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INTERFACING ARRANGEMENT AND SOFTWARE DEVELOPMENT FOR ACQUISITION AND ANALYSIS OF RESPIRATORY DATA

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ABSTRACT

Lung diseases are still major killers in Bangladesh due to absence of proper diagnostic equipment primarily because of high cost. Indigenous development of transducer, hardware interface and application software can bring the benefit of modern technology at the doorstep of the people. In this respect, computerisation of a mechanical spirometer is an attempt to make the dream of poor people into reality. A wedge bellow type spirometer as transducer, modified ISA card circuit with low cost arrangement for hardware interface and window based easy operating software have been developed to reach to the target.

Key words: Spirometer, interfacing acquizition, respirotory data, software.

I. INTRODUCTION

Diseases related to lung are very common medical problems. Bronchitis, asthma and pneumoconiosis are harmful diseases and cause a lot of sufferings to the patients. The device, ‘Spirometer’ is used to determine how the lungs receive, hold and utilize air, to establish the severity of a lung disease and also to find out whether the lung disease is restrictive (decreased airflow) [1-2] or obstructive (disruption of airflow). Therefore, spirometer is an important device needed in our country where lung diseases are very widespread. But the available devices are imported thereby costly. As a result everybody cannot reach to test the condition of lung, which has results the need to develop some means would serve the purpose of the people of this country.

II. PERSPECTIVE OF SPIROMETER

A spirometer essentially has two basic parts (i) a sensing part that responds to air flow rate or air volume when a person blows through or into the device, and (ii) a recording system that records the time variation of the parameter being measured. The recorded values are then analysed to get various desired parameters. Some of them are briefly described below[3-4]:

i. Forced Vital Capacity (FVC)

It denotes the volume of gas that is exhaled during a forced expiration starting from a position of full inspiration and ending at complete expiration. Normal value is nearly 5 litres for young men of European population and about 4 litres for Bangladeshi people (Ref 1 & 2). This is less in women and FVC decreases with age.

ii. Forced Expiratory Volume (FEV_1)

This is the volume of air expired at one second following full inspiration and normally expressed as a percentage of FVC.

$$\text{i.e. } FEV_1\% = \frac{FEV_1}{FVC} \times 100$$

For young men the FEV_1 is about 80 – 85% of FVC.

iii. Peak Expiratory Flow Rate (PEFR)

This is the maximum flow rate during forced expiration following full inspiration.

iv. Peak Expiratory Flow Rate (PEFR)

This is the maximum flow rate during forced expiration following full inspiration.

The values measured by the spirometer vary due to age, height, sex and race. However, if the values fall below reasonable percent of the average, it may indicate a lung disease or other airflow obstruction.

A. Mechanical End Part

Modern spirometers normally use either a small turbine or a fine mesh of wire as sensor. Both the devices have some basic shortcomings. In the former, the turbine continues to rotate even after a person stops blowing because of inertia. In the latter, water particles coming out with expired air clog some of the holes of the fine mesh so that on repetitive trials it gives different readings.

The Biomedical Physics laboratory of Dhaka University has an old manual spirometer that measures the volume of air rather than flow rate. It uses a wedged bellows (figure 1), which expands when a person blows into it through an opening. A rigid plate that forms the top part of the bellows rotates while the bottom plate is fixed to the base of the instrument. The angle through which the top part rotates is directly proportional to the volume of air inside the bellows. This device does not have the shortcomings mentioned above for the modern sensors, and this age-old device can still be considered as a 'gold standard'. It was reasoned that if this old device can be appropriately tagged to a computer, it could make very reliable and accurate equipment.

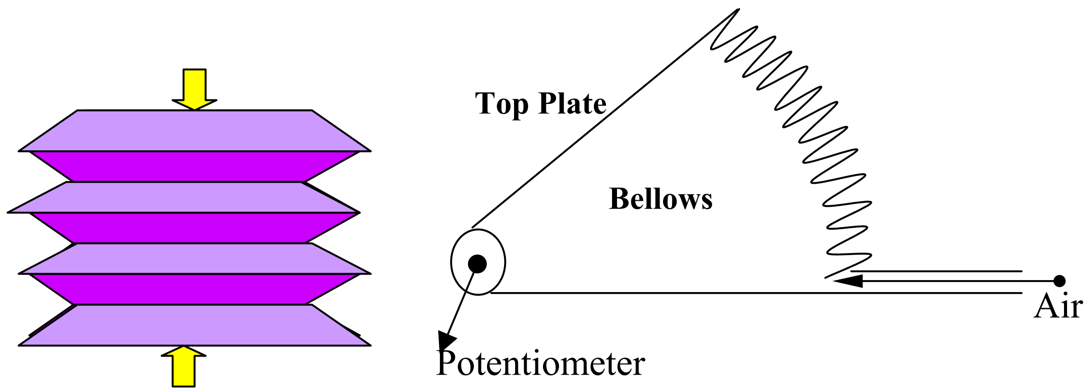

Fig. 1

B. Conversion to Electrical Signal

A linear potentiometer was placed at the pivot of the bellows as a transducer to give electrical signal due to angler motion of the top plate. In the potentiometer the resistance track is circular and the brush rotates co-axially as shown in fig 2(a). A DC voltage source (V_{in}) was connected to the outermost terminals of the potentiometer and the brush connected to the axle of the bellows taps a certain voltage (V_{out}), which is equivalent to angular displacement of the bellows.

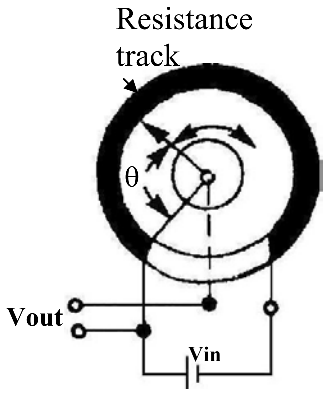

Fig. 2(a)

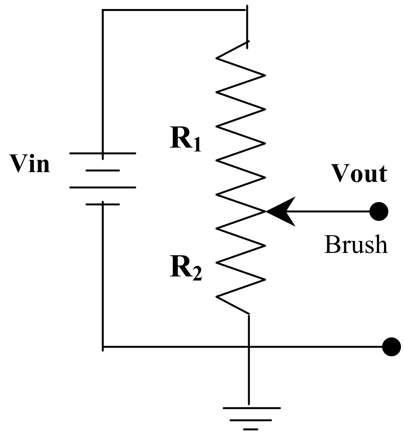

Fig. 2(b)

Here,

$$\text{Vout} = V_{in} \frac{R_2}{R_1 + R_2}$$

Since Vin and ($R_1 + R_2$) do not change in the set up, the output terminal voltage Vout is directly proportional to R_2 which is again proportional to the angular expansion of the bellows.

The multiplexer selects one of the 16 channels at a time to allow analogue electrical signal to go to a successive approximation type 8-bit analogue to digital converter. The converter is controlled using start conversion (SC) and enable output (EN) signals. Selection of the 16 channels is performed using address lines A_0-A_3 of the microcomputer through a Data-Latch. In this interface card memory addresses Hex 300 to Hex 30F was used to select the 16 channels. The analogue signals of the spirometer are fed through channel Y1 of the multiplexer, whose address is H301. The input DC voltage of the sensor (potentiometer) has a range of a 0 to 2.55 V so that it can be simply related to the digital output in the range of 0 to 255.

III. SOFTWARE INTERFACING

A. Triggering for Data Acquisition

The prime requirement of the software is to acquire respiratory data, which is basically the air volume of the lung versus time and to perform subsequent analyses with graphical display as required. Therefore, the software has to provide the necessary signals for the interfacing card to acquire electrical signal produced by the potentiometer.

It is planned to capture 500 data at 10 milliseconds interval from the spirometer through hardware interfacing circuitry. The interval has been chosen considering the human exhalation of 5 seconds. Therefore, 500 data can be taken in a total time of 5 seconds if interval is 10 milliseconds.

B. Hardware Interfacing

When dealing with data acquisition, CPU needs interfacing circuits to monitor events in the real world and to send signals to microprocessor as and when asked by the software. A 16-chhannel analogue interfacing card was used for this purpose. A block diagram of the interfacing card is illustrated in fig 3.

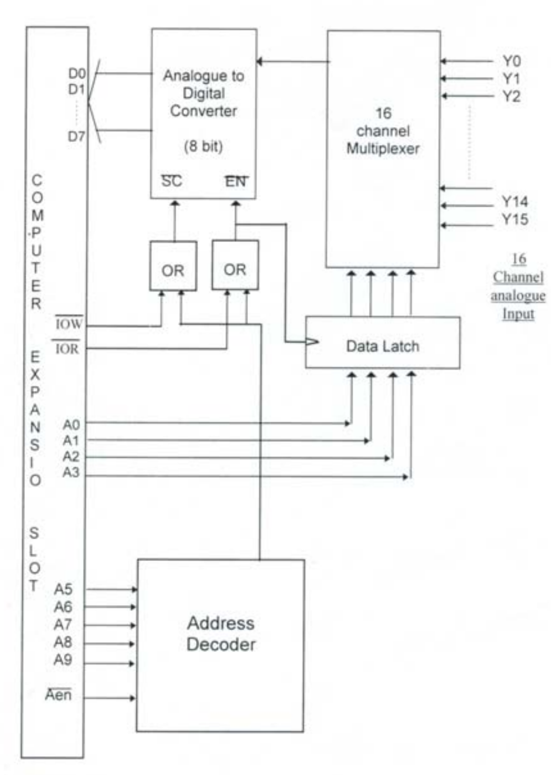

Fig. 3

C. Data Acquisition Loop

The analogue signals are fed through channel Y1of the multiplexer of interfacing card. The basic protocol used in this regard is as follows (The address of the I/O port is H300 to H3FF and the port address of channel 1 is H301):

i. Input (READ) a dummy number from the address H301 (channel Y1). This command automatically latches the multiplexer output to channel Y1.

ii. Output (WRITE) a number to address H300 (any number between H300 to H3FF would do). This command asks the A/D converter to get a sample of input voltage and convert the value to 8-bit binary number. This number is then kept ready at its output buffer.

iii. Wait for a certain time to ensure complete A/D conversion. This is carried out using an appropriate dummy loop in the software.

iv. After the wait loop, input a 8-bit digital data from the address H301 and store in allocated memory location {say X(1)}. The value X(i) transmitted from spirometer has been arranged in the main program as shown below:

```
For i = 1 to 500 then
X(i) = VbInp(&H301)
VbOut (&H300, 0)
X(i) = VbInp(&H301)
Next i
```

v. The input command enables the output buffer of the A/D converter ($\overline{EN}$) and the data is read by the computer from the data bus. This input will be the first data acquired from spirometer. The sampling interval is of 10 ms. Thus it repeats the above procedures (ii) to (iv) 500 times to collect the necessary data set and store in a memory array.

The summarized proposition of data acquisition activities is represented in the flowchart of Fig 4.

D. Data analysis

The data received from the spirometer is proportional to the volume of air blown with respect to time. This single information cannot reveal the lung condition. Some more lung function parameters such as FVC (Forced Vital Capacity), $FEV_{0.5}$ (Forced Expiratory Volume in 0.5 second), FEV_1 (Forced Expiratory Volume in one second) and PEFR (Peak Expiratory Flow Rate) as discussed before are required in order to obtain requisite diagnostic information. Since the temperature of the air and its humidity within the lungs of a human subject and when it is blown into the bellows are different, necessary corrections were incorporated to make the volume correspond to that within the lungs using standard methods.

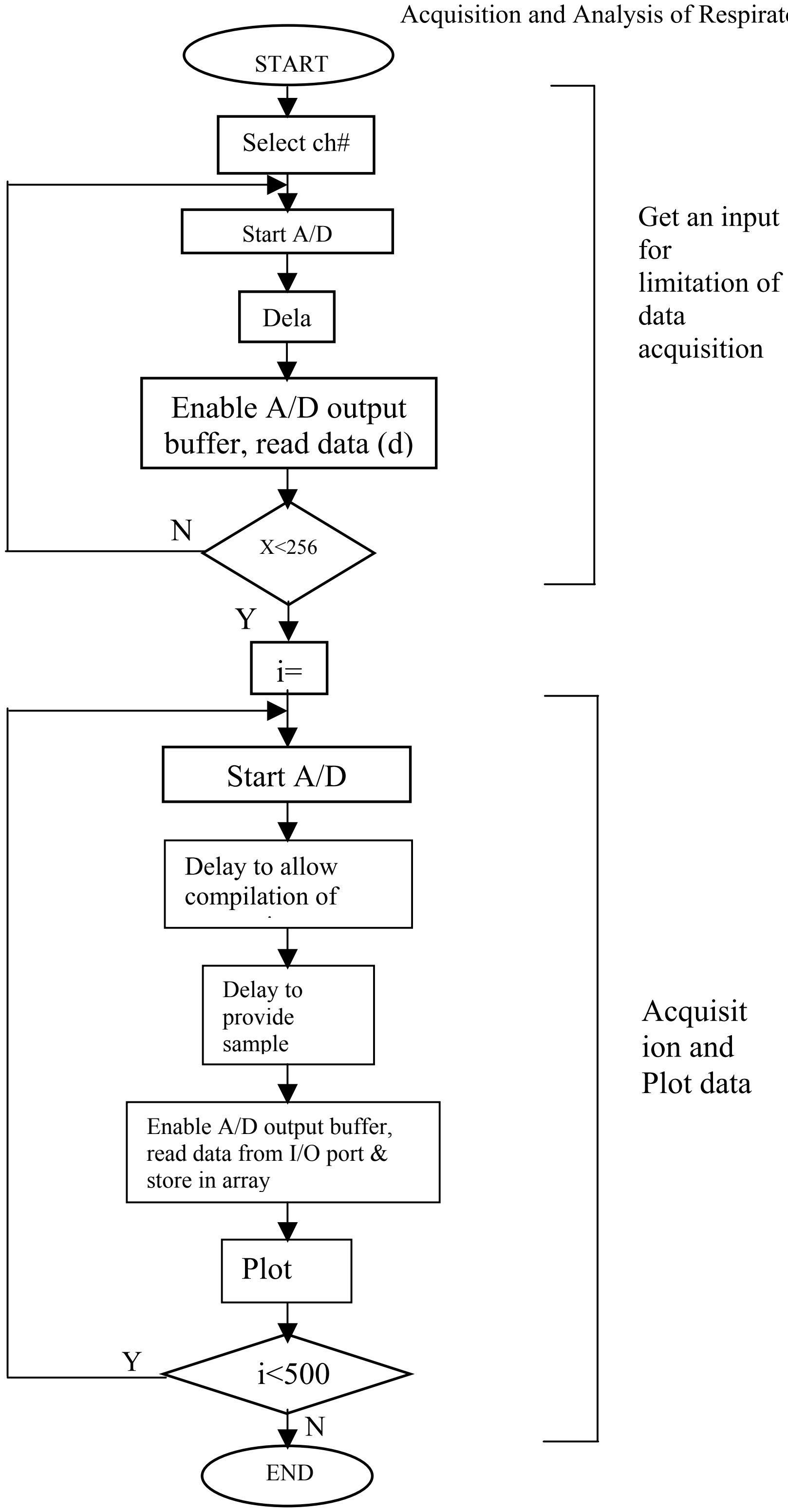
START
Select ch#
Start A/D
Dela
Enable A/D output buffer, read data (d)
N
X<256
Y
i=
Start A/D
Delay to allow compilation of
Delay to provide sample
Enable A/D output buffer, read data from I/O port & store in array
Plot
Y
i<500
N
END
Get an input for limitation of data acquisition
Acquisit ion and Plot data

Fig. 4

IV. BRIEF DESCRIPTION OF DEVELOPED SOFTWARE

The software was developed under the 'Microsoft windows' operating system using the 'Visual Basic (VB)' language. To access the parallel port of the computer with the standard I/O device, Windows needs to be reconfigured for which a system file Win95io.dll was placed as a module.

The main window of the software, which has nine menu items and two object items, will open automatically with the start of software. Sixteen forms and two modules have been integrated to activate the menu items. On left click or shortcut key (Alt+I) the data entry window is unfolded. The operator now can enter name and other particulars of the patient for onward identification. Five command buttons namely new, save, open, print and close have been given. Validation of numeric, non-numeric & date has been provided to verify that the values of appropriate nature has entered in all the columns.

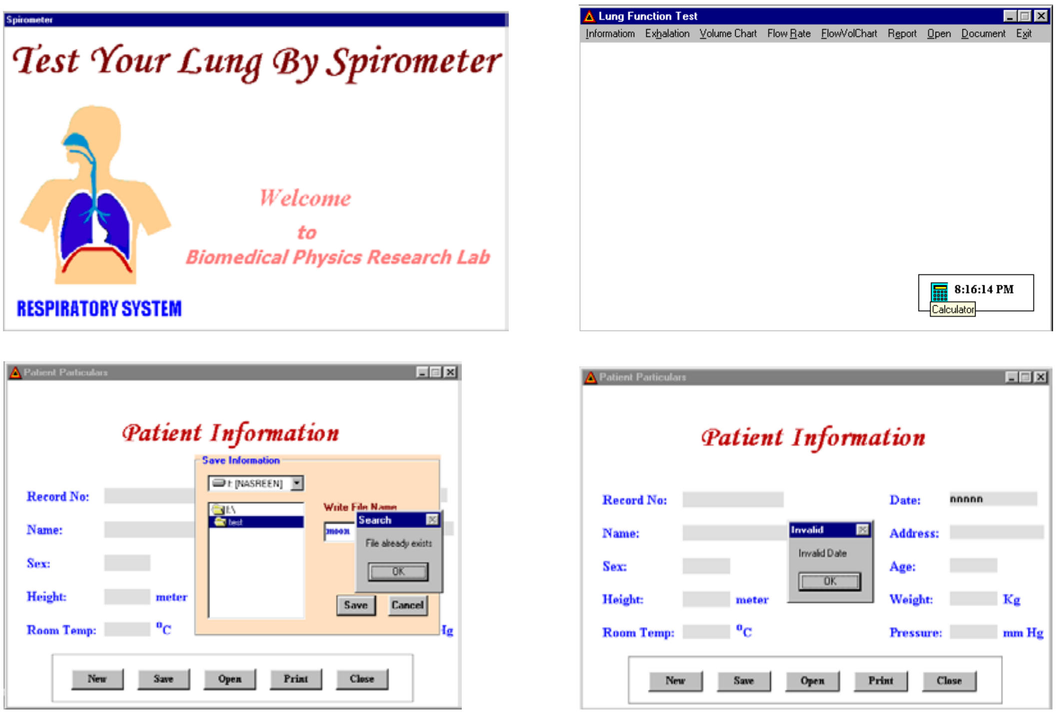

Fig. 5a

The 'Exhalation' menu has been programmed for data acquisition purpose. Left click or shortcut key (Alt+H) can activate the exhalation menu. Here the operator is given the option to choose whether to save the real time the data or to check only for instant.

If NO option of the 'Exhalation With Save!' message box is chosen, it will directly lead to the window for real time graph of volume Vs time.

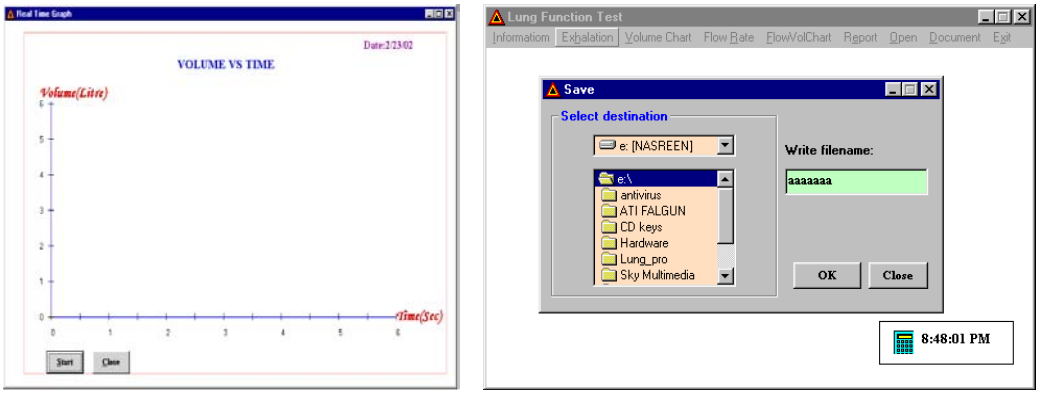

Fig. 5b

The START button switches the hardware interfacing and keeps the window ready to receive the acquired data. With the click of START button graph of lung air volume in litre with respect to time in sec will be plotted automatically. The total time duration for data acquisition for each case has been selected for 5 seconds. During this period 500 samples will be acquired and plotted to display the graphical representation of lung function. The 'Close' command button has incorporated to return to the main window on completion of data acquisition.

The volume chart menu, Flow Rate Menu and Flow Volume menu are operated to plot the captured data in Volume VS time chart, to convert into and display the graph of flow rate Vs time, to convert and display Flow Rate VS Volume data respectively. The movement of the mouse on the curve has been programmed to display the FVC, FEV_1%, PEFR etc. The printing facility of all graphs on line has been provided with. The report menu is there to display the patient information and corresponding graphs along with lung condition parameters FVC, $FEV_{0.5}$%, FEV_1%, PEFR as a comprehensive picture.

Since the acquired data needs to be stored automatically in any specified file in a hard disk as soon as it is available in the RAM of the computer, the provision of automatic and sequential saving of the data is incorporated. Moreover, the software has been developed so that it is user friendly, so that a clinician can use it easily under guidance appearing on the screen of the monitor. The developed software is a complete package for installation to a computer. The operator will be able to operate the developed application software in acquiring the respiratory data from the spirometer with minimum effort.

V. RESULTS AND DISCUSSION

The computerised data acquisition system was tested to acquire data from human subjects and to perform the necessary analyses needed the diagnosis. The parameters like volume vs time, flow rate vs time and flow rate vs volume were also plotted. A typical output report page is shown in fig 8. However, the A/D converter used is capable to handle 8 bit digital output, which limits its resolution to about ½ % of the input signal. The precision can be increased using a 12 bit or a 16 bit A/D converter.

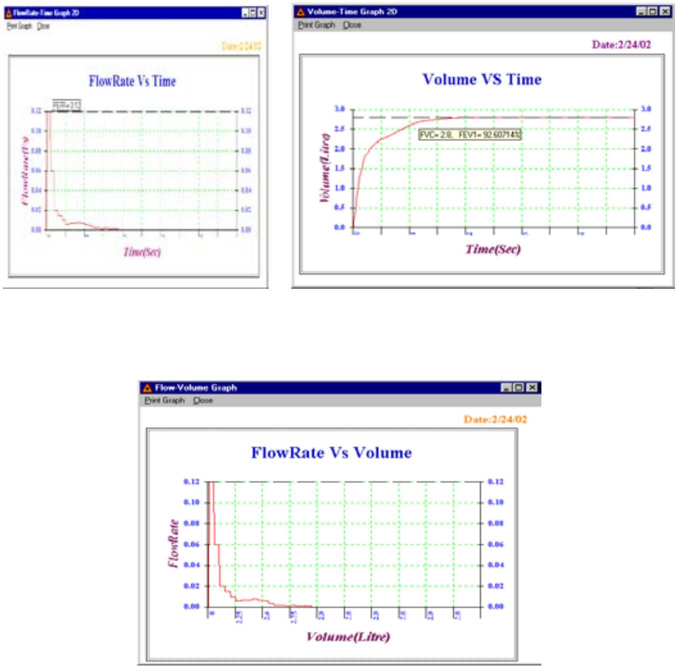
FlowRate Vs Time
Time(Sec)
Volume-Time Graph 2D
Print Graph Close
Date:2/24/02
Volume VS Time
Volume(Litre)
Time(Sec)
Flow-Volume Graph
Print Graph Close
Date:2/24/02
FlowRate Vs Volume
FlowRate
Volume(Litre)

Fig. 6

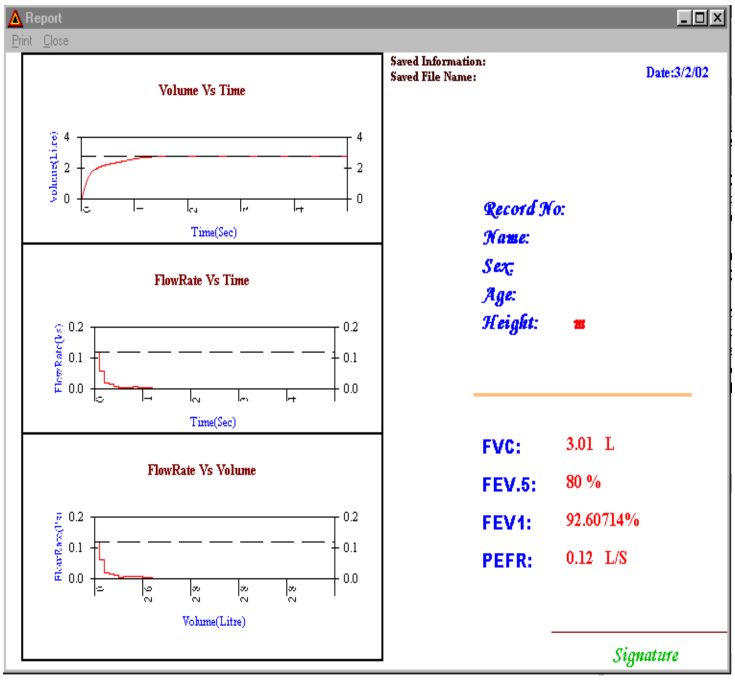
Report
Print Close
Volume Vs Time
Time(Sec)
FlowRate Vs Time
Time(Sec)
FlowRate Vs Volume
Volume(Litre)
Saved Information:
Saved File Name:
Date:3/2/02
Record No:
Name:
Sex:
Age:
Height:
FVC: 3.01 L
FEV.5: 80 %
FEV1: 92.60714%
PEFR: 0.12 L/S
Signature

Fig. 7

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