Research Paper

Volume : 3 | Issue : 11 | November 2014 • ISSN No 2277 - 8179

Design And Construction of a Cost Effective Precision Prototype Portable Spirometer

Medical devices

KEYWORDS : spirometery, micro controller, dynamic lung volumes, forced vital capacity

Mohsen Ahmadi — Department of Biomedical Engineering, Faculty of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Faezeh Sadat Mousavi — Biomedical Engineering Department, Faculty of Medicine, Shahid Beheshi University of Medical Sciences, Tehran, Iran

ABSTRACT

Spirometery is the most essential part of any pulmonary function study and provides the most information. In spirometery, a device called spirometer is used to measure certain dynamic lung volumes. These volumes are determinants of some respiratory diseases. The two most important dynamic volumes measured are Forced Vital Capacity (FVC) and Forced Expiratory Volume in the first second (FEV1) of expiration [1]. The aim of this work is to design and develop a cost effective, user-friendly spirometer that uses sophisticated technology and measures the dynamic volumes with precision. It is robust and portable, yet, one can manufacture it easily. The device is programmable and can incorporate new trends and ideas in spirometry with little effort. People in less affluent countries can benefit from this technology immensely.

I: INTRODUCTION

Respiratory diseases cover a broad range of chronic and acute illnesses of the nose, ears, throat, and lungs (i.e., colds, influenza, pneumonia, tuberculosis, bronchitis, asthma, and lung cancer) [2]. Adult respiratory diseases in the developing world are a major burden in terms of morbidity and mortality and, particularly as related to chronic respiratory disease, are of increasing concern [3], [4]. Hence, there must be a need for applying a cost effective diagnosis and therapy in these countries. Pulmonary function test is the way to control or detect the respiratory diseases. It can be used to: 1. Differentiate obstructive lung disease from restrictive lung disease, 2. Assess the severity of lung disease, and 3. Evaluate response to therapy. Having these capacities, pulmonary function test is applied widely to evaluate a broad range of lung disorders [5],[6]. Spirometer is an apparatus for measuring the lung vital volumes. In this work, we design, develop and construct a cost effective, portable prototype touch spirometer. It is user friendly, sophisticated, low cost and can be globally utilized. It compares very well with available commercial systems

II: MATERIALS AND METHODS:

SYSTEM DESIGN

A. Hardware: Electronic control board

System hardware consists of an electronic board, a flow sensor and a 7 inches touch liquid crystal display (LCD) as well as a 9 volts DC battery (Figure 1). At the heart of the board, there is a powerful microcontroller, IC, PIC18F452 from Microchip Corporation. All relevant input output signals to the micro are shown in Figure 1. A 7 inches LCD, 240128-D, from Hitachi, 240*128 pixel resolution, is used for displaying data and user interactions with the device, as shown in Figure 2. The "TOUCH" capability is integrated into the LCD by the use of a four-wire resistive touch screen, TSR5413 from Densitron. Data can be stored and retrieved from a serial EEPROM IC, which is in communication with the micro.

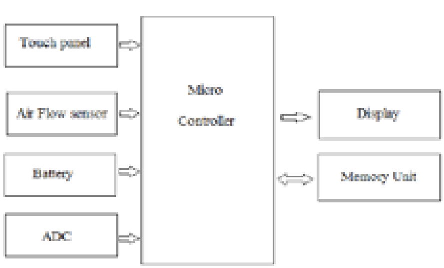

Figure.1) *block diagram of the microcontroller with all relevant signals*

Figure.2) *Portable Spiromer with LCD incorporated*

In this work, we measure variation of airflow during patient expiration using flow sensor AWM720p1 from Honeywell Corporation. The sensor's output is already amplified and temperature compensated. The signal from the sensor is connected to the analog to digital converter (ADC) of the micro to be digitized. Digital flow signal is low pass filtered through sample averaging to further remove the effect of noise and increase the accuracy of the data (Figure 2). In total, 1000 expiration airflow samples are collected from the patient within 5 seconds, which is then reduced to 250 after averaging to be displayed on the LCD (Figure 3). We extract dynamic lung volumes extracted from this data.

A Two-Wire Serial EEPROMA IC, 24C04, from Atmel Corporation has been used to store data that can be subsequently retrieved and sent to a computer or a printer to be stored on other mediums. The spirometer uses a 9 volt DC battery for all its power requirements.

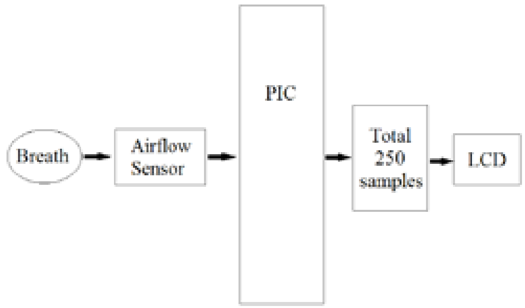

Figure.3) *Block diagram of the flow signal*

B: Software

The program for the micro was written in C language and we used "MikroC Pro for PIC" compiler to develop the code. Figure 4, shows an overview of the code flow diagram. As shown, the ADC and the LCD are initialized first. As patient expires into the flow sensor, the airflow signal is digitized and stored, next.

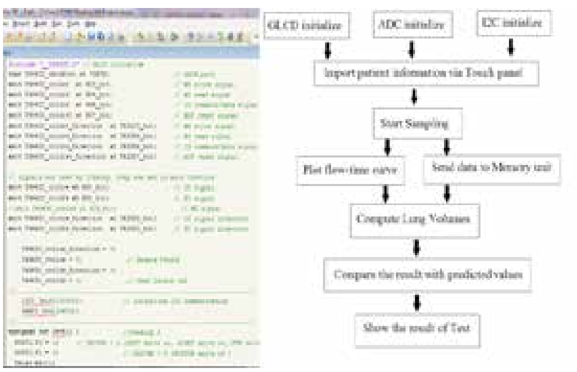

Figure.4) Micro's *code flow diagram*

For respiratory disease evaluation, we need to compute FVC and FEV1 lung volumes. We obtain FVC by integrating expiration flow-time curve, while FEV1 is the integral of the flow-time cure during the first second of expiration. Diagnosis of the degree of lung obstruction and or restriction tendencies is done based on comparison of the two lung volumes with predicted values from standard sources. The formula used to measure FVC and FEV1 is based on the previous work described in the literature [7]:

FVC = 0/842 + 0/083 (sex) + 0/010 (height) + 0/003 (weight)

FEV1 = -0/651 – 0.004 (age) + 0/020 (height)

Patient No	Test 1	Test 2	Test 3	Largest difference
1	FVC= 2971 FEV1= 2224	2877 2128	2899 2152	3.2%
2	FVC= 3372 FEV1= 2625	3146 2403	3175 2421	6.9%
3	FVC= 3380 FEV1= 2614	3217 2462	3175 2428	6.2%

As can be seen, patient gender, weight, height and age are all taken into consideration.

EVALUATION OF DEVICE PERFORMANCE

To evaluate the performance of the sprirometer comprehensively, some test protocol was devised that would principally verify the accuracy and repeatability of the device when measuring lung volumes. To test how accurate the device measurements were, we used five patients and measured their lung volumes on both, a market standard spirometer, SPIOLABШ from MIR Corporation, and our spirometer. The results are shown in table 1. As can be seen the differences in measured volumes are quite negligible and within an acceptable range.

However, to verify the repeatability of the spirometer measurements, we chose 3 patients and asked them to perform standard expiration maneuver for three times each. Table 2 shows the results for this test. In each case, the largest difference obtained for FVC and FEV1 volumes for the same patient is less than 7% of the average volumes, which is quite acceptable for such pulmonary function tests. The device shows persistent repeatability when measuring the required volumes.

Table.1) *Comparison of lung volume measurements by an standard spirometer versus ours*

Patient No	Standard spirometer	Our spiro	Diff.	Error %
1	FVC= 2080 FEV1=2080	2090 2026	10 -54	0.5% 2.6%
2	FVC= 2930 FEV1=2670	2847 2531	-84 -139	2.8% 5.2%
3	FVC= 3860 FEV1= 3700	3617 3319	-243 -381	6.3% 10%
4	FVC= 1600 FEV1= 1470	1696 1633	96 163	6% 11%
5	FVC= 1190 FEV1= 1190	1145 1081	45 109	3.7% 9.1%

Table.2) *Repeatability test result of 3 patients*

DISCUSSIONS

During the evaluation phase of the prototype system, we verified the correct interaction of system's hardware and software. It measures dynamic lung functions with accuracy and repeatability. The simple formulas used to calculate FVC and FEV1 yields measurements which are reliable, since they compare well with those of standard common spirometers on the market from reputable international companies. The device gives clear indication of the type of pulmonary disease (resrictive or obstructive) as well as the severity level of the same. The system has capability to store patient data when power is off. Data can be retrieved into the LCD for viewing and be sent to a computer or a printer if or when required. The power consumption of the device is very low and a 9 volt standard Alcalyne battery lasts a long time. One great aspect of the design of this device is its remarkable ease of use for medical satff with practically no training.

CONCLUSIONS

In this work, we presented design and construction of a low cost and user-friendly portable spirometer, vital for diagnosis and evaluation of pulmonary function disorders. The developed system measures two most important lung volumes with high accuracy and repeatability. The components used in the construction of the device are widely available in any electronic lab and or can be obtained from any electronic component supplier. The device is very light, portable and easy to interact with since we have incorporated "touch" capability into the LCD. Patient's specifics such as gender, age, weight and height are stored with pulmonary data for record purposes. The device code written in C language is revisable and new ideas regarding the functionality of the device can easily be programmed into the micro. Considering the air pollution and associated respiratory diseases round the world, one can construct this device in no time at a very low cost. In particular, it can be available and accessible to medical healthcare establishments as an effective diagnosis tool in less affluent and developing countries.

ACKNOELEDGEMENTS

The authors declare no competing financial interests. This paper is a major part of a Msc. thesis in Biomedical Engineering by Miss Faezeh Sadat Mousavi. We thank Dr. Hejazi at School of Health, Bojnourd Medical Sciences University for his valuable cooperation. We acknowledge and thank all those involved in the project at Biomedical Engineering Department at Shahid Beheshti University of Medical Sciences.

REFERENCE

Ali Altalag, Jeremy Road, Pearce Wilcox, "Pulmonary Function Tests in Clinical Practice", Springer Science & Business Media, 2009, page1 | [2] James A. Listorti, Fadi M. Doumani, "Environmental Health: Bridging the Gaps", World Bank Publications, Dey 12, 1379 AP - Medical, volume 422, pages 107-112 | [3] Frank E. Speizer, Susan Horton, Jane Batt, and Arthur S. Slutsky, "Disease Control Priorities in Developing Countries", 2nd edition, Washington (DC): World Bank; 2006 | [4] Murray, C. J. L., and A. D. Lopez, eds. 1996. "The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries and Risk Factors", in 1990 and Projected to 2020. Cambridge, MA: Harvard University Press. | [5] Craig Frances, "Clinical Clerkship in Inpatient Medicine", Lippincott Williams & Wilkins, Medical, 2009, pages 123-125 |