

magnetic field is sensed by Hall Effect sensor, then it will produce an output voltage in the form of pulses. LED will turn on according to the pulse count i.e. if the pulse count is 50 then LED will turn on 50 times.

BC547 has been used for the purpose of switching the buzzer on/off. The signal from the microcontroller is fed directly to the base of a transistor. It is used to trigger the buzzer which identifies the passing of air inside the mouthpiece, causing the switching on of LED2 and buzzer for a particular time that has been set for the test. This feature alerts the patient that the test has been started, and he/she should try to keep blowing until the buzzer stops. Keypad is designed with four push button switches. LM7805 receives input voltage of 12 V from a Li-ion battery. This alternate is used to make the system portable and less bulky.

The LCD display is used to show different conditional messages and calculated values for parameters FVC, FEV1, FER. The MAX232 circuit is used to level the voltage difference between RS232 and microcontroller. The parameters FVC, FEV1 and FEV1/FVC are calculated and displayed over LCD and PC.

All the operations are synchronized by a software code that is developed for the present system. Software maintains the proper coordination among the different modules and satisfies the conditions which are required for the proper functioning of the Turbine based FSD.

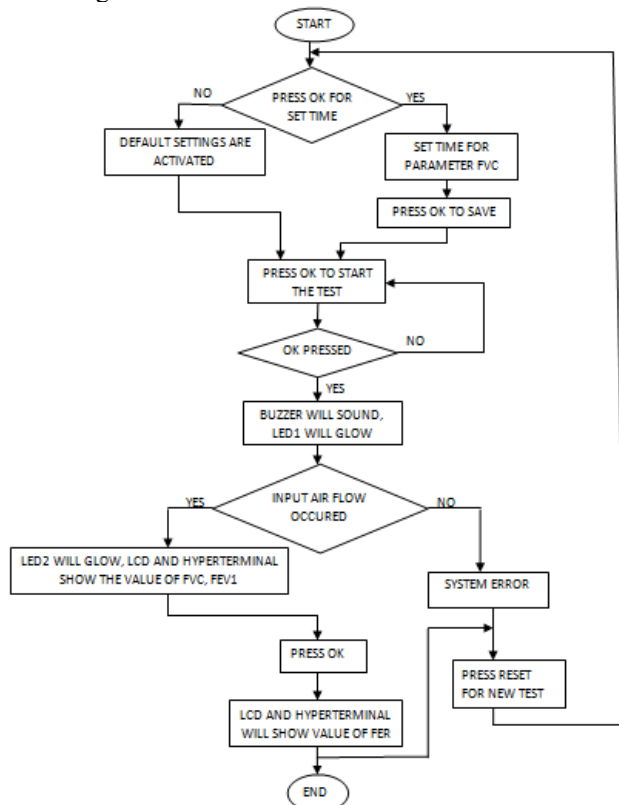


Figure 3: Flow Chart

When the power button is pressed, the system will turn on. Operator is asked to set the time. If within the preset delay time, OK switch is pressed the user comes in manual mode of setting time, else default settings will be activated. Default value for FVC is set as 6 seconds. The values for parameters FVC, FEV1 are displayed over LCD and Hyper Terminal. If

the test has started but no input flow has occurred, the display will show system error, and user is advised to press the RESET switch in order to perform the test from the beginning. Now press the OK switch, and value of FER is displayed over LCD and Hyper Terminal. These values can be saved. To take the next test, press the RESET switch and the process will continue as mentioned

5. Mouthpiece and Turbine construction

Mouthpiece is made of white nylon plastic sheet of 6mm thickness. With this nylon sheet a hollow pipe is made. The radius of inlet pipe is smaller than the outlet pipe. This is done so that maximum air can be flown from input to output. If the area of inlet pipe is smaller than the outlet pipe then less force is required to flow the maximum air. Miniature turbine is placed in the middle area of mouthpiece. Turbine is made of black nylon sheet material. Two Neodymium magnets are placed at an equal distance on the rotor of the turbine. Neodymium magnets are permanent magnets and are preferred to use because they exhibit very strong adhesive force, occupies very less space as they are very tiny in size and are very light in weight. Hence they are preferred to use in applications where miniaturization is required.

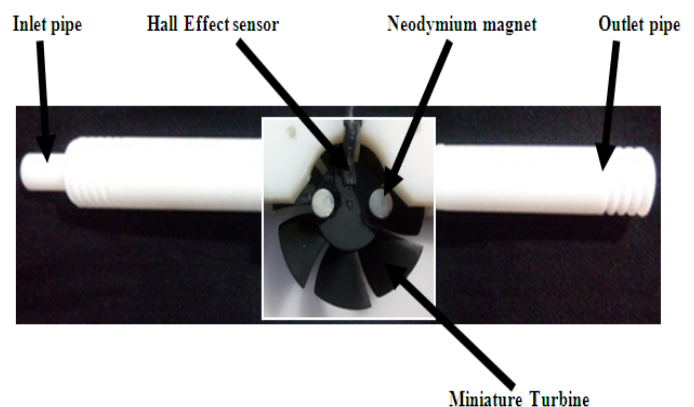


Figure 4: Mouthpiece Internal Structure

Turbine is fixed inside the mouthpiece and the covering of turbine is done with thin sun sheet material made of polycarbonate. Turbine is visible from the top and the cover can be removed when cleaning or some replacement is required.

6. Calibration Process

The quality of any spirometer is closely dependent to its calibration. A check on quality is necessary to rate the accuracy and precision of the device after calibration. When a known volume of air is measured by the spirometer and it is found is approximately same of the known value, then the device is considered accurate. If the same parameter is calculated repetitively and the resulting values are related, then the device is precise. The devices used for both spirometry and flow volume measurements have to be calibrated with a 3L syringe. This calibration is carried out each day the device is used. Present work is based on Turbine based spirometers, which are free from frequent calibration problems. The proposed system implements a Hall Effect Sensor, which senses the rotations of the turbine.

The Hall Effect sensor WSH130 produces an output voltage in the form of pulses. The number of output pulses is proportional to the rotations of the turbine. LED will turn on according to the pulse count i.e. if the pulse count is 50 then LED will turn on 50 times. The units of a spirometer are in liters or milliliters. Hence the system needs to be calibrated in the same units that are used in spirometer. For precision and accuracy purpose this pulse count is calibrated in terms of milliliters.

The calibration a flow sensing device can be done with a standard spirometer. A reference spirometric device known as RMS Med-Spiro is taken. Constant and similar air flow is fed to both the Turbine based FSD and RMS Med-Spiro simultaneously. Time is kept constant. Different readings are taken, values are approximated and a calibration graph is plotted. Reference value to be set in Turbine based FSD is calculated by using standard formulas of mathematics and used to develop the software code for the air flow measurements. Now Turbine based FSD gives the output in milliliters.

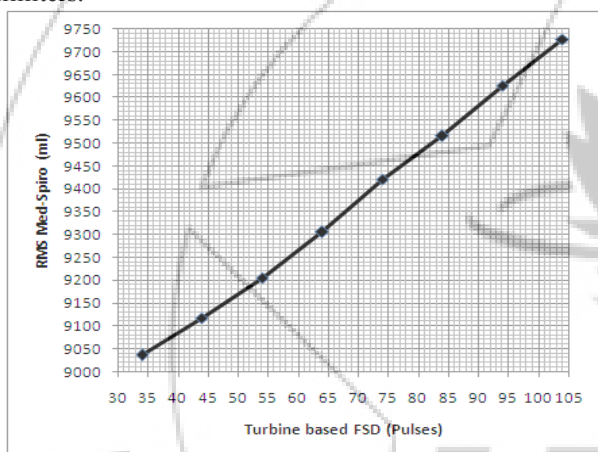


Figure 5: Calibration graph

7. Results

The objectives of present work have been achieved and an efficient system is developed which consists miniaturized turbine with implementation of Hall Effect sensor to measure the volumetric flow of air inhaled or exhaled by lungs. Main goal of the system was to develop a Turbine based FSD that can measure the air flow and display it on LCD, Hyper Terminal according to the input provided by patient and to develop a software code that can calculate the parameters FVC, FEV1, FER as per the input flow.

The device developed is properly working and is ready to use as a spirometer. The designed system is functional and all tests implementing the hardware and software are done. When the system is functional and all tests implementing the hardware and software are done then results are displayed over LCD and Hyper Terminal. At least three tests should be done on a patient and it is acceptable to select the highest FVC, highest FEV1 from different tests, till the maximal effort is obtained from the patient. The results can be analyzed with reference to ATS standards.

Spirometry tests are totally dependent on efforts of the operator and subject. Hence, the patient should fully

collaborate with the operator while performing the test. The developed prototype is used to test its functionality and performance. Different readings are taken and parameters are calculated. The details of test are given in Table 7.1

Table 1: Breathing test results:

S.No.	Parameter	Value of the Parameter
1.(a)	FVC (ml)	11810
1.(b)	FEV1 (ml)	9160
1.(c)	FER (%)	77
2.(a)	FVC (ml)	9980
2.(b)	FEV1 (ml)	8250
2.(c)	FER (%)	82
3.(a)	FVC (ml)	9840
3.(b)	FEV1 (ml)	8660
3.(c)	FER (%)	88

From the above values physicist can analyze the results of the tests. Normally, the value for FEV1/FVC is 75%, or more. Lower value for this ratio indicates an obstructive defect in the lungs. A high value for this ratio (i.e. >85%) depicts very fast lung emptying and is indicative of a restrictive defect.

The system is designed to meet the ATS standards. According to ATS the acceptable flow range for FVC, FEV1 should be 0-14 L/s and FVC time should not exceed more than 15 seconds. In order to obtain the maximal values for FVC and FEV1, operator should make sure that the patient initially inhales to his/her Total Lung capacity (TLC), and then exhale with maximal effort.

8. Conclusion

The demand for accurate diagnosis of breathing problems is at high pace, because of increased contaminations in the atmosphere and rise in habits like smoking, alcohol use etc. Proposed system is a solution to these problems. It can be used as an application in spirometry and flow-volume measurements. It provides effective measure of PFT parameters such as FVC, FEV1 and FEV1/FVC. It provides highly reliable and time efficient way to measure the PFT parameters. The proposed system is especially appropriate for its clinical use. The proposed system is simple and easy to operate and install. It incorporates simple hardware by using small number of components. The system is portable, small in size, consumes less power and is of low cost. It implements fast and reliable technology, for efficient diagnosis of any respiratory illness.

9. Future Scope

Although the designed system is very efficient, but there is always a room for improvements. Graphic LCD can be embedded in the system so that real time values of parameters can be plotted. Moreover system can make use of EEPROM which can hold the multiple records of various patients. Android application or window based application software can be designed for the proposed system, which will show real time interfacing of the device. The present system is powered from a battery. The use of battery can be eliminated by designing the system in such a way so that it can receive power directly from the computer.

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Author Profile



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Jaspal Singh graduated with distinction from Thapar University in the year 1991. He has hands on experience in the entire range of medical instrumentation and systems. He worked in multinational, GE medical systems. He was involved in teaching and training medical equipment technology at various levels. He completed his MBA. He received M tech degree in electronic instrumentation from Punjab University. Thereafter he has worked extensively on development of various electronics & embedded system technologies for healthcare.