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Virtual Instrumentation Based Monitoring of Respiration Parameters

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Abstract
This work proposes a respiration measurement system comprising of differential air pressure sensor and a mouthpiece. Exchange of air in and out of the lungs is a result of pressure difference created between chest cavity and atmosphere. A differential air pressure sensor is employed for measurement of Tidal Volume, Inspiratory Reserve Volume) and Expiratory Reserve Volume). Differential pressure sensor has two ports: positive pressure port (port 1) and vacuum pressure port (port 2). The subject is instructed to exhale in port 1 and port 2 is exposed to atmosphere. The pressure difference between these two ports is obtained as differential voltage in order of millivolts. The same signal is then amplified using precision instrumentation amplifier. The amplified signal is interfaced with the virtual instrumentation.

Keywords; *TV; IRV; ERV; Differential pressure senor*

I. INTRODUCTION

Respiration is one of the most essential physiological process of human body that provides energy required for metabolism. Lungs play a key role in this process by oxygenating blood which eventually gets transformed to all body parts. In order to check functional ability of lungs, it is important to measure the amount of air contained in it. The measurable volume in the lung can be divided into three units: tidal volume (TV), expiratory reserve volume (ERV), inspiratory reserve volume (IRV) [1].

Table 1. Typical lung volumes in healthy human subjects

Lung Volume (ml)	**Male**	**Female**
Tidal Volume	500	500
IRV	3000	2000
ERV	1100	700

Depending upon the pressure difference generated between intra pleural cavity and atmosphere, the amount of air that flows into and out of the lungs changes [2-4]. Differential pressure sensor was used to measure this pressure difference between atmosphere and pressure exerted by test subject. output of differential pressure sensor was calibrated into various lung volumes by using Boyle's law. Deviation of test subject`s lung volume from standard values shows presence of some respiratory disorder.

II. DESIGN OF PROTOTYPE

MX10DP differential pressure sensor with sensitivity of 3.5mV/kPa was used for measuring pressure difference generated between inspiratory and expiratory cycles. The optical cavity and pressure sensor are shown in Fig. 1.

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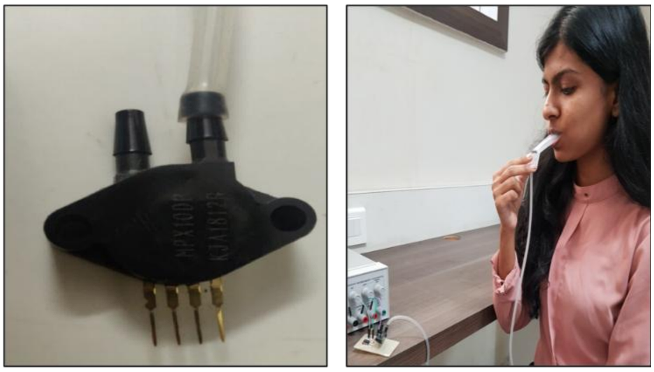

(a) *(b)*

Fig. 1. (a)Differential Pressure Sensor (b) Measurement of respiration parameters with test subject

II.METHODOLOGY

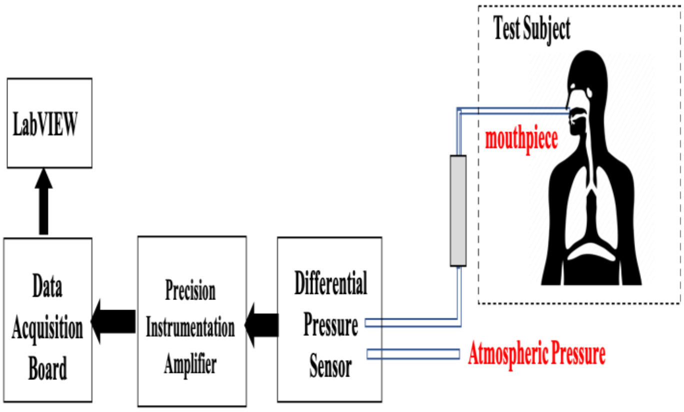

Fig. 2. Block diagram of total system setup

Test subject was instructed to blow into mouth piece which is connected to one of the inlets of differential pressure sensor. Sensor gives output in mV corresponding to the pressure difference present between atmosphere and pressure exerted by patient. This output is then amplified by instrumentation amplifier INA114 and interfaced with DAQ board. The complete block diagram of present setup is shown in Fig. 2. Further it is processed by using virtual instrumentation. Pressure output (P) is calibrated in terms of volume (V) by applying Boyle`s law.

$PV = k$ (1)

Different breathing patterns were obtained on performing normal breathing, forceful inspiration and forceful expiration. TV, IRV and ERV were calculated from these graphs respectively. Vital capacity of lungs was measured by forcefully expiring after maximum forceful expiration. Optimum value of subject`s vital capacity is predicted according to his/her age (A) and height (H) based on equation (2) and equation (3):

Female:

$VC=(21.78-0101 \times A) \times H$ (2)

Male:

$VC=(27.63-0.112 \times A) \times H$ (3)

Measured and predicted values of vital capacity are compared and abnormality is indicated if measured value is less than twenty percent of predicted value.

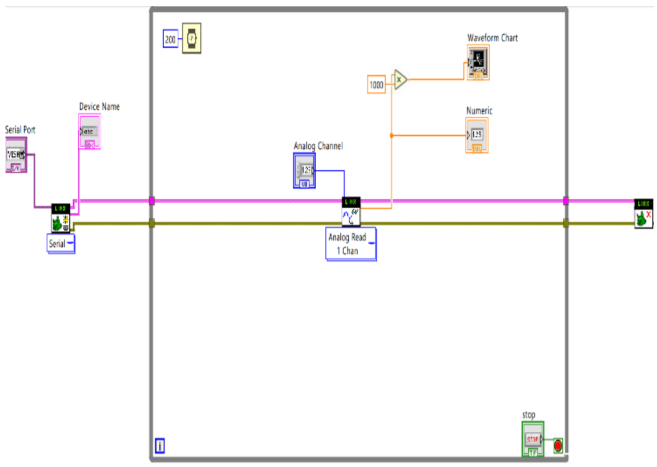

Fig. 3. Graphical code for virtual instrumentation

Fig. 3 represents graphical code written in LabView for designing virtual instrumentation system for monitoring respiration parameters.

IV.RESULTS

Output of Differential Pressure Sensor interfaced with virtual instrumentation

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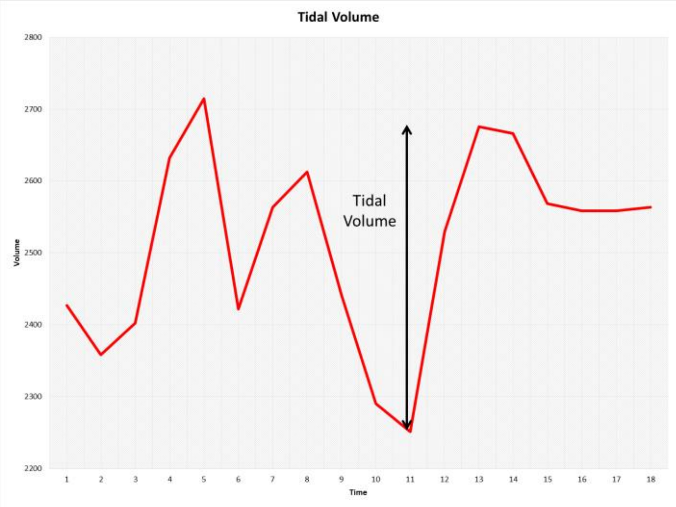

Fig. 4. Respiration pattern obtained on performing quiet breathing

Fig. 4 shows output of pressure sensor when test subject was instructed to breath normally without any extra effort. This graphical representation provides information about amount of air that moves in and out of the lungs during quiet breathing. Difference between maximum value and minimum value is calculated which corresponds to tidal volume of the test subject. This value is then compared with standard value of tidal volume suggested for subject. Pulmonary dis-functionality is reported if the measured value is above or below 20 percent of standard value.

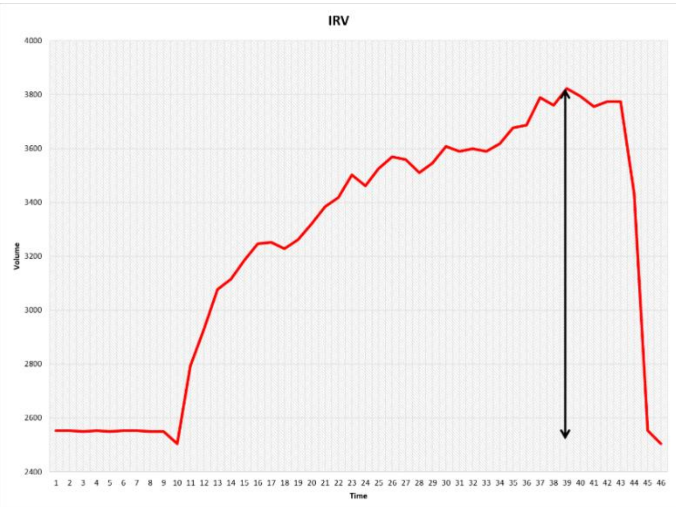

Fig. 5. Respiration pattern obtained on performing forceful inspiration after tidal inhalation

Fig. 5 shows output of pressure sensor when test subject was instructed to inhale maximally. This graphical representation provides information about maximum amount of air that can be incorporated in lungs during forceful inspiration. Difference between maximum value and minimum value is calculated which corresponds to inspiratory reserve volume of the test subject. This value is then compared with standard value of inspiratory reserve volume suggested for subject. Presence of restrictive airway disease is reported if the measured value is below 20 percent of standard value.

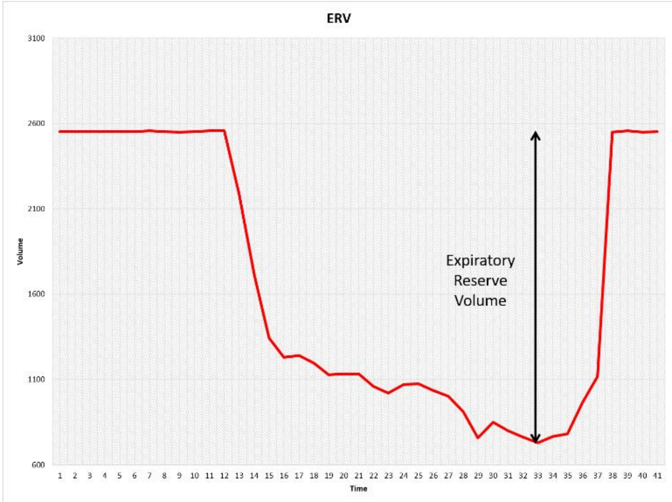

Fig. 6. Respiration pattern obtained on performing forceful expiration after tidal exhalation

Fig. 6 shows output of pressure sensor when test subject was instructed to exhale maximally. This graphical representation provides information about maximum amount of air that can be forcefully expired out of the lungs during forceful expiration. Difference between maximum value and minimum value is calculated which corresponds to expiratory reserve volume of the test subject. This value is then compared with standard value of expiratory reserve volume suggested for subject. Presence of obstructive airway disease is reported if the measured value is above 20 percent of standard value.

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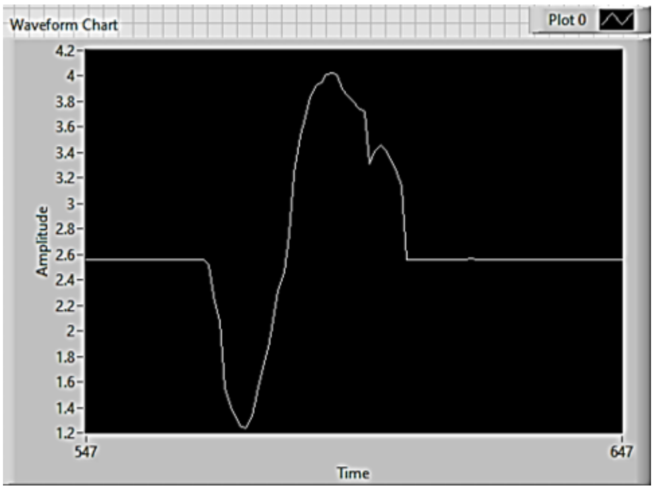

Fig. 7. Respiration pattern obtained on performing forceful exhalation after a maximum forceful inhalation

Fig. 7 shows output of pressure sensor when test subject was instructed to inhale maximally followed by maximal exhalation. This graphical representation provides information about maximum amount of air that can be forcefully expired out of the lungs after maximal forceful inspiration. Difference between maximum value and minimum value is calculated which corresponds to vital capacity of the test subject. This value is then compared with standard value of vital capacity obtained based on the formula. Weakness of lungs is reported if the measured value is above or below 20 percent of standard value.

Table 2. Observed Lung Volumes of test subject

Lung Volumes	Measured Volume (ml)
Tidal Volume	348
IRV	1831
ERV	1319
Vital Capacity	3498

CONCLUSION

In this research, the use of differential pressure sensor is reported which is capable of measuring pressure differences. The pressure differences are developed during different conditions of breathing including quiet breathing, forceful inspiration and forceful expiration. The use of pressure sensor having required sensitivity (3.5mV/kPa) to pick up small pressure changes overcomes drawback of currently used spirometer where multiple attempts of breathing are required by patient. It provides cost effective way of measuring respiratory parameters. Respiration patterns for various physiological conditions are obtained from the calibrated output of pressure senor. By comparing these results with waveforms of healthy subject`s breathing patterns, it is possible to detect any abnormality in pulmonary function of patient. Thus, the present system works as a complete pulmonary function analyzer for real time monitoring of patient`s respiration. The minimal use of electronic components used in set up reduces risk of electric hazards which is required for biomedical measurements

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