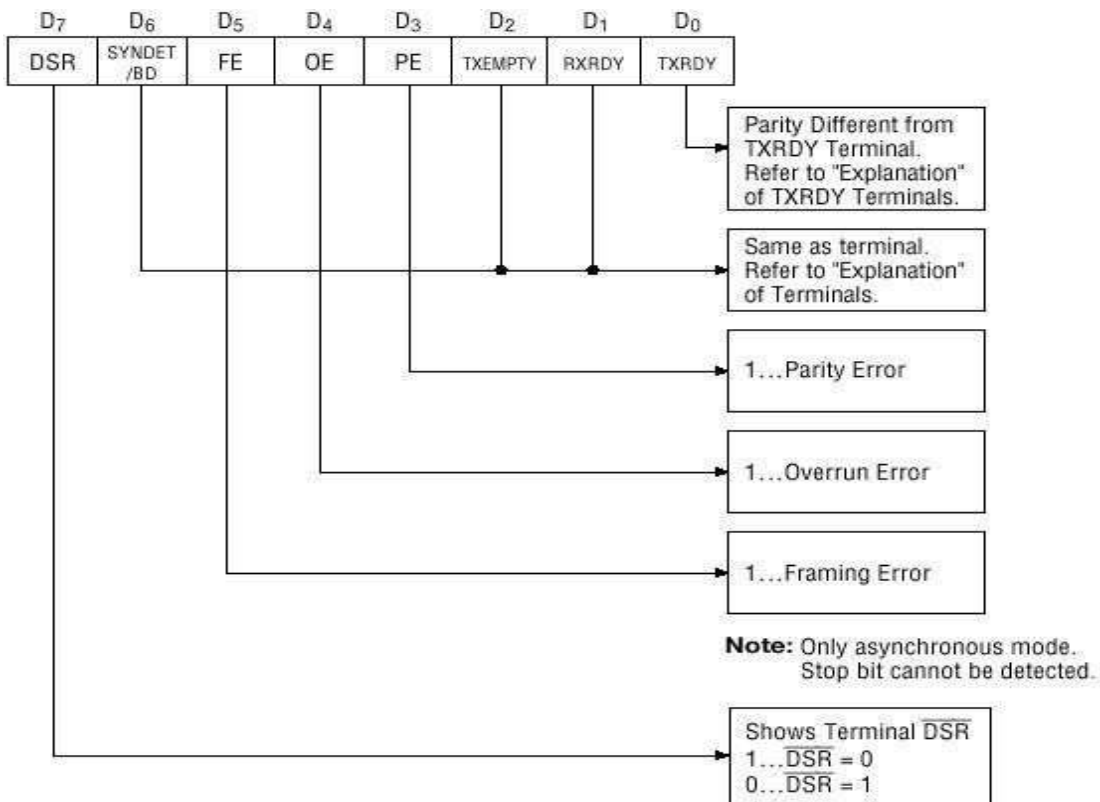


Fig. 5 Bit Configuration of Status Word

Fig 3.13: Bit configuration of Status Word

8253(8254) PROGRAMMABLE INTERVAL TIMER:

The 8254 programmable Interval timer consists of three independent 16-bit programmable counters (timers). Each counter is capable of counting in binary or binary coded decimal. The maximum allowable frequency to any counter is 10MHz. This device is useful whenever the microprocessor must control real-time events. The timer in a personal computer is an 8253. To operate a counter a 16-bit count is loaded in its register and on command, it begins to decrement the count until it reaches 0. At the end of the count it generates a pulse, which interrupts the processor. The count can count either in binary or BCD. Each counter in the block diagram has 3 logical lines connected to it. Two of these lines, clock and gate, are inputs. The third, labeled OUT is an output.

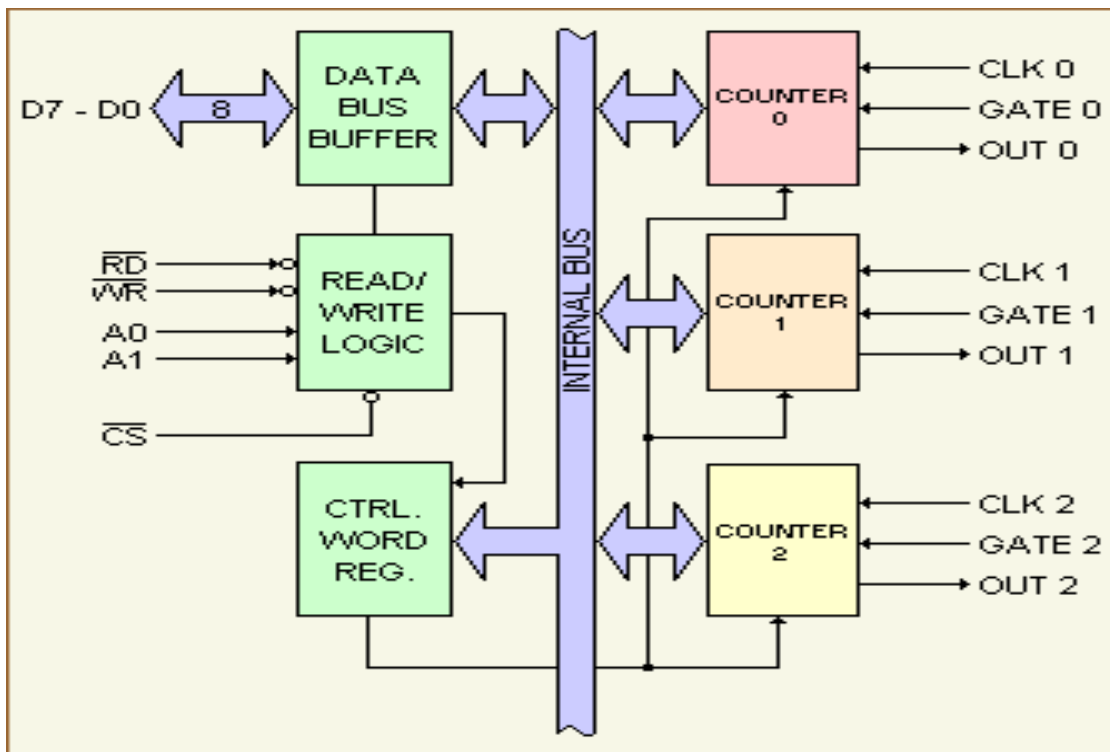


Fig : 3.14 Block Diagram of 8253 programmable interval timer

Data bus buffer- It is a communication path between the timer and the microprocessor. The buffer is 8-bit and bidirectional. It is connected to the data bus of the microprocessor. Read/write logic controls the reading and the writing of the counter registers. Control word register, specifies the counter to be used and either a Read or a write operation. Data is transmitted or received by the buffer upon execution of INPUT instruction from CPU as shown in figure 16. The data bus buffer has three basic functions,

- (i). Programming the modes of 8253.
- (ii). Loading the count value in times
- (iii). Reading the count value from timers.

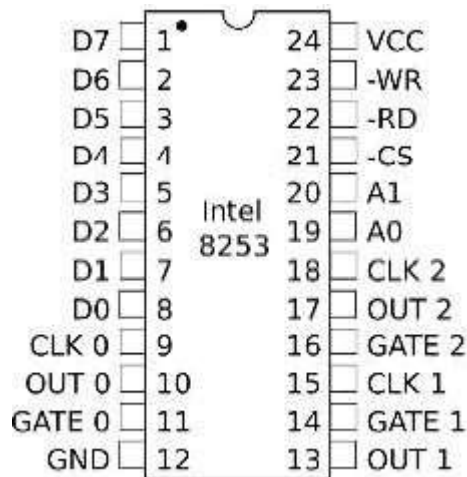


Fig 3.15:Pin Diagram of 8253

The data bus buffer is connected to microprocessor using D7 – D0 pins which are also bidirectional. The data transfer is through these pins. These pins will be in high- impedance (or this state) condition until the 8253 is selected by a LOW or CS and either the read operation requested by a LOW RD on the input or a write operation WR requested by the input going LOW.

Read/ Write Logic:

It accepts inputs for the system control bus and in turn generation the control signals for overall device operation. It is enabled or disabled by CS so that no operation can occur to change the function unless the device has been selected as the system logic.

CS : The chip select input is used to enable the communicate between 8253 and themicroprocessor by means of data bus. A low an CS enables the data bus buffers, while a high disable the buffer. The CS input does not

have any affect on the operation of threetimes once they have been initialized. The normal configuration of a system employs an decode logic which activates \overline{CS} line, whenever a specific set of addresses thatcorrespond to 8253 appear on the address bus.

\overline{RD} & \overline{WR} :

The read (\overline{RD}) and write \overline{WR} pins central the direction of data transfer on the 8-bit bus.

Whenthe input \overline{RD} pin is low. Then CPU is inputting data from 8253 in the form of counter

value. When \overline{WR} pins is low, then CPU is sending data to 8253 in the form of mode information or loading counters. The \overline{RD} & \overline{WR} should not both be low simultaneously. When \overline{RD} & \overline{WR} pins are HIGH, the data bus buffer is disabled.

A_0 & A_1 :

These two input lines allow the microprocessor to specify which one of the internal register in the 8253 is going to be used for the data transfer. Fig shows how these two lines are used to select either the control word register or one of the 16-bit counters.

\overline{CS}	\overline{RD}	\overline{WR}	A_1	A_0	operation
0	1	0	0	0	Load counter '0'
0	1	0	0	1	Load counter '1'
0	1	0	1	0	Load counter '2'
0	1	0	1	1	Write mode word
0	0	1	0	0	Read TM_0
0	0	1	0	1	Read TM_1
0	0	1	1	0	Read TM_2
0	0	1	1	1	No- operation 3- state
1	X	X	X	X	Disable -- state
0	1	1	X	X	No- operation 3- state

Control word register:

It is selected when A0 and A1 . It the accepts information from the data bus buffer and stores it in a register. The information stored in then register controls the operation mode of each counter, selection of binary or BCD counting and the loading of each counting and the loading of each count register. This register can be written into, no read operation of this content is available.

Counters:

Each of the times has three pins associated with it. These are CLK (CLK) the gate (GATE) and the output (OUT).

CLK:

This clock input pin provides 16-bit times with the signal to causes the times to decrement \max^m clock input is 2.6MHz. Note that the counters operate at the negative edge (H1 to L0) of this clock input. If the signal on this pin is generated by a fixed oscillator then the user has implemented a standard timer. If the input signal is a string of randomly occurring pulses, then it is called implementation of a counter.

GATE:

The gate input pin is used to initiate or enable counting. The exact effect of the gate signal dependson which of the six modes of operation is chosen.

OUTPUT:

The output pin provides an output from the timer. It actual use depends on the mode of operationof the timer. The counter can be read —in the fly|| without inhibiting gate pulse or clock input.

CONTROL WORD OF 8253

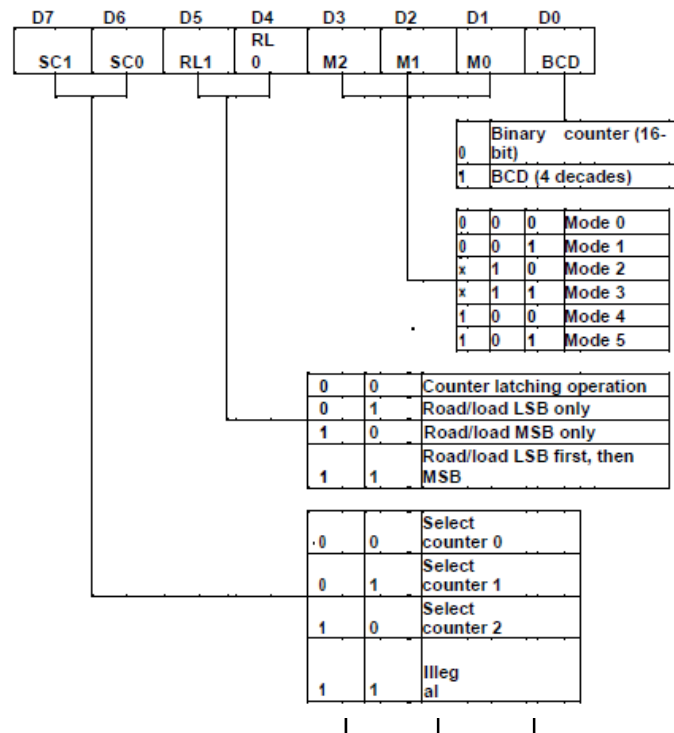


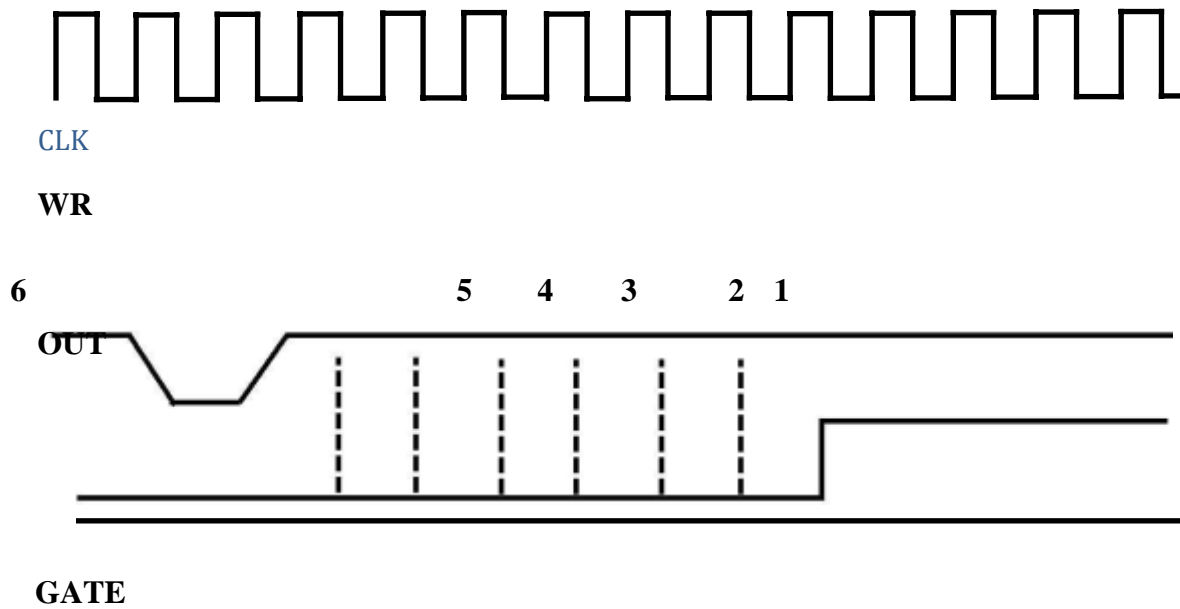
Fig 3.16: Control word format-8253

Control Register

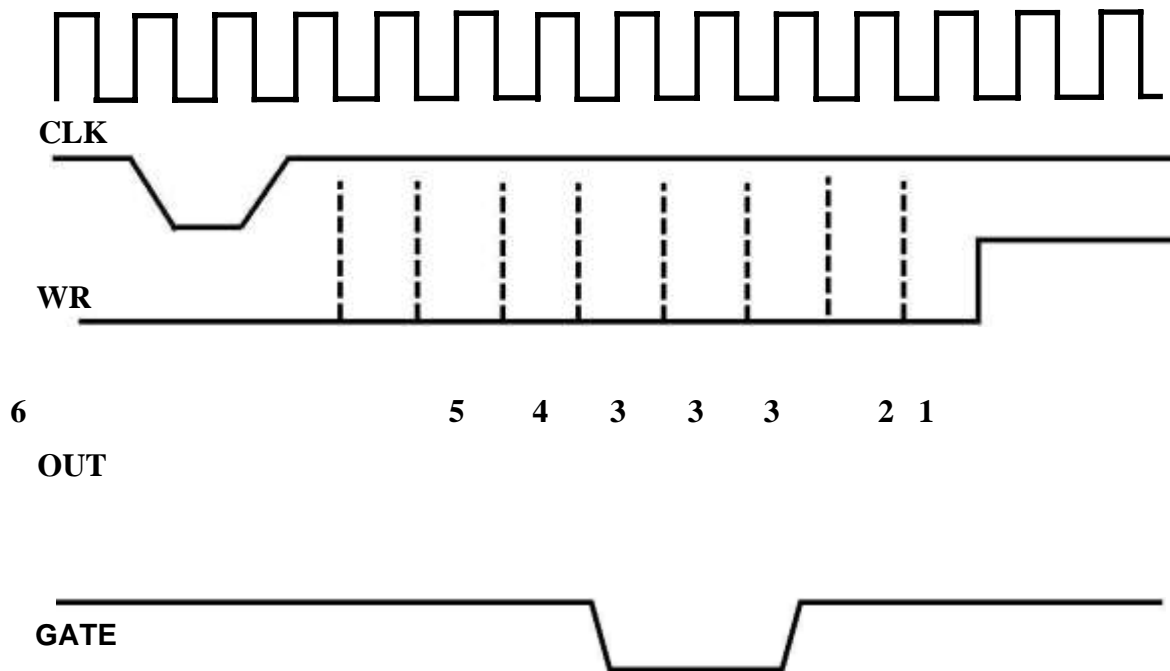
MODES OF OPERATION

Mode 0 Interrupt on terminal count **Mode 1** Programmable one shot **Mode 2** Rate Generator **Mode 3** Square wave rate Generator **Mode 4** Software triggered strobe **Mode 5** Hardware triggered strobe

Mode 0: The output goes high after the terminal count is reached. The counter stops if the Gate is low. The timer count register is loaded with a count (say 6) when the WR line is made low by the processor. The counter unit starts counting down with each clock pulse. The output goes high when the register value reaches zero. In the mean time if the GATE is made low the count is suspended at the value(3) till the GATE is enabled again.



Mode 0 count when Gate is high (enabled)

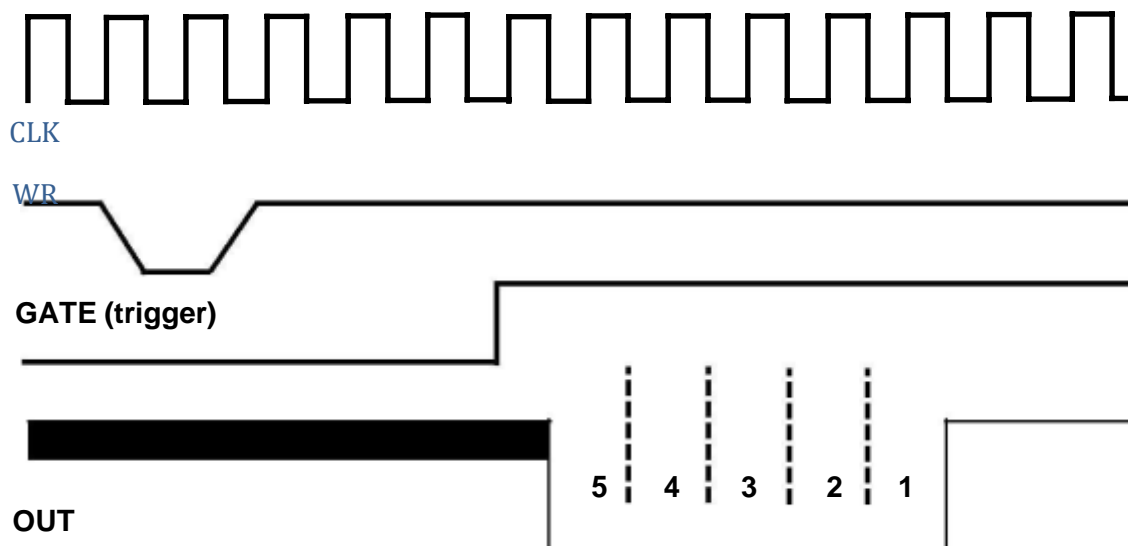


Mode 0 count when Gate is low temporarily (disabled) Mode 1

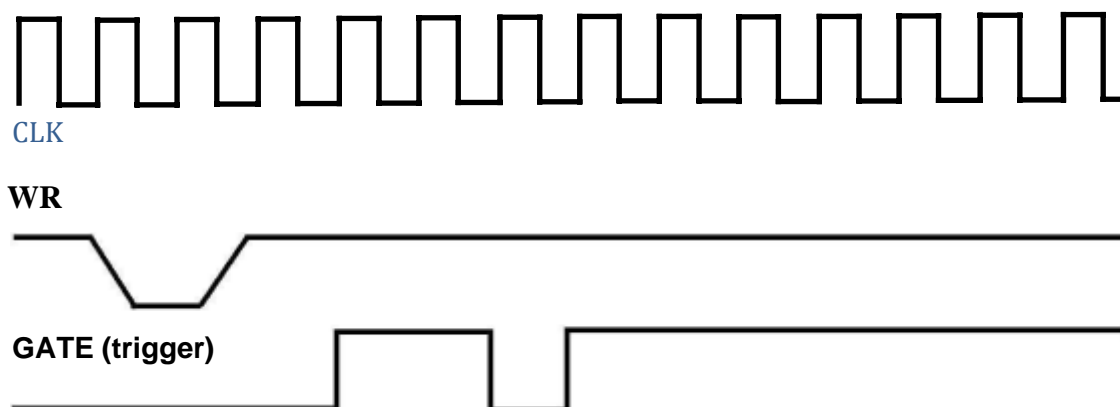
Programmable mono-shot

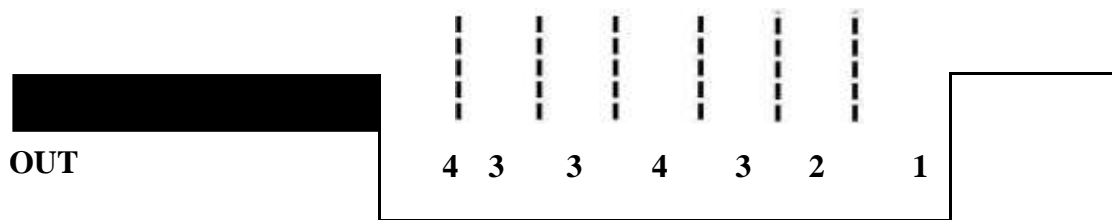
The output goes low with the Gate pulse for a predetermined period depending on the

counter. The counter is disabled if the GATE pulse goes momentarily low. The counter register is loaded with a count value as in the previous case (say 5). The output responds to the GATE input and goes low for period that equals the count down period of the register (5 clock pulses in this period). By changing the value of this count the duration of the output pulse can be changed. If the GATE becomes low before the count down is completed then the counter will be suspended at that state as long as GATE is low. Thus it works as a monoshot.



Mode 1 The Gate goes high. The output goes low for the period depending on the count

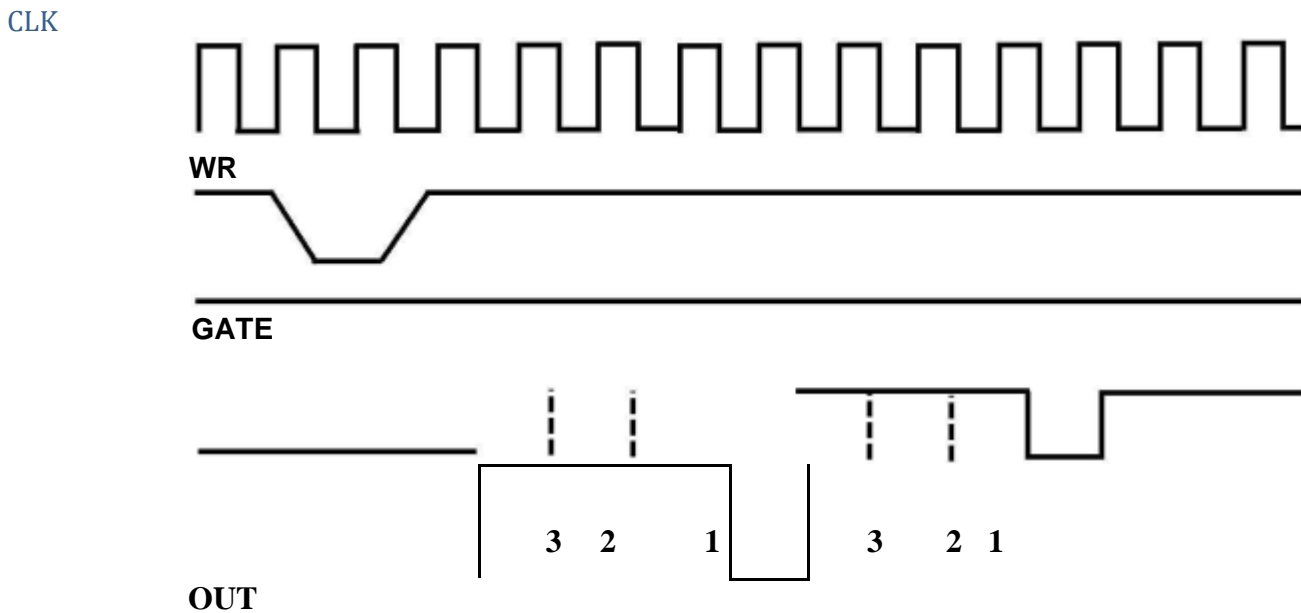




Mode 1 The Gate pulse is disabled momentarily causing the counter to stop.

Mode 2 Programmable Rate Generator

In this mode it operates as a rate generator. The output goes high for a period that equals the time of count down of the count register (3 in this case). The output goes low exactly for one clock period before it becomes high again. This is a periodic operation.



Mode 2 Operation when the GATE is kept high

OUT 3 2 1 3 3 2 1 Mode 2 operation when the GATE is disabled

Mode 3 Programmable Square Wave Rate Generator

The timing diagram shows three signals over time:

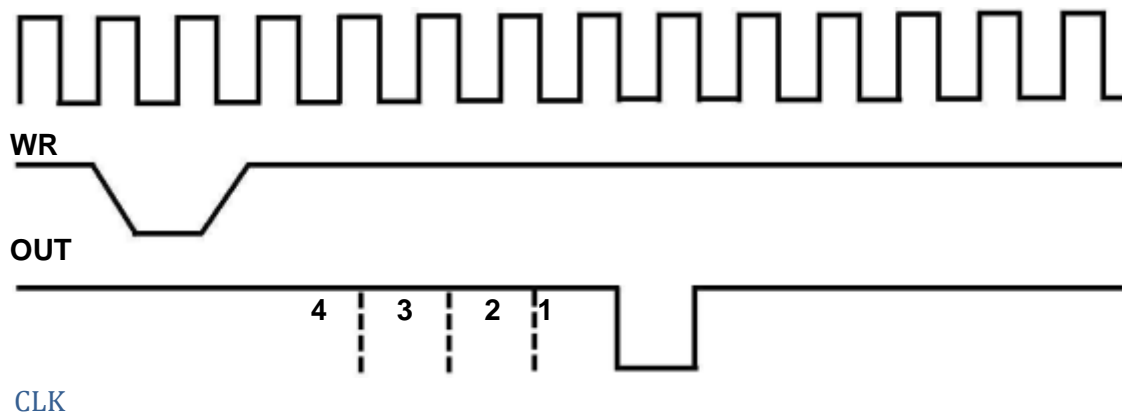
- WR (Write Enable):** A periodic square wave that is high for most of the cycle and low for a short duration. The low pulse is labeled $n=$.
- 4 OUT (n=4):** A square wave that is high during the low pulse of WR and low otherwise. It has a period of 4 clock cycles.
- OUT (n=5):** A square wave that is high during the low pulse of WR and low otherwise. It has a period of 5 clock cycles.

CLK

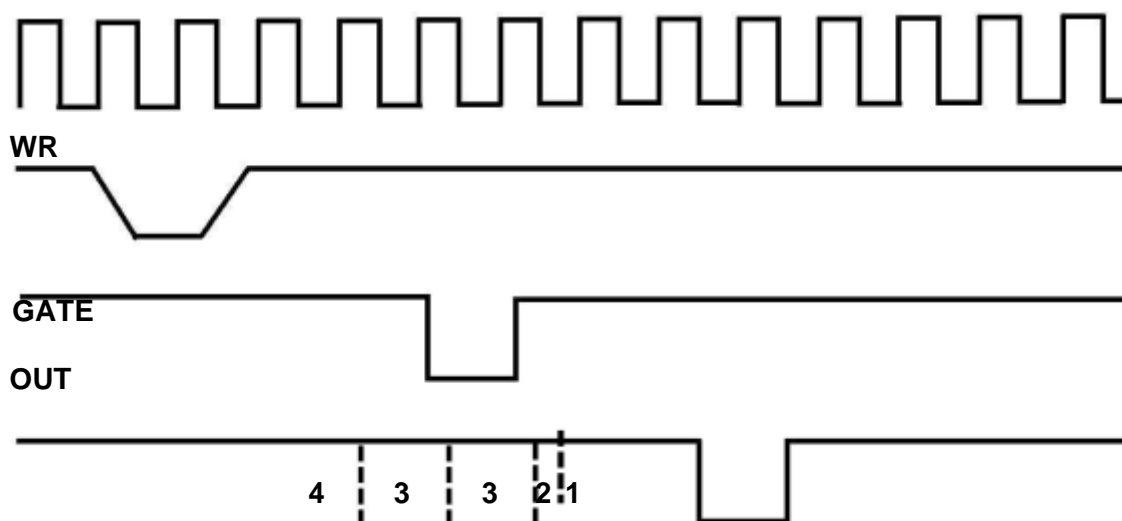
Mode3 Operation: Square Wave generator

Mode 4 Software Triggered Strobe

In this mode after the count is loaded by the processor the count down starts. The output goes low for one clock period after the count down is complete. The count down can be suspended by making the GATE low. This is also called a software triggered strobe as the count down is initiated by a program.



Mode 4 Software Triggered Strobe when GATE is high

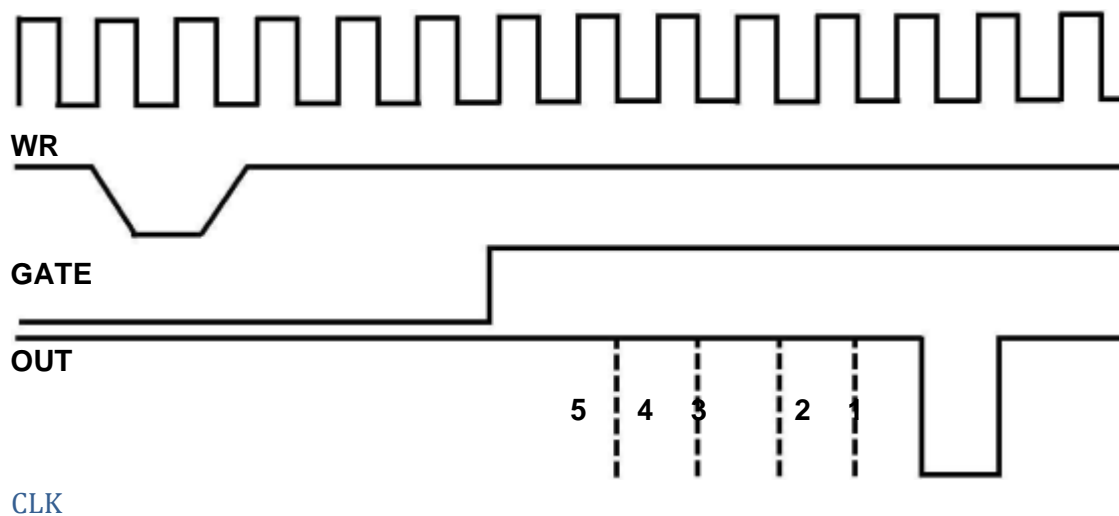


LK

Mode 4 Software Triggered Strobe when GATE is momentarily low

Mode 5 Hardware Triggered Strobe

The count is loaded by the processor but the count down is initiated by the GATE pulse. The transition from low to high of the GATE pulse enables count down. The output goes low for one clock period after the count down is complete.



Mode 5 Hardware Triggered Strobe

PROGRAMMABLE INTERRUPT CONTROLLER-8259

FEAUTURES OF 8259

- Eight-Level PriorityController Expandable to 64Levels Programmable Interrupt Modes
- 8086, 8088 Compatible
- MCS-80, MCS-85 Compatible
 - Individual Request Mask
 - Capability Single +5V Supply (No Clocks)
 - Available in 28-Pin DIP and 28-Lead PLCC Package Available in EXPRESS
 1. Standard Temperature Range
 2. Extended Temperature Range

The Intel 8259A Programmable Interrupt Controller handles up to eight vectored priority interrupts for the CPU. It is cascadable for up to 64 vectored priority interrupts without additional circuitry. It is packaged in a 28-pin DIP, uses NMOS technology and requires a single a5V supply. Circuitry is static, requiring no clock input. The 8259A is designed to minimize the software and real time overhead in handling multi-level priority interrupts. It has several modes, permitting optimization for a variety of system requirements. The 8259A is fully upward compatible with the Intel 8259. Software originally written for the 8259 will operate the 8259A in all 8259 equivalent modes (MCS-80/85, Non-Buffered, Edge Triggered). Pin Diagram of 8259 is shown in figure 3.17.

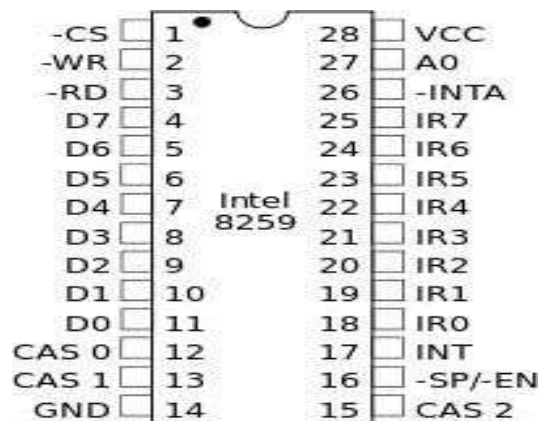


Fig.3.17 Pin Diagram of 8259

Pin Description of 8259

Symbol	Pin No.	Type	Name and Function
V _{CC}	28	I	SUPPLY: +5V Supply.
GND	14	I	GROUND
\overline{CS}	1	I	CHIP SELECT: A low on this pin enables \overline{RD} and \overline{WR} communication between the CPU and the 8259A. INTA functions are independent of CS.
\overline{WR}	2	I	WRITE: A low on this pin when CS is low enables the 8259A to accept command words from the CPU.
\overline{RD}	3	I	READ: A low on this pin when CS is low enables the 8259A to release status onto the data bus for the CPU.
D ₇ –D ₀	4–11	I/O	BIDIRECTIONAL DATA BUS: Control, status and interrupt-vector information is transferred via this bus.
CAS ₀ –CAS ₂	12, 13, 15	I/O	CASCADE LINES: The CAS lines form a private 8259A bus to control a multiple 8259A structure. These pins are outputs for a master 8259A and inputs for a slave 8259A.
$\overline{SP}/\overline{EN}$	16	I/O	SLAVE PROGRAM/ENABLE BUFFER: This is a dual function pin. When in the Buffered Mode it can be used as an output to control buffer transceivers (EN). When not in the buffered mode it is used as an input to designate a master (SP = 1) or slave (SP = 0).
INT	17	O	INTERRUPT: This pin goes high whenever a valid interrupt request is asserted. It is used to interrupt the CPU, thus it is connected to the CPU's interrupt pin.
IR ₀ –IR ₇	18–25	I	INTERRUPT REQUESTS: Asynchronous inputs. An interrupt request is executed by raising an IR input (low to high), and holding it high until it is acknowledged (Edge Triggered Mode), or just by a high level on an IR input (Level Triggered Mode).
INTA	26	I	INTERRUPT ACKNOWLEDGE: This pin is used to enable 8259A interrupt-vector data onto the data bus by a sequence of interrupt acknowledge pulses issued by the CPU.
A ₀	27	I	AO ADDRESS LINE: This pin acts in conjunction with the \overline{CS} , \overline{WR} , and \overline{RD} pins. It is used by the 8259A to decipher various Command Words the CPU writes and status the CPU wishes to read. It is typically connected to the CPU A0 address line (A1 for 8086, 8088).

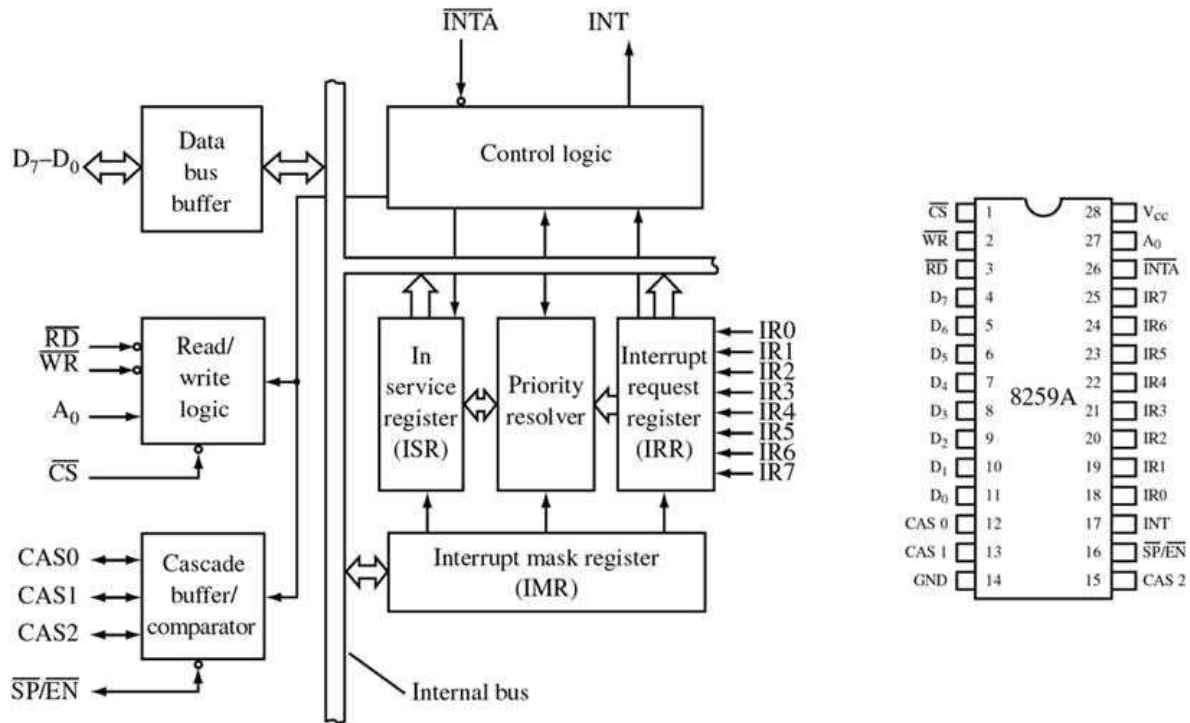


Fig. 3.18 Block Diagram of 8259

A more desirable method would be one that would allow the microprocessor to be executing its main program and only stop to service peripheral devices when it is told to do so by the device itself. In effect, the method would provide an external asynchronous input that would inform the processor that it should complete whatever instruction that is currently being executed and fetch a new routine that will service the requesting device. Once this servicing is complete, however, the processor would resume exactly where it left off. This method is called Interrupt. It is easy to see that system throughput would drastically increase, and thus more tasks could be assumed by the micro-computer to further enhance its cost effectiveness. Block Diagram of 8259 is shown in figure 18.

The Programmable Interrupt Controller (PIC) functions as an overall manager in an Interrupt-Driven system environment. It accepts requests from the peripheral equipment, determines which of the in-coming requests is of the highest importance (priority),

ascertains whether the incoming request has a higher priority value than the level currently being serviced, and issues an interrupt to the CPU based on this determination.

The 8259A is a device specifically designed for use in real time, interrupt driven microcomputer systems. It manages eight levels or requests and has built-in features for expandability to other 8259A's (up to 64 levels). It is programmed by the system's software as an I/O peripheral. A selection of priority modes is available to the programmer so that the manner in which the requests are processed by the 8259A can be configured to match his system requirements. The priority modes can be changed or reconfigured dynamically at any time during the main program. This means that the complete interrupt structure can be defined as required, based on the total system environment.

INTERRUPT REQUEST REGISTER (IRR) AND IN-SERVICE REGISTER (ISR)

The interrupts at the IR input lines are handled by two registers in cascade, the Interrupt Request Register (IRR) and the In-Service (ISR). The IRR is used to store all the interrupt levels which are requesting service; and the ISR is used to store all the interrupt levels which are being serviced.

PRIORITY RESOLVER

This logic block determines the priorities of the bits set in the IRR. The highest priority is selected and strobed into the corresponding bit of the ISR during INTA pulse.

INTERRUPT MASK REGISTER (IMR)

The IMR stores the bits which mask the interrupt lines to be masked. The IMR operates on the IRR. Masking of a higher priority input will not affect the interrupt request lines of lower quality.

INT (INTERRUPT)

This output goes directly to the CPU interrupt input. The VOH level on this line is designed to be fully compatible with the 8080A, 8085A and 8086 input levels.

INTA (INTERRUPT ACKNOWLEDGE)

INTA pulses will cause the 8259A to release vectoring information onto the data bus. The format of this data depends on the system mode (mPM) of the 8259A.

DATA BUS BUFFER

This 3-state, bidirectional 8-bit buffer is used to interface the 8259A to the system Data Bus. Control words and status information are transferred through the Data Bus Buffer.

READ/WRITE CONTROL LOGIC

The function of this block is to accept Output commands from the CPU. It contains the Initialization Command Word (ICW) registers and Operation Command Word (OCW) registers which store the various control formats for device operation. This function block also allows the status of the 8259A to be transferred onto the Data Bus.

CS (CHIP SELECT)

A LOW on this input enables the 8259A. No reading or writing of the chip will occur unless the device is selected.

WR (WRITE)

A LOW on this input enables the CPU to write control words (ICWs and OCWs) to the 8259A. RD (READ)

A LOW on this input enables the 8259A to send the status of the Interrupt Request Register (IRR), In Service Register (ISR), the Interrupt Mask Register (IMR), or the Interrupt level onto the Data Bus.

A0

This input signal is used in conjunction with WR and RD signals to write commands into the various command registers, as well as reading the various status registers of the chip. This line can be tied directly to one of the address lines.

INTERRUPT SEQUENCE

The powerful features of the 8259A in a microcomputer system are its programmability and the interrupt routine addressing capability. The latter allows direct or indirect jumping to the specific interrupt routine requested without any polling of the interrupting devices. The normal sequence of events during an interrupt depends on the type of CPU being used.

The events occur as follows in an MCS-80/85 system:

1. One or more of the INTERRUPT REQUEST lines ($IR_{7\pm0}$) are raised high, setting the corresponding IRR bit(s).
2. The 8259A evaluates these requests, and sends an INT to the CPU, if appropriate.
3. The CPU acknowledges the INT and responds with an INTA pulse.
4. Upon receiving an INTA from the CPU group, the highest priority ISR bit is set, and the corresponding IRR bit is reset. The 8259A will also release a CALL instruction code (11001101) onto the 8-bit Data Bus through its $D_{7\pm0}$ pins.
5. This CALL instruction will initiate two more INTA pulses to be sent to the 8259A from the CPU group.
6. These two INTA pulses allow the 8259A to re-lease its preprogrammed subroutine address onto the Data Bus. The lower 8-bit address is released at the first INTA pulse and the higher 8-bit address is released at the second INTA pulse.
7. This completes the 3-byte CALL instruction re-leased by the 8259A. In the AEOI mode the ISR bit is reset at the end of the third INTA pulse. Otherwise, the ISR

bit remains set until an appropriate EOI command is issued at the end of the interrupt sequence.

8. The events occurring in an 8086 system are the same until step 4.
9. Upon receiving an INTA from the CPU group, the highest priority ISR bit is set and the corresponding IRR bit is reset. The 8259A does not drive the Data Bus during this cycle.
10. The 8086 will initiate a second INTA pulse. During this pulse, the 8259A releases an 8-bit pointer onto the Data Bus where it is read by the CPU.
11. This completes the interrupt cycle. In the AEOI mode the ISR bit is reset at the end of the second INTA pulse. Otherwise, the ISR bit remains set until an appropriate EOI command is issued at the end of the interrupt subroutine.

If no interrupt request is present at step 4 of either sequence (i.e., the request was too short in duration) the 8259A will issue an interrupt level 7. Both the vectoring bytes and the CAS lines will look like an interrupt level 7 was requested.

When the 8259A PIC receives an interrupt, INT becomes active and an interrupt acknowledge cycle is started. If a higher priority interrupt occurs between the two INTA pulses, the INT line goes inactive immediately after the second INTA pulse. After an unspecified amount of time the INT line is activated again to signify the higher priority interrupt waiting for service. This inactive time is not specified and can vary between parts. The designer should be aware of this consideration when designing a system which uses the 8259A. It is recommended that proper asynchronous design techniques be followed.

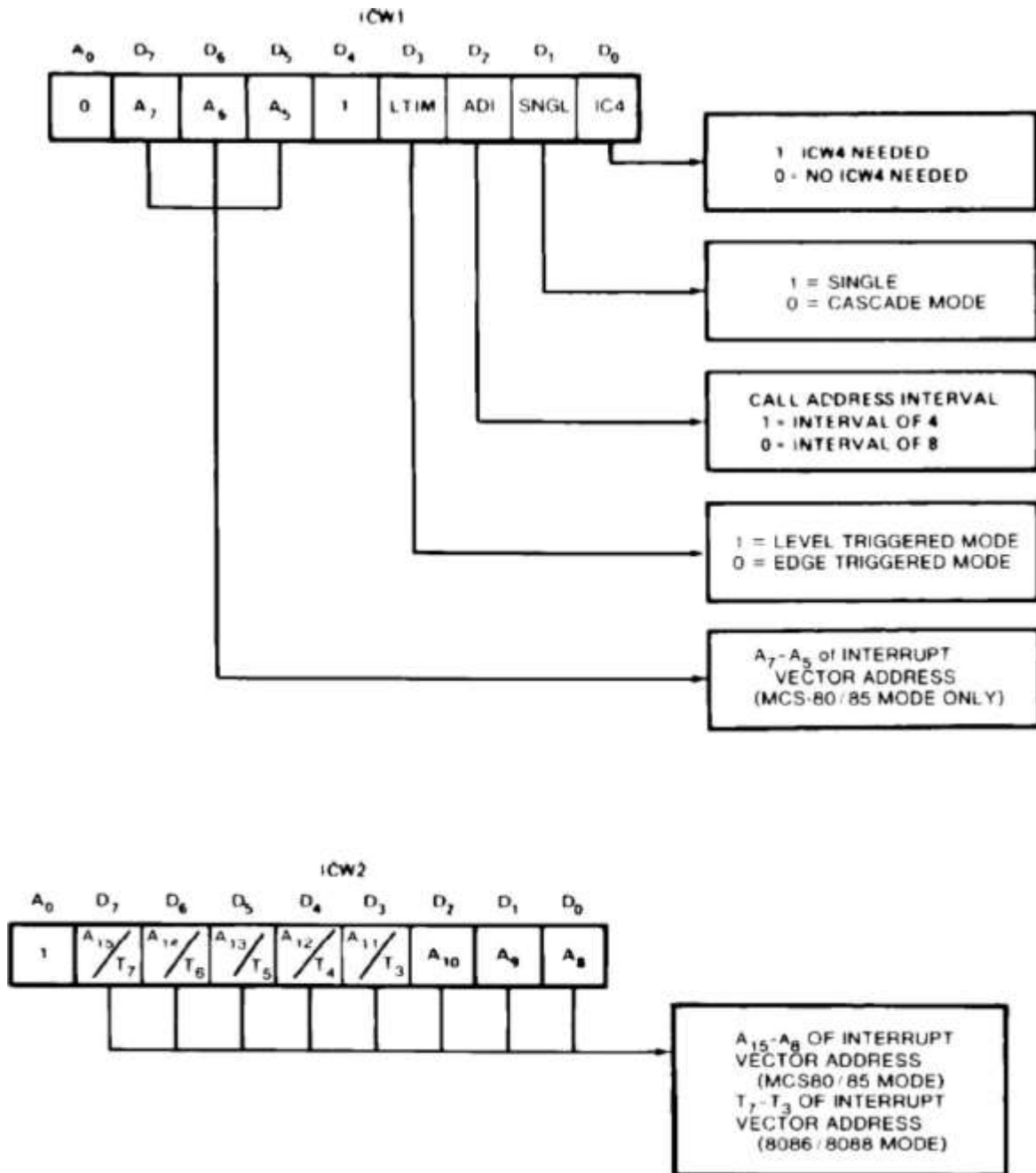
INITIALIZATION COMMAND WORDS

Whenever a command is issued with A0 = 0 and D4 = 1, this is interpreted as Initialization Command Word 1 (ICW1). ICW1 starts the initialization sequence during which the following automatically occur.

- a. The edge sense circuit is reset, which means that following initialization, an interrupt request (IR) input must make a low-to-high transition to generate an interrupt.
- b. The Interrupt Mask Register is cleared.
- c. IR7 input is assigned priority 7.

- d. The slave mode address is set to 7.
- e. Special Mask Mode is cleared and Status Read is set to IRR.
- f. If IC4 = 0, then all functions selected in ICW4 are set to zero. (Non-Buffered mode*, no Auto-EOI, MCS-80, 85 system).

Initialization Command Word Format is as shown in figure



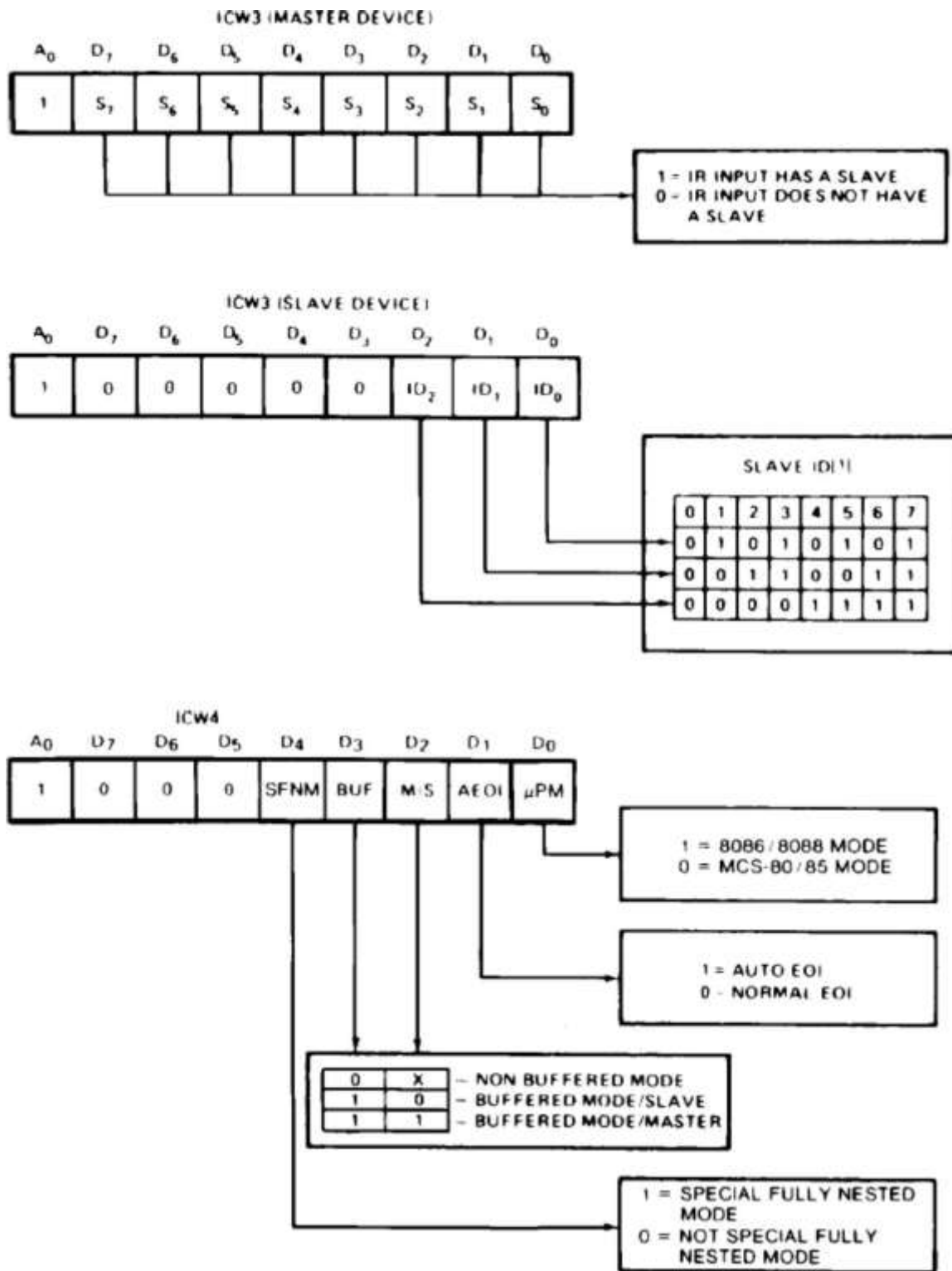


Fig 3.19 . Initialization Command Word Format

OPERATION COMMAND WORDS

After the Initialization Command Words (ICWs) are programmed into the 8259A, the chip is ready to accept interrupt requests at its input lines. However, during the 8259A operation, a selection of algorithms can command the 8259A to operate in various modes through the Operation Command Words (OCWs). Operation Command Word format is as shown in figure

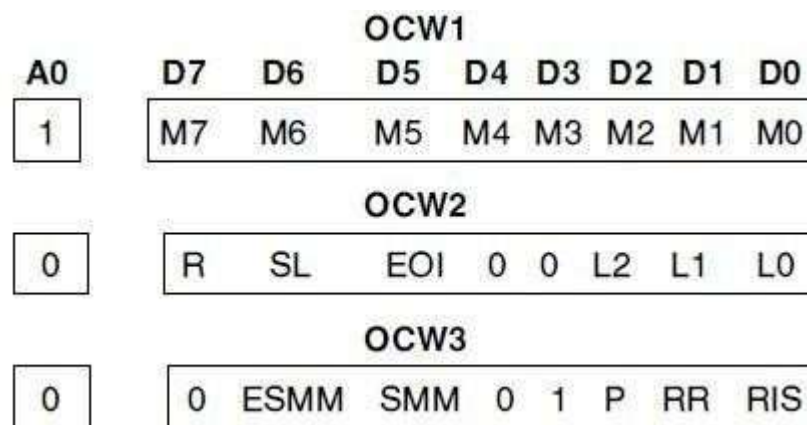
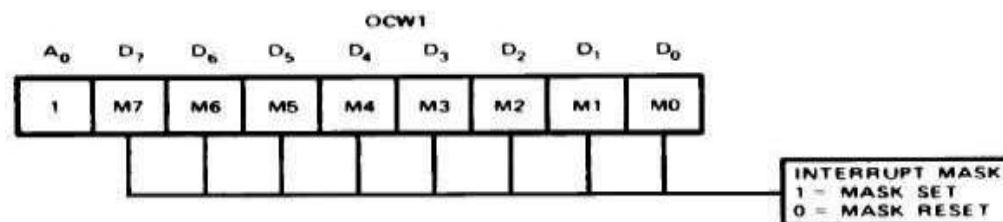


Fig 3.20 a. Operational Control Words



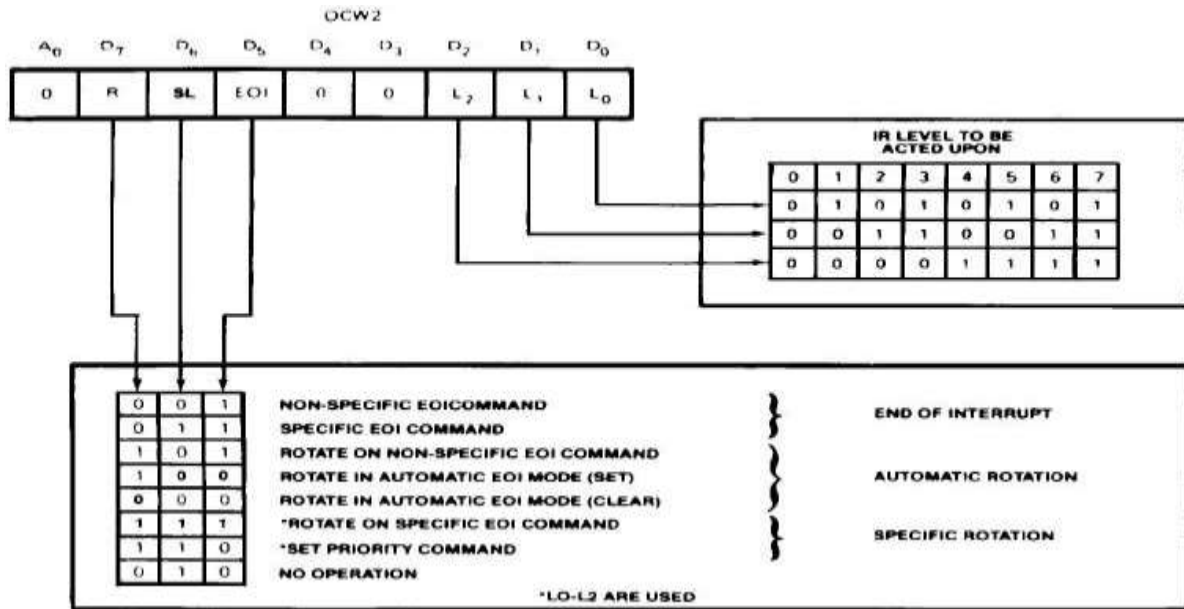


Fig 3.20 b. Operation Command Word Format

INTERFACING MEMORY CHIPS WITH 8085

8085 has 16 address lines (A₀ - A₁₅), hence a maximum of 64 KB (= 2¹⁶ bytes) of memory locations can be interfaced with it. The memory address space of the 8085 takes values from 0000H to FFFFH.

The 8085 initiates set of signals such as IO/M, RD and WR when it wants to read from and write into memory. Similarly, each memory chip has signals such as CE or CS (chip enable or chip select), OE or RD (output enable or read) and WE or WR (write enable or write) associated with it.

Generation of Control Signals for Memory:

When the 8085 wants to read from and write into memory, it activates IO/M, RD and WR signals as shown in Table .

Table 8 Status of IO/M , RD and WR signals during memory read and write operations

IO/M	RD	WR	Operation
0	0	1	8085 reads data from memory
0	1	0	8085 writes data into memory

Using IO/M , RD and WR signals, two control signals MEMR (memory read) and MEMW (memory write) are generated. Fig. 16 shows the circuit used to generate these signals.

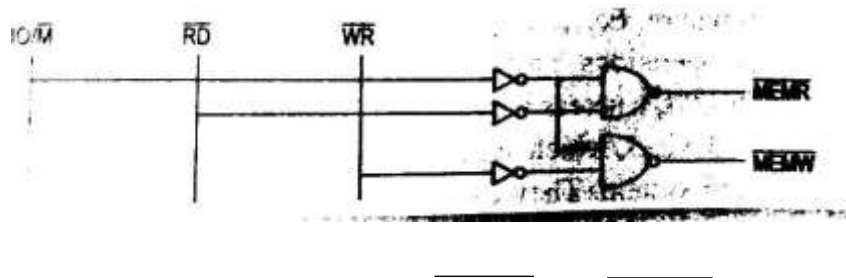


Fig. 3.21 Circuit used to generate MEMR and MEMW signals

When is IO/M high, both memory control signals are deactivated irrespective of the status of RD and WR signals.

Ex: Interface an IC 2764 with 8085 using NAND gate address decoder such that the address range allocated to the chip is 0000H – 1FFFH.

Specification of IC 2764:

8 KB (8×2^{10} byte) EPROM chip

13 address lines (2^{13} bytes = 8 KB)

Interfacing:

- ┐ 13 address lines of IC are connected to the corresponding address lines of 8085.
- ┐ Remaining address lines of 8085 are connected to address decoder formed using logic gates, the output of which is connected to the CE pin of IC.
- ┐ Address range allocated to the chip is shown in Table 9.
- ┐ Chip is enabled whenever the 8085 places an address allocated to EPROM chip in the address bus. This is shown in Fig. 17.

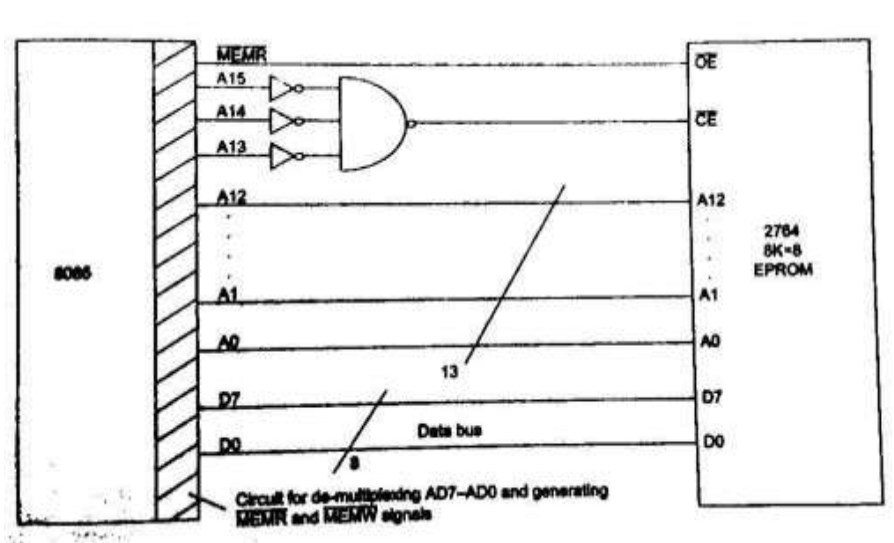


Fig. 3.22 Interfacing IC 2764 with the 8085 Table 9 Address allocated to IC 2764

A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	Address
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0000H
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0001H
.
.
0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1FFE H
0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1FFF H

Ex: Interface a 6264 IC (8K x 8 RAM) with the 8085 using NAND gate decoder such that the starting address assigned to the chip is 4000H.

Specification of IC 6264:

- ┐ 8K x 8 RAM

- 8 KB = 2^{13} bytes
- 13 address lines

The ending address of the chip is 5FFFH (since 4000H + 1FFFH = 5FFFH). When the address 4000H to 5FFFH are written in binary form, the values in the lines A15, A14, A13 are 0, 1 and 0 respectively. The NAND gate is designed such that when the lines A15 and A13 carry 0 and A14 carries 1, the output of the NAND gate is 0. The NAND gate output is in turn connected to the CE1 pin of the RAM chip. A NAND output of 0 selects the RAM chip for read or write operation, since CE2 is already 1 because of its connection to +5V. Fig. 18 shows the interfacing of IC 6264 with the 8085.

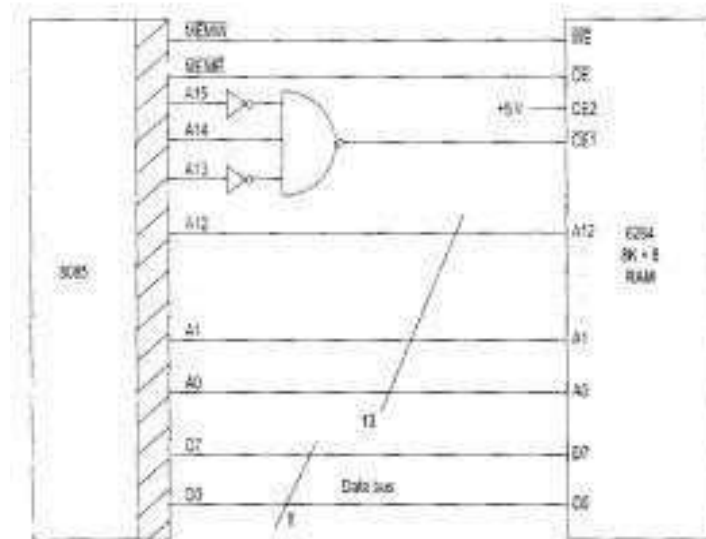


Fig. 3.23 Interfacing 6264 IC with the 8085

Ex: Interface two 6116 ICs with the 8085 using 74LS138 decoder such that the starting addresses assigned to them are 8000H and 9000H, respectively.

Specification of IC 6116:

- 2 K x 8 RAM
- 2 KB = 2^{11} bytes
- 11 address lines

6116 has 11 address lines and since 2 KB, therefore ending addresses of 6116 chip 1 is and chip 2 are 87FFH and 97FFH, respectively. Table 10 shows the address range of the two chips.

Table 3.1 Address range for IC 6116

A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	Address
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8000H
.
1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	87FFH (RAM chip 1)
1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	9000H
.
1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	97FFH (RAM chip 2)

Interfacing:

- Fig. 19 shows the interfacing.
- A0 – A10 lines of 8085 are connected to 11 address lines of the RAM chips.
- Three address lines of 8085 having specific value for a particular RAM are connected to the three select inputs (C, B and A) of 74LS138 decoder.
- Table 10 shows that A13=A12=A11=0 for the address assigned to RAM 1 and A13=0, A12=1 and A11=0 for the address assigned to RAM 2.
- Remaining lines of 8085 which are constant for the address range assigned to the two RAM are connected to the enable inputs of decoder.
- When 8085 places any address between 8000H and 87FFH in the address bus, the select inputs C, B and A of the decoder are all 0. The Y0 output of the decoder is also 0, selecting RAM 1.

- When 8085 places any address between 9000H and 97FFH in the address bus, the select inputs C, B and A of the decoder are 0, 1 and 0. The Y2 output of the decoder is also 0, selecting RAM 2.

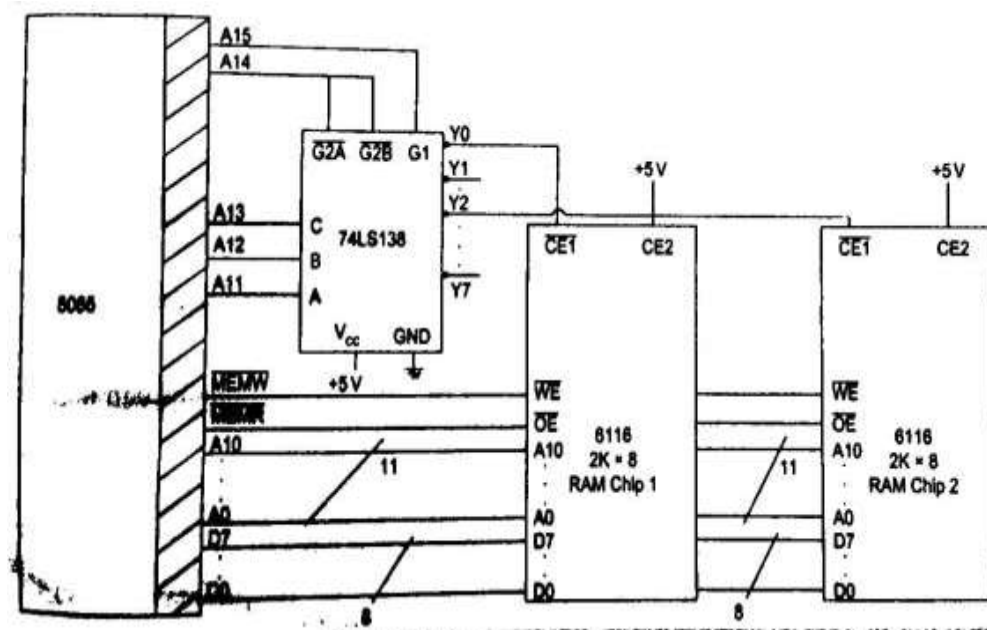


Fig. 3.24 Interfacing two 6116 RAM chips using 74LS138 decoder

3. PERIPHERAL MAPPED I/O INTERFACING

In this method, the I/O devices are treated differently from memory chips. The control signals I/O read (IOR) and I/O write (IOW), which are derived from the IO/M, RD and

WR signals of the 8085, are used to activate input and output devices, respectively.

Generation of these control signals is shown in Fig. 20. Table 11 shows the status of IO/M, RD and WR signals during I/O read and I/O write operation.

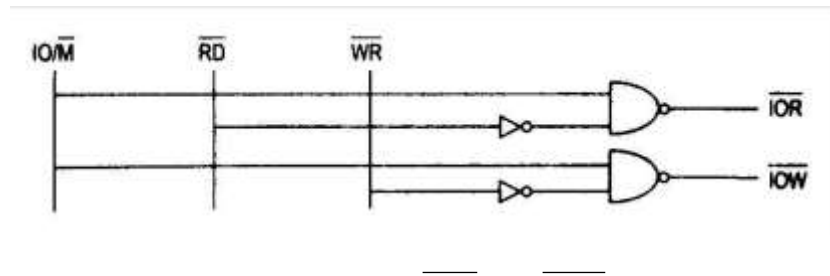


Fig. 3.25 Generation of IOR and IOW signals

IN instruction is used to access input device and **OUT** instruction is used to access output device. Each I/O device is identified by a unique 8-bit address assigned to it. Since the control signals used to access input and output devices are different, and all I/O device use 8-bit address, a maximum of 256 (2^8) input devices and 256 output devices can be interfaced with 8085.

Table 3.2 Status of IOR and IOW signals in 8085.

IO/ M	\overline{RD}	\overline{WR}	\overline{IOR}	\overline{IOW}	Operation
1	0	1	0	1	I/O read operation
1	1	0	1	0	I/O write operation
0	X	X	1	1	Memory read or write operation

Ex: Interface an 8-bit DIP switch with the 8085 such that the address assigned to the DIPswitch is F0H.

IN instruction is used to get data from DIP switch and store it in accumulator.

Stepsinvolved in the execution of this instruction are:

- Address F0H is placed in the lines A0 – A7 and a copy of it in lines A8 – A15.
- ii. The IOR signal is activated ($\overline{IOR} = 0$), which makes the selected input device to place its data in the data bus.
- iii. The data in the data bus is read and store in the accumulator.

Fig. 3.26 shows the interfacing of DIP switch.

A7	A6	A5	A4	A3	A2	A1	A0	
1	1	1	1	0	0	0	0	= F0H

A0 – A7 lines are connected to a NAND gate decoder such that the output of NAND gate is 0. The output of NAND gate is ORed with the IOR signal and the output of OR gate is

connected to 1G and 2G of the 74LS244. When 74LS244 is enabled, data from the DIP switch is placed on the data bus of the 8085. The 8085 read data and store in the accumulator. Thus data from DIP switch is transferred to the accumulator.

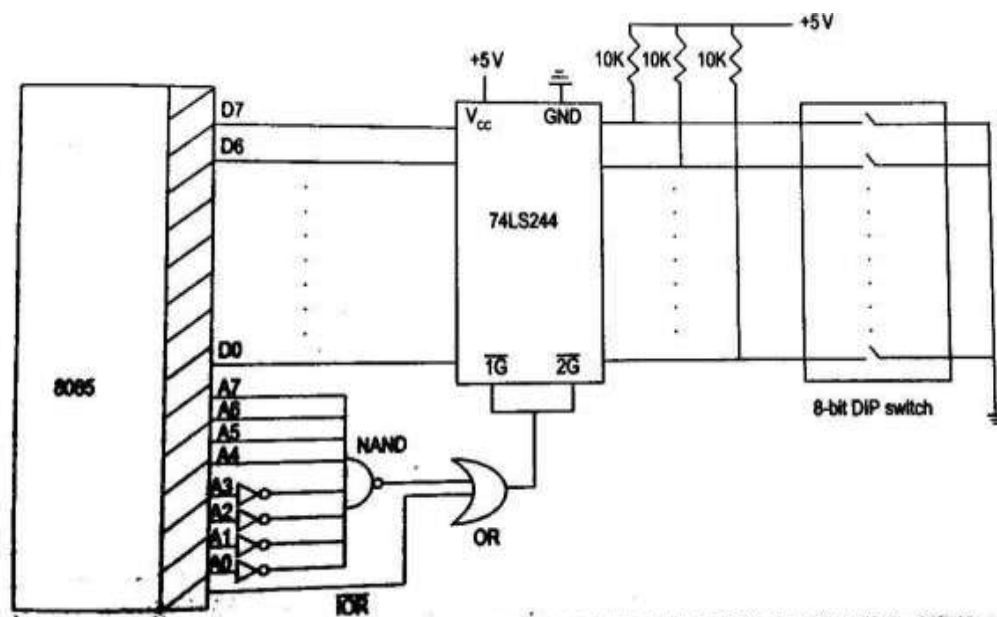


Fig. 3.26 interfacing of 8-bit DIP switch with 8085

4. MEMORY MAPPED I/O INTERFACING

In memory-mapped I/O, each input or output device is treated as if it is a memory location. The MEMR and MEMW control signals are used to activate the devices. Each input or output device is identified by unique 16-bit address, similar to 16-bit address assigned to memory location. All memory related instruction like LDA 2000H, LDAX B, MOV A, M can be used. Since the I/O devices use some of the memory address space of 8085, the maximum memory capacity is lesser than 64 KB in this method. Ex: Interface an 8-bit DIP switch with the 8085 using logic gates such that the address assigned to it is F0F0H. Since a 16-bit address has to be assigned to a DIP switch, the memory-mapped I/O technique must be used. Using LDA F0F0H instruction, the data from the 8-bit DIP switch can be transferred to the accumulator. The steps involved are:

- ┐ The address F0F0H is placed in the address bus A0 –
- ┐ A15. The MEMR signal is made low for some time.
- ┐ The data in the data bus is read and stored in the accumulator.

Fig. 3.27 shows the interfacing diagram.

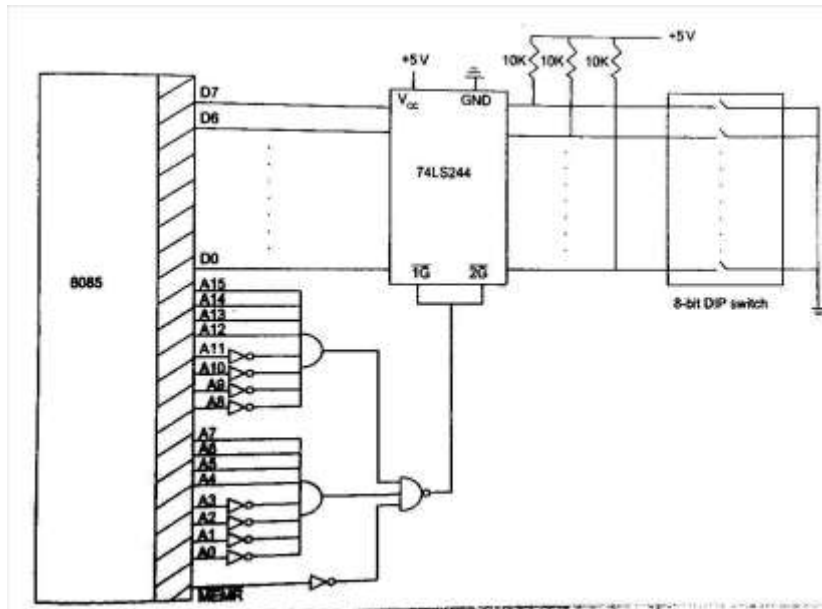


Fig. 3.27 Interfacing 8-bit DIP switch with 8085

When 8085 executes the instruction LDA F0F0H, it places the address F0F0H in the address lines A0 – A15 as:

A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
1	1	1	1	0	0	0	0	1	1	1	0	0	0	0	0=F0F0H

The address lines are connected to AND gates. The output of these gates along with MEMR signal are connected to a NAND gate, so that when the address F0F0H is placed in the address bus and MEMR = 0 its output becomes 0, thereby enabling the buffer 74LS244. The data from the DIP switch is placed in the 8085 data bus. The 8085 reads the data from the data bus and stores it in the accumulator.

nterfacing ADC with 8085 Microprocessor

To interface the ADC with 8085, we need 8255 Programmable Peripheral Interface chip with it. Let us see the circuit diagram of connecting 8085, 8255 and the ADC converter.

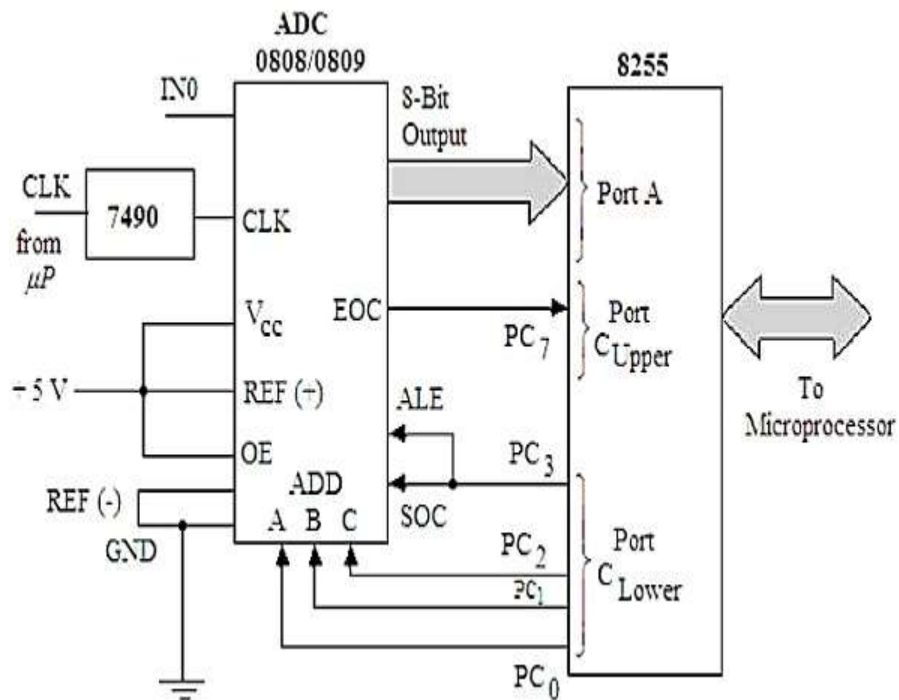


Fig 3.28: ADC interfacing

The PortA of 8255 chip is used as the input port. The PC₇ pin of Port C_{upper} is connected to the End of Conversion (EOC) Pin of the analog to digital converter. This port is also used as input port. The C_{lower} port is used as output port. The PC₂₋₀ lines are connected to three address pins of this chip to select input channels. The PC₃ pin is connected to the Start of Conversion (SOC) pin and ALE pin of ADC 0808/0809.

Now let us see a program to generate digital signal from analog data. We are using IN₀ as input pin, so the pin selection value will be 00H.

Program

MVI A, 98H ; Set Port A and C_{upper} as input, C_{Lower} as output

OUT 03H ; Write control word 8255-I to control Word register

XRA A ; Clear the accumulator

OUT 02H ; Send the content of Acc to Port C_{lower} to select

IN₀

MVI A, 08H ; Load the accumulator with 08H

OUT 02H ; ALE and SOC will be 0

XRA A ; Clear the accumulator

OUT 02H ; ALE and SOC will be low.

READ: IN 02H ; Read from EOC (PC₇)

RAL ; Rotate left to check C₇ is 1.

JNC READ ; If C₇ is not 1, go to READ

IN 00H ; Read digital output of ADC

STA 8000H ; Save result at 8000H

HLT ; Stop the program

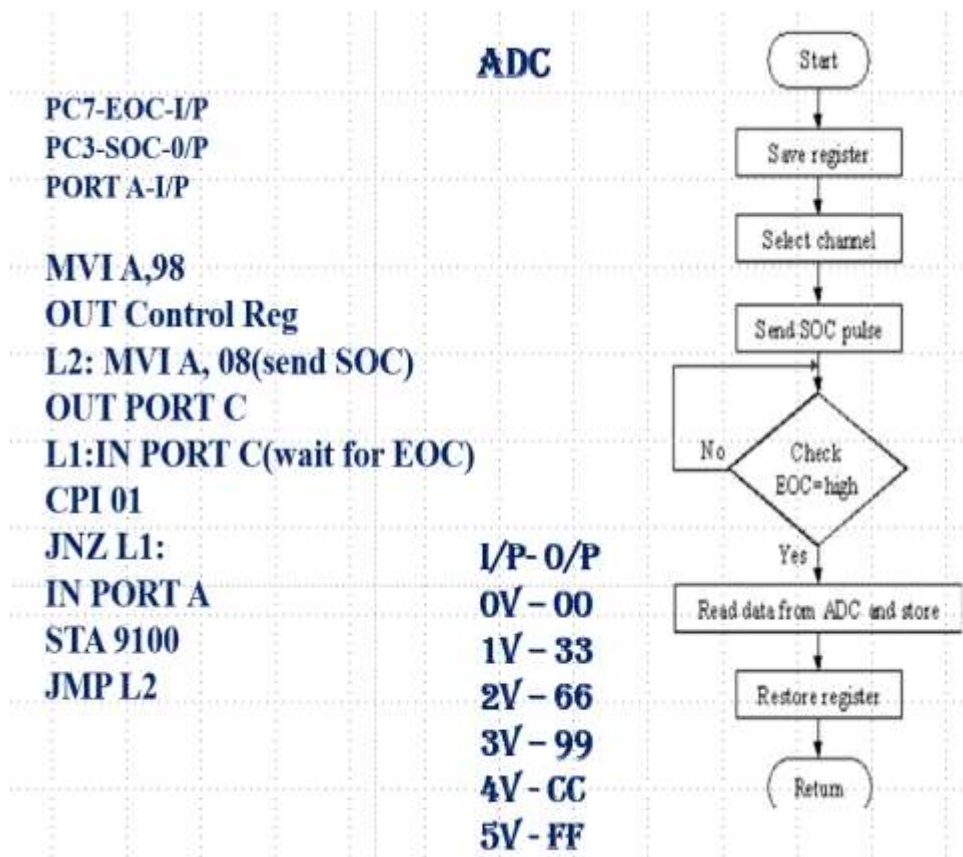


Fig 3.29: Flow chart-ADC

Either of the method can write the program.

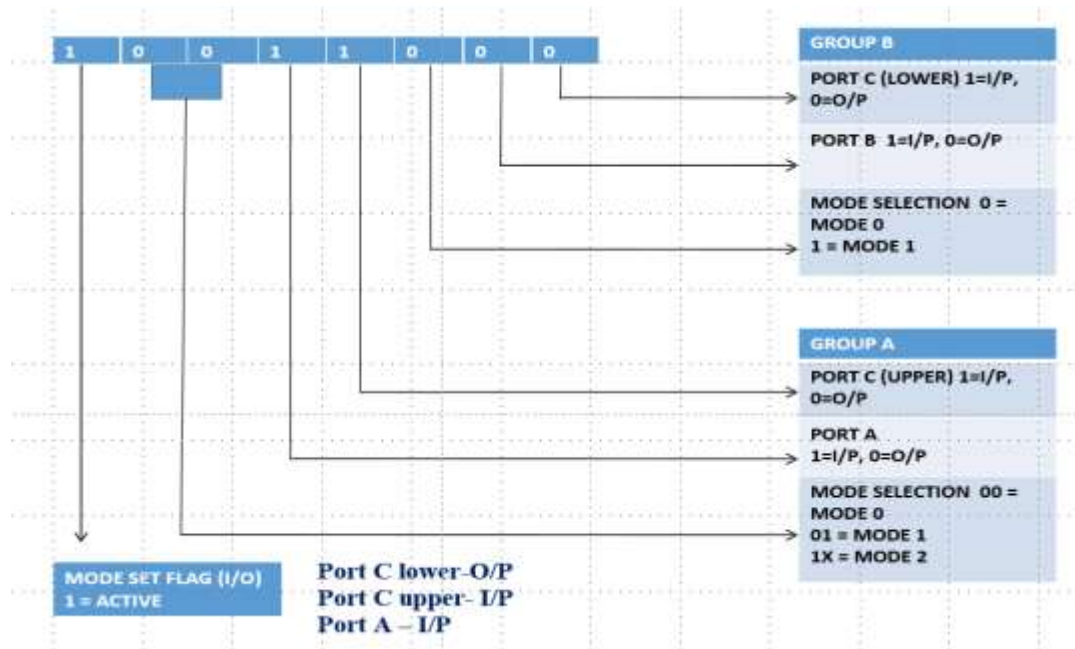


Fig 3.30: control word format

DAC

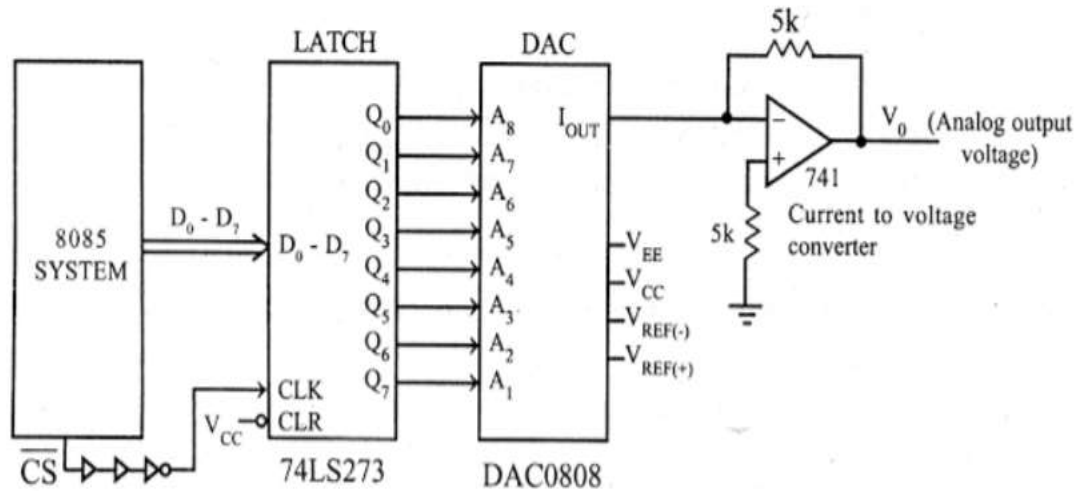


Fig 3.31: DAC Interfacing

- The processor sends an address, which is decoded by decoder in the microprocessor system to produce chip select signal.
- Then the processor sends a digital data to latch. The buffer and inverter will produce sufficient delay for CS signal so that, the latch is clocked only after the data is arrived at the input lines of the latch.
- When the latch is clocked the digital data is send to DAC. The DAC will produce a corresponding current signal, which is converted to voltage signal by the op-amp 741.
- The typical settling time of DAC0800 is 150nsec. Therefore the processor need not wait for loading next data

PROGRAMS FOR VARIOUS WAVEFORM GENERATION USING DAC

SAW TOOTH	SQUARE WAVE	STAIR CASE
<pre> L1:MVI A,00 OUT DAC INR A JMP L1: </pre>	<pre> L1:MVI A,00 OUT DAC CALL DELAY MVI A, FF OUT DAC CALL DELAY JMP L1: </pre>	<pre> L1:LXI H,9100 MVI C, 06 L2:MOV A, M OUT DAC CALL DELAY INX H DCR C JNZ L2: JMP L1: </pre>
TRIANGULAR		
<pre> L1:MVI A,00 OUT DAC INR A CPI FF JNZ L1: L2:OUT DAC DCR A JNZ L2 JMP L1: </pre>	<pre> DELAY MVI B,55 L2:DCR B JNZ L2: RET </pre>	<pre> 9100: 00 9101: 55 9102: AA 9103: FF 9104: AA 9105: 55 </pre>

QUESTION BANK

PART A

1. What is interfacing
2. Distinguish memory mapped I/O and I/O mapped I/O
3. Draw the control word for 8255
4. Configure 8255 as PORT A-I/P, PORT B-O/P & PORT C LOWER-I/P , PORTC UPPER-O/P
5. Set PCO using bit set reset mode
6. Write the control word to generate square wave using 8253
7. What is the need of Priority resolver in 8259
8. How many interrupts maximum a 8259 can support
9. What is USART
10. Define resolution in DAC and ADC
11. What is EOC and SOC in ADC
12. Write an ALP to generate sawtooth using DAC
13. What are the two command words used in 8259
14. Explain mode 5 of 8253
15. Explain the transmitter section of 8251 USART

PART B

1. Explain with neat diagram 8255 PPI
2. With neat diagram explain how serial communication is done using 8251
3. With neat diagram explain the 8253 timer
4. Explain the various modes of 8253 timer
5. Discuss about 8259 PIC
6. Interface ADC to 8085 and explain
7. Interface DAC with 8085 and generate various waveforms

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**SCHOOL OF ELECTRICAL AND ELECTRONICS
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**

UNIT – I V– MICROPROCESSORS AND MICROCONTROLLERS– SEC1201

UNIT 4 8051 MICROCONTROLLER

8051 Architecture: Microcontroller Hardware – I/O Pins, Ports – Internal and External memory – Counters and Timers – Serial data I/O – Interrupts – 8051 Assembly Language Programming: Addressing modes, Instruction set of 8051, Data transfer instructions, Arithmetic and Logical Instructions, Jump and Call Instructions interrupts and return interrupts and return interrupt handling.

ARCHITECTURE OF 8051 MICROCONTROLLER

An 8051 microcontroller has the following 11 major components:

1. ALU (Arithmetic and Logic Unit)
2. PC (Program Counter)
3. Registers
4. Timers and counters
5. Internal RAM and ROM
6. Four general purpose parallel input/output ports
7. Interrupt control logic with five sources of interrupt
8. Serial data communication
9. PSW (Program Status Word)
10. Data Pointer (DPTR)
11. Stack Pointer (SP)

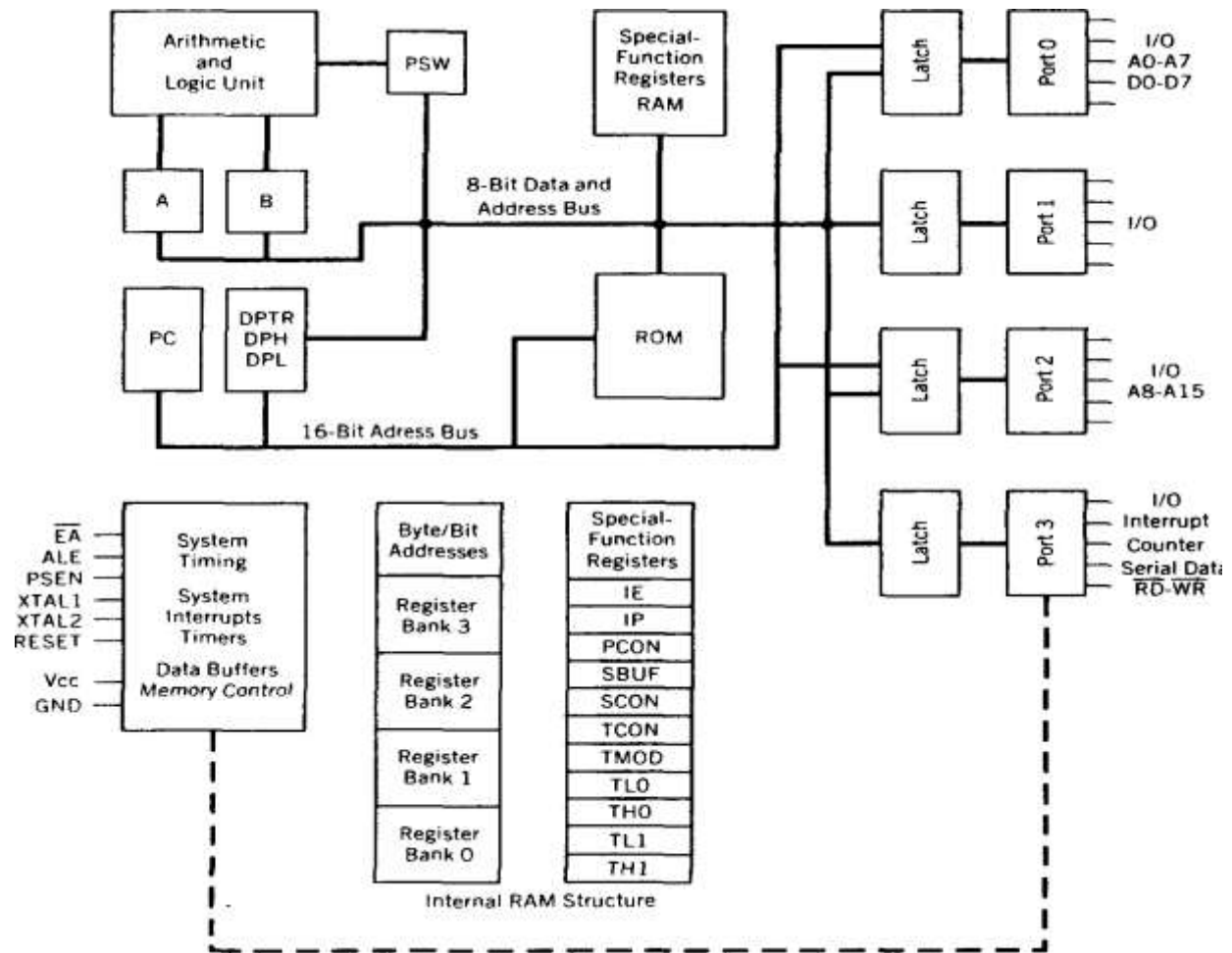


Fig 4.1: 8051- Architecture

The unique features are

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

PROGRAMMING MODEL OF 8051

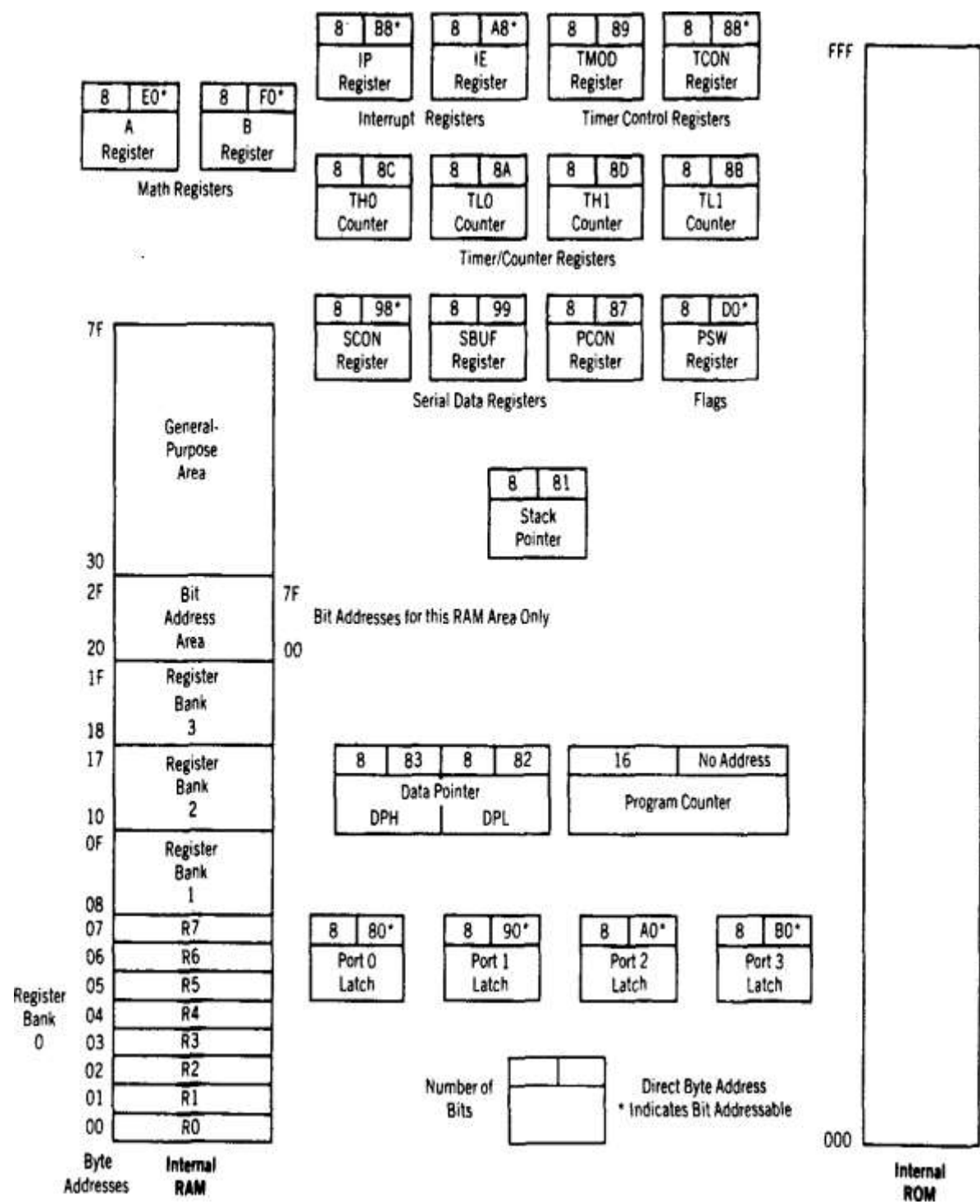


Fig 4.2: Programming Model

The above diagram shows the programming model of 8051.

The 8051 architecture consists of these specific features:

- 8 bit CPU with registers A and B
- **16 bit PC and DPTR**
- 8 bit Program status word (PSW)
- **8 bit Stack pointer(SP)**
- Internal ROM (4K)
- **Internal RAM of 128 bytes**
 - 4 register banks, each containing 8 registers
 - **16 bytes, which may be addressed at the bit level**
 - 80 bytes of general purpose data memory
- **32 input/output pins arranged as four 8 bit ports: P0-P3**
- Two 16 bit Timers/Counters: T0 and T1
- **Full duplex serial data receiver/transmitter: SBUF**
- Control Register: TCON,TMOD,SCON,PCON,IP and IE
- **Two external and three internal interrupt sources**
- Oscillator and clock circuits

Special Function Registers (SFRs)

Special Function Registers (SFRs) are a sort of control table used for running and monitoring the operation of the microcontroller. Each of these registers as well as each bit they include, has its name, address in the scope of RAM and precisely defined purpose such as timer control, interrupt control, serial communication control etc. Even though there are 128 memory locations intended to be occupied by them, the basic core, shared by all types of 8051 microcontrollers, has only 21 such registers. Rest of locations are intentionally left unoccupied in order to enable the manufacturers to further develop microcontrollers keeping them compatible with the previous versions. It also enables programs written a long time ago for microcontrollers which are out of production now to be used today.

F8									FF
F0	B								F7
E8									EF
E0	ACC								E7
D8									DF
D0	PSW								D7
C8									CF
C0									C7
B8	IP								BF
B0	P3								B7
A8	IE								AF
A0	P2								A7
98	SCON	SBUF							9F
90	P1								97
88	TCON	TMOD	TL0	TL1	TH0	TH1			8F
80	P0	SP	DPL	DPH				PCON	87

↑
Bit-addressable Registers

Fig 4.3 : SFR

A Register (Accumulator)

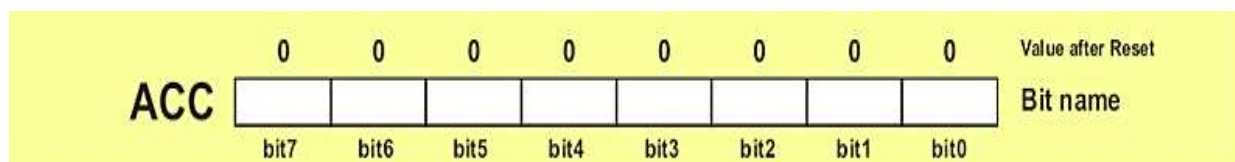


Fig 4.4: Accumulator

A register is a general-purpose register used for storing intermediate results obtained during operation. Prior to executing an instruction upon any number or operand it is necessary to store it in the accumulator first. All results obtained from arithmetical operations performed by the ALU are stored in the accumulator. Data to be moved from one register to another must go through the accumulator. In other words, the A register is the most commonly used register and it is impossible to imagine a microcontroller without it. More than half instructions used by the 8051 microcontroller use somehow the accumulator.

B Register

Multiplication and division can be performed only upon numbers stored in the A and B registers. All other instructions in the program can use this register as a spare accumulator

(A).

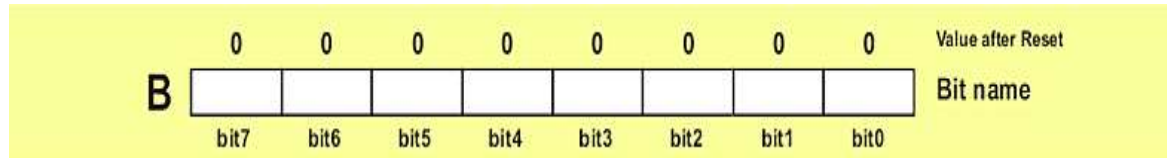


Fig 4.5: B Register

R Registers (R0-R7)

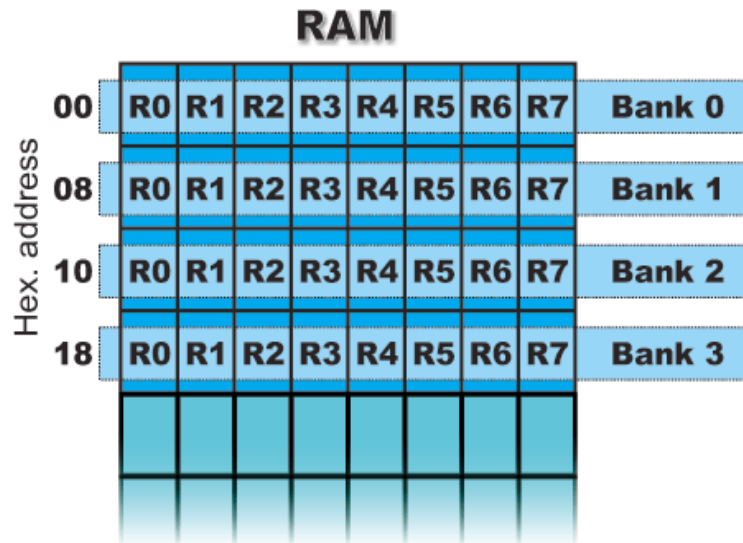


Fig 4.6: Register Banks

This is a common name for 8 general-purpose registers (R0, R1, R2 ...R7). Even though they are not true SFRs, they deserve to be discussed here because of their purpose. They occupy 4 banks within RAM. Similar to the accumulator, they are used for temporary storing variables and intermediate results during operation. Which one of these banks is to be active depends on two bits of the PSW Register. Active bank is a bank the registers of which are currently used.

The following example best illustrates the purpose of these registers. Suppose it is necessary to perform some arithmetical operations upon numbers previously stored in the R registers: $(R1+R2) - (R3+R4)$. Obviously, a register for temporary storing results of addition is needed. This is how it looks in the program:

MOV A,R3; Means: move number from R3 into accumulator
ADD A,R4; Means: add number from R4 to accumulator (result remains in accumulator)
MOV R5,A; Means: temporarily move the result from accumulator into R5
MOV A,R1; Means: move number from R1 to accumulator
ADD A,R2; Means: add number from R2 to accumulator
SUBB A,R5; Means: subtract number from R5 (there are R3+R4)

Program Status Word (PSW) Register

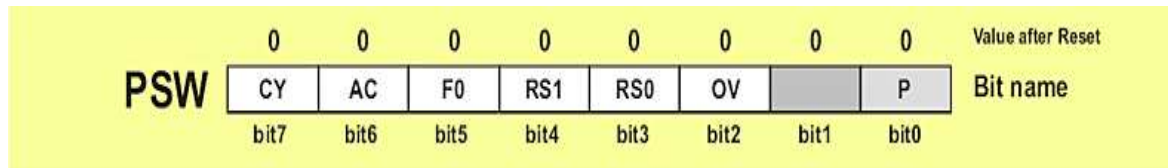


Fig 4.7: PSW

PSW register is one of the most important SFRs. It contains several status bits that reflect the current state of the CPU. Besides, this register contains Carry bit, Auxiliary Carry, two register bank select bits, Overflow flag, parity bit and user-definable status flag.

P - Parity bit. If a number stored in the accumulator is even then this bit will be automatically set (1), otherwise it will be cleared (0). It is mainly used during data transmit and receive via serial communication.

- Bit 1. This bit is intended to be used in the future versions of microcontrollers.

OV Overflow occurs when the result of an arithmetical operation is larger than 255 and cannot be stored in one register. Overflow condition causes the OV bit to be set (1). Otherwise, it will be cleared (0).

RS0, RS1 - Register bank select bits. These two bits are used to select one of four register banks of RAM. By setting and clearing these bits, registers R0-R7 are stored in one of four banks of RAM.

RS1 RS0 Space in RAM

0	0	Bank0 00h-07h
0	1	Bank1 08h-0Fh
1	0	Bank2 10h-17h
1	1	Bank3 18h-1Fh

F0 - Flag 0. This is a general-purpose bit available for use.

AC - Auxiliary Carry Flag is used for BCD operations only.

CY - Carry Flag is the (ninth) auxiliary bit used for all arithmetical operations and shift instructions.

Data Pointer Register (DPTR)

DPTR register is not a true one because it doesn't physically exist. It consists of two separate registers: DPH (Data Pointer High) and (Data Pointer Low). For this reason it may be treated as a 16-bit register or as two independent 8-bit registers. Their 16 bits are primarily used for external memory addressing. Besides, the DPTR Register is usually used for storing data and intermediate results.

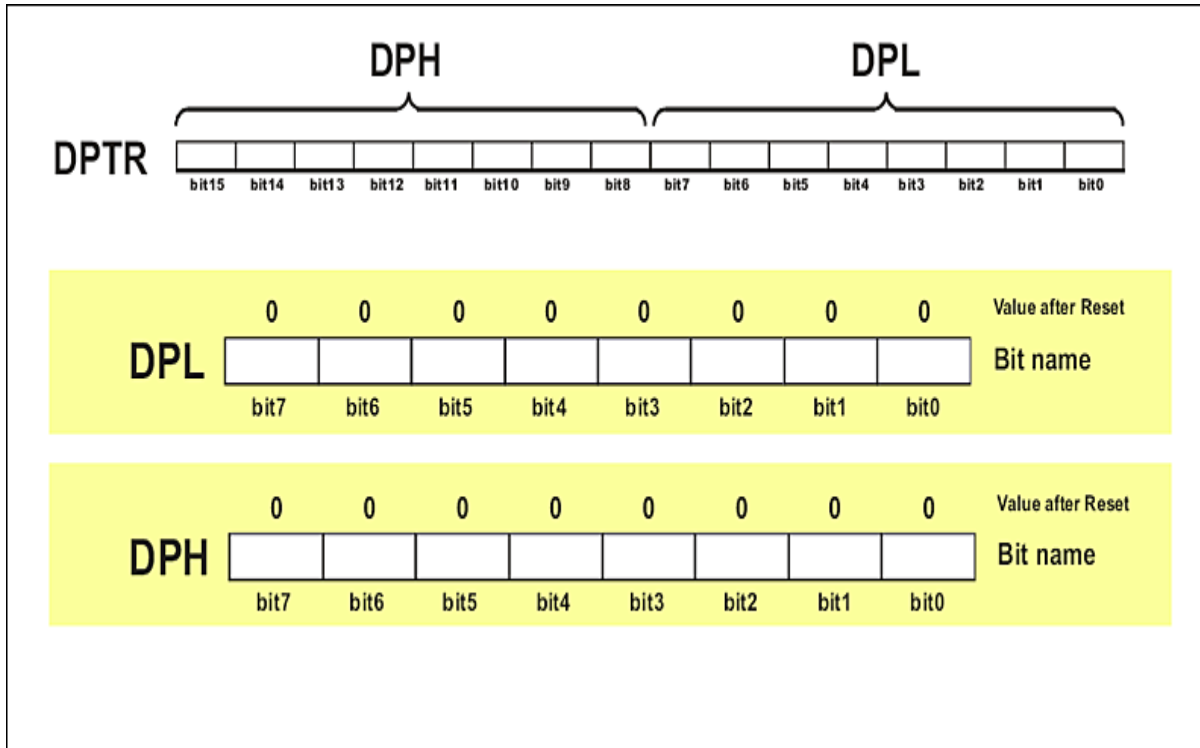


Fig 4.8: DPTR

Stack Pointer (SP) Register

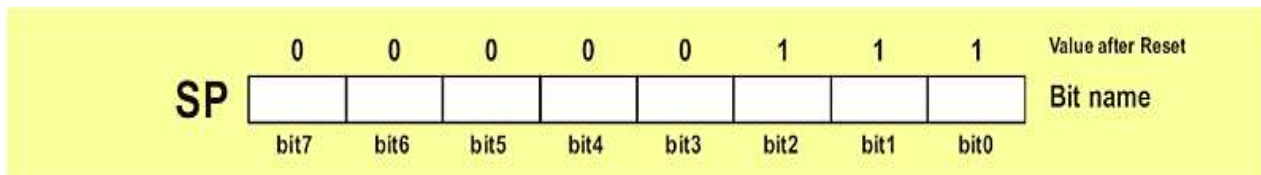


Fig 4.9: Stack Pointer

A value stored in the Stack Pointer points to the first free stack address and permits stack availability. Stack pushes increment the value in the Stack Pointer by 1. Likewise, stack pops decrement its value by 1. Upon any reset and power-on, the value 7 is stored in the Stack Pointer, which means that the space of RAM reserved for the stack starts at this location. If another value is written to this register, the entire Stack is moved to the new memory location.

P0, P1, P2, P3 - Input/Output Registers

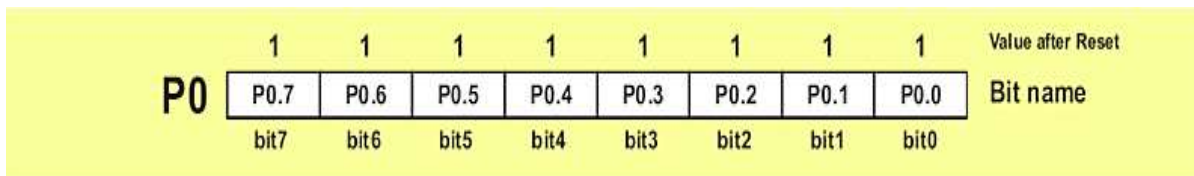


Fig 4.10: P0

If neither external memory nor serial communication system are used then 4 ports with in total of 32 input/output pins are available for connection to peripheral environment. Each bit within these ports affects the state and performance of appropriate pin of the microcontroller.

Thus, bit logic state is reflected on appropriate pin as a voltage (0 or 5 V) and vice versa, voltage on a pin reflects the state of appropriate port bit.

As mentioned, port bit state affects performance of port pins, i.e. whether they will be configured as inputs or outputs. If a bit is cleared (0), the appropriate pin will be configured as an output, while if it is set (1), the appropriate pin will be configured as an input. Upon reset and power-on, all port bits are set (1), which means that all appropriate pins will be configured as inputs.

Pinout Description

Pins 1-8: Port 1 Each of these pins can be configured as an input or an output.

Pin 9: RS A logic one on this pin disables the microcontroller and clears the contents of most registers. In other words, the positive voltage on this pin resets the microcontroller. By applying logic zero to this pin, the program starts execution from the beginning.

Pins 10-17: Port 3 Similar to port 1, each of these pins can serve as general input or output. Besides, all of them have alternative functions:

Pin 10: RXD Serial asynchronous communication input or Serial synchronous communication output.

Pin 11: TXD Serial asynchronous communication output or Serial synchronous communication clock output.

Pin 12: INT0 Interrupt 0 input.

Pin 13: INT1 Interrupt 1 input.

Pin 14: T0 Counter 0 clock

Pin 15: T1 input. Counter 1

Pin 16: WR lock input.

Write to external (additional)

Pin 17: RD RAM. Read from external RAM.

Pin 18, 19: X2, X1 Internal oscillator input and output. A quartz crystal which specifies

Operating frequency is usually connected to these pins. Instead of it, miniature ceramics resonators can also be used for frequency stability. Later versions of microcontrollers operate at a frequency of 0 Hz up to over 50 Hz.

Pin 20: GND Ground.

Pin 21-28: Port 2 If there is no intention to use external memory then these port pins are configured as general inputs/outputs. In case external memory is used, the higher address byte, i.e. addresses A8-A15 will appear on this port. Even though memory with capacity of 64Kb is not used, which means that not all eight port bits are used for its addressing, the rest of them are not available as inputs/outputs.

Pin 29: PSEN If external ROM is used for storing program then a logic zero (0) appears on it every time the microcontroller reads a byte from memory.

Pin 30: ALE Prior to reading from external memory, the microcontroller puts the lower address byte (A0-A7) on P0 and activates the ALE output. After receiving signal from the ALE pin, the external register (usually 74HCT373 or 74HCT375 add-on chip) memorizes the state of P0 and uses it as a memory chip address. Immediately after that, the ALU pin is returned its previous logic state and P0 is now used as a Data Bus. As seen, port data multiplexing is performed by means of only one additional (and cheap) integrated circuit. In other words, this port is used for both data and address transmission.

Pin 31: EA By applying logic zero to this pin, P2 and P3 are used for data and address transmission with no

PIN DIAGRAM OF 8051

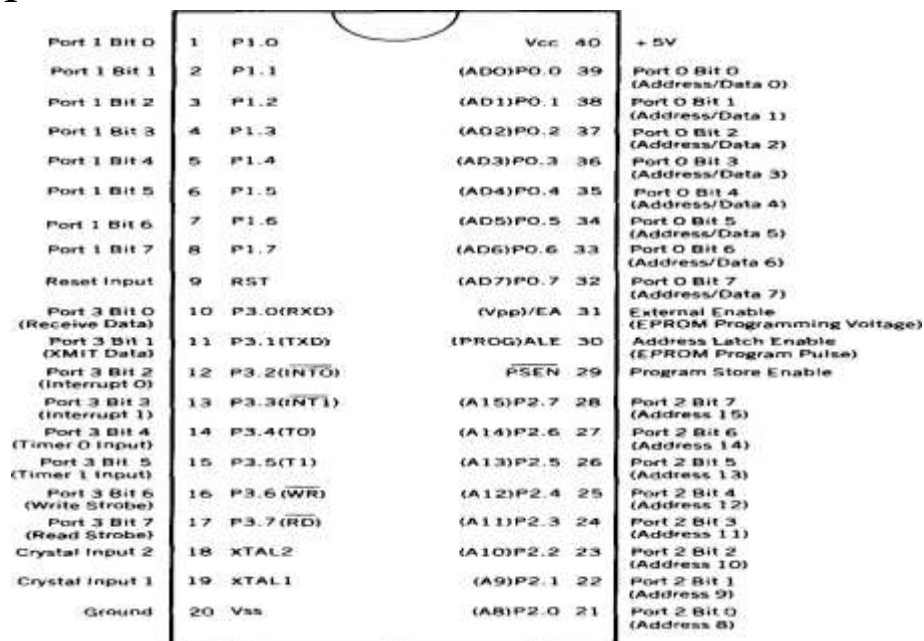


Fig 4.11: Pin Diagram-8051

Memory Organization

The 8051 has two types of memory and these are Program Memory and Data Memory. Program Memory (ROM) is used to permanently save the program being executed, while Data Memory (RAM) is used for temporarily storing data and intermediate results created and used during the operation of the microcontroller. Depending on the model in use (we are still talking about the 8051 microcontroller family in general) at most a few Kb of ROM and 128 or 256 bytes of RAM is used. However All 8051 microcontrollers have a 16-bit addressing bus and are capable of addressing 64 kb memory. It is neither a mistake nor a big ambition of engineers who were working on basic core development. It is a matter of smart memory organization which makes these microcontrollers a real “programmers’ goody”. Program Memory. The first models of the 8051 microcontroller family did not have internal program memory. It was added as an external separate chip. These models are recognizable by their label beginning with 803 (for example 8031 or 8032). All later models have a few Kbyte ROM embedded. Even though such an amount of memory is sufficient for writing most of the programs, there are situations when it is necessary to use additional memory as well. A typical example is so called lookup tables. They are used in cases when equations describing some processes are too complicated or when there is no time for solving them. In such cases all necessary estimates and approximates are executed in advance and the final results are put in the tables (similar to logarithmic tables).

How does the microcontroller handle external memory depends on the EA pin logic state:

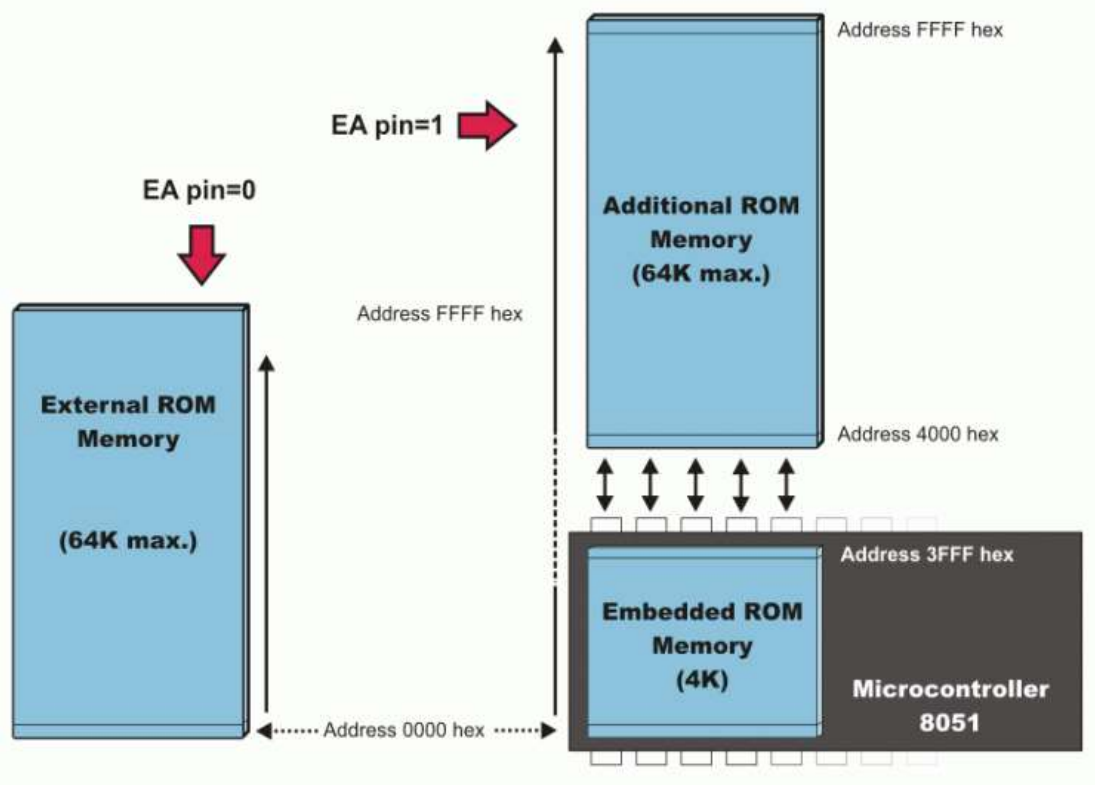


Fig 4.12: External memory EA pin

EA=0 In this case, the microcontroller completely ignores internal program memory and executes only the program stored in external memory.

EA=1 In this case, the microcontroller executes first the program from built-in ROM,

then the program stored in external memory.

In both cases, P0 and P2 are not available for use since being used for data and address transmission. Besides, the ALE and PSEN pins are also used.

Data Memory

As already mentioned, Data Memory is used for temporarily storing data and intermediate results created and used during the operation of the microcontroller. Besides, RAM memory built in the 8051 family includes many registers such as hardware counters and timers, input/output ports, serial data buffers etc. The previous models had 256 RAM locations, while for the later models this number was incremented by additional 128 registers. However, the first 256 memory locations (addresses 0-FFh) are the heart of memory common to all the models belonging to the 8051 family. Locations available to the user occupy memory space with addresses 0-7Fh, i.e. first 128 registers. This part of RAM is divided in several blocks.

The first block consists of 4 banks each including 8 registers denoted by R0-R7. Prior to accessing any of these registers, it is necessary to select the bank containing it. The next memory block (address 20h-2Fh) is bit-addressable, which means that each bit has its own address (0-7Fh). Since there are 16 such registers, this block contains in total of 128 bits with separate addresses (address of bit 0 of the 20h byte is 0, while address of bit 7 of the 2Fh byte is 7Fh). The third group of registers occupy addresses 2Fh-7Fh, i.e. 80 locations, and does not have any special functions or features.

Additional RAM

In order to satisfy the programmers' constant hunger for Data Memory, the manufacturers decided to embed an additional memory block of 128 locations into the latest versions of the 8051 microcontrollers. However, it's not as simple as it seems to be... The problem is that electronics performing addressing has 1 byte (8 bits) on disposal and is capable of reaching only the first 256 locations, therefore. In order to keep already existing 8-bit architecture and compatibility with other existing models a small trick was done.

What does it mean? It means that additional memory block shares the same addresses with locations intended for the SFRs (80h-FFh). In order to differentiate between these two physically separated memory spaces, different ways of addressing are used. The SFRs memory locations are accessed by direct addressing, while additional RAM memory locations are accessed by indirect addressing.

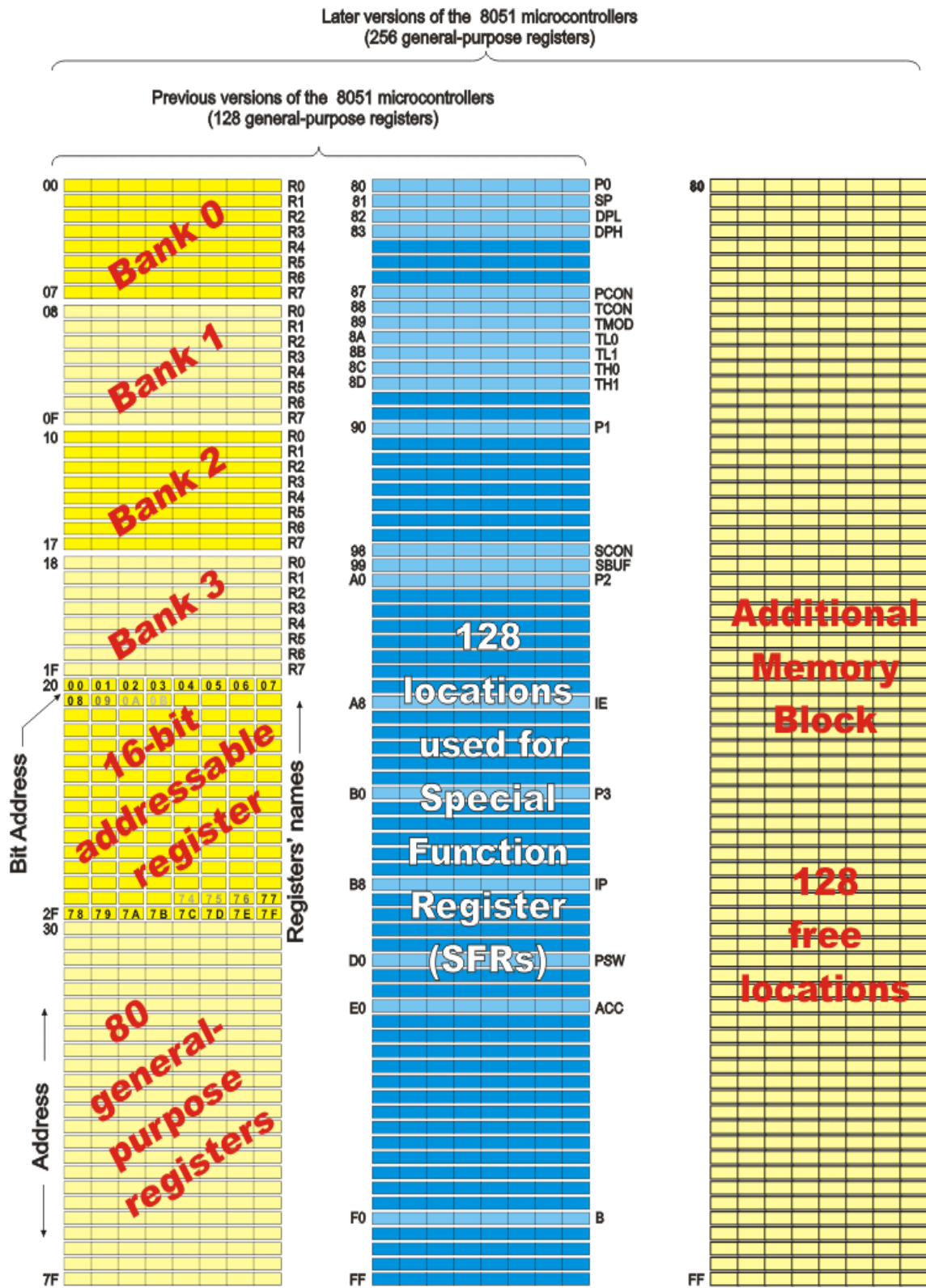


Fig 4.13 : Internal RAM

Memory expansion

In case memory (RAM or ROM) built in the microcontroller is not sufficient, it is possible to add two external memory chips with capacity of 64Kb each. P2 and P3 I/O ports are used for their addressing and data transmission.

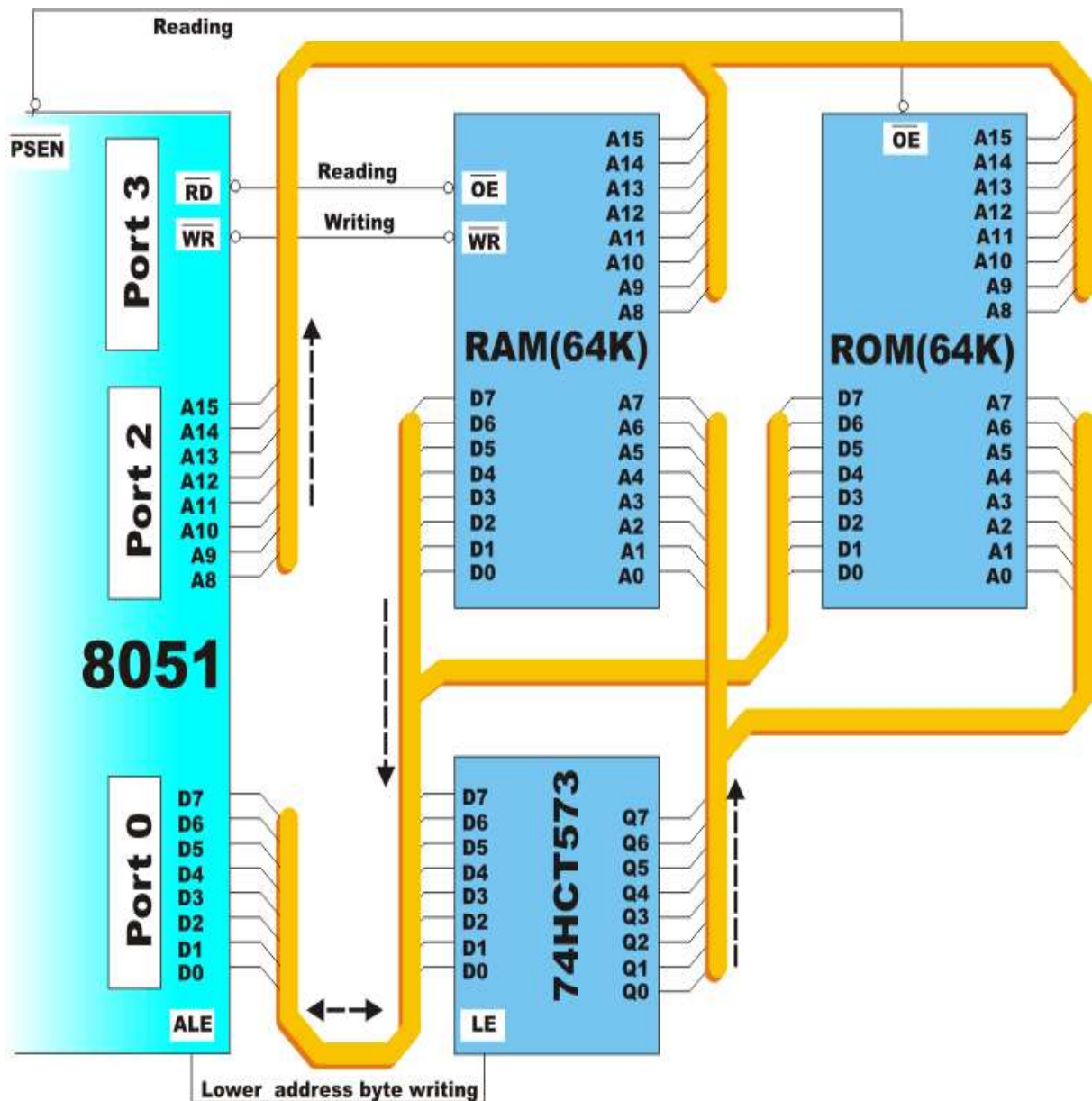


Fig 4.14: External Memory Interfacing

From the user's point of view, everything works quite simply when properly connected because most operations are performed by the microcontroller itself. The 8051 microcontroller has two pins for data read RD#(P3.7) and PSEN#. The first one is used for reading data from external data memory (RAM), while the other is used for reading data from external program memory (ROM). Both pins are active low. A typical example of memory expansion by adding RAM and ROM chips (Hardware architecture), is shown in figure above.

Even though additional memory is rarely used with the latest versions of the microcontrollers, we will describe in short what happens when memory chips are connected according to the previous schematic. The whole process described below is performed automatically.

- When the program during execution encounters an instruction which resides in external memory (ROM), the microcontroller will activate its control output ALE and set the first 8 bits of address (A0-A7) on P0. IC circuit 74HCT573 passes the first 8 bits to memory address pins.
- A signal on the ALE pin latches the IC circuit 74HCT573 and immediately afterwards 8 higher bits of address (A8-A15) appear on the port. In this way, a desired location of additional program memory is addressed. It is left over to read its content.
- Port P0 pins are configured as inputs, the PSEN pin is activated and the microcontroller reads from memory chip.

Similar occurs when it is necessary to read location from external RAM. Addressing is performed in the same way, while read and write are performed via signals appearing on the control outputs RD (is short for read) or WR (is short for write).

ADDRESSING MODES

An "addressing mode" refers to how you are addressing a given memory location. In summary, the addressing modes are as follows, with an example of each:

Immediate Addressing	MOV A,#20h
Direct Addressing	MOV A,30h
Indirect Addressing	MOV A,@R0
External Direct	MOVX
	A,@DPTR
Code Indirect	MOVC A,@A+DPTR

Each of these addressing modes provides important flexibility.

Immediate Addressing

Immediate addressing is so-named because the value to be stored in memory immediately follows the operation code in memory. That is to say, the instruction itself dictates what value will be stored in memory.

For example, the instruction:

```
MOV A,#6Ah
```

This instruction uses Immediate Addressing because the Accumulator will be loaded with the value that immediately follows; in this case 6A (hexidecimal).

Immediate addressing is very fast since the value to be loaded is included in the instruction. However, since the value to be loaded is fixed at compile-time it is not very flexible.

Direct Addressing

Direct addressing is so-named because the value to be stored in memory is obtained by directly retrieving it from another memory location. For example:

```
MOV A,30h
```

This instruction will read the data out of Internal RAM address 30 (hexidecimal) and store it in the Accumulator.

Direct addressing is generally fast since, although the value to be loaded isnt included in the instruction, it is quickly accessible since it is stored in the 8051s Internal RAM. It is also much more flexible than Immediate Addressing since the value to be loaded is whatever is found at the given address--which may be variable.

Also, it is important to note that when using direct addressing any instruction which refers to an address between 00h and 7Fh is referring to Internal Memory. Any instruction which refers to an address between 80h and FFh is referring to the SFR control registers that control the 8051 microcontroller itself.

Indirect Addressing

Indirect addressing is a very powerful addressing mode which in many cases provides an exceptional level of flexibility. Indirect addressing is also the only way to access the extra 128 bytes of Internal RAM found on an 8052.

Indirect addressing appears as follows:

```
MOV A,@R0
```

This instruction causes the 8051 to analyze the value of the R0 register. The 8051 will then load the accumulator with the value from Internal RAM which is found at the address indicated by R0.

For example, lets say R0 holds the value 40h and Internal RAM address 40h holds the value 67h. When the above instruction is executed the 8051 will check the value of R0. Since R0 holds 40h the 8051 will get the value out of Internal RAM address 40h (which holds 67h) and store it in the Accumulator. Thus, the Accumulator ends up holding 67h.

Indirect addressing always refers to Internal RAM; it never refers to an SFR. Thus, in a prior example we mentioned that SFR 99h can be used to write a value to the serial port. Thus one may think that the following would be a valid solution to write the value 1 to the serial port:

```
MOV R0,#99h ;Load the address of the serial port
MOV @R0,#01h ;Send 01 to the serial port -- WRONG!!
```

This is not valid. Since indirect addressing always refers to Internal RAM these two instructions would write the value 01h to Internal RAM address 99h on an 8052. On an 8051 these two instructions would produce an undefined result since the 8051 only has 128 bytes

of Internal RAM.

External Direct

External Memory is accessed using a suite of instructions which use what I call "External Direct" addressing. I call it this because it appears to be direct addressing, but it is used to access external memory rather than internal memory.

There are only two commands that use External Direct addressing mode:

```
MOVXA,@DPTR  
MOVX  
@DPTR,A
```

Both commands utilize DPTR. In these instructions, DPTR must first be loaded with the address of external memory that you wish to read or write. Once DPTR holds the correct external memory address, the first command will move the contents of that external memory address into the Accumulator. The second command will do the opposite: it will allow you to write the value of the Accumulator to the external memory address pointed to by DPTR.

External Indirect

External memory can also be accessed using a form of indirect addressing which I call External Indirect addressing. This form of addressing is usually only used in relatively small projects that have a very small amount of external RAM. An example of this addressing mode is:

```
MOVX @R0,A
```

Once again, the value of R0 is first read and the value of the Accumulator is written to that address in External RAM. Since the value of @R0 can only be 00h through FFh the project would effectively be limited to 256 bytes of External RAM. There are relatively simple hardware/software tricks that can be implemented to access more than 256 bytes of memory using External Indirect addressing.

INSTRUCTION SET:

The process of writing program for the microcontroller mainly consists of giving instructions (commands) in the specific order in which they should be executed in order to carry out a specific task. As electronics cannot “understand” what for example an instruction “if the push button is pressed- turn the light on” means, then a certain number of simpler and precisely defined orders that decoder can recognise must be used. All commands are known as INSTRUCTION SET. All microcontrollers compatible with the 8051 have in total of 255 instructions, i.e. 255 different words available for program writing.

At first sight, it is imposing number of odd signs that must be known by heart. However, It is not so complicated as it looks like. Many instructions are considered to be “different”, even though they perform the same operation, so there are only 111 truly different commands. For example: ADD A,R0, ADD A,R1, ... ADD A,R7 are instructions that perform the same

operation (addition of the accumulator and register). Since there are 8 such registers, each instruction is counted separately. Taking into account that all instructions perform only 53 operations (addition, subtraction, copy etc.) and most of them are rarely used in practice, there are actually 20-30 abbreviations to be learned, which is acceptable.

Types of instructions

Depending on operation they perform, all instructions are divided in several groups:

- Arithmetic Instructions
- Branch Instructions
- Data Transfer Instructions
- Logic Instructions
- Bit-oriented Instructions

The first part of each instruction, called **MNEMONIC** refers to the operation an instruction performs (copy, addition, logic operation etc.). Mnemonics are abbreviations of the name of operation being executed. For example:

- INC R1 - Means: Increment register R1 (increment register R1);
- LJMP LAB5 - Means: Long Jump LAB5 (long jump to the address marked as LAB5);
- JNZ LOOP - Means: Jump if Not Zero LOOP (if the number in the accumulator is not 0, jump to the address marked as LOOP);

The other part of instruction, called **OPERAND** is separated from mnemonic by at least one whitespace and defines data being processed by instructions. Some of the instructions have no operand, while some of them have one, two or three. If there is more than one operand in an instruction, they are separated by a comma. For example:

- RET - return from a subroutine;
- JZ TEMP - if the number in the accumulator is not 0, jump to the address marked as TEMP;
- ADD A,R3 - add R3 and accumulator;
- CJNE A,#20,LOOP - compare accumulator with 20. If they are not equal, jump to the address marked as LOOP;

Arithmetic instructions

Arithmetic instructions perform several basic operations such as addition, subtraction, division, multiplication etc. After execution, the result is stored in the first operand. For example:

ADD A,R1 - The result of addition (A+R1) will be stored in the accumulator.

Arithmetic Instructions

Mnemonic	Description	Byte Cycle	
ADD A,Rn	Adds the register to the accumulator	1	1
ADD A,direct	Adds the direct byte to the accumulator	2	2
ADD A,@Ri	Adds the indirect RAM to the accumulator	1	2
ADD A,#data	Adds the immediate data to the accumulator	2	2

ADDC A,Rn	Adds the register to the accumulator with a carry flag	1	1
ADDC A,direct	Adds the direct byte to the accumulator with a carry flag	2	2
ADDC A,@Ri	Adds the indirect RAM to the accumulator with a carry flag	1	2
ADDC A,#data	Adds the immediate data to the accumulator with a carry flag	2	2
SUBB A,Rn	Subtracts the register from the accumulator with a borrow	1	1
SUBB A,direct	Subtracts the direct byte from the accumulator with a borrow	2	2
SUBB A,@Ri	Subtracts the indirect RAM from the accumulator with a borrow	1	2
SUBB A,#data	Subtracts the immediate data from the accumulator with a borrow	2	2
INC A	Increments the accumulator by 1	1	1
INC Rn	Increments the register by 1	1	2
INC Rx	Increments the direct byte by 1	2	3
INC @Ri	Increments the indirect RAM by 1	1	3
DEC A	Decrements the accumulator by 1	1	1
DEC Rn	Decrements the register by 1	1	1
DEC Rx	Decrements the direct byte by 1	1	2
DEC @Ri	Decrements the indirect RAM by 1	2	3
INC DPTR	Increments the Data Pointer by 1	1	3
MUL AB	Multiplies A and B	1	5
DIV AB	Divides A by B	1	5
DA A	Decimal adjustment of the accumulator according to BCD code	1	1

Branch Instructions

There are two kinds of branch instructions:

Unconditional jump instructions: upon their execution a jump to a new location from where the program continues execution is executed.

Conditional jump instructions: a jump to a new program location is executed only if a specified condition is met. Otherwise, the program normally proceeds with the next instruction.

Jump Instruction Ranges

Memory Address (HEX)

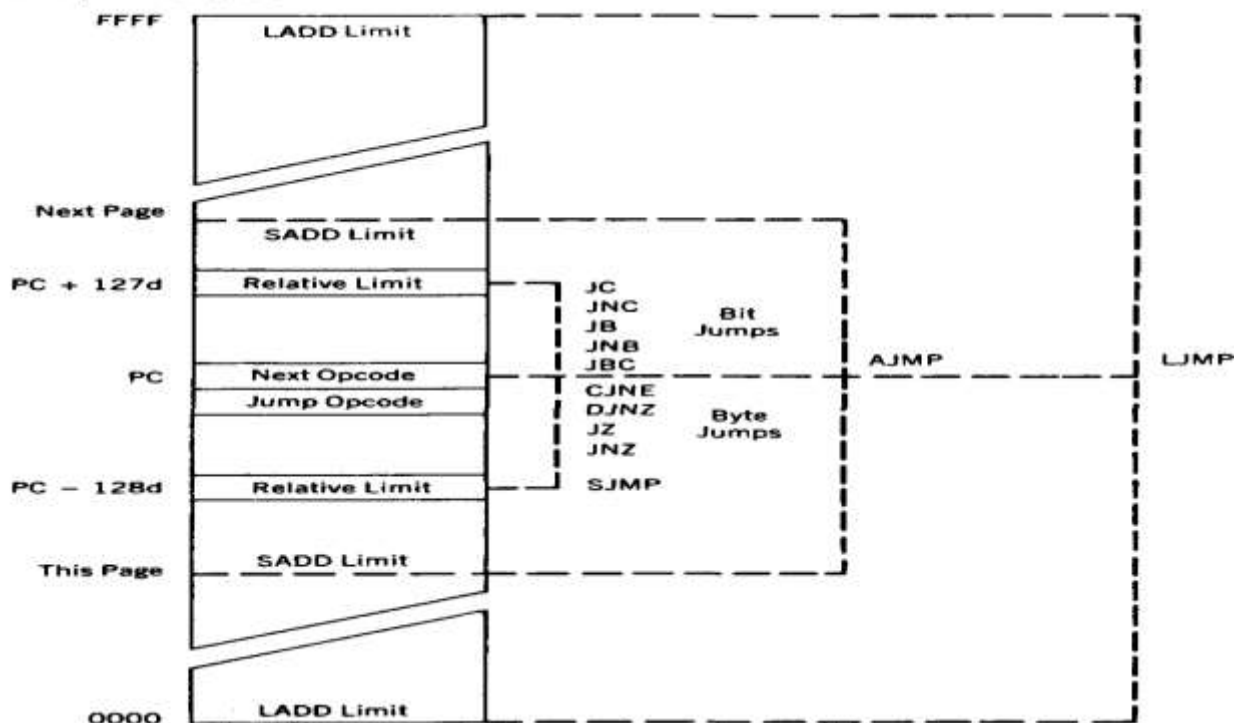


Fig 4.15: Jump Address Range

Branch Instructions

Mnemonic	Description	Byte	Cycle
ACALL addr11	Absolute subroutine call	2	6
LCALL addr16	Long subroutine call	3	6
RET	Returns from subroutine	1	4
RETI	Returns from interrupt subroutine	1	4
AJMP addr11	Absolute jump	2	3
LJMP addr16	Long jump	3	4
SJMP rel	Short jump (from -128 to +127 locations relative to the following instruction)	2	3
JC rel	Jump if carry flag is set. Short jump.	2	3
JNC rel	Jump if carry flag is not set. Short jump.	2	3
JB bit,rel	Jump if direct bit is set. Short jump.	3	4
JBC bit,rel	Jump if direct bit is set and clears bit. Short jump.	3	4
JMP @A+DPTR	Jump indirect relative to the DPTR	1	2
JZ rel	Jump if the accumulator is zero. Short jump.	2	3
JNZ rel	Jump if the accumulator is not zero. Short jump.	2	3
CJNE A,direct,rel	Compares direct byte to the accumulator and jumps if not equal. Short jump.	3	4
CJNE A,#data,rel	Compares immediate data to the accumulator and jumps if not equal. Short jump.	3	4
CJNE Rn,#data,rel	Compares immediate data to the accumulator and jumps if not equal. Short jump.	3	4

CJNE			
DJNZ Rn,rel	Decrements register and jumps if not 0. Short jump.	2	3
DJNZ Rx,rel	Decrements direct byte and jump if not 0. Short jump.	3	4
NOP	No operation	1	1

Data Transfer Instructions

Data transfer instructions move the content of one register to another. The register the content of which is moved remains unchanged. If they have the suffix “X” (MOVX), the data is exchanged with external memory.

Data Transfer Instructions

Mnemonic	Description	Byte Cycle	
MOV A,Rn	Moves the register to the accumulator	1	1
MOV A,direct	Moves the direct byte to the accumulator	2	2
MOV A,@Ri	Moves the indirect RAM to the accumulator	1	2
MOV A,#data	Moves the immediate data to the accumulator	2	2
MOV Rn,A	Moves the accumulator to the register	1	2
MOV Rn,direct	Moves the direct byte to the register	2	4
MOV Rn,#data	Moves the immediate data to the register	2	2
MOV direct,A	Moves the accumulator to the direct byte	2	3
MOV direct,Rn	Moves the register to the direct byte	2	3
MOV direct,direct	Moves the direct byte to the direct byte	3	4
MOV direct,@Ri	Moves the indirect RAM to the direct byte	2	4
MOV direct,#data	Moves the immediate data to the direct byte	3	3
MOV @Ri,A	Moves the accumulator to the indirect RAM	1	3
MOV @Ri,direct	Moves the direct byte to the indirect RAM	2	5
MOV @Ri,#data	Moves the immediate data to the indirect RAM	2	3
MOV DPTR,#data	Moves a 16-bit data to the data pointer	3	3
MOVC	Moves the code byte relative to the DPTR to the accumulator	1	3
A,@A+DPTR	(address=A+DPTR)		
MOVC A,@A+PC	Moves the code byte relative to the PC to the accumulator (address=A+PC)	1	3
MOVX A,@Ri	Moves the external RAM (8-bit address) to the accumulator	1	3-10
OVX A,@DPTR	Moves the external RAM (16-bit address) to the accumulator	1	3-10
MOVX @Ri,A	Moves the accumulator to the external RAM (8-bit address)	1	4-11
MOVX @DPTR,A	Moves the accumulator to the external RAM (16-bit address)	1	4-11
PUSH direct	Pushes the direct byte onto the stack	2	4
POP direct	Pops the direct byte from the stack	2	3
XCH A,Rn	Exchanges the register with the accumulator	1	2
XCH A,direct	Exchanges the direct byte with the accumulator	2	3
XCH A,@Ri	Exchanges the indirect RAM with the accumulator	1	3

XCHD A,@Ri **Exchanges the low-order nibble indirect RAM with the accumulator** **1 3**

Logic Instructions

Logic instructions perform logic operations upon corresponding bits of two registers. After execution, the result is stored in the first operand.

Logic Instructions

Mnemonic	Description	Byte Cycle	
ANL A,Rn	AND register to accumulator	1	1
ANL A,direct	AND direct byte to accumulator	2	2
ANL A,@Ri	AND indirect RAM to accumulator	1	2
ANL A,#data	AND immediate data to accumulator	2	2
ANL direct,A	AND accumulator to direct byte	2	3
ANL direct,#data	AND immediate data to direct register	3	4
ORL A,Rn	OR register to accumulator	1	1
ORL A,direct	OR direct byte to accumulator	2	2
ORL A,@Ri	OR indirect RAM to accumulator	1	2
ORL direct,A	OR accumulator to direct byte	2	3
ORL direct,#data	OR immediate data to direct byte	3	4
XRL A,Rn	Exclusive OR register to accumulator	1	1
XRL A,direct	Exclusive OR direct byte to accumulator	2	2
XRL A,@Ri	Exclusive OR indirect RAM to accumulator	1	2
XRL A,#data	Exclusive OR immediate data to accumulator	2	2
XRL direct,A	Exclusive OR accumulator to direct byte	2	3
XORL direct,#data	Exclusive OR immediate data to direct byte	3	4
CLR A	Clears the accumulator	1	1
CPL A	Complements the accumulator (1=0, 0=1)	1	1
SWAP A	Swaps nibbles within the accumulator	1	1
RL A	Rotates bits in the accumulator left	1	1
RLC A	Rotates bits in the accumulator left through carry	1	1
RR A	Rotates bits in the accumulator right	1	1
RRC A	Rotates bits in the accumulator right through carry	1	1

Bit-oriented Instructions

Similar to logic instructions, bit-oriented instructions perform logic operations. The difference is that these are performed upon single bits.

Bit-oriented Instructions

Mnemonic	Description	Byte Cycle	
CLR C	Clears the carry flag	1	1
CLR bit	Clears the direct bit	2	3
SETB C	Sets the carry flag	1	1
SETB bit	Sets the direct bit	2	3
CPL C	Complements the carry flag	1	1
CPL bit	Complements the direct bit	2	3
ANL C,bit	AND direct bit to the carry flag	2	2
ANL C,/bit	AND complements of direct bit to the carry flag	2	2
ORL C,bit	OR direct bit to the carry flag	2	2
ORL C,/bit	OR complements of direct bit to the carry flag	2	2
MOV C,bit	Moves the direct bit to the carry flag	2	2
MOV bit,C	Moves the carry flag to the direct bit	2	3

8051 Microcontroller Interrupts

There are five interrupt sources for the 8051, which means that they can recognize 5 different events that can interrupt regular program execution. Each interrupt can be enabled or disabled by setting bits of the IE register. Likewise, the whole interrupt system can be disabled by clearing the EA bit of the same register. Refer to figure below.

Now, it is necessary to explain a few details referring to external interrupts- INT0 and INT1. If the IT0 and IT1 bits of the TCON register are set, an interrupt will be generated on high to low transition, i.e. on the falling pulse edge (only in that moment). If these bits are cleared, an interrupt will be continuously executed as far as the pins are held low.

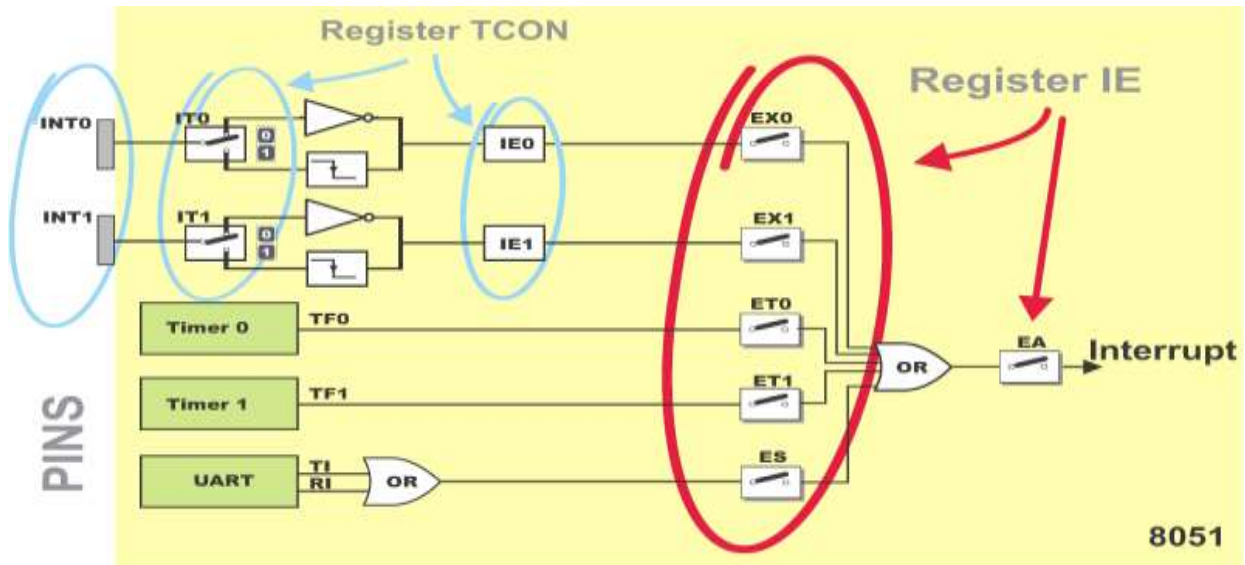


Fig 4.16:TCON

IE Register (Interrupt Enable)

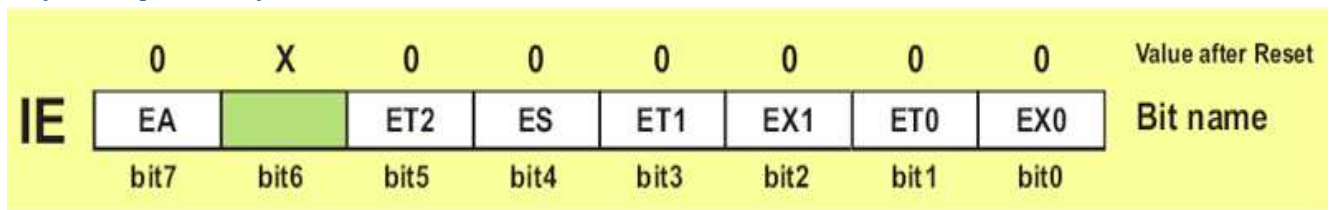


Fig 4.17: IE

- **EA** - global interrupt enable/disable:
 - 0 - disables all interrupt requests.
 - 1 - enables all individual interrupt requests.
- **ES** - enables or disables serial interrupt:
 - 0 - UART system cannot generate an interrupt.
 - 1 - UART system enables an interrupt.
- **ET1** - bit enables or disables Timer 1 interrupt:
 - 0 - Timer 1 cannot generate an interrupt.
 - **1 - Timer 1 enables an interrupt.**
- **EX1** - bit enables or disables external 1 interrupt:
 - 0 - change of the pin INT0 logic state cannot generate an interrupt.
 - 1 - enables an external interrupt on the pin INT0 state change.
- **ET0** - bit enables or disables timer 0 interrupt:
 - 0 - Timer 0 cannot generate an interrupt.
 - 1 - enables timer 0 interrupt.
- **EX0** - bit enables or disables external 0 interrupt:
 - 0 - change of the INT1 pin logic state cannot generate an interrupt.
 - 1 - enables an external interrupt on the pin INT1 state change.

Interrupt Priorities

It is not possible to foresee when an interrupt request will arrive. If several interrupts are enabled, it may happen that while one of them is in progress, another one is requested. In order

that the microcontroller knows whether to continue operation or meet a new interrupt request, there is a priority list instructing it what to do.

The priority list offers 3 levels of interrupt priority:

1. Reset! The absolute master. When a reset request arrives, everything is stopped and the microcontroller restarts.
2. Interrupt priority 1 can be disabled by Reset only.
3. Interrupt priority 0 can be disabled by both Reset and interrupt priority 1.

The IP Register (Interrupt Priority Register) specifies which one of existing interrupt sources have higher and which one has lower priority. Interrupt priority is usually specified at the beginning of the program. According to that, there are several possibilities:

- If an interrupt of higher priority arrives while an interrupt is in progress, it will be immediately stopped and the higher priority interrupt will be executed first.
 - If two interrupt requests, at different priority levels, arrive at the same time then the higher priority interrupt is serviced first.
 - If the both interrupt requests, at the same priority level, occur one after another, the one which came later has to wait until routine being in progress ends.
 - If two interrupt requests of equal priority arrive at the same time then the interrupt to be serviced is selected according to the following priority list:
1. External interrupt INT0
 2. Timer 0 interrupt
 3. External Interrupt INT1
 4. Timer 1 interrupt
 5. Serial Communication Interrupt

IP Register (Interrupt Priority)

The IP register bits specify the priority level of each interrupt (high or low priority).

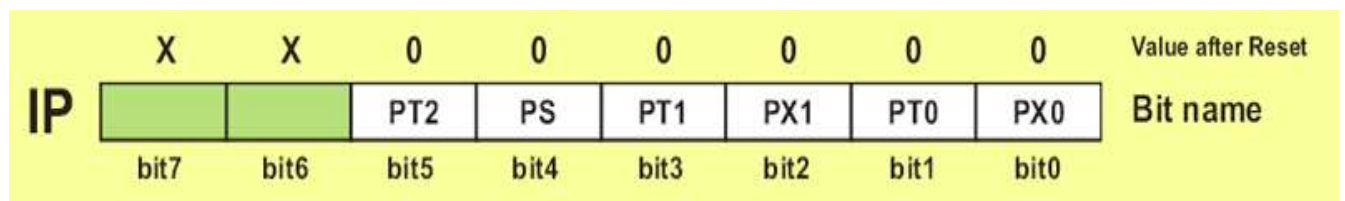


Fig 4.18: IP

- **PS** - Serial Port Interrupt priority bit
 - Priority 0
 - Priority 1
- **PT1** - Timer 1 interrupt priority
 - Priority 0
 - Priority 1
- **PX1** - External Interrupt INT1 priority

- Priority 0
 - Priority 1
- **PT0** - Timer 0 Interrupt Priority
 - Priority 0
 - Priority 1
- **PX0** - External Interrupt INT0 Priority
 - Priority 0
 - Priority 1

Handling Interrupt

When an interrupt request arrives the following occurs:

1. Instruction in progress is ended.
2. The address of the next instruction to execute is pushed on the stack.
3. Depending on which interrupt is requested, one of 5 vectors (addresses) is written to the program counter in accordance to the table below:
- 4.

Interrupt Source	Vector (address)
IE0	3 h
TF0	B h
TF1	1B h
RI, TI	23 h

All addresses are in hexadecimal format

5. These addresses store appropriate subroutines processing interrupts. Instead of them, there are usually jump instructions specifying locations on which these subroutines reside.
6. When an interrupt routine is executed, the address of the next instruction to execute is popped from the stack to the program counter and interrupted program resumes operation from where it left off.

Reset

Reset occurs when the RS pin is supplied with a positive pulse in duration of at least 2 machine cycles (24 clock cycles of crystal oscillator). After that, the microcontroller generates an internal reset signal which clears all SFRs, except SBUF registers, Stack Pointer and ports (the state of the first two ports is not defined, while FF value is written to the ports configuring all their pins as inputs). Depending on surrounding and purpose of device, the RS pin is usually connected to a power-on reset push button or circuit or to both of them. Figure below illustrates one of the simplest circuit providing safe power-on reset.

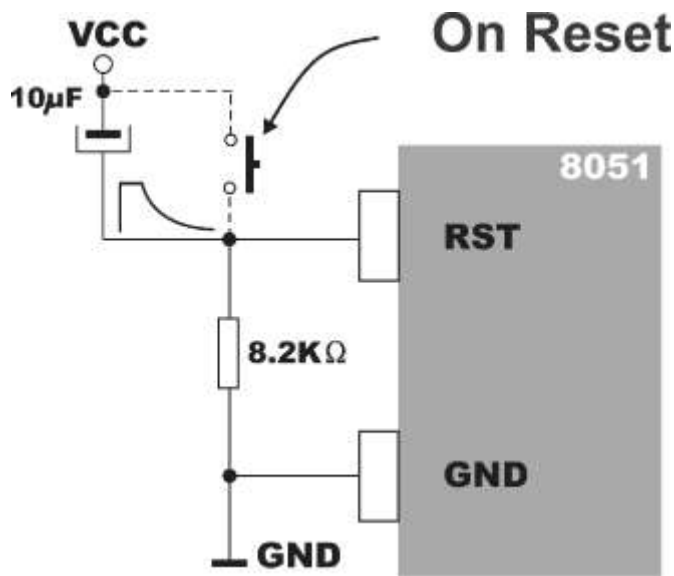


Fig 4.19:Reset

Basically, everything is very simple: after turning the power on, electrical capacitor is being charged for several milliseconds through a resistor connected to the ground. The pin is driven high during this process. When the capacitor is charged, power supply voltage is already stable and the pin remains connected to the ground, thus providing normal operation of the microcontroller. Pressing the reset button causes the capacitor to be temporarily discharged and the microcontroller is reset. When released, the whole process is repeated...

Through the program- step by step...

Microcontrollers normally operate at very high speed. The use of 12 Mhz quartz crystal enables 1.00.00 instructions to be executed per second. Basically, there is no need for higher operating rate. In case it is needed, it is easy to built in a crystal for high frequency. The problem arises when it is necessary to slow down the operation of the microcontroller. For example during testing in real environment when it is necessary to execute several instructions step by step in order to check I/O pins' logic state.

Interrupt system of the 8051 microcontroller practically stops operation of the microcontroller and enables instructions to be executed one after another by pressing the button. Two interrupt features enable that:

- Interrupt request is ignored if an interrupt of the same priority level is in progress.
- Upon interrupt routine execution, a new interrupt is not executed until at least one instruction from the main program is executed.

In order to use this in practice, the following steps should be done:

1. External interrupt sensitive to the signal level should be enabled (for example INT0).
2. Three following instructions should be inserted into the program (at the 03hex. address):

JNB P3.2\$	← Means: wait here until the pin P3.2 (INT0) is set to “1”.
JB P3.2\$	← Means: wait here until the pin P3.2 (INT0) is set to “0”.
RETI	← Means: go back to the main program

What is going on? As soon as the P3.2 pin is cleared (for example, by pressing the button), the microcontroller will stop program execution and jump to the 03hex address will be executed. This address stores a short interrupt routine consisting of 3 instructions.

The first instruction is executed until the push button is realised (logic one (1) on the P3.2 pin). The second instruction is executed until the push button is pressed again. Immediately after that, the RETI instruction is executed and the processor resumes operation of the main program. Upon execution of any program instruction, the interrupt INT0 is generated and the whole procedure is repeated (push button is still pressed). In other words, one button press - one instruction

INPUT/OUTPUT PORTS

All 8051 microcontrollers have 4 I/O ports each comprising 8 bits which can be configured as inputs or outputs. Accordingly, in total of 32 input/output pins enabling the microcontroller to be connected to peripheral devices are available for use.

Pin configuration, i.e. whether it is to be configured as an input (1) or an output (0), depends on its logic state. In order to configure a microcontroller pin as an output, it is necessary to apply a logic zero (0) to appropriate I/O port bit. In this case, voltage level on appropriate pin will be 0.

Similarly, in order to configure a microcontroller pin as an input, it is necessary to apply a logic one (1) to appropriate port. In this case, voltage level on appropriate pin will be 5V (as is the case with any TTL input). This may seem confusing but don't lose your patience. It all becomes clear after studying simple electronic circuits connected to an I/O pin.

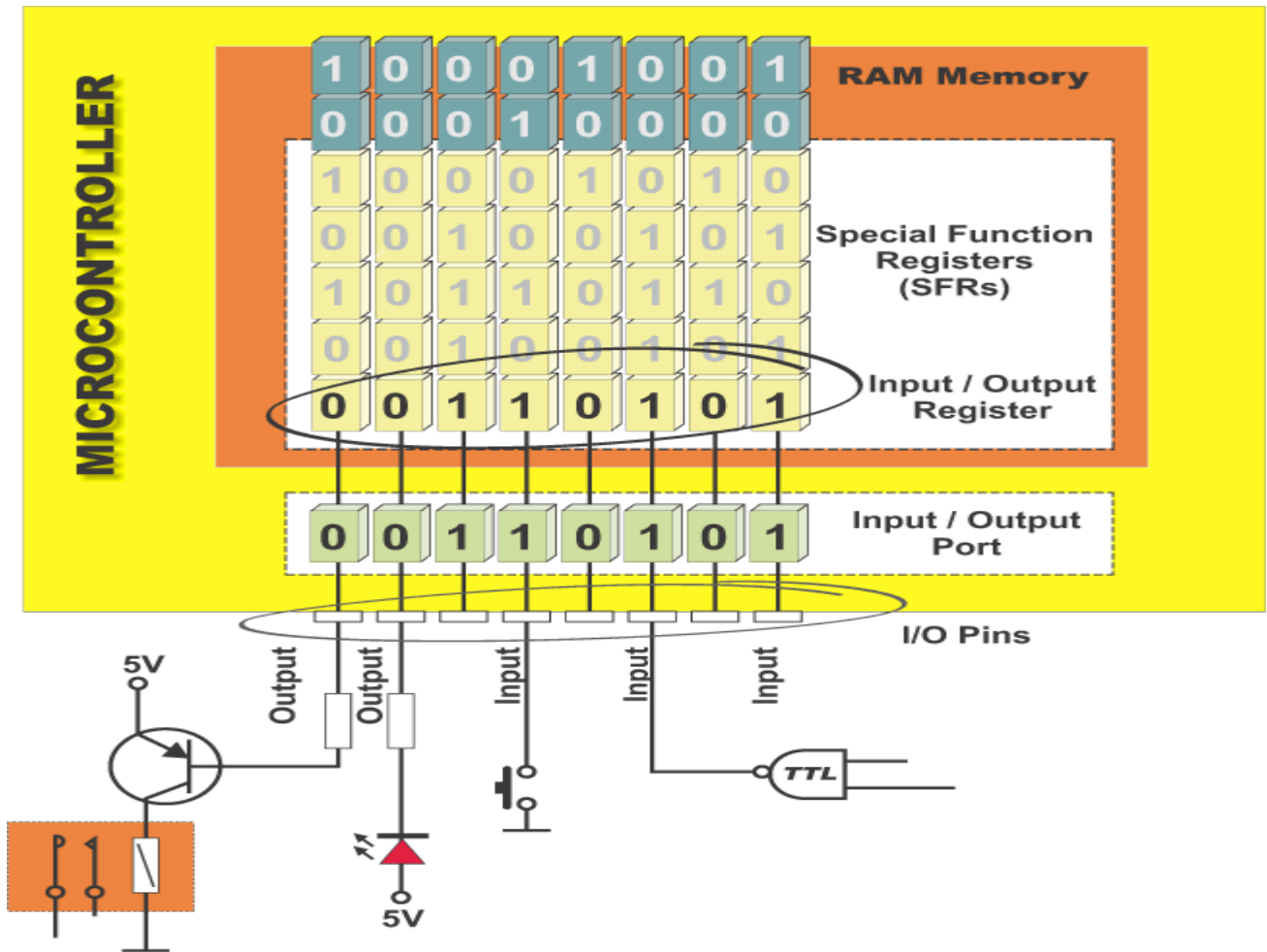


Fig 4.20: Input / Output

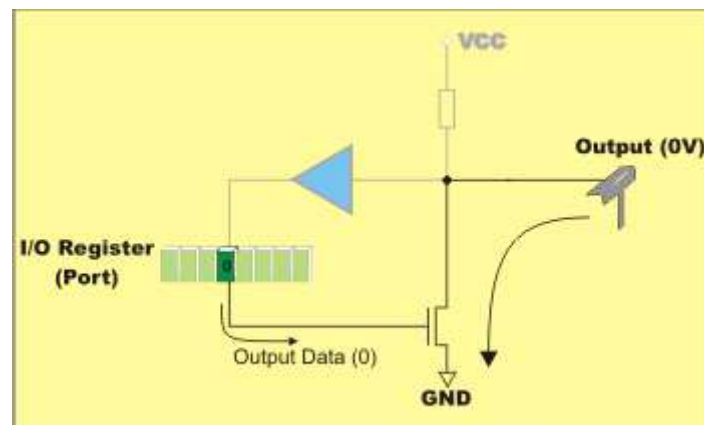


Fig 4.21: Output

Input/Output

(I/O)

pin

Figure above illustrates a simplified schematic of all circuits within the microcontroller connected to one of its pins. It refers to all the pins except those of the P0 port which do not have pull-up resistors built-in.

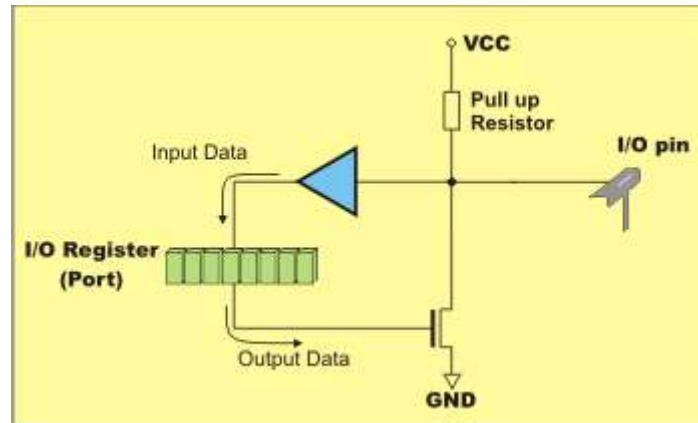


Fig 4.22: Input / output

Output

pin

A logic zero (0) is applied to a bit of the P register. The output FE transistor is turned on, thus connecting the appropriate pin to ground.

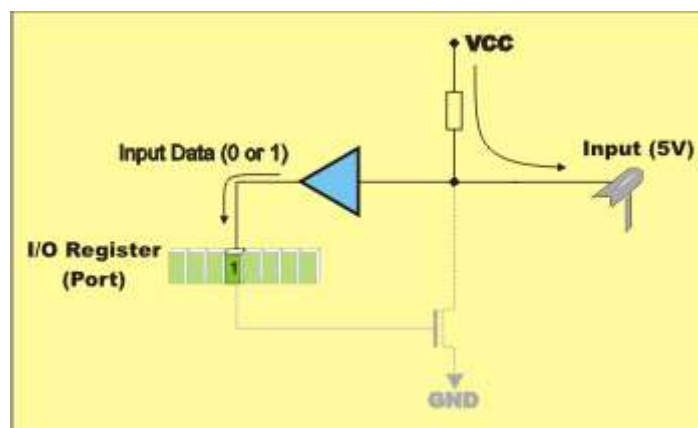


Fig 4.23 output

Hardware interrupts of 8085

Input pin

A logic one (1) is applied to a bit of the P register. The output FE transistor is turned off and the appropriate pin remains connected to the power supply voltage over a pull-up resistor of high resistance.

Logic state (voltage) of any pin can be changed or read at any moment. A logic zero (0) and logic one (1) are not equal. A logic one (0) represents a short circuit to ground. Such a pin acts as an output.

A logic one (1) is “loosely” connected to the power supply voltage over a resistor of high resistance. Since this voltage can be easily “reduced” by an external signal, such a pin acts as an input.

The P0 port is characterized by two functions. If external memory is used then the lower address byte (addresses A0-A7) is applied on it. Otherwise, all bits of this port are configured as inputs/outputs.

The other function is expressed when it is configured as an output. Unlike other ports consisting of pins with built-in pull-up resistor connected by its end to 5 V power supply, pins of this port have this resistor left out. This apparently small difference has its consequences:

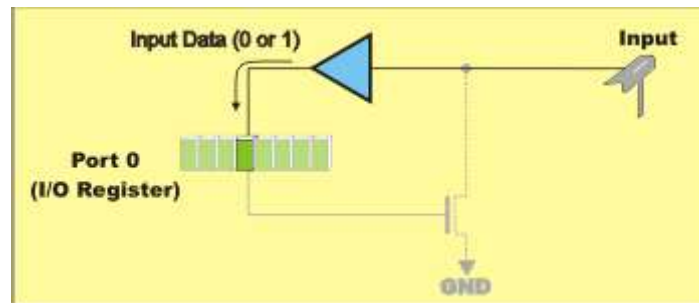


Fig 4.24: Port 0 configuration-input

If any pin of this port is configured as an input then it acts as if it “floats”. Such an input has unlimited input resistance and indetermined potential.

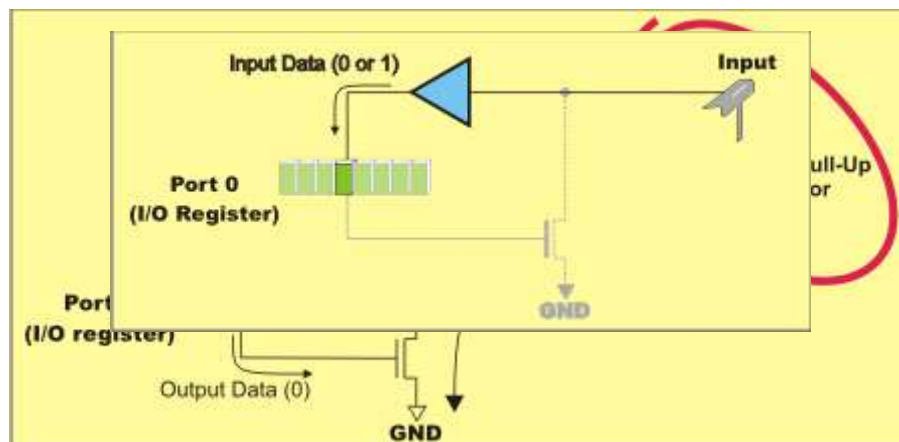


Fig 4.25: Port 0 configuration-output

When the pin is configured as an output, it acts as an “open drain”. By applying logic 0 to a port bit, the appropriate pin will be connected to ground (0V). By applying logic 1, the external output will keep on “floating”. In order to apply logic 1 (5V) on this output pin, it is necessary to built in an external pull-up resistor.

Only in case P0 is used for addressing external memory, the microcontroller will provide internal power supply source in order to supply its pins with logic one. There is no need to add external pull-up resistors.

Port 1

P1 is a true I/O port, because it doesn't have any alternative functions as is the case with P0, but can be configured as general I/O only. It has a pull-up resistor built-in and is completely compatible with TTL circuits.

Port 2

P2 acts similarly to P0 when external memory is used. Pins of this port occupy addresses intended for external memory chip. This time it is about the higher address byte with addresses A8-A15. When no memory is added, this port can be used as a general input/output port showing features similar to P1.

Port 3

All port pins can be used as general I/O, but they also have an alternative function. In order to use these alternative functions, a logic one (1) must be applied to appropriate bit of the P3 register. In terms of hardware, this port is similar to P0, with the difference that its pins have a pull-up resistor built-in.

Pin's Current limitations

When configured as outputs (logic zero (0)), single port pins can receive a current of 10mA. If all 8 bits of a port are active, a total current must be limited to 15mA (port P0: 26mA). If all ports (32 bits) are active, total maximum current must be limited to 71mA. When these pins are configured as inputs (logic 1), built-in pull-up resistors provide very weak current, but strong enough to activate up to 4 TTL inputs of LS series.

As seen from description of some ports, even though all of them have more or less similar architecture, it is necessary to pay attention to which of them is to be used for what and how.

For example, if they shall be used as outputs with high voltage level (5V), then P0 should be avoided because its pins do not have pull-up resistors, thus giving low logic level only. When using other ports, one should have in mind that pull-up resistors have a relatively high resistance, so that their pins can give a current of several hundreds microamperes only.

Counters and Timers

As you already know, the microcontroller oscillator uses quartz crystal for its operation. As the frequency of this oscillator is precisely defined and very stable, pulses it generates are always of the same width, which makes them ideal for time measurement. Such crystals are also used in quartz watches. In order to measure time between two events it is sufficient to count up pulses coming from this oscillator. That is exactly what the timer does. If the timer is properly programmed, the value stored in its register will be incremented (or decremented) with each coming pulse, i.e. once per each machine cycle. A single machine-cycle instruction lasts for 12 quartz oscillator periods, which means that by embedding

quartz with oscillator frequency of 12MHz, a number stored in the timer register will be changed million times per second, i.e. each microsecond.

The 8051 microcontroller has 2 timers/counters called T0 and T1. As their names suggest, their main purpose is to measure time and count external events. Besides, they can be used for generating clock pulses to be used in serial communication, so called Baud Rate.

Timer T0

As seen in figure below, the timer T0 consists of two registers – TH0 and TL0 representing a low and a high byte of one 16-digit binary number.

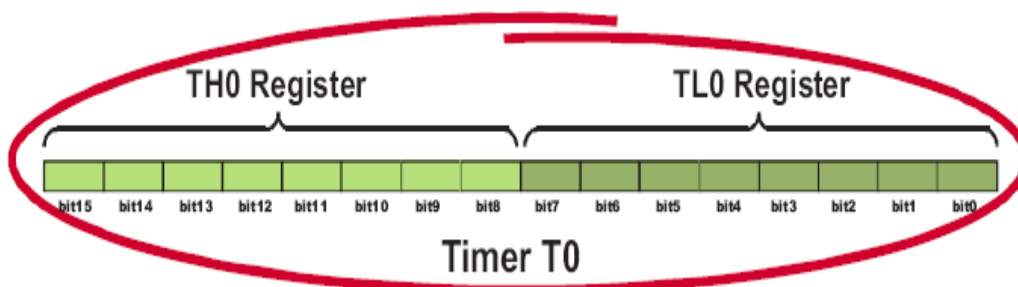


Fig 4.26: Timer 0

Accordingly, if the content of the timer T0 is equal to 0 ($T0=0$) then both registers it consists of will contain 0. If the timer contains for example number 1000 (decimal), then the TH0 register (high byte) will contain the number 3, while the TL0 register (low byte) will contain decimal number 232.

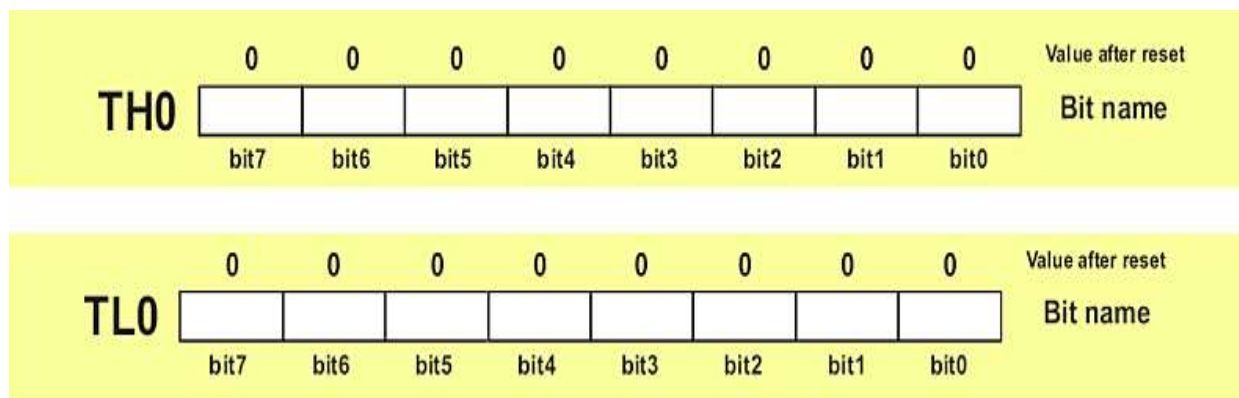


Fig 4.27: Timer 0-TL0 & TH0

Formula used to calculate values in these two registers is very

simple: $TH0 \times 256 + TL0 = T$

Matching the previous example it would be as

follows: $3 \times 256 + 232 = 1000$

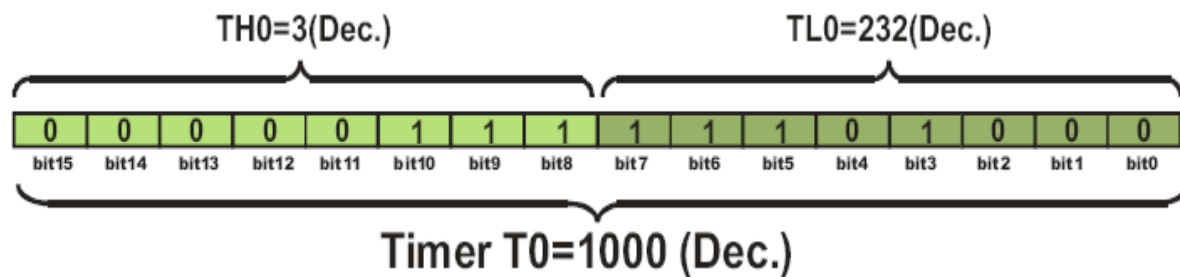


Fig 4.28: Timer 0

Since the timer T0 is virtually 16-bit register, the largest value it can store is 65 535. In case of exceeding this value, the timer will be automatically cleared and counting starts from 0. This condition is called an overflow. Two registers TMOD and TCON are closely connected to this timer and control its operation.

TMOD Register (Timer Mode)

The TMOD register selects the operational mode of the timers T0 and T1. As seen in figure below, the low 4 bits (bit0 - bit3) refer to the timer 0, while the high 4 bits (bit4 - bit7) refer to the timer 1. There are 4 operational modes and each of them is described herein.

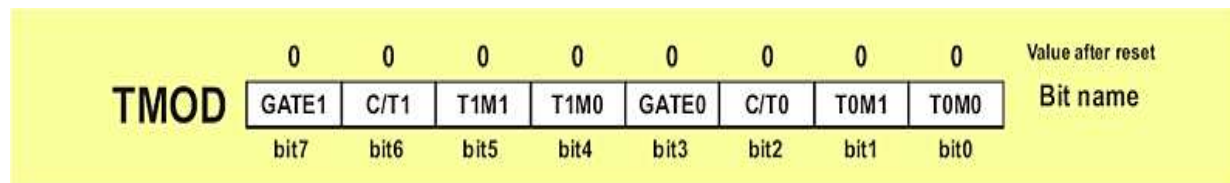


Fig 4.29: TMOD

Bits of this register have the following function:

- **GATE1** enables and disables Timer 1 by means of a signal brought to the INT1 pin (P3.3):
 - **1** - Timer 1 operates only if the INT1 bit is set.
 - **0** - Timer 1 operates regardless of the logic state of the INT1 bit.
- **C/T1** selects pulses to be counted up by the timer/counter 1:
 - **1** - Timer counts pulses brought to the T1 pin (P3.5).
 - **0** - **Timer counts pulses from internal oscillator.**
- **T1M1, T1M0** These two bits select the operational mode of the Timer 1.

T1M1 T1M0 Mode Description

0	0	0	13-bit timer
0	1	1	16-bit timer
1	0	2	8-bit auto-reload

1 1 3 Split mode

- **GATE0** enables and disables Timer 1 using a signal brought to the INT0 pin (P3.2):
 - **1** - Timer 0 operates only if the INT0 bit is set.
 - **0** - Timer 0 operates regardless of the logic state of the INT0 bit.
- **C/T0** selects pulses to be counted up by the timer/counter 0:
 - **1** - Timer counts pulses brought to the T0 pin (P3.4).
 - **0** - **Timer counts pulses from internal oscillator.**
- **T0M1,T0M0** These two bits select the oprtaional mode of the Timer 0.

T0M1	T0M0	Mode	Description
0	0	0	13-bit timer
0	1	1	16-bit timer
1	0	2	8-bit auto-reload
1	1	3	Split mode

Timer 0 in mode 0 (13-bit timer)

This is one of the rarities being kept only for the purpose of compatibility with the prevuios versions of microcontrollers. This mode configures timer 0 as a 13-bit timer which consists of all8 bits of TH0 and the lower 5 bits of TL0. As a result, the Timer 0 uses only 13 of 16 bits. How does it operate? Each coming pulse causes the lower register bits to change their states. After receiving 32 pulses, this register is loaded and automatically cleared, while the higher byte (TH0)is incremented by 1. This process is repeated until registers count up 8192 pulses. After that, both registers are cleared and counting starts from 0.

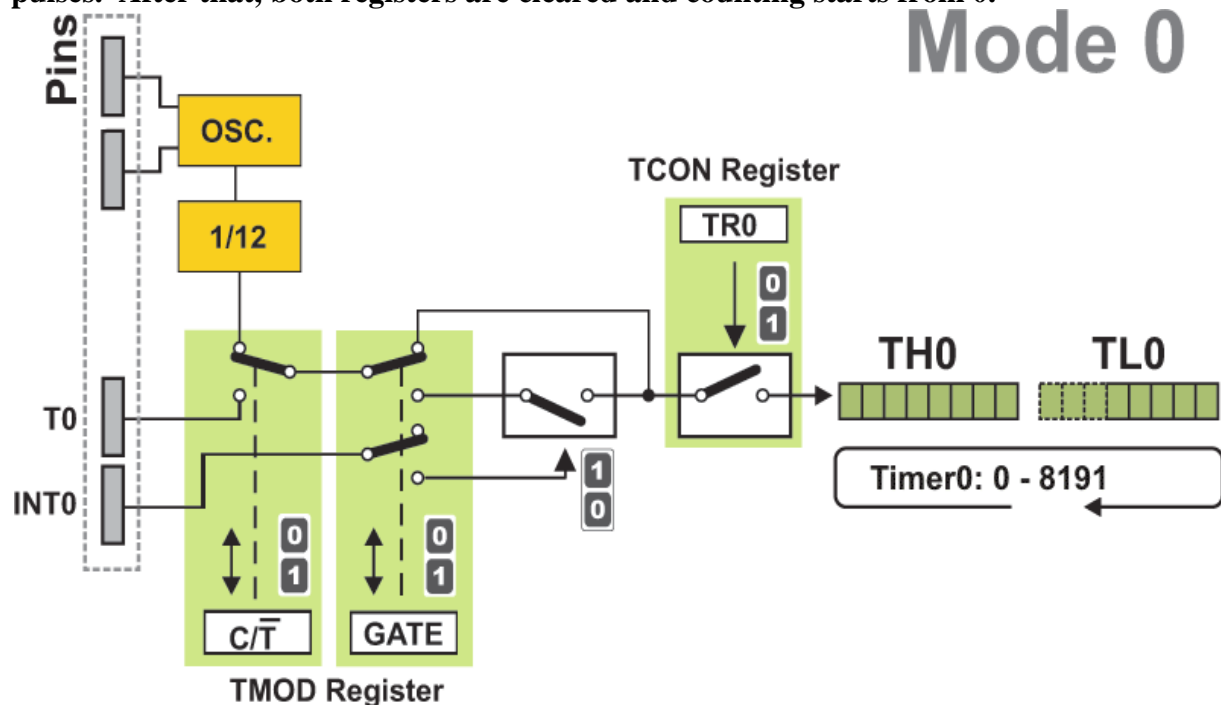


Fig 4.30: Timer Mode 0

Timer 0 in mode 1 (16-bit timer)

Mode 1 configures timer 0 as a 16-bit timer comprising all the bits of both registers TH0 and TL0. That's why this is one of the most commonly used modes. Timer operates in the same way as in mode 0, with the difference that the registers count up to 65536 as allowable by the 16 bits.

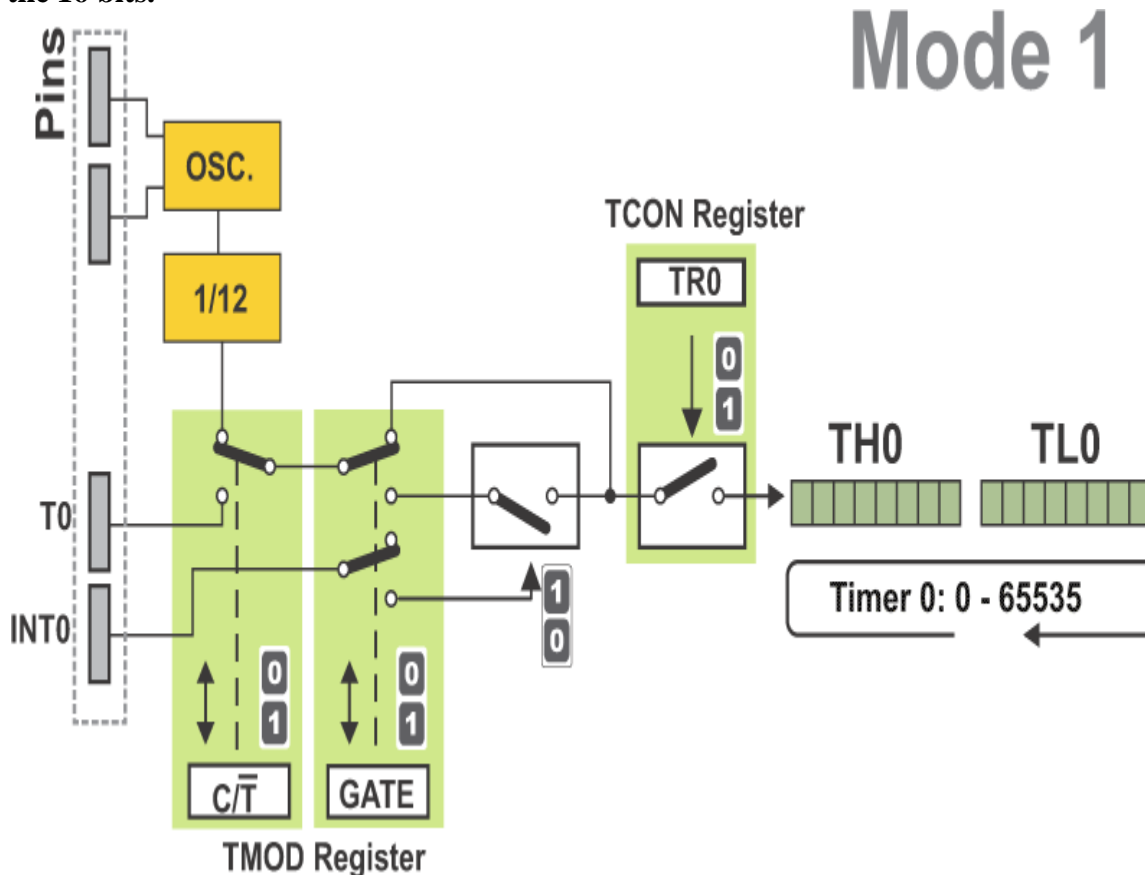


Fig 4.31: Timer Mode 1

Timer 0 in mode 2 (Auto-Reload Timer)

Mode 2 configures timer 0 as an 8-bit timer. Actually, timer 0 uses only one 8-bit register for counting and never counts from 0, but from an arbitrary value (0-255) stored in another (TH0) register.

The following example shows the advantages of this mode. Suppose it is necessary to constantly count up 55 pulses generated by the clock.

If mode 1 or mode 0 is used, It is necessary to write the number 200 to the timer registers and constantly check whether an overflow has occurred, i.e. whether they reached the value 255. When it happens, it is necessary to rewrite the number 200 and repeat the whole procedure. The same procedure is automatically performed by the microcontroller if set in mode 2. In fact, only the TL0 register operates as a timer, while another (TH0) register stores the value from which the counting starts. When the TL0 register is loaded, instead of being cleared, the contents of TH0 will be reloaded to it. Referring to the previous example, in

order to register each 55th pulse, the best solution is to write the number 200 to the TH0 register and configure the timer to operate in mode 2.

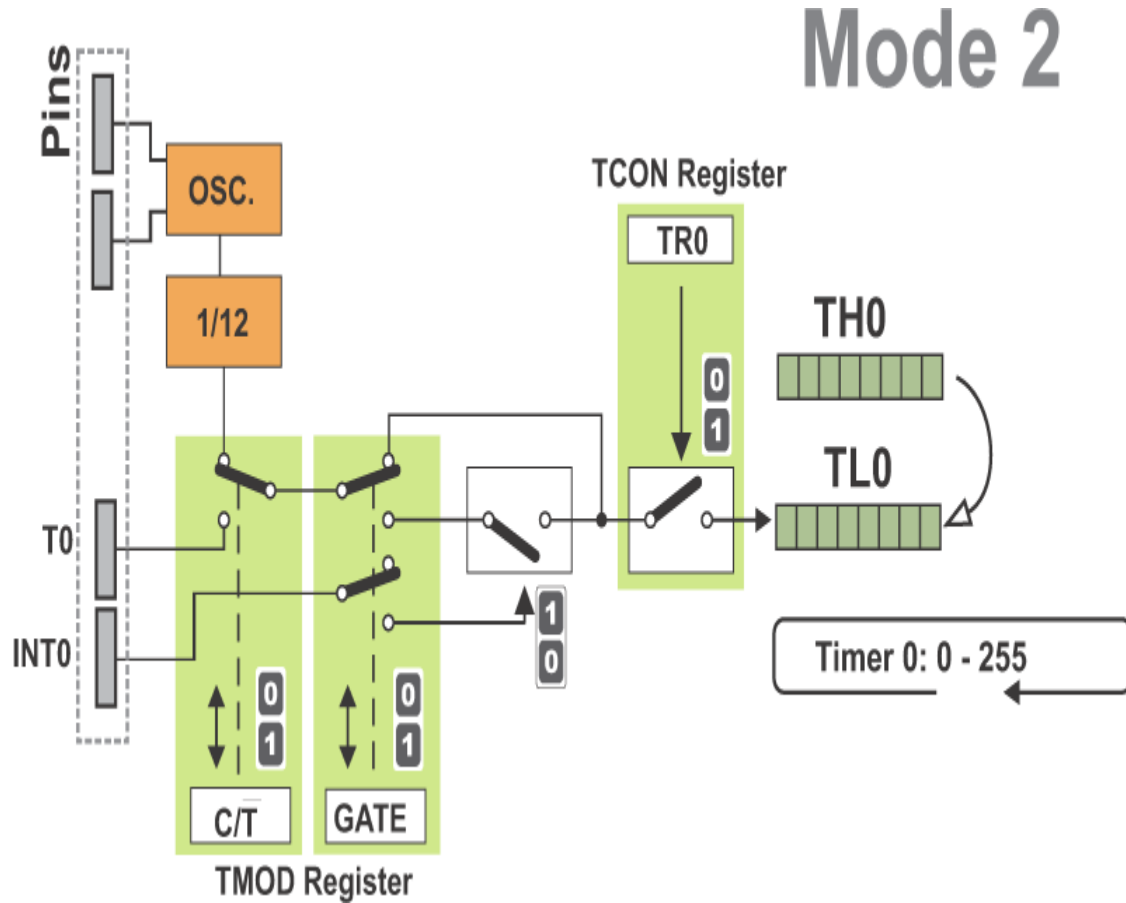


Fig 4.32: Timer Mode 2

Timer 0 in Mode 3 (Split Timer)

Mode 3 configures timer 0 so that registers TL0 and TH0 operate as separate 8-bit timers. In other words, the 16-bit timer consisting of two registers TH0 and TL0 is split into two independent 8-bit timers. This mode is provided for applications requiring an additional 8-bit timer or counter. The TL0 timer turns into timer 0, while the TH0 timer turns into timer 1. In addition, all the control bits of 16-bit Timer 1 (consisting of the TH1 and TL1 register), now control the 8-bit Timer 1. Even though the 16-bit Timer 1 can still be configured to operate in any of modes (mode 1, 2 or 3), it is no longer possible to disable it as there is no control bit to do it. Thus, its operation is restricted when timer 0 is in mode 3.

Mode 3

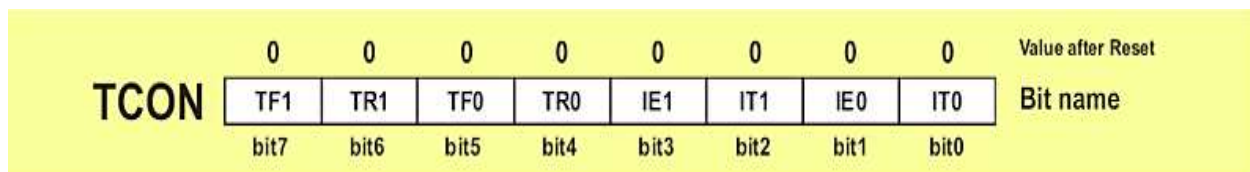
The diagram illustrates the internal logic of Mode 3 operation for Timer 0 and Timer 1. The TCON Register (TR1, TR0) and the TMOD Register (C/T, GATE) are shown. The TCON Register (TR1, TR0) controls the start/stop of the timers. The TMOD Register (C/T, GATE) controls the clock source and gate for the timers. The TCON Register (TR1, TR0) and the TMOD Register (C/T, GATE) are shown. The TCON Register (TR1, TR0) controls the start/stop of the timers. The TMOD Register (C/T, GATE) controls the clock source and gate for the timers.

Fig 4.33: Timer Mode 3

The only application of this mode is when two timers are used and the 16-bit Timer 1 the operation of which is out of control is used as a baud rate generator.

Timer Control (TCON) Register

TCON register is also one of the registers whose bits are directly in control of timer operation. Only 4 bits of this register are used for this purpose, while rest of them is used for interrupt control to be discussed later.

**Fig 4.34: TCON**

- **TF1** bit is automatically set on the Timer 1 overflow.
- **TR1** bit enables the Timer 1.
 - **1** - Timer 1 is enabled.

- **0** - Timer 1 is disabled.
- **TF0** bit is automatically set on the Timer 0 overflow.
- **TR0** bit enables the timer 0.
 - **1** - Timer 0 is enabled.
 - **0** - Timer 0 is disabled.

How to use the Timer 0 ?

In order to use timer 0, it is first necessary to select it and configure the mode of its operation. Bits of the TMOD register are in control of it:

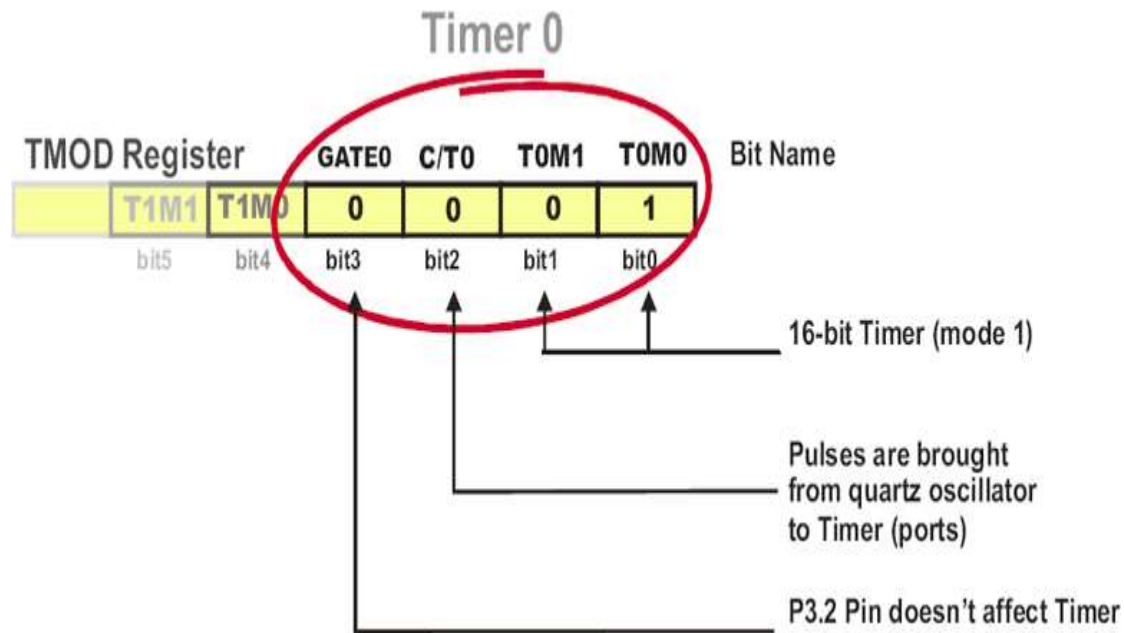


Fig 4.35: Timer 0 configuration

Referring to figure above, the timer 0 operates in mode 1 and counts pulses generated by internal clock the frequency of which is equal to 1/12 the quartz frequency.

Turn on the timer:

Timer Control Bits

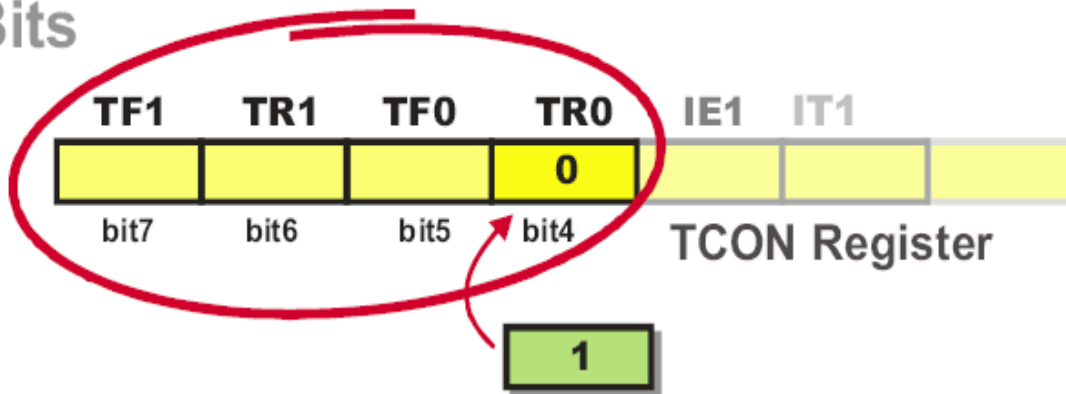


Fig 4.36: TCON control bits

The TR0 bit is set and the timer starts operation. If the quartz crystal with frequency of 12MHz is embedded then its contents will be incremented every microsecond. After 65.536 microseconds, the both registers the timer consists of will be loaded. The microcontroller automatically clears them and the timer keeps on repeating procedure from the beginning until the TR0 bit value is logic zero (0).

How to 'read' a timer?

Depending on application, it is necessary either to read a number stored in the timer registers or to register the moment they have been cleared.

- It is extremely simple to read a timer by using only one register configured in mode 2 or 3. It is sufficient to read its state at any moment. That's all!
- It is somehow complicated to read a timer configured to operate in mode 2. Suppose the lower byte is read first (TL0), then the higher byte (TH0). The result is:

TH0 = 15 TL0 = 255

Everything seems to be ok, but the current state of the register at the moment of reading

was: **TH0 = 14 TL0 = 255**

In case of negligence, such an error in counting (255 pulses) may occur for not so obvious but quite logical reason. The lower byte is correctly read (255), but at the moment the program counter was about to read the higher byte TH0, an overflow occurred and the contents of both registers have been changed (TH0: 14→15, TL0: 255→0). This problem has a simple solution. The higher byte should be read first, then the lower byte and once again the higher byte. If the number stored in the higher byte is different then this sequence

should be repeated. It's about a short loop consisting of only 3 instructions in the program.

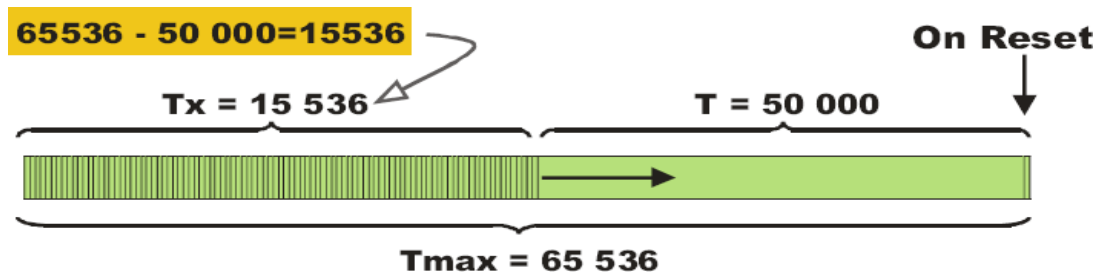
There is another solution as well. It is sufficient to simply turn the timer off while reading is going on (the TR0 bit of the TCON register should be cleared), and turn it on again after reading is finished.

Timer 0 Overflow Detection

Usually, there is no need to constantly read timer registers. It is sufficient to register the moment they are cleared, i.e. when counting starts from 0. This condition is called an overflow. When it occurs, the TF0 bit of the TCON register will be automatically set. The state of this bit can be constantly checked from within the program or by enabling an interrupt which will stop the main program execution when this bit is set. Suppose it is necessary to provide a program delay of

0.05 seconds (50 000 machine cycles), i.e. time when the program seems to be

stopped: First a number to be written to the timer registers should be calculated:



Then it should be written to the timer registers TH0 and TL0:

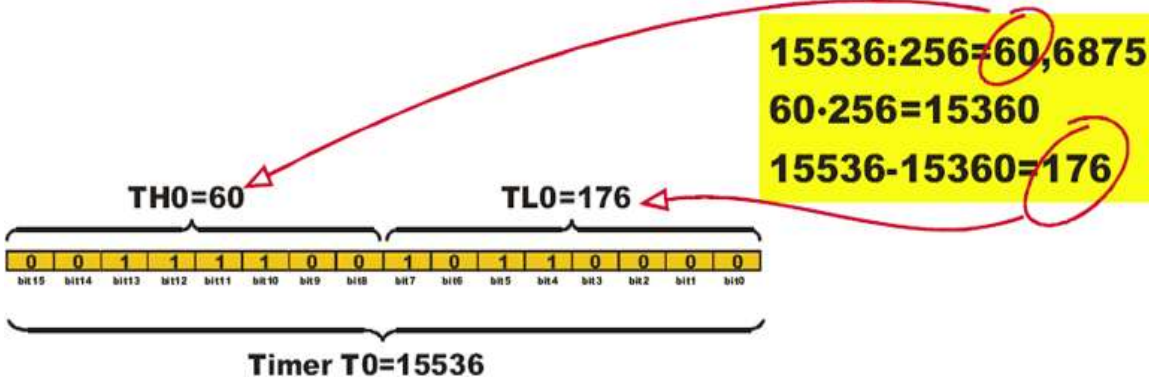


Fig 4.37: Timer 0 -TLO & TH0 count write

When enabled, the timer will resume counting from this number. The state of the TF0 bit, i.e. whether it is set, is checked from within the program. It happens at the moment of overflow, i.e. after exactly 50.000 machine cycles or 0.05 seconds.

How to measure pulse duration?

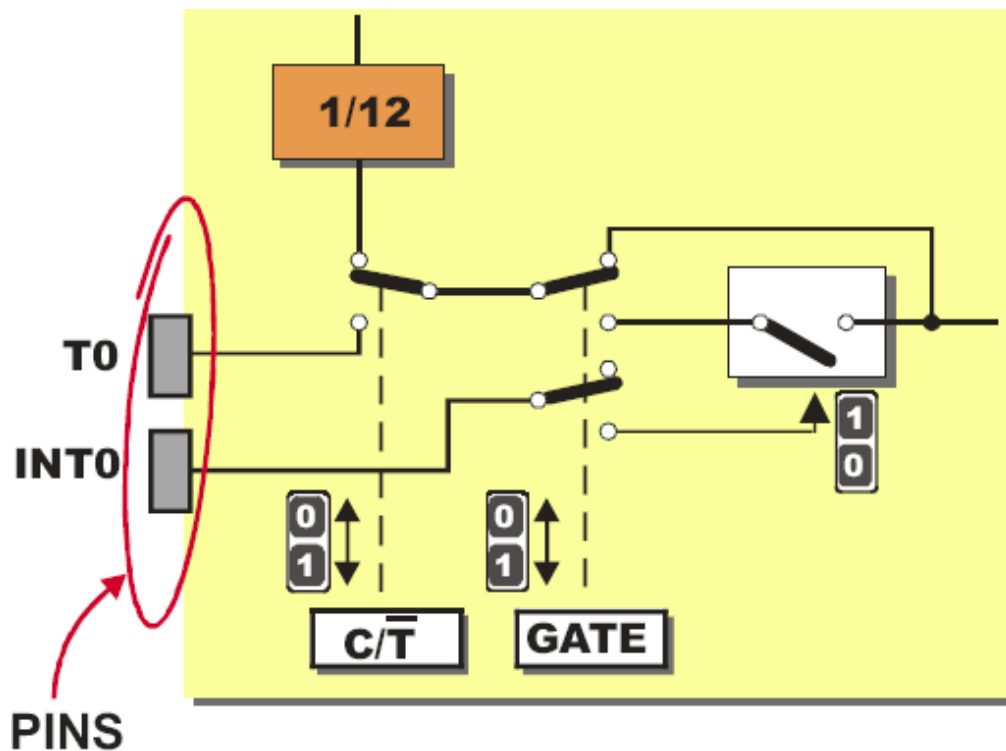


Fig 4.38: Measure Pulse duration

Suppose it is necessary to measure the duration of an operation, for example how long a device has been turned on? Look again at the figure illustrating the timer and pay attention to the function of the GATE0 bit of the TMOD register. If it is cleared then the state of the P3.2 pin doesn't affect timer operation. If $GATE0 = 1$ the timer will operate until the pin P3.2 is cleared. Accordingly, if this pin is supplied with 5V through some external switch at the moment the device is being turned on, the timer will measure duration of its operation, which actually was the objective.

How to count up pulses?

Similarly to the previous example, the answer to this question again lies in the TCON register. This time it's about the C/T0 bit. If the bit is cleared the timer counts pulses generated by the internal oscillator, i.e. measures the time passed. If the bit is set, the timer input is provided with pulses from the P3.4 pin (T0). Since these pulses are not always of the same width, the timer cannot be used for time measurement and is turned into a counter, therefore. The highest frequency that could be measured by such a counter is 1/24 frequency of used quartz-crystal.

Timer 1

Timer 1 is identical to timer 0, except for mode 3 which is a hold-count mode. It means that they have the same function, their operation is controlled by the same registers TMOD and TCON and both of them can operate in one out of 4 different modes.

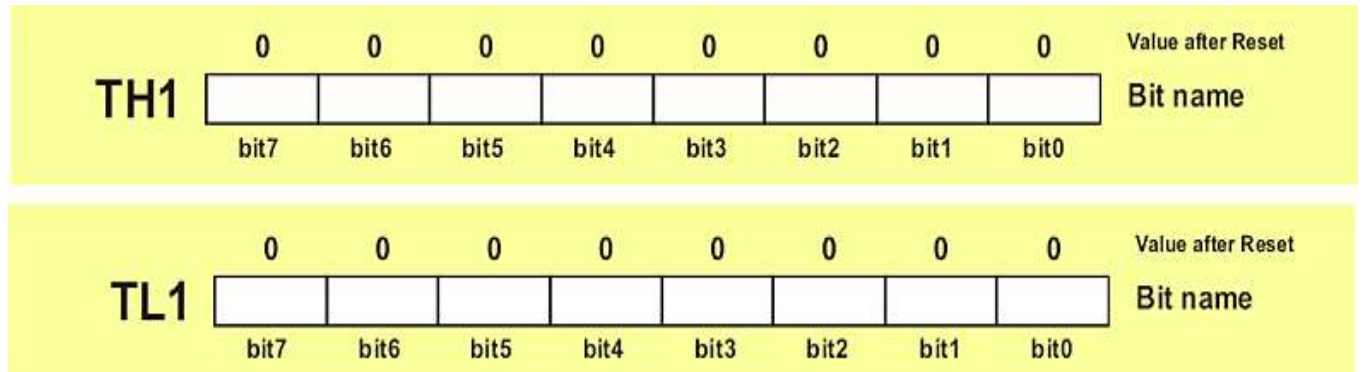
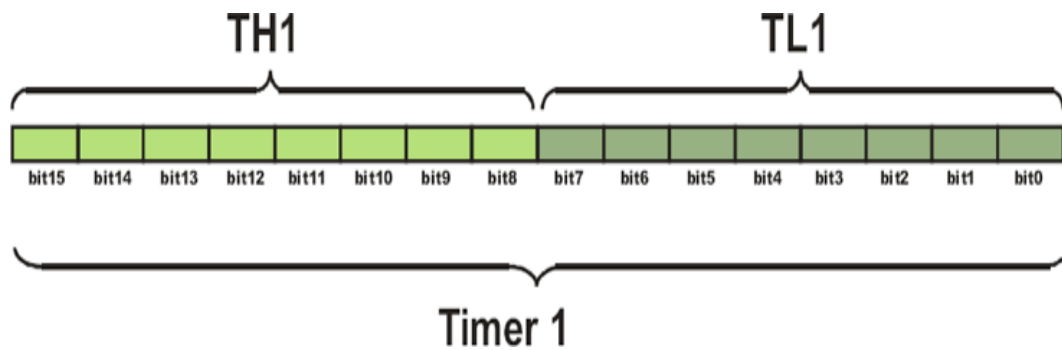


Fig 4.39: timer 1

SERIAL COMMUNICATION

One of the microcontroller features making it so powerful is an integrated UART, better known as a serial port. It is a full-duplex port, thus being able to transmit and receive data simultaneously and at different baud rates. Without it, serial data send and receive would be an enormously complicated part of the program in which the pin state is constantly changed and checked at regular intervals. When using UART, all the programmer has to do is to simply select serial port mode and baud rate. When it's done, serial data transmit is nothing but writing to the SBUF register, while data receive represents reading the same register. The microcontroller takes care of not making any error during data transmission.

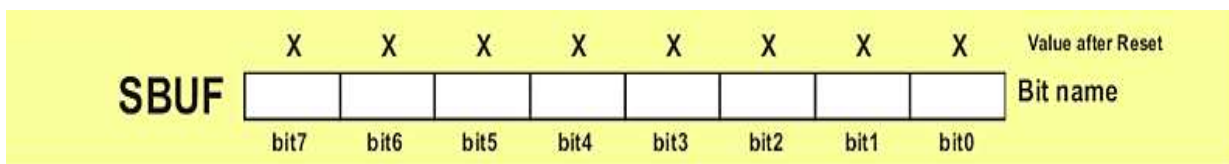


Fig 4.40: SBUF

Serial port must be configured prior to being used. In other words, it is necessary to determine how many bits is contained in one serial "word", baud rate and synchronization clock source. The whole process is in control of the bits of the SCON register (Serial Control).

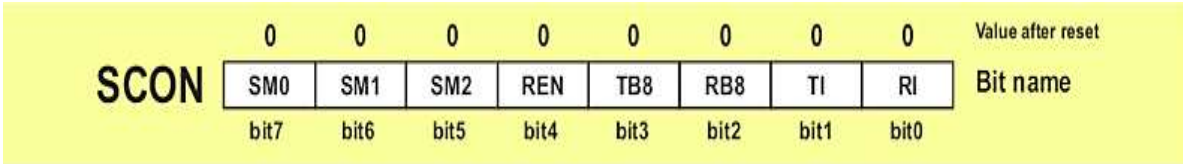


Fig 4.41: SCON

- **SM0** - Serial port mode bit 0 is used for serial port mode selection.
- **SM1** - Serial port mode bit 1.
- **SM2** - Serial port mode 2 bit, also known as multiprocessor communication enable bit. When set, it enables multiprocessor communication in mode 2 and 3, and eventually mode 1. It should be cleared in mode 0.
- **REN** - Reception Enable bit enables serial reception when set. When cleared, serial reception is disabled.
- **TB8** - Transmitter bit 8. Since all registers are 8-bit wide, this bit solves the problem of transmitting the 9th bit in modes 2 and 3. It is set to transmit a logic 1 in the 9th bit.
- **RB8** - Receiver bit 8 or the 9th bit received in modes 2 and 3. Cleared by hardware if 9th bit received is a logic 0. Set by hardware if 9th bit received is a logic 1.
- **TI** - Transmit Interrupt flag is automatically set at the moment the last bit of one byte is sent. It's a signal to the processor that the line is available for a new byte transmits. It must be cleared from within the software.
- **RI** - Receive Interrupt flag is automatically set upon one byte receive. It signals that byte is received and should be read quickly prior to being replaced by a new data. This bit is also cleared from within the software.

As seen, serial port mode is selected by combining the SM0 and SM2 bits:

SM0	SM1	Mode	Description	Baud Rate
0	0	0	8-bit Shift Register	1/12 the quartz frequency
0	1	1	8-bit UART	Determined by the timer 1
1	0	2	9-bit UART	1/32 the quartz frequency (1/64 the quartz frequency)
1	1	3	9-bit UART	Determined by the timer 1

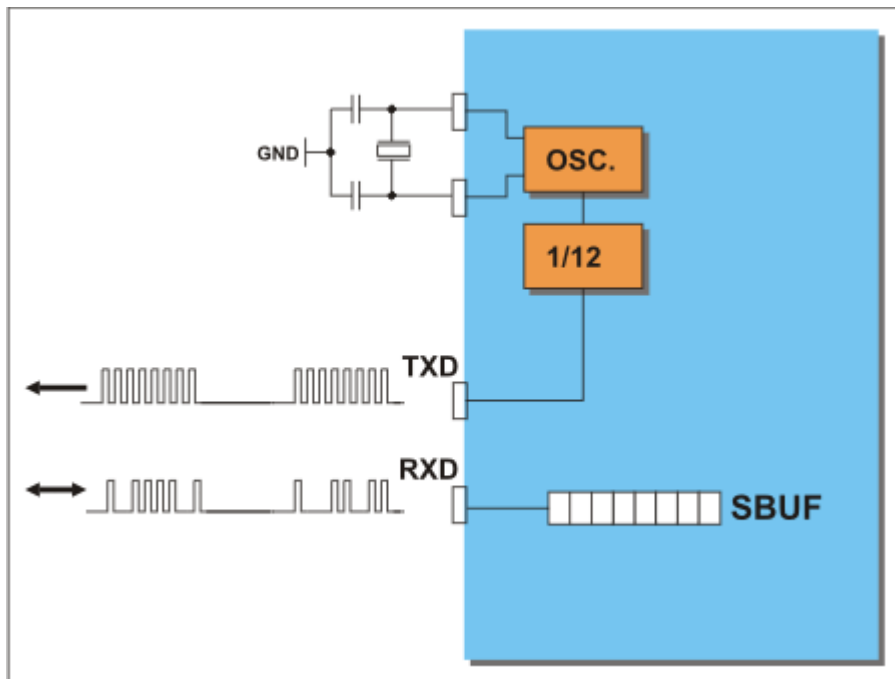


Fig 4.42: TXD , RXD

In mode 0, serial data are transmitted and received through the RXD pin, while the TXD pin output clocks. The baud rate is fixed at 1/12 the oscillator frequency. On transmit, the least significant bit (LSB bit) is sent/received first.

TRANSMIT - Data transmit is initiated by writing data to the SBUF register. In fact, this process starts after any instruction being performed upon this register. When all 8 bits have been sent, the TI bit of the SCON register is automatically set.

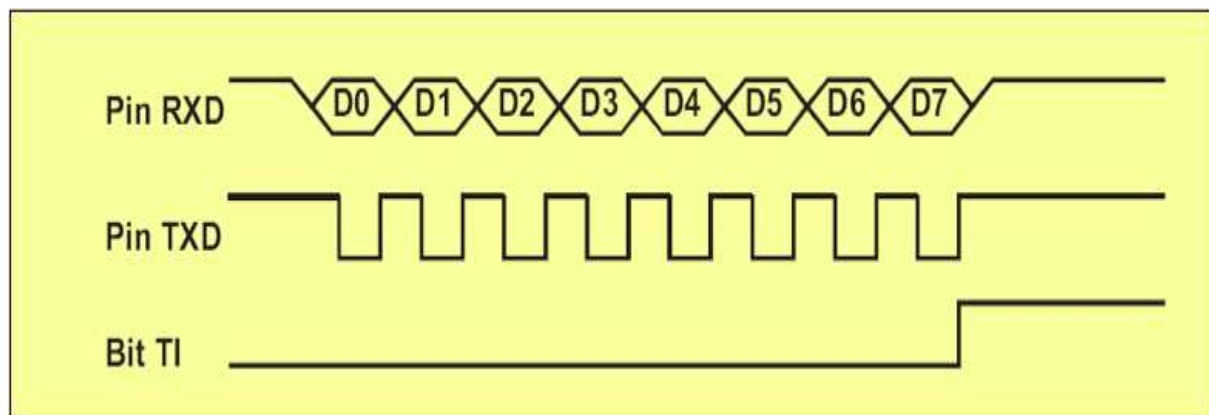


Fig 4.43: TXD , RXD status- TI-mode 0

RECEIVE - Data receive through the RXD pin starts upon the two following conditions are met: bit REN=1 and RI=0 (both of them are stored in the SCON register). When all 8 bits have been received, the RI bit of the SCON register is automatically set indicating that one byte receive is complete.

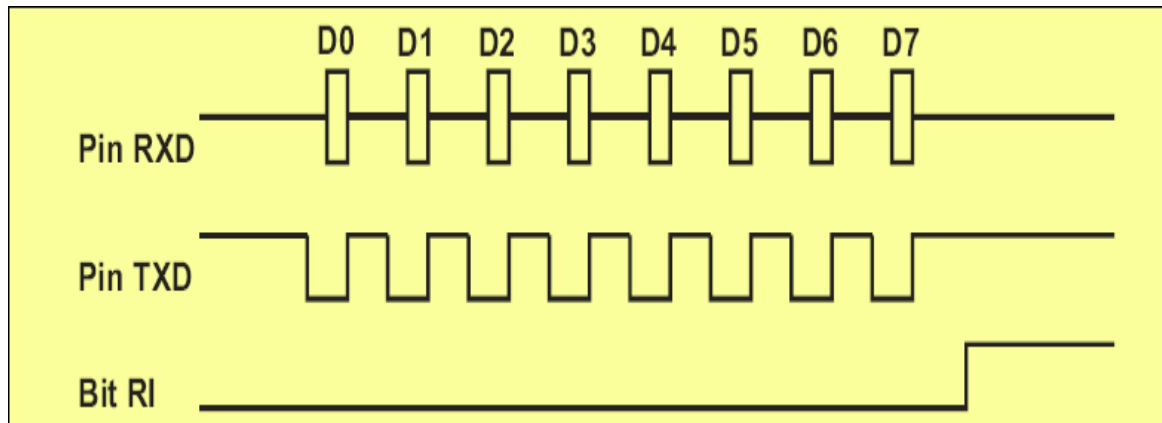


Fig 4.44: TXD , RXD-RI-mode 0

Since there are no START and STOP bits or any other bit except data sent from the SBUF register in the pulse sequence, this mode is mainly used when the distance between devices is short, noise is minimized and operating speed is of importance. A typical example is I/O port expansion by adding a cheap IC (shift registers 74HC595, 74HC597 and similar).

Mode 1

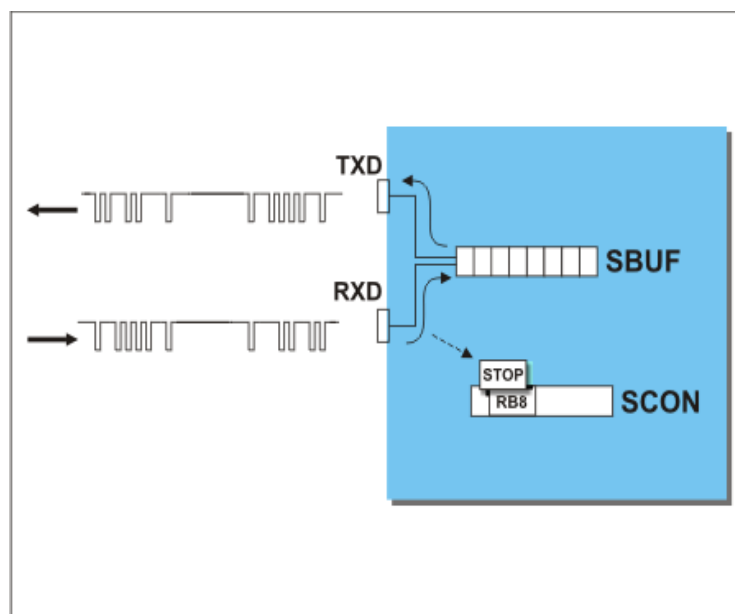


Fig 4.45: TXD , RXD, SBUF,SCON-mode 1

In mode 1, 10 bits are transmitted through the TXD pin or received through the RXD pin in the following manner: a START bit (always 0), 8 data bits (LSB first) and a STOP bit (always 1).

The START bit is only used to initiate data receive, while the STOP bit is automatically written to the RB8 bit of the SCON register.

TRANSMIT - Data transmit is initiated by writing data to the SBUF register. End of data transmission is indicated by setting the TI bit of the SCON register.

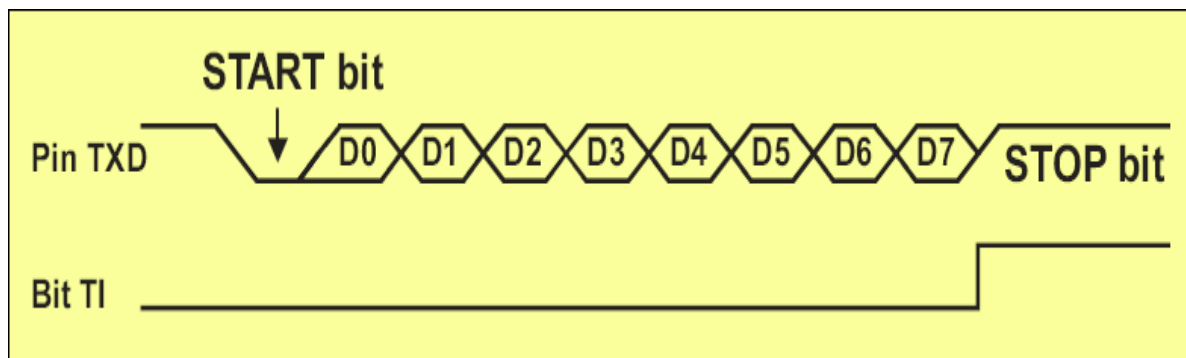


Fig 4.46: TXD , TI-mode 1

RECEIVE - The START bit (logic zero (0)) on the RXD pin initiates data receive. The following two conditions must be met: bit REN=1 and bit RI=0. Both of them are stored in the SCON register. The RI bit is automatically set upon data reception is complete.

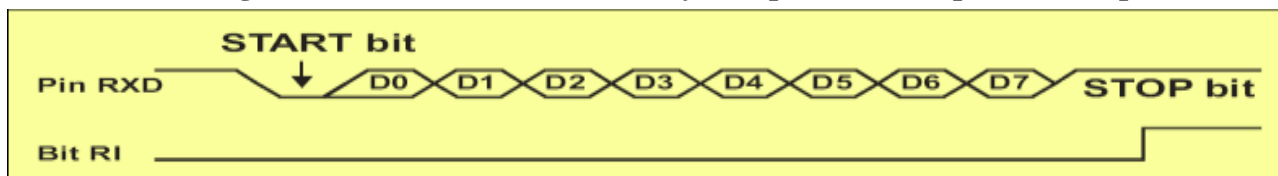


Fig 4.47: RXD-RI-mode 1

The Baud rate in this mode is determined by the timer 1 overflow.

Mode 2

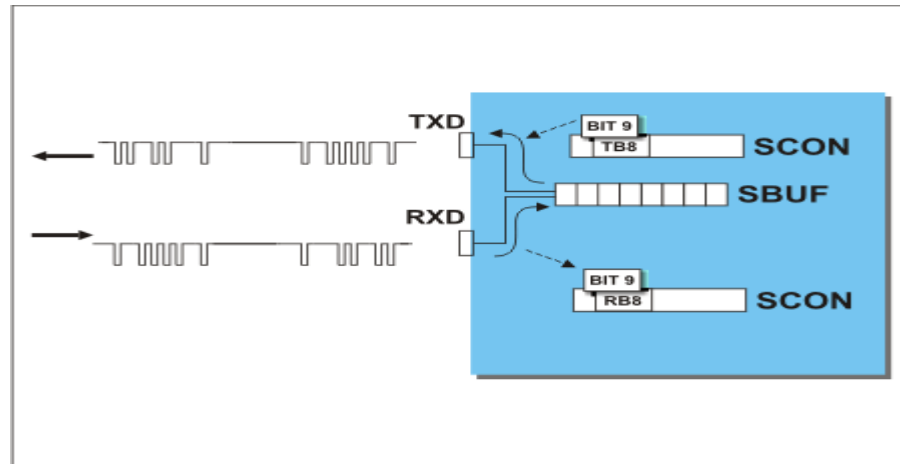


Fig 4.48: TXD , RXD-mode 2

In mode 2, 11 bits are transmitted through the TXD pin or received through the RXD pin: a START bit (always 0), 8 data bits (LSB first), a programmable 9th data bit and a STOP bit (always 1). On transmit, the 9th data bit is actually the TB8 bit of the SCON register. This bit usually has a function of parity bit. On receive, the 9th data bit goes into the RB8 bit of the same register (SCON). The baud rate is either 1/32 or 1/64 the oscillator frequency.

TRANSMIT - Data transmit is initiated by writing data to the SBUF register. End of data transmission is indicated by setting the TI bit of the SCON register.

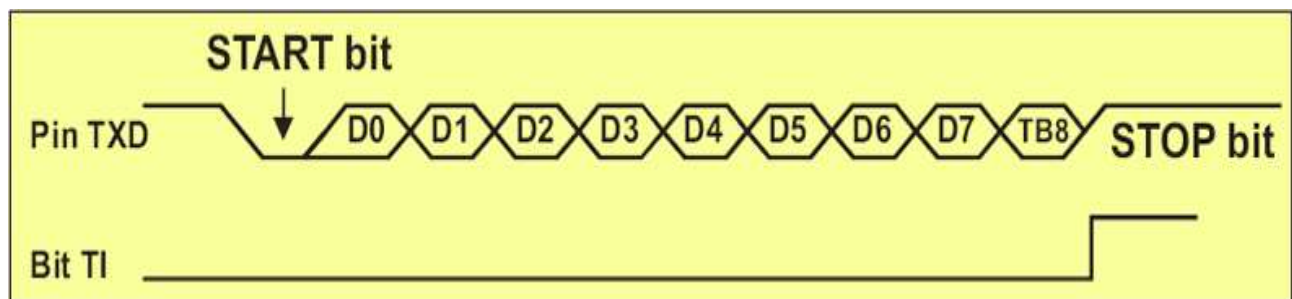


Fig 4.49: mode 2

RECEIVE - The START bit (logic zero (0)) on the RXD pin initiates data receive. The following two conditions must be met: bit REN=1 and bit RI=0. Both of them are stored in the SCON register. The RI bit is automatically set upon data reception is complete.

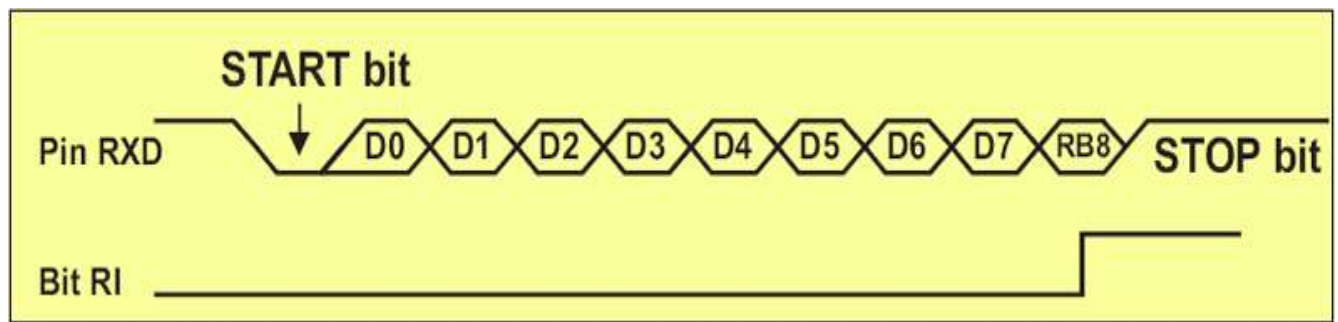


Fig 4.50: mode 2

Mode 3 is the same as Mode 2 in all respects except the baud rate. The baud rate in Mode 3 is variable.

Baud Rate

Baud Rate is a number of sent/received bits per second. In case the UART is used, baud rate depends on: selected mode, oscillator frequency and in some cases on the state of the SMOD bit of the SCON register. All the necessary formulas are specified in the table:

	BAUD RATE	BITSMOD
Mode 0	$F_{osc} / 12$	
Mode 1	$1 F_{osc} / 16 / 12 (256-TH1)$	BitSMOD
Mode 2	$F_{osc} / 32 F_{osc} / 64$	1 0
Mode 3	$1 F_{osc} / 16 / 12 (256-TH1)$	

Timer 1 as a clock generator

Baud Rate	Fosc. (MHz)				Bit SMOD
	11.0592	12	14.7456	16	20

150	40 h	30 h	00 h	0
300	A0 h	98 h	80 h	75 h 52 h 0
600	D0 h	CC h C0 h	BB h A9 h	0
1200	E8 h	E6 h E0 h	DE h D5 h	0
2400	F4 h	F3 h F0 h	EF h EA h	0

4800	F3 h	EF h	EF h	1
4800	FA h	F8 h	F5 h	0
9600	FD h	FC h		0
9600			F5 h	1
19200	FD h	FC h		1
38400		FE h		1
76800		FF h		1

Multiprocessor Communication

As you may know, additional 9th data bit is a part of message in mode 2 and 3. It can be used for checking data via parity bit. Another useful application of this bit is in communication between two or more microcontrollers, i.e. multiprocessor communication. This feature is enabled by setting the SM2 bit of the SCON register. As a result, after receiving the STOP bit, indicating end of the message, the serial port interrupt will be generated only if the bit RB8 = 1 (the 9th bit).

This is how it looks like in practice:

Suppose there are several microcontrollers sharing the same interface. Each of them has its own address. An address byte differs from a data byte because it has the 9th bit set (1), while this bit is cleared (0) in a data byte. When the microcontroller A (master) wants to transmit a block of data to one of several slaves, it first sends out an address byte which identifies the target slave. An address byte will generate an interrupt in all slaves so that they can examine the received byte and check whether it matches their address.

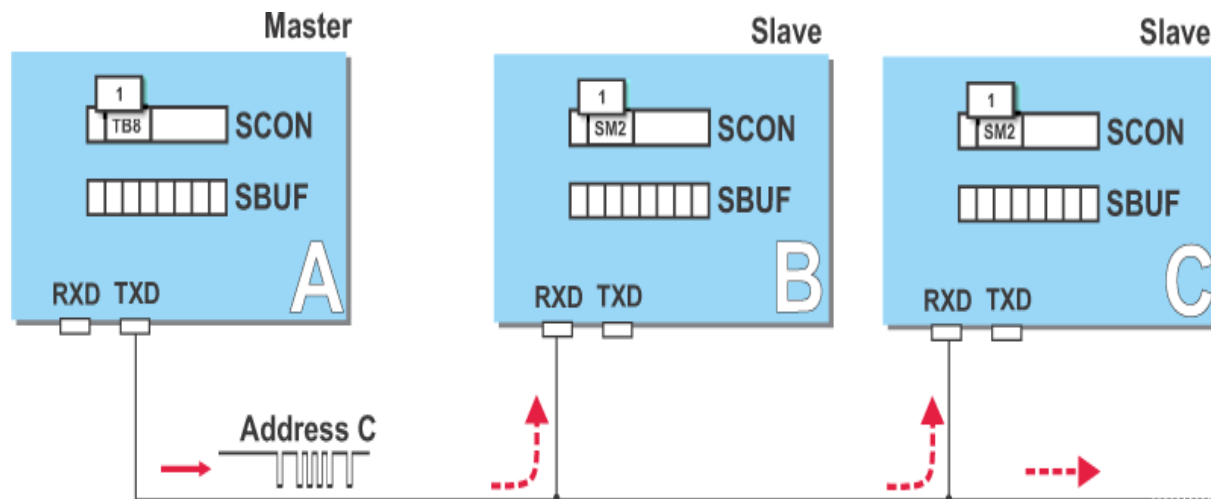


Fig 4.51: multiprocessor communication

Of course, only one of them will match the address and immediately clear the SM2 bit of the SCON register and prepare to receive the data byte to come. Other slaves not being addressed leave their SM2 bit set ignoring the coming data bytes.

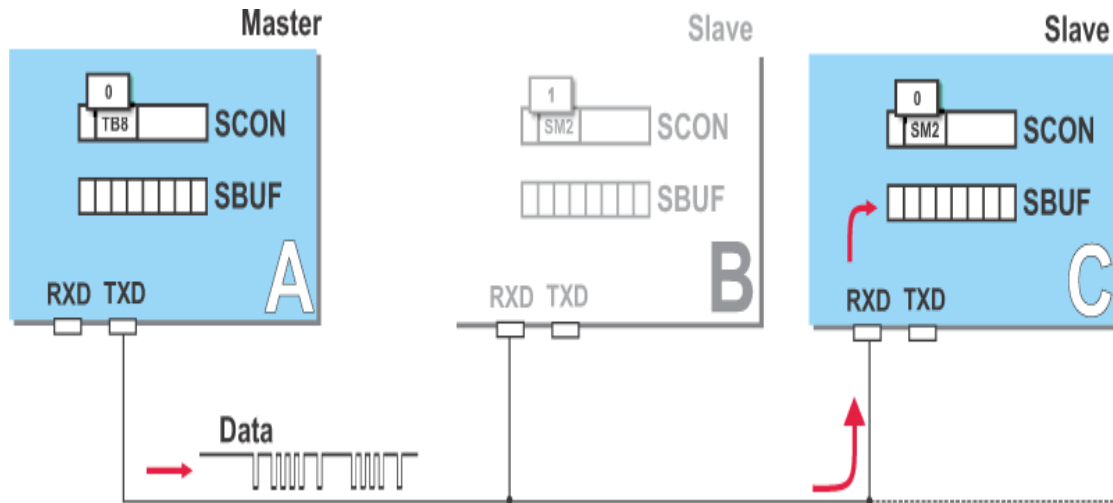


Fig 4.52: multiprocessor communication

PROGRAMS USING 8051

Addition

```

mov
r0,#50
mov
a,@r0
inc r0
add
a,@r0
mov 60,a
lcall 00bb

```

Input: 50-55, 51-66

Output: 60-bb

Subtraction

```

clr c
mov
r0,#50
mov
a,@r0
inc r0
subb
a,@r0
mov
60,a
lcall 00bb

```

Input: 50-66, 51-55

Output: 60-11

Multiplication

```
mov r0,#50
```

```
mov a,@r0
```

```
inc r0
```

```
mov f0,@r0
```

```
mul ab
```

```
mov 60,a
```

```
mov 61,0f0
```

```
lcall 00bb
```

Input: 50-ff, 51-ff

Output: 60-01(LSB),
61-FE
(MSB)

Division

```
mov r0,#50
```

```
mov a,@r0
```

```
inc r0
```

```
mov f0,@r0
```

```
div ab
```

```
mov 60,a
```

```
mov 61,0f0
```

```
lcall 00bb
```

Input: 50-ff, 51-fd

Output: 60-01(Q) , 61-02 (R)

Smallest of an array

```
mov r0,#50h
```

```
mov r1,#05
```

```
mov 60,#ff
```

```
back:mov a,@r0
```

```
cjne a,60,loop
```

```
jnc loop
```

```
mov 60,a
```

```
loop:inc r0
```

```
djnz r1,back
```

```
lcall 00bb
```

Input:

50-99, 51-80, 52-70,

53-66, 54-77

Output: 60-66 Largest of an

array

```
mov r0,#50h
mov r1,#05
mov 60,#00
back:mov a,@r0
cjne a,60,loop
jc loop
mov 60,a
loop:inc r0
djnz r1,back
lcall 00bb
```

Input: 50-99, 51-80, 52-70, 53-66, 54-77

Output: 60-99

Factorial

```
mov
ro,#50mov
a,@r0mov
r1,a dec r1
l1:mov f0,r1
mul ab
djnz r1,l1:
mov 60,a
lcall 00bb
```

i/p 50-05

o/p 60-78

sum of an array

```
mov r1,#05
mov r0,#50
mov a,@r0
dec r1
l1:inc r0
add a,@r0
djnz r1,l1
mov 60,a
lcall 00bb
```

i/p 50-01,51-02,52-03,54-04,55-05

o/p-60-0f

```

Ascending order
mov r7,#05
b2:mov r6,#04
mov r0,#50
b1:mov a,@r0
inc r0
mov 0f0,@ro
cjne a,0f0,next
sjmp back
next jc back (descending order change jc to jnc)

mov @r0,a
dec r0
mov @ro,0f0
inc r0
back: djnz r6,b1
      djnz r7, b2
      lcall 00bb
i/p
50-05, 51-04,52-03,53-04,54-05
o/p
50-01,51-02,52-03,53-04,54-05

```

QUESTION BANK

PART A

1. What are the addressing modes of 8051.
2. Differentiate microcontroller and microprocessor.
3. Write short notes on interrupts.
4. Write briefly about the timer of 8051.
5. What is an SFR.
6. List the SFR in 8051.
7. Write an assembly language program to transfer
8. a.10 data from internal to external
b.10 data from external to internal
9. Explain how to interface I/O devices to 8051.
10. Write a program to find a square of a number using look up table.10. Write a program to find the given number is odd or even.
11. Write a program to generate a square wave of 1ms using timer.
12. List the bits of PSW.
13. What are the different ranges of jump.
14. Classify jump instruction
15. Write about stack
16. On reset the value of SP is_____, I/O ports are configured as_____.
17. Write about EA pin of 8051.
18. Draw one machine cycle of 8051.

19. What is ALE?

20. The internal RAM size is _____ and the internal ROM size is _____.

PART B

- 1. With neat diagram explain the architecture of 8051.**
- 2. Classify the instruction set of 8051 and explain the instruction with suitable examples.**
- 3. Write in detail how serial communication is carried out in 8051.**
- 4. Explain in detail about timers in 8051 microcontroller**
- 5. Explain the interrupts of 8051 microcontroller**
- 6. Write the following programs**
 - a. programs using arithmetic and logical instruction**
 - b. Programs to convert hexa to ascii and ascii to hexa**
 - c. Programs using program transfer instructions.**
 - d. Programs using I/O ports**
- 7. Explain the following instructions with example**
 - a. movc a,@a+dptr b. movx @r0,a c. JBC b,radd**
 - d. XCHD A,@Rp e. Swap A**

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**SCHOOL OF ELECTRICAL AND ELECTRONICS
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**

UNIT – I – MICROPROCESSORS AND MICROCONTROLLERS– SEC1201

UNIT 5 APPLICATIONS BASED ON 8085 AND 8051

Interfacing Basic concepts, interfacing LED, 7 segment LED, Stepper motor control system, Temperature control system, Traffic light control system, Motor speed control system, Waveform generation, Interfacing LCD.

7-SEGMENT LED

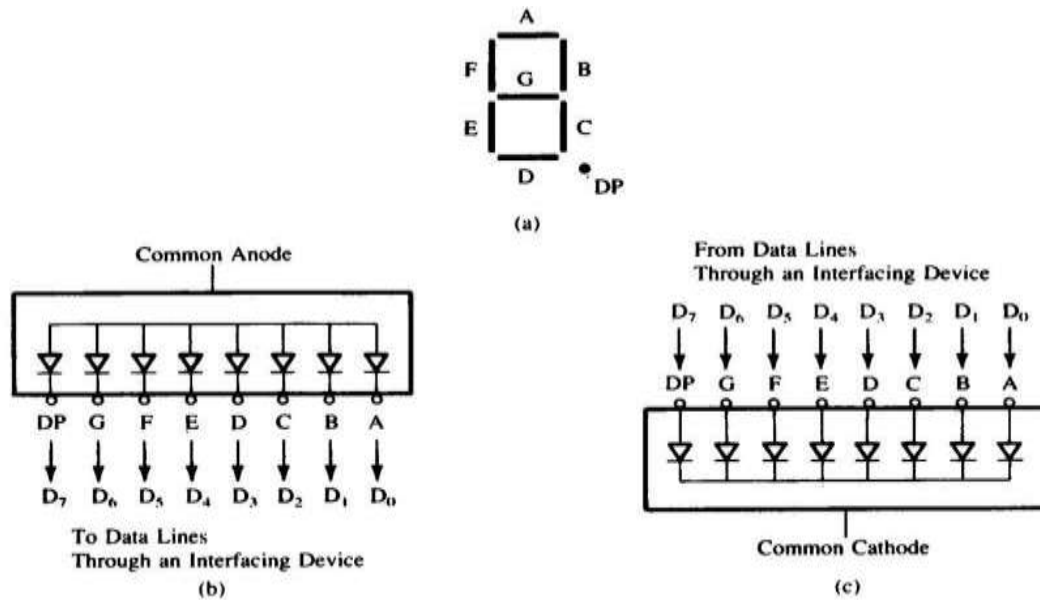


Fig 5.1: 7-sement LED types

- Fig shows two different type of 7-segment display; *common cathode* and *common anode*.
- 7-segment display consists of a few LEDs and are arranged physically as shown in figure a.
- It has seven segments from A to G that normally connected to data bus D₀ to D₆ respectively.
- If decimal point is used, D₇ will be connected to DP; and left unconnected if it is unused.

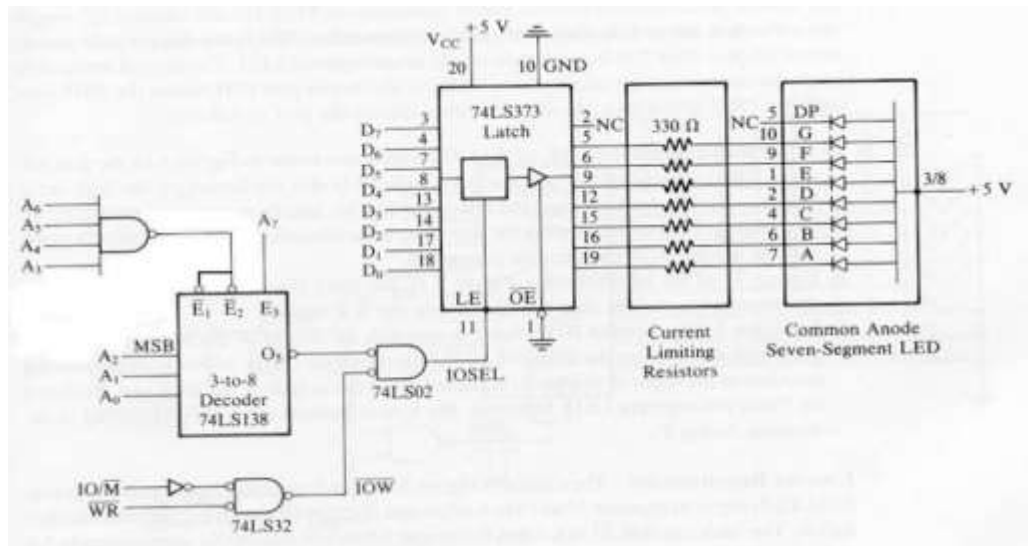


Fig 5.2: 7-sement LED interfacing

- Fig. shows the example to interface seven segment display and address decoder with an address of FDH.
- The common anode display is used therefore 0 logic is needed to activate the segment.
- Suppose to display number 4 at seven segment display, therefore the segment F, G, B and C have to be activated.
- Follows are the instructions to execute it:
 –MVI A, 66H
 OUT FDH

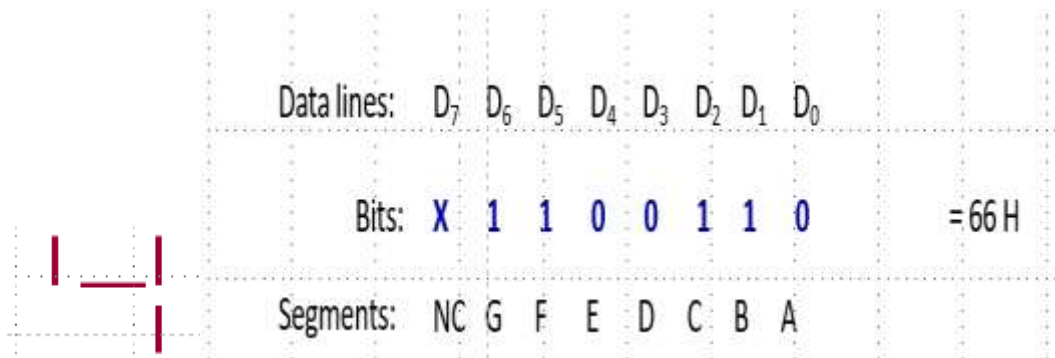


Fig 5.3: 7-sement LED code for 4

PROGRAM (FLASH 4)

```

MVI A,80          DELAY
OUT CR            LXI D,FFFF
L1:MVI A,00        L2:DCX D
OUT PA            MOV A,E
CALL DELAY        ORA D

```

**MVI A,66
OUT PA
CALL DELAY
JMP L1:**

**JNZ L2:
RET**

Traffic light control system using 8085

The traffic lights placed at the road crossings can be automatically switched ON/OFF in the desired sequence using the microprocessor system. The system can also have a manual control option, so that during heavy traffic (or during traffic jam) the duration of ON/OFF time can be varied by the operator.

A typical traffic light control system (demonstration type) is shown in fig 1. The systems have been developed using 8085 as CPU. The system has EPROM memory for system program storage and RAM memory for stack operation. For manual control a keyboard have been provided. It will be helpful for the operator if the direction of traffic flow is displayed during manual control. Hence 7-segment LEDs are interfaced to display the direction of traffic flow both during manual and automatic mode.

The primary function of the microprocessor in the system is to switch ON/OFF the Red/Yellow/Green lights in the specified sequence. In the demonstration system of fig, Red/Yellow/Green LEDs are provided instead of lights (lamps). The LEDs are interfaced to the system through buffer (74LS245) and ports of 8255.

In the practical implementation scheme the lights can be turned ON/OFF using driver transistors and relays. In practical implementation the output of buffer (74LS245) can be connected to the driver transistor. A reverse biased diode is connected across relay coil to prevent relay chattering (for free-wheeling action).

The microprocessor send High through a port line to switch ON the light and LOW to switch OFF the light. A switching schedule (or sequence) can be developed as shown in Table. In this switching sequence it is assumed that the traffic is allowed only in one direction at time.

In table, "1" represents ON condition and "0" represents OFF condition. These 1's and 0's

Can be directly output to 8255 ports to switch ON/OFF the light. A flowchart for traffic light control program is shown in fig .

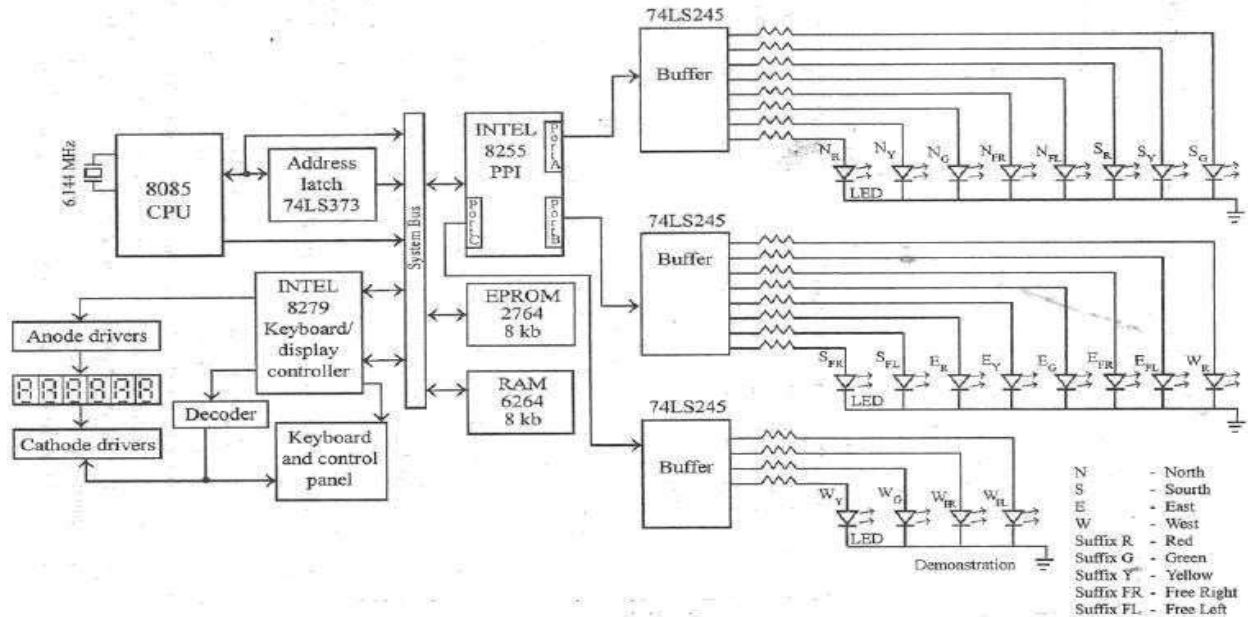


Fig.5.4: 8085 Microprocessor based Traffic light control system.

ON/OFF status of traffic lights																				
SWITCHING SCHEDULE	PA ₀ N _R	PA ₁ N _Y	PA ₂ N _G	PA ₃ N _{FR}	PA ₄ N _{FL}	PA ₅ S _R	PA ₆ S _Y	PA ₇ S _G	PB ₀ S _{FR}	PB ₁ S _{FL}	PB ₂ E _R	PB ₃ E _Y	PB ₄ E _G	PB ₅ E _{FR}	PB ₆ E _{FL}	PC ₀ W _R	PC ₁ W _Y	PC ₂ W _G	PC ₃ W _{FR}	PC ₄ W _{FL}
Schedule I	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Schedule II	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Schedule III	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Schedule IV	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Schedule V	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0
Schedule VI	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0
Schedule VII	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0
Schedule VIII	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0
Schedule IX	1	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0
Schedule X	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0
Schedule XI	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Schedule XII	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1	1

Fig. 5.5: Switching schedule for Traffic light

The processor can output the codes for switching the lights for schedule-I and then waits. After a specified time delay the processor output the codes for schedule-II and so on. For each schedule the processor can wait for a specified time. After schedule-XII, the processor can again return to schedule-I. On observing the schedules we can conclude that three different delay routines are sufficient for implementing the twelve switching schedules.

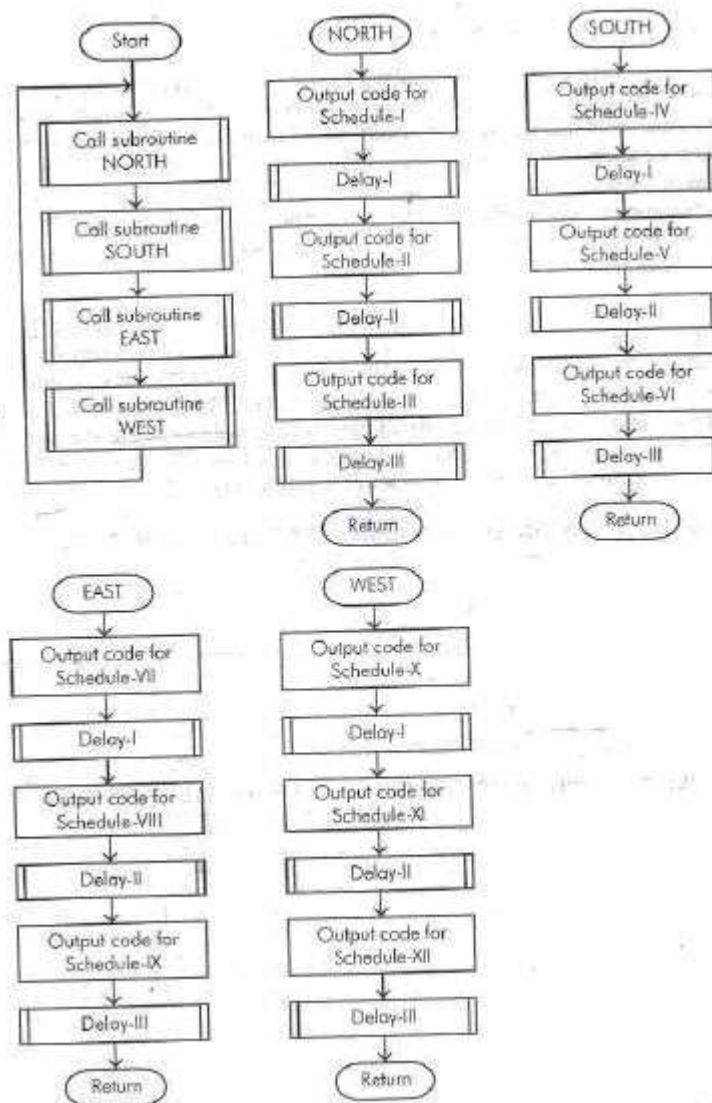


Fig.5.6: Flow chart for Traffic light control system.

Temperature controller using 8085

The microprocessor based temperature control system can be used for automatic control of the temperature of a body. A simplified block diagram of 8085 microprocessor based temperature control system is shown in fig 4 . The system consist of 8085 microprocessor as CPU, ERROM&RAM memory for program & data storage, INTEL 8279 for keyboard and display Interface, ADC, DAC, INTEL 8255 for I/O' ports, Amplifiers, Signal conditioning circuit, Temperature sensor and Supply control circuit. In this system the temperature is controlled by controlling the power input to the heating element.

The temperature of the body is measured using a temperature sensor. The different types of temperature sensor that can be used for temperature measurement are Thermo-couple, Thermistors , PN-junctions, IC sensors. This sensor will convert the input temperature to Proportional analog voltage or current. The output signal of the sensor will be a weak signal and so has to be amplified by using high input impedance op-amp. Then the analog signal is scaled to suitable level by the signal conditioning circuit.

The microprocessor can process only digital signals and so the analog signal from signal conditioning circuit cannot be read by the processor directly. The system has an analog-to-digital converter (ADC) to convert the analog signal to proportional digital data. In this system the ADC is interfaced to 8085 processor through port-A of 8255. The 8085 processor send signal to ADC to start conversion and at the end of conversion it read the digital data from the port-A of 8255.

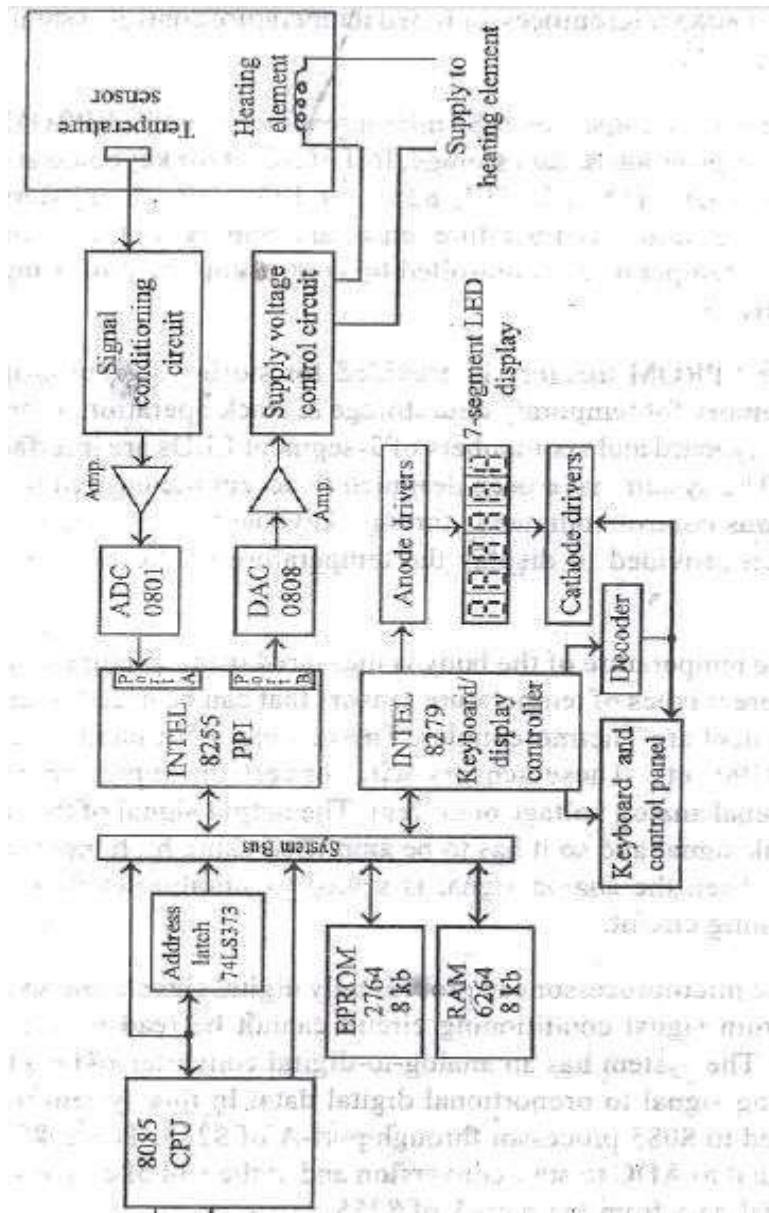


Fig.5.7 : 8085 Microprocessor based Temperature control system.

The 8085 processor calculate the actual temperature using the input data and display it on the 7- segment LED. Also, the processor compare the desired temperature with actual temperature (The operator can enter the desired temperature through keyboard) and calculate the error (the difference between actual temperature and desired temperature).

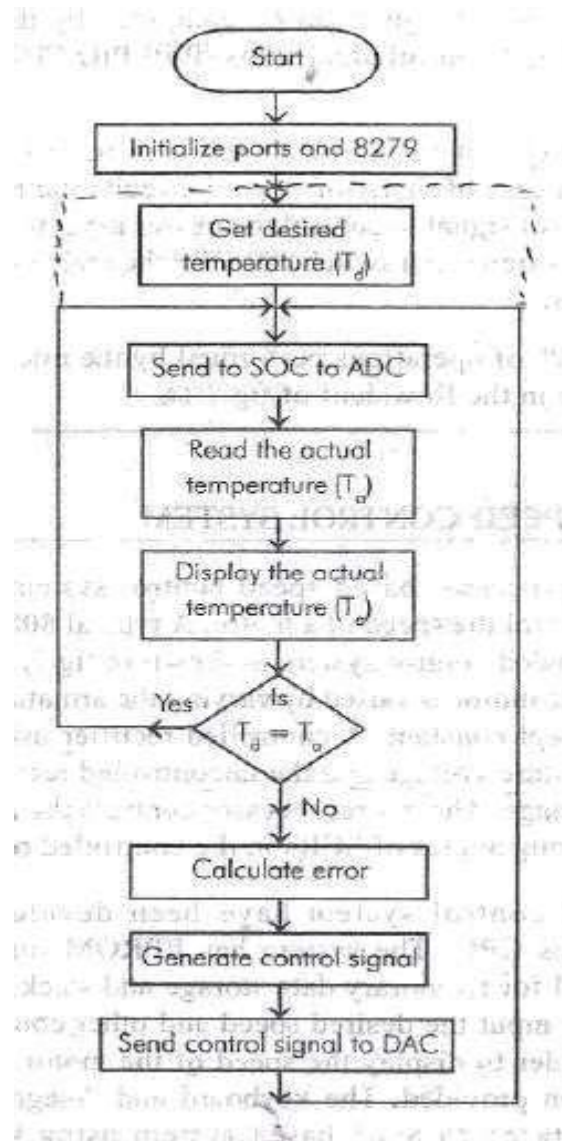


Fig.5.8: Flow chart for Temperature control system.

The error is used to compute a digital control signal, which is converted to analog control signal by DAC. The DAC is interfaced to the system through port-B of 8255. The analog control signal produced by DAC is used to control the power supply of the heating element of the body.

The digital control signal can be computed by the 8085 processor using different

digital control algorithms (PI/PID/FUZZY logic control algorithms).

The control circuit for power supply can be either thyristor based circuit or relay. In case of thyristor control circuits the firing angle can be varied by the control signal to control the power input to the heater.

Stepper motor controller system using 8085

The stepper motors are popularly used in computer peripherals, plotters, robots and machine tools for 'precise incremental rotation. In stepper motor, the stator windings are excited by electrical pulses and for each pulse the motor shaft advances by one angular step. (Single the stepper motor can be driven by digital pulses; it is also called digital motor). The step size in the motor is determined by the number of poles in the rotor and the number 'of pairs of stator windings (one pair of stator winding is called one 'phase). The stator windings are also called control windings.

The motor is controlled by switching ON/OFF the control winding. The popular stepper motor used for demonstration in laboratories has a step size of 1.8° (i.e, 200 steps per revolution). This motor consist of four stator winding and require four switching sequence as shown in table 1. The basic step size of the motor is called full-step. By altering the switching sequence, the motor can be made to run with incremental motion of half the full-step value.

A typical stepper motor control system is shown in fig 6. a two-phase or four winding stepper motor is show in fig 6. The system consists of 8085 microprocessor as CPU, EPROM and RAM memory for program & data storage and for stack. Using INTEL 8279, a keyboard and six number of 7-segment LED display has been interfaced in the system. Through the keyboard the operator can issue commands to control the system. The LED display has been provided to display messages to the operator. The windings of stepper motor connected to the collector of Darlington pair transistors. The transistors are switched ON/OFF by the microprocessor through the ports of 8255 and buffer (74LS245). A free wheeling diode is connected across each winding for fast switching. The flowchart for the operational flow of the stepper motor control system is shown in fig 7. The processor has to output a switching sequence and wait for 1 to 5 msec before Sending next switching sequence. (The delay is necessary to allow be motor transients to die-out).

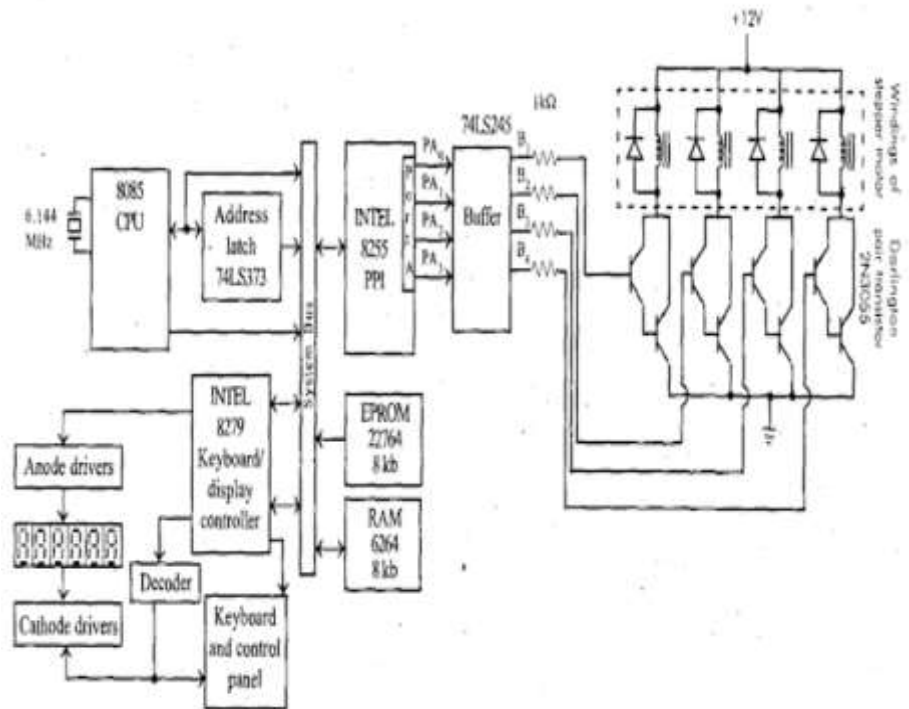


Fig.5.9: 8085 Microprocessor based StepperMotor control system.

TABLE 1: Switching sequence for Full Step Rotation

Switching sequence	Clockwise rotation				Anticlockwise rotation			
	PA ₃	PA ₂	PA ₁	PA ₀	PA ₃	PA ₂	PA ₁	PA ₀
Sequence-1	1	1	0	0	0	0	1	1
Sequence-2	0	1	1	0	0	1	1	0
Sequence-3	0	0	1	1	1	1	0	0
Sequence-4	1	0	0	1	1	0	0	1

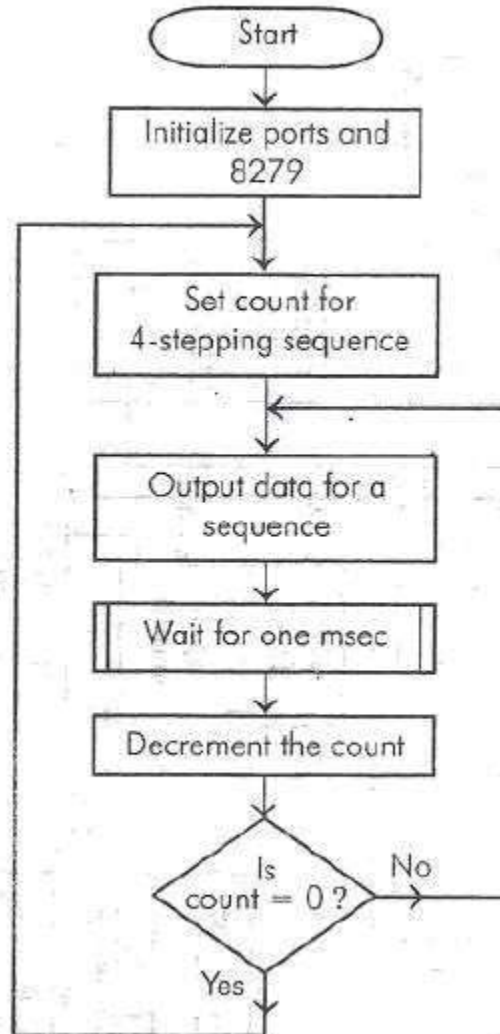


Fig.5.10: Flow chart for Stepper motor control system.

INTERFACING STEPPER MOTOR with 8051

The Stepper Motor to microcontroller. As you can see the stepper motor is connected with Microcontroller output port pins through a ULN2803A array. So when the microcontroller is giving pulses with particular frequency to ls293A, the motor is rotated in clockwise or anticlockwise. **Fig. Interfacing Stepper Motor to Microcontroller**

To control a stepper motor in 8051 trainer kit. It works by turning ON & OFF. A four I/O port lines generating at a particular frequency. The 8051 trainer kit has three numbers of I/O port connectors, connected with I/O Port lines (P1.0 – P1.7),(p3.0 – p3.7) to rotate the stepper motor. Ls293d is used as a driver for port I/O lines, drivers output connected to stepper motor, connector provided for external power supply if needed.

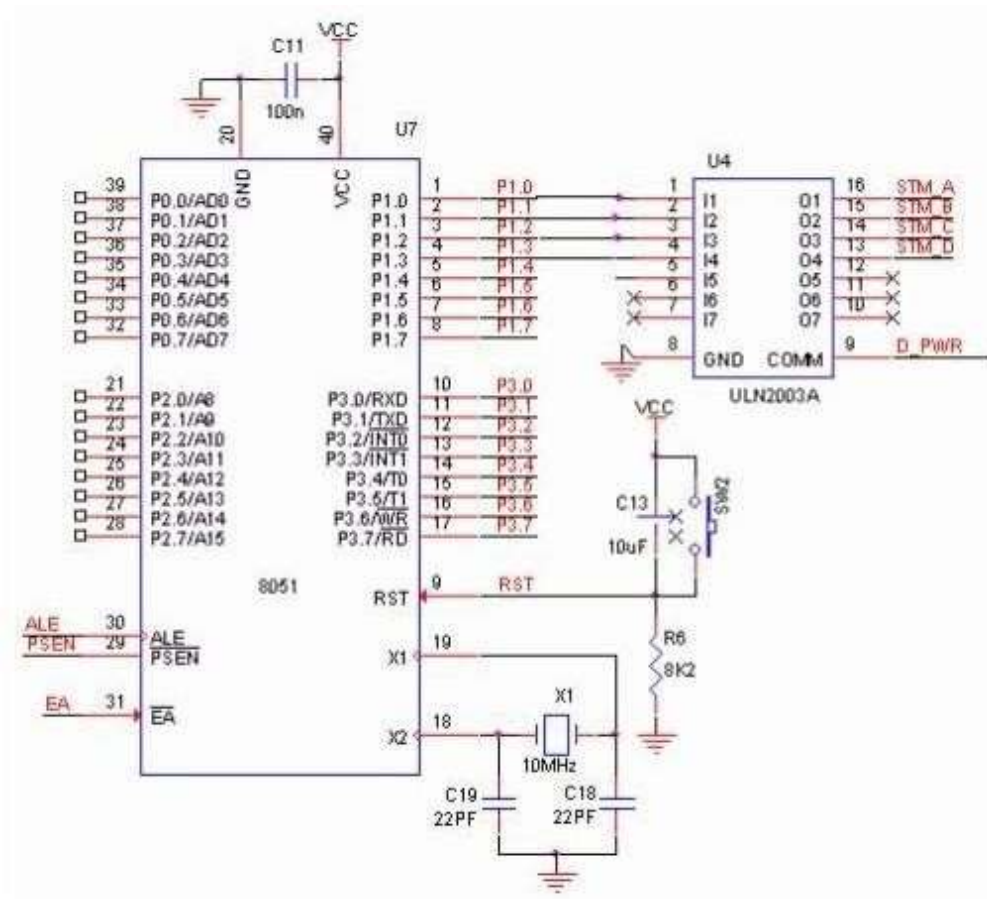


Fig 5.11: stepper motor interfacing- proteus

DC motor interfacing

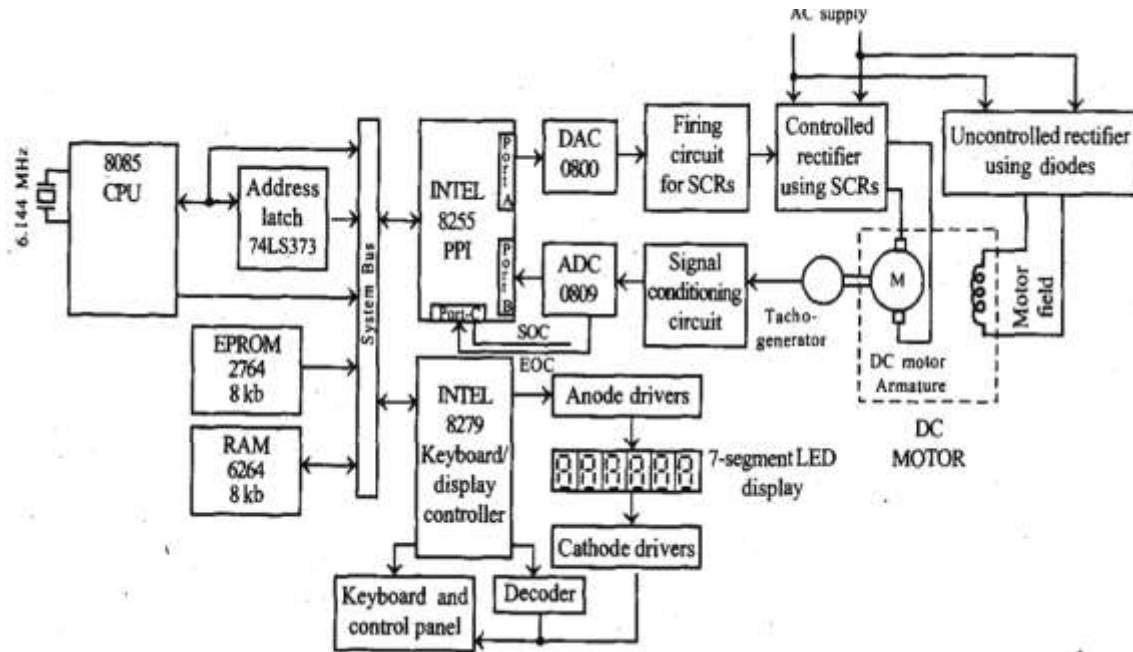


Fig 5.12: DC motor interfacing

Varying the armature voltage varies the speed of the dc motor and e field voltage is kept constant. A controlled rectifier using SCR develops the required armature voltage and the uncontrolled rectifier generates the required field voltage.

- The microprocessor controls the speed of the motor by varying the firing angle of SCRs in the controlled rectifier.
- The system has EPROM for system program storage, and RAM for temporary data storage and stack.
- A keyboard has been provided to input the desired speed and other commands to operate the system.
- In order to display the speed of the motor, 7-segment LED display has been provided. The keyboard and 7-segment LED display has been interfaced to 8085 based system using Keyboard display controller INTEL 8279.

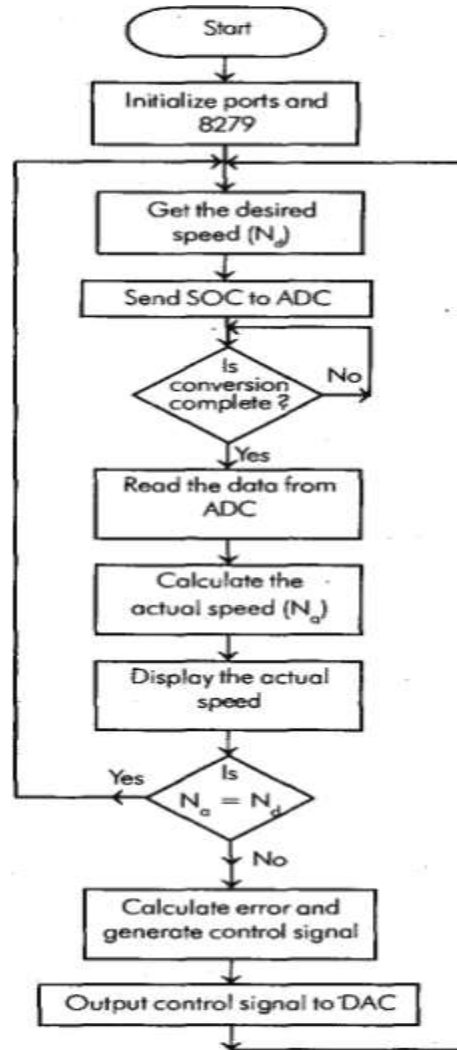


Fig 5.13: DC motor interfacing-flow chart

The speed of the dc motor is measured using a tachogenerator. It produces an analog voltage proportional to the speed of the motor.

- Then the analog signal is scaled to desired level by the signal conditioning circuit and digitized using ADC. (The processor cannot process the analog signal directly, hence the analog signal is digitized using ADC).
- The ADC is interlaced to 8085 processor through the port-B and port-C of 8255. The processor can send a start of conversion to ADC through port-C pin and at the end of conversion it can read the digital data from port-B of 8255. This digital data is proportional to actual speed.
- The processor calculates the actual speed and displays it on LEDs.
- Also, the processor compares the actual speed with desired speed entered by the operator through the keyboard. If there is a difference then the error is estimated. The error can be modified by a digital control algorithm, (P/PI/PID/FUZZY logic control algorithm) to produce a digital control signal.

- The digital control signal is converted to analog signal by the DAC. The analog signal is used to alter the firing angle of SCRS in the controlled rectifiers. The operational the speed control system is shown in the flowchart.

WAVE FORM GENERATION

```
L1:SETB 90
LCALL DELAY
CLR 90
LCALL DELAY
SJMP L1:
```

```
DELAY
MOV R0,#33
L2:DJNZ R0,L2
RET
```

Connect the positive of the CRO to P1.0

Gnd to gnd

Set the bit, call delay so that the on time also depends on the delay

Clear the bit, call delay so that the off time also depends on the delay

Steps to generate a square wave using 8051

1. Set the output of any port on the 8051 to logic high.
2. Wait for some time.
3. Set the output of the same port to logic low.
4. Again wait for the same amount of time as done earlier.
5. Loop around the same.

Subsequently, for obtaining the desired frequency on the square wave. We have to manipulate with the delay. We know that the machine cycle frequency is 1/12 of the crystal oscillator frequency. So, with the crystal oscillator's frequency as 11.0592 Mhz the machine cycle frequency is 921.6 Khz. To sum up, thats equivalent to 1.085 μ second.

To generate a square wave of 1 KHz, in other words, a wave of time period 1 millisecond, we have to use the delay in such a way that it causes a delay of 1 millisecond. We will have to loop around doing nothing for about 461 machine cycles to generate a square wave of 50% duty cycle. That is to say, an on time and an off time of 0.5 millisecond.

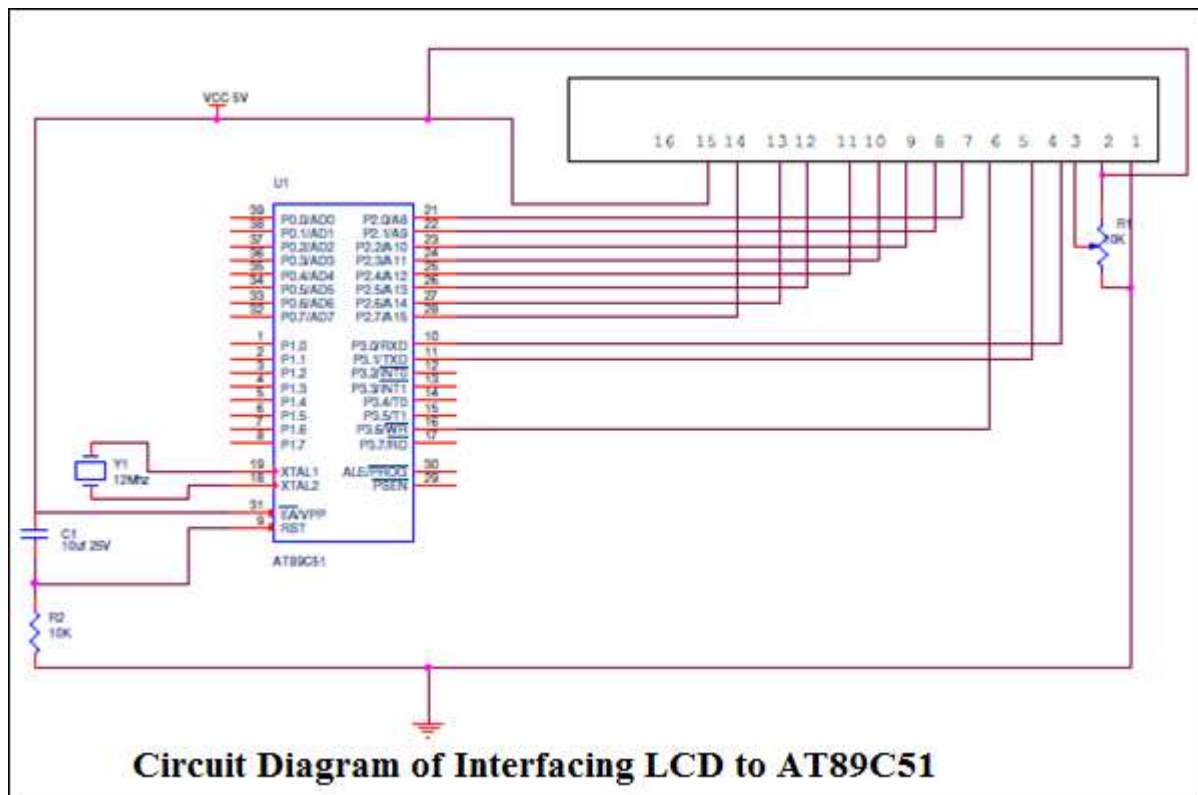


Fig 5.14: LCD interfacing using proteus

LCD: 16×2 Liquid Crystal Display which will display the 32 characters at a time in two rows (16 characters in one row). Each character in the display of size 5×7 pixel matrix, Although this matrix differs for different 16×2 LCD modules if you take JHD162A this matrix goes to 5×8. This matrix will not be same for all the 16×2 LCD modules. There are 16 pins in the LCD module, the pin configuration us given below

LCD UNIT

Pin Number	Symbol	Pin Function
1	VSS	Ground
2	VCC	+5v

3	VEE	Contrast adjustment (VO)
4	RS	Register Select. 0:Command, 1: Data
5	R/W	Read/Write, R/W=0: Write & R/W=1: Read
6	EN	Enable. Falling edge triggered
7	D0	Data Bit 0
8	D1	Data Bit 1
9	D2	Data Bit 2
10	D3	Data Bit 3
11	D4	Data Bit 4
12	D5	Data Bit 5
13	D6	Data Bit 6
14	D7	Data Bit 7/Busy Flag
15	A/LED+	Back-light Anode(+)
16	K/LED-	Back-Light Cathode(-)

Let us look at a pin diagram of a commercially available LCD like **JHD162** which uses a **HD44780** controller and then describe its operation.



Fig 5.15: LCD

Apart from the voltage supply connections the important pins from the programming perspective are the data lines(8-bit Data bus), Register select, Read/Write and Enable pin.

Data Bus: As shown in the above figure and table, an alpha numeric lcd has a 8-bit data bus referenced as D0-D7. As it is a 8-bit data bus, we can send the data/cmd to LCD in bytes. It also provides the provision to send the the data/cmd in chunks of 4-bit, which is used when there are limited number of GPIO lines on the microcontroller.

Register Select(RS): The LCD has two register namely a Data register and Command register. Any data that needs to be displayed on the LCD has to be written to the data register of LCD. Command can be issued to LCD by writing it to Command register of LCD. This signal is used to differentiate the data/cmd received by the LCD. If the RS signal is **LOW** then the LCD interprets the 8-bit info as **Command** and writes it **Command register** and performs the action as per the command. If the RS signal is **HIGH** then the LCD interprets the 8-bit info as **data** and copies it to **data register**. After that the LCD decodes the data for generating the 5x7 pattern and finally displays on the LCD.

Read/Write(RW): This signal is used to write the data/cmd to LCD and reads the busy flag of LCD. For write operation the RW should be **LOW** and for read operation the R/W should be **HIGH**.

Enable(EN): This pin is used to send the enable trigger to LCD. After sending the data/cmd, Selecting the data/cmd register, Selecting the Write operation. A HIGH-to-LOW pulse has to be send on this enable pin which will latch the info into the LCD register and triggers the LCD to act accordingly.

□ E=1; enable pin should be high

□ RS=1; Register select should be high

□ R/W=0; Read/Write pin should be low.

Follow these simple steps for displaying a character or data

To send a command to the LCD just follows these steps:

□ E=1; enable pin should be high

□ RS=0; Register select should be low

□ R/W=1; Read/Write pin should be high.

The crystal oscillator is connected to XTAL1 and XTAL2 which will provide the system clock to the microcontroller the data pins and remaining pins are connected to the microcontroller as shown in the circuit. The potentiometer is used to adjust the contrast of the LCD. You can connect data pins to any port. If you are connecting to port0 then you have to use pull up registers. The enable, R/W and RS pins are should be connected to the 10, 11 and 16 (P3.3, P3.4 and P3.5).

Steps for Sending Command:

- step1: Send the I/P command to LCD.
- step2: Select the Control Register by making RS low.
- step3: Select Write operation making RW low.
- step4: Send a High-to-Low pulse on Enable PIN with some delay_us.

```
/* Function to send the command to LCD */
void LCD_CmdWrite( char cmd)
{
    LcdDataBus=cmd;    // Send the command to LCD
    LCD_RS=0;          // Select the Command Register by pulling RS LOW
    LCD_RW=0;          // Select the Write Operation by pulling RW LOW
    LCD_EN=1;          // Send a High-to-Low Pusle at Enable Pin
    delay_us(10);
    LCD_EN=0;
    delay_us(1000);
}
```

Steps for Sending Data:

- step1: Send the character to LCD.
- step2: Select the Data Register by making RS high.
- step3: Select Write operation making RW low.
- step4: Send a High-to-Low pulse on Enable PIN with some delay_us.

The timings are similar as above only change is that **RS** is made high for selecting Data register.

```
/* Function to send the Data to LCD */
void LCD_DataWrite( char dat)
```

```

{
    LcdDataBus=dat;        // Send the data to LCD
    LCD_RS=1;              // Select the Data Register by pulling RS HIGH
    LCD_RW=0;              // Select the Write Operation by pulling RW LOW
    LCD_EN=1;              // Send a High-to-Low Pulse at Enable Pin
    delay_us(10);
    LCD_EN=0;
    delay_us(1000);
}

```

HARDWARE CONNECTION

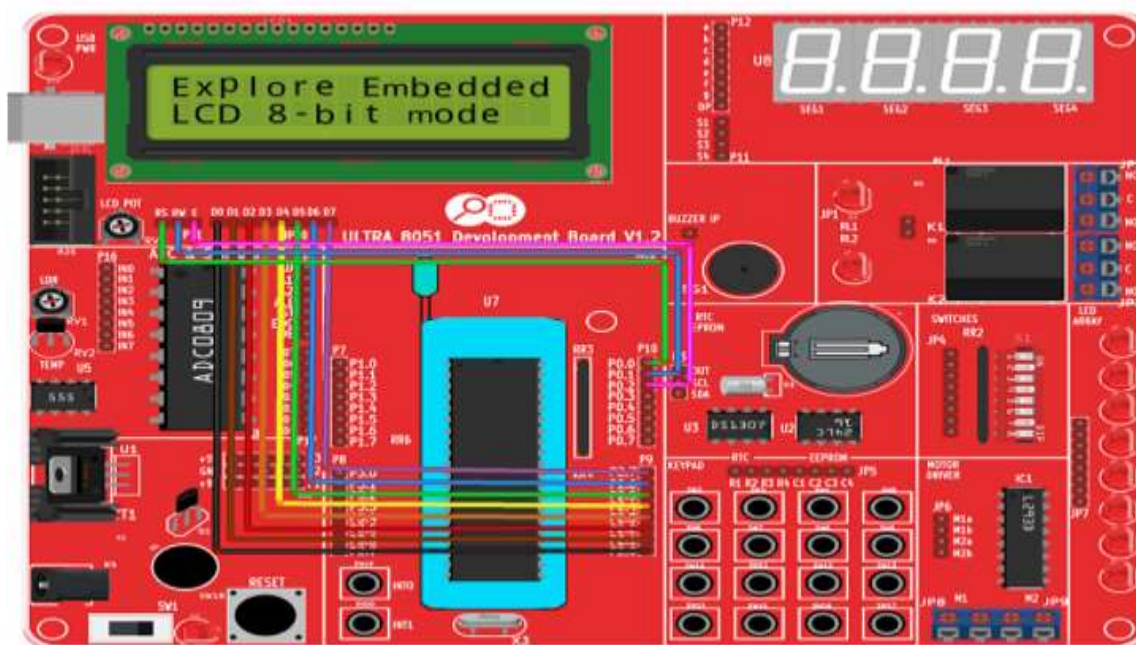


Fig 5.16: LCD interfacing-hardware

Code Examples

code for displaying the data on 2x16 LCD in 8-bit mode.

```

#include<reg51.h>

/* Configure the data bus and Control pins as per the hardware connection
   Databus is connected to P2_0:P2_7 and control bus P0_0:P0_2*/
#define LcdDataBus P2
sbit LCD_RS = P0^0;

```

```

sbit LCD_RW = P0^1;
sbit LCD_EN = P0^2;

/* local function to generate delay */
void delay_us(int cnt)
{
    int i;
    for(i=0;i<cnt;i++);
}

/* Function to send the command to LCD */
void LCD_CmdWrite( char cmd)
{
    LcdDataBus=cmd;    // Send the command to LCD
    LCD_RS=0;          // Select the Command Register by pulling RS LOW
    LCD_RW=0;          // Select the Write Operation by pulling RW LOW
    LCD_EN=1;          // Send a High-to-Low Pusle at Enable Pin
    delay_us(10);
    LCD_EN=0;
    delay_us(1000);
}

/* Function to send the Data to LCD */
void LCD_DataWrite( char dat)
{
    LcdDataBus=dat;    // Send the data to LCD
    LCD_RS=1;          // Select the Data Register by pulling RS HIGH
    LCD_RW=0;          // Select the Write Operation by pulling RW LOW
    LCD_EN=1;          // Send a High-to-Low Pusle at Enable Pin
    delay_us(10);
    LCD_EN=0;
    delay_us(1000);
}

int main()
{
    char i,a[]={ "Good morning!"};

    Lcd_CmdWrite(0x38);    // enable 5x7 mode for chars
    Lcd_CmdWrite(0x0E);    // Display OFF, Cursor ON
    Lcd_CmdWrite(0x01);    // Clear Display
    Lcd_CmdWrite(0x80);    // Move the cursor to beginning of first line

```

```

    Lcd_DataWrite('H');
    Lcd_DataWrite('e');
    Lcd_DataWrite('l');
    Lcd_DataWrite('l');
    Lcd_DataWrite('o');
    Lcd_DataWrite(' ');
    Lcd_DataWrite('w');
    Lcd_DataWrite('o');
    Lcd_DataWrite('r');
    Lcd_DataWrite('l');
    Lcd_DataWrite('d');

    Lcd_CmdWrite(0xc0);          //Go to Next line and display Good Morning
    for(i=0;a[i]!=0;i++)
    {
        Lcd_DataWrite(a[i]);
    }

    while(1);
}

```

QUESTION BANK

PART A

1. What are the two types of seven segment LED
2. Draw the schematic of 7 segment LED
3. Stepper motor interfaced to 8085. How?
4. Write 7 segment common cathode and anode code for displaying 'E'
5. Write the traffic light schedule for N-G, S-R, E-R, W-R and NFL & NFR-ON
6. Write the stepping sequence for stepper motor
7. What is the drawback of LCD
8. Write a program to generate square wave using 8051
9. Compare 7-segment LED and LCD

10. How the speed of the motor can be varied

11. List the applications of Stepper motor

PART B

1. Explain how the 7-segment LED is interfaced to 8085/8051

2. With neat diagram explain the stepper motor interfacing

3. Discuss in detail about temperature control system

4. Explain motor speed control system with necessary diagram

5. Discuss in detail about LCD interfacing with 8051

6. Interface traffic light controller to 8085/8051 and control the traffic.

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