Section - I

Microprocessor, Microcomputer and Development of Some Interfacing Devices
2.1 INTRODUCTION

Unbelievably, man had not the slightest idea about the microprocessor -- the second biggest breakthrough in electronics after the invention of the transistor -- until 1971. The microprocessor had come as a result of the powerful thrust in digital electronics towards miniaturisation, first implementing a complete processing unit on a single integrated circuit (the microprocessor), and then increasing the processing power of that chip. Since then microprocessor technology has been such a rapidly advancing field that revolutionising developments happen almost monthly, if not daily. It is difficult to predict what will happen in electronics over the next ten years but it may be predicted that microprocessors will remain pivotal to advances in science and technology for many decades to come. A microprocessor is a programmable logic device fabricated according to the concept of large scale integration having a large degree of flexibility. To perform a given task, the microprocessor must be programmed and connected to a set
of system devices including memory elements and input output sections. In general, a set of system devices including the microprocessor memory and input/output elements, interconnected for the purpose of performing some well defined function, is known as a microcomputer or a microprocessor system.

The microprocessor is finding new applications every day in different spheres of technology. Presently, for control [97, 107, 118, 119, 152, 153, 164, 166, 168] and protection [71, 117], microprocessors have been widely used. In the communication area, it can handle routine tasks for larger computers, perform simple conversions, detect signals and adjust analog settings, interface lines operating with different speeds and perform editing functions. They can also provide programmability, control displays and operator messages, handle keyboards and allow easy interfacing of equipment, thus increasing reliability and reducing communication costs. Besides all these, microprocessors have also been used successfully in industrial fields, business equipments, in transportation, navigation mobile, and satellite communication systems, consumer area including various games and appliances. Microprocessors are also vital elements in the control and protection of electrical machines and power system, process control and instrumentations, chemical processes and automobiles. Though there are many limitations, the number and variety of microprocessor applications demonstrate the advantages offered by this new technology.

2.2 HISTORICAL DEVELOPMENT

Datapoint Corporation of San Antonio, Texas, is a manufacturer of "intelligent terminals" and small computer systems. In 1969 Datapoint engineers designed a very elementary central processing unit and
contracted with the INTEL Corporation to build the design on a single logic chip. INTEL succeeded to build, and the first microprocessor INTEL 4004 was announced by INTEL Corporation in 1971. It was a 4-bit microprocessor having capability of performing simple arithmetical and logical operations, various control functions etc.

The success of the first microprocessor in various fields had made it possible for the announcement of various microprocessors very soon. INTEL corporation had developed INTEL-4040, an enhanced version of 4004, Rockwell International had developed PPS4, Toshiba had built T3472 and many others had tried to do so. All these are the 4-bit microprocessors.

The first 8-bit microprocessor, INTEL 8008, was developed by INTEL Corporation again in 1973. This processor performs arithmetic and logical operations on 8-bit words. Now, there exists various 8-bit microprocessors of which Zilog Corporation's Z80, National Semiconductors' SC-1 MP, Motorola's M6800, INTEL's 8085, Fair child's F8 etc. gained popularity.

The main object of the microprocessor evolution is to get a device that can perform all the CPU functions of a minicomputer. Typical minicomputers have 16- or 32-bit wide data buses and they can address megabytes of memory. Keeping these in mind, various processors like INTEL iAPX 86/10, Motorola MC68000, Texas Instruments TMS 9900 etc. with minicomputer type CPUs, have been developed. All these are the 16-bit microprocessors.

INTEL'S iAPX 432, Hewlett Packard's HP 32 etc. are the examples of the 32-bit microprocessors which deserve the improved development in this field.

The market today is plagued with numerous types, designs, and families of microprocessor. They are hitting the market like an
avalanche and to many seem to propagate at a mushrooming rate. All of these microprocessors co-exist and may complement each other. The advent of 16-bit and 32-bit microprocessor has not affected the importance of 8-bit devices in the least; rather, it has served to enhance microprocessor performance in terms of speed and range of problems and led to systems with novel functions. Importantly, microprocessors of the same word size often differ in speed and memory size. Obviously, each may advantageously be used to tackle problem of the specific class.

2.3 GENERAL ORGANISATIONS

The block diagram of a simple microcomputer or microprocessor system [89, 103, 140, 141, 179] is shown in fig. 2.1. The three major parts of the microprocessor are the CPU, MEMORY and I/O PORTS.

The system hardware, the physical components and circuits that a microcomputer system comprises, is capable of performing only a small number of different operations. For additional operational capabilities, the microcomputer must be accomplished by programming, called the software which is an organised collection of instructions that manipulate informations and is the most challenging problem in the design of microprocessor based control system.

2.3.1 CENTRAL PROCESSING UNIT (CPU)

In any microcomputer system, the microprocessor acts as the central processing unit. The Arithmetic Logical Unit (ALU) and the Control Unit (CU) together are normally called the Central Processing Unit (CPU) which fetches the instructions from the memory, decodes them and executes them. It also generates timing and control signals, transfers data to or from the memory and input / output sections, performs arithmetic and logical functions, and recognises external signals.
Actual data manipulations within the CPU are handled by proper logic through the units collectively known as the Arithmetic and Logic Unit (ALU). An Arithmetic Logic Unit is the unit which performs arithmetic, logical and some other operations. The arithmetic operations are shifting, addition, subtraction, multiplication and division. The basic logical operations are logical multiplication (logical AND), logical addition (logical OR) and logical negation, inversion or complementation (logical NOT). Some further logical operations include logical NAND (the Scheffer stroke), logical NOR (the Pierce stroke), EXCLUSIVE OR (often called module-2 addition) and some other. If the ALU cannot perform a function directly, several instructions are necessary in order to obtain the desired result. Fig. 2.2 shows a typical ALU having two data inputs, function inputs, a carry input, data outputs and the status outputs.

The Control Unit (CU) obtains the instructions which are stored in the memory, interrupts them, and sequences the operation of the other units to perform each instruction. A complete set of instructions that, when executed on a computer, will perform a required task constituting what is known as a program. A set of instructions to perform a self contained task is called a 'ROUTINE'.

Every CPU has a set of registers that are used for a variety of purposes during the execution of the programs. Fig. 2.3 shows a typical set of registers having many different purpose.

The most important and frequently used register in the microcomputer is the Accumulator (ACC.) which normally contains one of the operands prior to a computation and the results after the computation. The microcomputer may also use ACC. in logical operations, shifts and other instructions.

The status registers hold flags that represent the state of
FIG. 2.1 BLOCK DIAGRAM OF A SIMPLE MICROPROCESSOR SYSTEM.

FIG. 2.2 BLOCK DIAGRAM OF AN ARITHMETIC AND LOGIC UNIT.
FIG. 2.3 A TYPICAL SET OF REGISTERS.
conditions inside the CPU or external serial inputs or outputs. The programmer can use the flags for decision making. The modern microcomputers have several flags of which the common ones are: CARRY, OVERFLOW, SIGN, PARITY, INTERRUPT ENABLE, ZERO etc. The set of flag bits indicating the results of computations and tests is often kept in a special register called the program status word (PSW).

2.3.2 MEMORY SECTION

The memory section of a microcomputer or microprocessor system contains storage units which usually consist of magnetic cores or semiconductor cells. Most microcomputers use semiconductor memory chips whereas only a few use the magnetic cores that are common in larger computers. The memory section is divided into substorage units called the registers each of which is capable of holding one computer word and the place where each substorage unit appears is known as a location identified by an address. The address is simply an integral number that uniquely designates a substorage unit.

An important feature of the digital computer is that both the data and the instructions represented as binary numbers are stored in its memory leading to the two basic design philosophies. In Harvard type computers, it has two separate and distinct memories for the data and the instructions. On the other hand, the computers that use the same format and memory for data and instructions are called the Von Neumann type computers. In this type, the program can appear anywhere within the memory.

Microcomputers frequently have two different forms within its memory units, one being the non destructive read-out or READ ONLY MEMORY (ROM) and the other, the volatile READ / WRITE MEMORY (RAM). Once information
is placed into a read only memory, it can not be modified easily and hence there is no need to write the data back into the memory. In ROM, there is no provision for writing words in the memory during operation. Its contents are either established by the manufacturer or by the user with the aid of the special PROM programmers. For changing the informations once placed in the ROM as required by the user, Erasable and Reprogrammable ROM (EPROM) chips (which can be erased by placing them in front of an ultra violet light source followed by the reprogramming using the PROM programmer) are also available. The Read / write memories which are conventionally referred to as the RANDOM ACCESSIBLE MEMORY (RAM) are the most complex and expensive memories but the easiest to change its contents. These are volatile losing their contents when the power is removed. Read only memories and read / write memories are both randomly accessible. Nevertheless, common terminology refers to Read Only Memories as ROMs and read / write memories as RAMs.

2.3.3 INPUT / OUTPUT UNITS

The input / output units establish the contact between the computer and the outside world. The input unit receives data or instructions from the outside world while the output unit receives the computed result and communicates them to the operator or to another system. The interface of the computer with the outside world is often called input-output ports (I/O ports) which are also addressable so that several input and output devices can be connected to the microprocessor.

The main problem in I/O section is the tremendous variations in its peripherals. The peripherals may be mechanical, electromechanical, electronic and many others which may use digital voltage signals, current signals of continuous (analog) signals. A simple I/O section may
be provided to transfer a single data every 5 minutes or 250,000 bits or more per second. Thus the data on the input lines may change independently and it is necessary for the signals to hold or transform data and to control the operating modes of the peripherals.

In digital computer operations, all informations are handled in discrete form, i.e. with finite integers. It is sometimes necessary for a digital computer to communicate with another system not capable of handling discrete information. In that case, there must be a transformation between continuous and discrete informations. The input and output devices capable of performing this type of transformation are called analog to digital converters or digital to analog converter.

There are many different ways by which data transfer between the microcomputer and the external system occurs. But all these methods may be included in the following three categories:—

i) Programmed I/O : In this system all data transfers are controlled by the microprocessor by executing a program.

There must have some well defined ways by which the output data to be placed in a location where external logic can access it, or alternatively, the microcomputer will indicate in some pre-defined ways that it is waiting for external logic for placing data in some pre-defined locations, from where it will pick up for input purpose.

ii) Interrupt I/O : In this system, the interrupts force the microcomputer to suspend its present work in order to attend the needs of the external system.

iii) Direct Memory Access (DMA) : In this category, data is directly transferred between the memory and the external devices without immediate intervention of the program. A microcomputer system based upon any microprocessor can be made to have direct memory access. To minimise
the data pathways, most microprocessors have a special provision that allows their normal bus system to be used by releasing its control of the bus system at the time of direct memory access data transfer.

2.3.4 BUSES

Different units of a microcomputer are connected by buses each of which is actually a set of lines over which informations are transferred from one unit to the other. A typical bus structure of a microcomputer is shown in Fig. 2.4. Generally, information is transferred in the form of words consisting of a group of bits. In parallel bus, the separate line accommodates each bit of a word while in serial bus, a single line is shared in time by all bits of a word.

The major buses linking the CPU, memory and the I/O ports are the address bus, data bus and the control bus.

ADDRESS BUS:

This bus consisting of 8, 12 or more parallel lines, is used to read or write the address of a memory location send out by the CPU and also to select a particular input or output port.

DATA BUS:

This is a bi-directional bus depending on the operation, data may be coming out from or going to any of the memory, the CPU or the I/O ports. The data bus consists of 4, 8, 12 or more parallel lines.

CONTROL BUS:

The control bus carries signals send out by the CPU and these signals such as memory read, memory write, input read, output write etc. enable memory or I/O ports for proper operations.

The system used for the present study is INCONIX INTELLIGENT
FIG. 2.4 TYPICAL BUS STRUCTURE.
MICRO SYSTEM IMS 5808 built around industry standard based on INTEL 8085A as the CPU. The system features of IMS 5808 has been presented in Appendix - I.

2.4 DEVELOPMENT OF SOME USEFUL INTERFACING DEVICES

In the field of on-line control of power apparatus and transmission system and in designing protective systems, microprocessor has gained popularity because of its compactness, intelligence and reliability.

In developing microprocessor based smart intelligent controller for on-line control of power apparatus and power supply system, proper interfacing arrangement should be made for communication with external world. The microprocessor is a voltage operated device and accepts and transmits voltage signal of magnitude 0 to +5V with its digital form. So, signals from the external world should be converted to microprocessor compatible voltage signal. Some special types of I/O devices become advantageous for interfacing the microprocessor with the on-line real systems of external world, the advent of which dramatically affected the concepts and principles underlying the structure led to the development of automatic control in energy conversion and supply system. Some examples of such devices related to subsequent chapters are the zero crossing detector (ZCD), the peak detector (PD), the triggering circuitry (TC), Analog to Digital Converter (ADC) etc.

2.4.1 ZERO CROSSING DETECTOR (ZCD)

The zero crossing Detector (ZCD) is an useful input device which detects and outputs a voltage signal at the zero crossing instant of waveform under observation. In a microprocessor based triggering system, to trigger a thyristor at correct instant, the trigger angle is to be
calculated with reference to the zero crossing instant of the sinusoid at the positive and negative half cycles and hence synchronisation of control circuit with power signal is necessary. This may be performed by using a ZCD. The ZCD has been so developed that, it converts the positive half of the AC waveform to a rectangular waveform and outputs low during the negative half cycle. The microprocessor, receiving the signal from ZCD through I/O ports, detects the rising and falling moments of AC waveform through software execution and controls the equipment according to the given software.

In developing ZCD circuitry, attempt has been made to produce a microprocessor compatible train of rectangular square wave pulses for a sinusoidal input signal. The detailed ZCD circuitry based on IC LM-339 [175, 176] has been presented in fig 2.5 where the ZCD senses the zero instant of AC waveform by the method of voltage comparison. In this circuitry, the pin - 12 is grounded which acts as a reference. When the input becomes equal to the reference voltage, square wave output is available. If the reference voltage is zero, square wave output is available starting at zero instant. In the case of an operational amplifier there is no feedback and hence the square wave is available due to saturation. The supply voltage has been kept fixed at 5V to make it compatible with I/O port of the microcomputer. The oscillogram of the sinusoidal input and the corresponding output has been presented in fig. 2.6.

2.4.2 PEAK DETECTOR (PD)

Over current protection of power apparatus of house appliances is vital from the safety point of view. In over current protection scheme and / or to measure the instantaneous value of the current, the current
FIG. 2.5 ZERO CROSSING DETECTOR (ZCD).

FIG. 2.6 INPUT AND OUTPUT WAVEFORM OF ZCD.
sensor is necessary, which produces the voltage signal corresponding to the current flowing through the power apparatus. A current transformer (CT) or a low valued resistance can be used for this purpose, which scale down the instantaneous current signal. However, the fault detector (may be microprocessor or electronic) needs the DC voltage signal. Hence to generate the DC voltage signal corresponding to the peak value of the current, a peak detector can be used.

For over voltage and/or under voltage protection scheme, the same peak detector can be used.

The peak detector is useful in the operation with the sinusoidal voltage or fluctuating DC voltage or non-sinusoidal alternating voltages where the magnitude of the peak (maximum) value of the voltage in operation is only needed. It is well known that, the magnitude of AC waveform or fluctuating DC varies instantaneously and the average and RMS values of voltage are proportional to the peak value of the AC waveform. The peak detector outputs the peak value of AC voltage and conveys the same to the microprocessor through A/D converter in case of microprocessor based digital system.

The detailed circuit diagram of a peak detector has been presented in fig. 2.7 which measures the positive peak values of the sine wave input. During the positive half cycle of signal (Vin), the output of the Op-Amp (LM-324) drives diode (D1) on, charging capacitor 'C' to the positive value 'Vp' of the input voltage 'Vin'. Thus, when 'D1' is forward biased, the Op-Amp operates as a voltage follower. On the other hand, during negative half cycle of 'Vin', diode 'D1' is reverse biased and voltage across 'C' is retained. The only discharge path for 'C' is through R. Since the input bias current 'I(B)' is negligible, for proper operation of the circuit, charging time constant (CR) should be less
FIG. 2.7 PEAK DETECTOR (PD) CIRCUIT.

FIG. 2.8 INPUT AND OUTPUT WAVEFORM OF PEAK DETECTOR.
than \((T/10)\) ms and the discharging time constant \((CR)\) must be greater than \((10 \times T)\) ms where 'T' is the time period of the input waveform. The oscillogram of 50 Hz sinusoidal input and the corresponding PD output has been presented in fig. 2.8. The output of peak detector is compatible to the microprocessor and it may be directly connected to the microprocessor through I/O port. Through a proper software, the peak value of alternating waveform may be measured.

2.4.3 TRIGGERING CIRCUITRY (TC)

In triggering the thyristor if the microprocessor output is to be utilised to control the power in power apparatus operating from high powered supply, it is necessary to isolate the load circuit from the logic circuit. In other words, an output logic level from the microprocessor must control a high voltage, high power device without electrical connection between the two devices. The necessary isolation may be provided with an opto-isolator chip MCT-2E with an amplifier circuit.

The optically isolated triggering circuitry has been presented in fig. 2.9. In this circuit, when the microprocessor output is high, it will cause current to flow through in built light emitting diode (LED) of MCT-2E which energises the photo transistor and thus the voltage connected externally with it is impressed on the base of the transistor SL-100 of the amplifier circuit.

The opto-coupler circuitry is extremely helpful to isolate optically the microprocessor based control circuit with the power circuit. It provides protection to the microprocessor and prevents reverse flow of power to the microprocessor.
FIG. 2.9 TRIGGERING CIRCUITRY.
2.4.4 ANALOG-TO-DIGITAL CONVERTER (ADC)

The analog-to-digital converter, ADC, come in the form of LSI chips, is the mandatory building block of any microprocessor based digital system and may be used to convert an analog signals to digital one. Most often, A/D converters are classed according to the manner in which the unknown voltage is digitised for conversion into a digital code. The most popular type of analog to digital converter is the successive approximation (or successive-trial) type.

In the present investigation ADC 0809 has been used. The block diagram of the same has been shown in fig. 2.10(a) and the pin configuration has been shown in fig. 2.10(b). The ADC-0809 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic [51, 178]. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilised comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8 channel multiplexer can directly access any of 8-single-ended analog signals.

The device eliminates the need of external zero and full scale adjustments. Easy interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched TTL TRI- STABLE outputs.

The ADC0809 offers high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability, and consumes minimal power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications.
FIG. 2.10 (a) BLOCK DIAGRAM OF A/D CONVERTER.
FIG. 2.10 (b) PIN DIAGRAM OF ADC0809.