CHAPTER II

DESIGN AND CONSTRUCTION OF COMPUTER BASED VISCOMETER
SECTION 2.1

PRINCIPLE

Absolute Viscosity measurement using poiseuill's law is rather difficult and requires corrections for the kinetic energy of flow, deviations from ideal flow pattern at the end of tube etc. For most practical measurement one uses instruments by which the unknown viscosity is compared with that of the standard liquid, e.g., water. Such an instrument is a glass capillary viscometer. The time \( t \) and \( t_0 \) required for equal volumes of the known liquids to flow through the capillary are measured. Then at a given temperature (T)

\[
\frac{n}{n_0} = \frac{(d* t)}{(d_0* t_0)}
\]

\[
n = \frac{n_0}{(d_0* t_0)*d}t
\]

\[
= B* d* t
\]

Where 
- \( n \) is the viscosity of the experimental liquid
- \( d \) is the density of the experimental liquid
- \( t \) is the time of flow of the experimental liquid
- \( n_0 \) is the viscosity of pure water
- \( d_0 \) is the density of pure water
- \( t_0 \) is the time of flow
- \( B \) is called viscometer constant at temperature T.

Hence, the measurement of viscosity depends on the accurate measurement of time of flow of the liquid through capillary and density measurement.

The commonly used glass capillary viscometer for viscosity measurement is shown is Fig.2.1.1. In this measurement, the liquid in bulb A is drawn into bulb B above the
Fig. 2.1.1
mark U and the flow time is measured using the stopwatch and observing the level crossing of the liquid at marks U and L. The accuracy of time of flow measured depends on the accuracy of stopwatch and on the efficiency and skill of the investigator with respect to the coordination of eye and hand. Several observations are needed for obtaining reproducibility.

These problems are eliminated by replacing (1) the stopwatch with the timer of the personal computer and (2) the coordination of eye and hand with the opto electronic detection system at both the upper and lower marks. The light coming from LED is focused on a phototransistor, which is kept in bridge circuit. The phototransistor detects the level crossing and records the time of the internal clock of the personal computer.

The difference of the times recorded, when liquid is crossing the upper and lower fiducial marks gives the time of flow. This is an automatic measurement and hence the precision of measurement is improved.
The Decade of 1980's has witnessed a phenomenal growth in information processing power and automation. The personal computer, hereafter called the PC, has proven to be very popular and versatile system that can be used in many applications—at home, at work, in the classroom, or in the lab and in the industry. It is relatively inexpensive and available in a compact form.

The Busybee, supplied by Hindustan Computers Limited (HCL), consists of the system unit, the 84 key-full function keyboard, monochrome display and a graphics printer.

The heart of the system unit is the processor board which fits horizontally in the base of the system unit. It contains 8088 (Intel) microprocessor, 640 KB of Random access memory (RAM), Read only memory (ROM), I/O adaptors for the keyboard, audio speaker and system bus expansion slots (62 pin) that allow additional features and interface devices to be added to the system unit (See Appendix 1, for details of the expansion slot). The SMPS power supply unit and two numbers of 5½-inch-360 KB-floppy diskette drives (one is optional) are housed in the system unit. One of the expansion slots on the mother board is used for housing disk controller card. The power supply provides +5 volts and +12 volts.
The monochrome graphics adaptor (MGA) card, which sits in one of the system bus slots on the mother board of the processor board, which can support two functions, has at the rear of the system unit a 9 pin D-type connector for connecting the monochrome video monitor and a standard 25 pin D-type shell connector for connecting parallel printer with the industry standard centronics parallel interface.

The Epson RX80, Dot Matrix printer featuring 8 K byte ROM, 100 cps print speed, 80 column pin feed paper, is attached to the PC through a 25 pin printer interface of the MGA card.

The PC supports the MSDOS operating system versions 3.0/3.1/3.2/4.01 etc., The operating system is a kind of system software closely associated with the hardware. It serves as a link between the user and the computer. The main functions of MS DOS are

1. The control of input and output information. The operating system activates the computer to respond to the information entered either via key board or a disk. It also sends the entered information to the video display, the printer and other output devices.

2. The management of files in the computer. The operating system provides information about name, type and size of the file.

3. To allow one to load program files into the memory of the computer and run them. Program files include utility programs, word processing or other types of application programs.
One can also use advanced personal computers like, PC-XT, PC-AT of 80286/80386/80486/80586 processors with high clock speed and hard disk facilities instead of a just PC. But in the present work any computer of minimum configuration is sufficient and hence only a PC is used. However, the software developed and the interface designed is upward compatible and can work in any advanced computer environment.

In the present work, the system timer and printer port of the personal computer are utilised for interfacing the viscometer. Hence, the important features of the system timer and printer port are described in the following sub-sections.
In several experiments in Physics, measurement of time between events or counting the events occurred in a given time duration is an important activity. This can be done by computer automation, making use of the PC, system timer.

All the activities inside the PC and 8088 microprocessor are synchronised by the clock signal. Many of the processor board functions derive their timing information and signals from the master or base system oscillator. The base system oscillator is driven from a 14.31818 MHz crystal. The 8284A clock chip divides this base frequency by three to derive the 4.772727 MHz signal for the 8088 microprocessor. This results in a system clock time of approximately 210 nano seconds. Both 14.31818 MHz and 4.772727 MHz signals are available on the system bus slots. The 4.772727 is further divided by a factor of four to give a 1.9318 MHz signal that is used to drive the clock inputs on the system board timer counters. The clock circuitry is shown in Fig.2.2.2.1

Each timer counter has a clock input signal and a gate input signal, where the gate controls the clock input to the timer counter. Each timer counter has an output signal whose function is set by programming the mode of operation of the channel. In the PC design, the clock input to all channels is the same, 1.1931517 MHz square wave signal. Thus each tick of the timer counter channels is approximately 838.1 nanoseconds in duration.
The IBM PC clock circuitry

Fig. 2.2.2.1.
**Channel 0**

Channel 0 is used as a general system timer. Its gate signal is tied high, or "on," all the time and the clock input signal is a 1.19318-MHz square-wave signal. The output of the Channel 0 timer is tied to interrupt level 0, the highest maskable interrupt request level. This channel is set up by PC-BIOS to generate an interrupt request on level 0 for every 54.936 milliseconds, or 18.206 times a second. These interrupt requests are counted by a BIOS routine, which generates a time-of-day clock count that can be read or written. The counts are stored in a set of memory locations 40:6C-70H.

**Channel 1**

This timer counter channel is used in a dedicated manner to support the memory refresh function of the system. The clock input is tied to the 1.19318-MHz square-wave signal and the gate is tied high, or always on. The output of the time channel is used to generate a direct-memory access (DMA) cycle request on DMA Channel 0. This DMA channel is used to refresh the system's dynamic memory by creating dummy memory-read cycles every 72 processor clock cycles (Each clock cycle is of 210 nanoseconds duration, or for every 15.12 nanoseconds).

The PC's BIOS initializes the time counter channel in a mode that allows the output to generate an 838-nanosecond output pulse for every 18 ticks of the input clock. Because the input clock is approximately 838 nanoseconds in duration, the timer counter output is generated approximately every 15 microseconds.
Since the system's dynamic memory refresh function is critical to the proper operation of the system, it is highly recommended that this timer counter channel not be modified or used in any manner.

Channel 2

This timer counter channel serves a dual purpose in the PC. First, it is used to output serial data written to the audio cassette port of the system. Secondly, it is used to drive the audio speaker of the System Unit.
2.2.3 PARALLEL PRINTER PORT

The printer adopter of MGA card is specifically designed to attach printers with a parallel port interface, but it can be used as a general input/output port for any device or application that matches its input/output capabilities.

This card provides an 8-bit digital output register that can also be read, a 4-bit output register that can be read and changed to an input register, a 5-bit input register, and an output register bit that can be enabled to generate an interrupt on level 7. The card is designed so that its address can be modified such that it will not conflict with another printer port card in the system. All of the input/output port bits are available for interfacing on a 25-pin D-type connector PCB mounted at the back of the card. This connector protrudes through the rear panel of the system.

Address Modification

The parallel-printer port card normally decodes the I/O port hex addresses 0378, 0379, and 037A. The card is designed to be easily modified such that the port addresses are moved to hex addresses 0278, 0279, and 027A.

An 8-Bit Output Port

At hex address 0378, or 0278 on MGA card, there exists an 8-bit digital output register. The output of this
register is connected to the connector pins, as defined in Fig. 2.2.3.1. Thus, an OUT instruction to these port addresses can write data directly to the connector pins.

A 4-Bit Input/Output Port

At hex address 037A, or 027A on an MGA card, there exists a 5-bit digital output register. Four of the output bits are wired to the 25-pin D-type connector. The fifth bit is used to enable and disable interrupt requests on level 7. The output of the digital output register, and the connector pins that it is attached to, can be read by issuing an IN command to the same port address. Fig. 2.2.3.2 defines the register-bit active levels and the connector pins that they are attached to. Since the four output bits that are attached to the connector pins are driven with open-collector drivers, it is possible to use these points as input bits. If the output register is set to a value that produces a high TTL logic level at the connector pins, the outputs may be dotted low by incoming signals on these pins and, by using the input portion of this register, their states can be sensed. Thus, by programming the output bits to a high level, they can be used as input port bits.

A 5-Bit Input Port

At hex address 0379, or 0279 on a modified card, there exists a 5-bit digital input register Fig.2.2.3.3 defines the active signal levels and the connector-pin assignments for this
register. Bit 7 of this register can be used to create an interrupt on level 7, if it is enabled by the port bit in the 5-bit input/output register port.

p indicates that it is a port of D25 pin connector

OUT 378H

IN 378H (3BC)

D7 D6 D5 D4 D3 D2 D1 D0
P9 P8 P7 P6 P5 P4 P3 P2

Fig.2.2.3.1

OUT 37A_H

IN 37A_H (3BE)

D4 D3 D2 D1 D0
IRQ enable P17 P16 P14 P1

Fig.2.2.3.2.

IN 379H (3BD)

D7 D6 D5 D4 D3 D2 D1 D0
P11 P10 P12 P13 P15 - - -

Fig 2.2.2.3.
SECTION 2.3
I/O CARD DETAILS

The I/O card has two programmable peripheral interface devices (Intel 8255A) and one programmable internal timer (Intel 8253). The card can be plugged into any of the free extension slots available on the mother board of the personal computer. (Shown in Appendix.1) The block diagram of the I/O timer card is shown in Fig.2.3.1.

The PPI used with I/O card is an INTEL 8255A. It is a general purpose Programmable Peripheral Interface device. It is compatible with any microprocessor. It can be programmed to
transfer data under various conditions, from simple I/O to interrupt I/O. It is a silicon gate MOS chip available in a 40 pin, dual in-line package. The 8255 has 24 I/O lines which can be grouped primarily into two 8-bit parallel ports-A and B, with remaining 8-bits as port-C. The eight bits of Port-C can be used as individual bits or can be grouped into two 4-bit ports: C upper(C_u) and C lower(C_l). The functions of these ports are defined by writing a control word in the control register as mentioned in Figure 2.3.2.

The functions of 8255A, can be classified into two major modes of operation. (1) Bit set/Reset (BSR) Mode and (2) I/O Mode. The BSR Mode is used to set or reset the bits in port C. The I/O mode is further divided into three modes: Mode 0, Mode 1, and Mode 2. In Mode 0, all ports function as simple I/O posts. Mode 1 is a hand shake Mode where by ports A and/or B use bits from port C as hand shake signals. In the hand shake Mode, two types of I/O data transfer can be implemented: (a) Status check and (b) Interrupt. In Mode 2, port A can be set up for bidirectional data transfer using hand shake signals from port C and port B can be set up either in Mode 0 or Mode 1.

The 8255A can be interfaced with any microprocessor for parallel transfer of data under program control. In the present study, the 8255 is used in simple I/O mode, i.e., mode 0, and port A is configured as INPUT port to interface the viscometer with appropriate software.
Fig. 2.3.2.
Section 2.4
DETAILS OF EXPERIMENTAL SETUP

Of the several techniques that are available for the measurement of viscosity in liquids and solutions, in this work, the viscometer is suitably modified and improvised for semiautomatic measurement of viscosity by interfacing with the personal computer with appropriate electronic circuitry.

The block diagram of the experimental set up is given in figure 2.4.1.

The function and scope of each block is described in detail.

Regulated power supply

The circuit for the regulated power supply designed with IC 7805 is given in figure 2.4.2. The step down transformer in the circuit gives 6v Ac output with 3A current rating. The bridge rectifier converts A.C into an unidirectional voltage. It is filtered and given to a 3 pin regulator, 7805, which gives 5V D.C regulated output.

IMPROVISED GLASS CAPILLARY VISCOMETER WITH OPTO ELECTRONIC DETECTION:

The improvised glass Capillary Viscometer shown in fig.2.4.3, is used for measuring the viscosities of liquids and liquid mixtures. It consists of two wider bulbs A and B of the same capacity (approx. 15 cm). A capillary E, F is connected to the wider bulb B through a small bulb H. U tube is fixed
REGULATED POWER SUPPLY

TEMPERATURE CONTROLLER

MODIFIED STAND

VISCOMETER WITH OPTO ELECTRONIC DETECTION SYSTEM

BRIDGE DETECTOR I

BRIDGE DETECTOR II

Fig. 2.4.1. DIAGRAM OF THE EXPERIMENTAL SET UP

BLOCK DIAGRAM OF THE EXPERIMENTAL SET UP

Fig. 2.4.1.
Fig. 2.4.2 Regulated Power Supply for 5V.
between capillary and bulb A. A fixed mark G is placed above the bulb A to maintain constant volume.

Two fudicial marks U and L are identified at the upper and lower parts of the bulb B. Light Emitting Diodes (LED's) L1 and L2 with holders, are fixed with araldite at one and of the fudicial marks U and L respectively. LED holders are properly shaped for this purpose. Exactly on the opposite direction two phototransistors P1 and P2 covered with pin holed caps and proper holders are fixed with araldite. LED's and phototransistors are placed in such a way that light from LED is correctly focussed onto the phototransistors. (The intensity of the light falling on the phototransistor depends on the medium in the glass tube).

A 9 pin D type female connector D is fixed on an aluminium sheet bent to a proper shape. It is fixed to the vertical stems of the glass viscometer near the top portion I,J. The anodes of the LED's (at upper and lower marks) are connected to pin No.1 and cathodes of the LED's are connected to pin No.3 of D-type connector. The collector of the upper Phototransistor is connected to pin No.6 and the emitter is connected to pin No.7 (ground). Similarly the emitter of the lower Phototransistor is connected to pin No.7 (common ground) and the collector is connected to pin No.8. A male type D connector is used to take connections to the interfacing unit, where the remaining circuit is housed. Pins 1 and 3 are taken to 5V DC supply through a current limiting resistor (220 ohms).
Modified stand:

In the use of viscometer, it is essential that the hydrostatic head be the same in all experiments as in calibration experiment. The position of the instrument, relative to the vertical must therefore be reproduced with high degree of accuracy. The time of flow is directly proportional to the hydrostatic head. Any deviation from the vertical position will cause considerable error in the time of flow measurement. Hence, in the present work an improvised stand which can keep the viscometer always in vertical position is developed (See Fig.2.4.4.).

For this purpose, a rectangular U-tube T is fixed to an aluminium sheet which is firmly mounted vertically on an iron base Z. A rectangular aluminium pipe R which exactly fits into the U-slot is taken and another aluminium sheet S is fixed to it in a horizontal direction making $90^\circ$ with respect to the vertical pipe. Two round holes, V and W are drilled on the sheet such that the two limbs of the viscometer can be inserted into it.

Another aluminium round rod G which is mounted vertically in the centre of the iron base Z and which passes through a hole X on aluminium sheet S provides additional guidance for firm vertical movement. The viscometer is firmly fixed to the stand by clamp MN.
When the rectangular rod R moves in the U-slot T and the two limbs of the viscometer are inserted into the two holes V and W of the aluminium sheet, the whole viscometer will be exactly in vertical position. The verticality can be reproduced with high degree of accuracy.

Without the above arrangement, the error in the measurement of time of flow was as high as ± 1.5 or 2 seconds between two consecutive experimental readings when the viscometer is reinserted into the Thermostat bath.

After this improvised design of the stand, the time of flow measurements are reproducable with an accuracy of ± 0.05 seconds when the same volume of same sample is taken.

Bridge detectors (I & II):

There are two bridges, one for detecting the liquid cross over at the upper mark U and the other at the lower mark L. The phototransistor forms one of the arms of the bridge circuit. Other arms being two 10 K ohm fixed resistors and a 10k ohm multiturn variable potentiometer in series with 4.7 k ohm fixed resistor (Refer circuit diagram of the experimental set up Fig.2.4.5.

When the glass tube is not filled with the liquid, the ten turn potentiometer PM1 is adjusted such that the bridge is balanced. PM2 is also adjusted such that the other bridge is also balanced. The output of the bridge circuit will be zero under this condition.
Whenever the glass tube is filled with liquid, the light falling on the phototransistor changes and the bridge gets imbalanced. It results in high voltage at the bridge output. The output of the bridge circuit is fed to the differential amplifier.

**Differential amplifiers (I and II)**

One of the quad opamp (LM 324) is used as differential amplifier. The differential amplifier can amplify small signals that are buried in much larger signals. If $E_1$ and $E_2$ are the input voltages of the differential amplifier then the output voltage $V_q$ given by

$$V_q = m(E_1 - E_2) \quad \text{(1)}$$

where 'm' is the differential gain.

When the bridge is balanced, the output of the bridge circuit is equal to zero, then the output voltage of the differential amplifier is also equal to zero. When the bridge is imbalanced, the output of the differential amplifier will be high. The output of the differential amplifier is fed to the voltage follower.

**Voltage follower (I and II)**

The output voltage of the differential amplifier $V_0$ is applied directly to the noninverting input. Since the voltage between inverting and noninverting pins of opamp can be considered as zero in voltage follower configuration, the output $V_{0f}$ is given by
\[ V_{0f} = V_0 \]  

This output voltage equals the input voltage in both magnitude and sign. This output \( V_{0f} \) is passed to the buffer.

**Buffer (I and II)**

The buffer consists of two inverters the first being a transistor inverter. This inverts the input and produces a TTL compatible output. The output is fed to the input of a TTL IC inverter 7404. Hence, the first and second inverters together acts a buffer producing a output which is almost in phase with the input. A LED indicator in series with 1 k ohm resistor is used to visually observe the state of the first inverter. This helps in bridge balancing. Because of the second inverter when the LED is glowing the output of the buffer will be zero. When the LED is off, the output of the buffer will be one.

The output of both the upper and lower half of the circuits which indicate the status at the upper and lower fiducial marks are given to either I/O timer or printer terminal depending on the method followed.

**PC. INTERFACE:**

PC. Interface can be through an I/O timer card or printer port. In this work, measurements are made using both the methods. Details are given in Sections 2.4.1 and 2.4.2.
2.4.1 INTERFACING WITH I/O TIMER CORD

The output of both the upper buffer and lower buffer of the circuits which relate to the crossing of the liquid level at the upper and lower fiducial marks are given to D1 and Do pins of Port A of 8255 of the I/O cord.

The I/O cord contains two 8255 IC's and one 8253 timer. Details are given in section 2.3. The I/O cord is inserted into the mother board of the personal computer. The 8255 programmable peripheral interface IC derives power from the regulated power supply of the personal computer.

The data bus of the 8255 are connected to the data bus lines of the processor on the mother board. The 8255 programmable peripheral interface is configured in mode 0 and all the ports are programmed as input ports through an appropriate control word 9B. It is illustrated in Fig.2.4.1.1.

The addresses of the various ports of this I/O cord are selectable by an 8 way dip switch as described below:

- **SW1-1** - ON - Internal clock of 1.19 MHz to Counter 0
- **SW1-1** - OFF - Counter 0 to use external clock
- **SW1-2** - ON - Internal clock of 1.19 MHz to Counter 1
- **SW1-2** - OFF - Counter 1 to use external clock
- **SW1-3** - ON - Internal clock of 2.38 MHz to Counter 2
- **SW1-3** - OFF - Counter 2 to use external clock
- **SW1-4** - OFF - Use for selecting card address
Fig. 2.4.1.1 CONTROL WORD FOR 8255 PORT CONFIGURATION
SW1-5 Use for selecting card address
SW1-6 NOT USED
SW1-7 NOT USED
SW1-8 NOT USED

PORT ADDRESS:
The Port address of the card can either be &H1F0 or &H1B0 depending upon the position of DIP Switch SW1-4 & SW1-5. Once Port address is decided the addresses of the devices used in the card are as follows:

Port = &H1F0 OR &H1B0

8255 - 1
Port A - Port + 0
Port B - Port + 1
Port C - Port + 2
Central word - Port + 3

8255 - 2
Port A - Port + 8 + 0
Port B - Port + 8 + 1
Port C - Port + 8 + 2
Central word - Port + 8 + 3

8253
Counter 0 - Port + 4 + 0
Counter 1 - Port + 4 + 1
Counter 2 - Port + 4 + 2
Central word - Port + 4 + 3

The personal computer should detect the liquid crossing the fiducial marks at U and L through the 8255 port and display the time of the internal clock both when the liquid is falling below the upper mark and when it is falling below the lower mark. Difference of these two times gives us the flow time.
2.4.2 INTERFACING WITH PRINTER PORT

Instead of interfacing with I/O Cord one can also interface the viscometer with printer port. The details of Printer port are given in section 2.2.3. The output of both upper buffer and lower buffer of the circuits which relate to the crossing of liquid level at the upper and lower fudicial marks are given to pin no 12 and 13 of the printer port.

Pin 12 and 13 represent D3 and D4 bits of port 3, which is configured as an input port. Its address is 40:379(H).

Pin 25 is connected to the ground of the circuit. The advantage of this method being, we need not use any additional I/O timer cord. The viscometer can be interfaced to any computer having a printer port. Of course one has to be sure with regard to the addresses of the printer port.
REFERENCES


