

# Real Time Monitoring of Respiratory Parameters Using a Wireless Portable System

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**Abstract** - Respiratory ensures permeation of oxygen into the human body. Respiratory parameters are used for featuring human health state. The parameter of respiration is measured implantable over duration of time. A wireless portable system using sensors is proposed to monitor the respiratory parameters. The monitoring system measures the users respiratory air flow using a thermal flow sensor, body posture using a triaxis accelerometer and a photo electric sensor is used to monitor oxygen saturation. Algorithms are proposed for derivation of respiration parameters and estimation of body posture. Additionally, the monitored parameters are transmitted wirelessly to a PC connected in the hospital through a ZigBee transmitter so that the testing results can be recorded and analyzed or transmitted to a remote center or physicians. Respiratory flow sensor can detect weak respiration. Tri axis accelerometer that detects body posture provides a reference for respiration movement. Respiratory parameters like tidal volume, peak inspiratory flow, minute ventilation and respiration rate are derived from the obtained respiratory flow data. The system can act as both sleep recorder and spirometer making the system capable of monitoring and diagnosing various respiratory diseases like obstructive sleep apnea, asthma and chronic obstructive pulmonary diseases. A laptop or mobile connected to the internet is capable of serving the system as remote monitoring and timely risk alarming if any respiratory distress occurs and makes telemedicine achievable.

**Index Terms** – Respiratory disease, Wireless Monitoring, telemedicine

## I. INTRODUCTION

Disturbance of the normal breathing process can cause the development of severe metabolic, organic, central nervous and physical disorders. Respiration monitoring allows the continuous measurement and analysis of breathing dynamics and the detection of various disorders. A remote monitor with a respiratory monitoring and the oximetry will greatly ease the patients from frequently coming and going to hospitals. In short, a simplest monitor for such respiratory diseases must be capable of monitoring the respiratory air flow and deducing certain respiratory parameters based on the air flow. Respiratory (breathing) parameters are set of tests that measure the strength of the breathing muscles.

The most common respiratory diseases all around the world are obstructive sleep apnea (OSA), chronic obstructive pulmonary disease (COPD) and asthma. OSA (Obstructive sleep apnea) affects the way you breathe when you're sleeping. Sleep apnea is a sleep related breathing disorder. In untreated sleep apnea, breathing is briefly interrupted or becomes very shallow during sleep. Each pause in breathing called an apnea last for several seconds to several minutes, and it may occur 5 to 30 times or more in an hour of sleep. Each abnormally shallow breathing event is called a hypopnea .

COPD stands for chronic obstructive pulmonary disease. COPD is a condition where the airways become inflamed and the air sacs in the lungs are damaged . It causes the airways narrow, which makes it harder to breathe . COPD is a preventable and treatable disease. It describes a number of conditions including emphysema and chronic bronchitis. Emphysema affects the air sacs in the lungs (alveoli), and chronic bronchitis affects the airways (bronchi). The main cause of COPD is smoking , it affects people over the age of 35 . COPD in 2010 become the third leading cause of death in the United States. It is projected to be the fourth leading cause of death worldwide by 2030 due to an increase in smoking rates and demographic changes in many countries.

Asthma is a chronic lung disease that inflames and narrows the airways. The inside walls of an airways are inflamed or swollen . This swelling or inflammation makes the airways extremely sensitive to irritations and increases susceptibility to an allergic reaction. As inflammation causes the airways to become narrower, less air pass to and from the lungs. Asthma affects people of all ages, but it most often starts during childhood. According to WHO estimates, 235 million people suffer from asthma.

Polysomnography is used to diagnose sleep disorders. This test is used to record electrocardiogram (ECG), electrooculogram (EOG), electroencephalogram (EEG), electromyogram (EMG), nasal air flow (NAF), abdominal movements, body position, snore microphone, and saturation of peripheral oxygen (SpO2) during the study. The costs of using PSG in a sleep laboratory are high because of the cost of the examination time, the need for a qualified technician and sleep specialist, and equipment costs. As a result, the requirement of using laboratory PSG to obtain an accurate diagnosis of OSA has been debated for years, and the use of portable monitoring devices has been proposed.

The diagnosis of COPD and asthma is performed based on the results of a lung function test which includes spirometry and oximetry. Spirometry is the most common COPD lung function test. This machine measures how much air lungs can hold and how fast lungs can blow air out . Spirometry measures the forced expiratory volume in one second (FEV1), which is the greatest volume of air that can be breathed out in the first second of a breath. Spirometry also measures the forced vital capacity (FVC), which is the

greatest volume of air that can be breathed out in a whole in large breath. Normally, at least 70% of the FVC comes out in the first second, giving a FEV1/FVC ratio of greater than 70%. A ratio of less than this defines a person as having COPD. It can also be used to track the progression of disease and to monitor how well treatment is working.

Pulse oximetry is a procedure used to measure the oxygen level (or oxygen saturation) in the blood. SpO<sub>2</sub> of greater than 95% is generally considered to be normal. Patients with COPD has SpO<sub>2</sub> of 92% or less .

Several studies have been done since 1993 for developing portable monitors for OSA . Chang et al. developed a wireless portable sleep monitor with a triaxis accelerometer and electrocardiogram. They used the accelerometer to monitor sleep posture and Bluetooth for wireless transmission of information [1]. Oh et al. developed a ubiquitous health monitoring system for diagnosis of sleep apnea with ZigBee network and wireless LAN. The system supported monitoring five different biomedical signals:

electrocardiogram, body motion by a gyroscope, nasal airflow by a pressure sensor, abdomen/chest efforts by a piezoelectric sensor and oxygen saturation [2]. Rofouei et al. developed a non-invasive, wearable neck-cuff system capable of real-time monitoring and visualization of physiological signals. The system monitored oximetry, breath, and body movement. They used a microphone to record the breathing sounds and provided an end-user view and a clinician view of the monitoring results [3].

Thus, respiratory airflow and oximetry are necessary parameters for monitoring and diagnosing OSA. In addition, body posture can provide complementary information for analyzing the respiratory movement and wireless transmission can further facilitate the ease of use of the portable monitor.

## II. SYSTEM DESIGN

### A. System Overview

Fig. 1 shows the system configuration, which is comprised of thermal air flow sensor, a body posture sensor, an pulse oximeter, wireless transmitters and a PC or cell phone that connects with the Internet.

The test subject should wear the body posture sensor on his upper body and the respiratory airflow is collected using a nasal cannula or a facemask connecting with a tube where thermal flow sensor is installed. The oximeter is a clip worn on the fingertip of the subject. The outputs of the sensors are transmitted wirelessly via ZigBee to a PC or cell phone on which the data are processed, respiratory flow waveform, tri axial acceleration and blood oxygen saturation are displayed and the respiratory parameters and body posture are figured out. The PC or cell phone can also transmit the signals to the remote monitoring center or physicians through the internet,

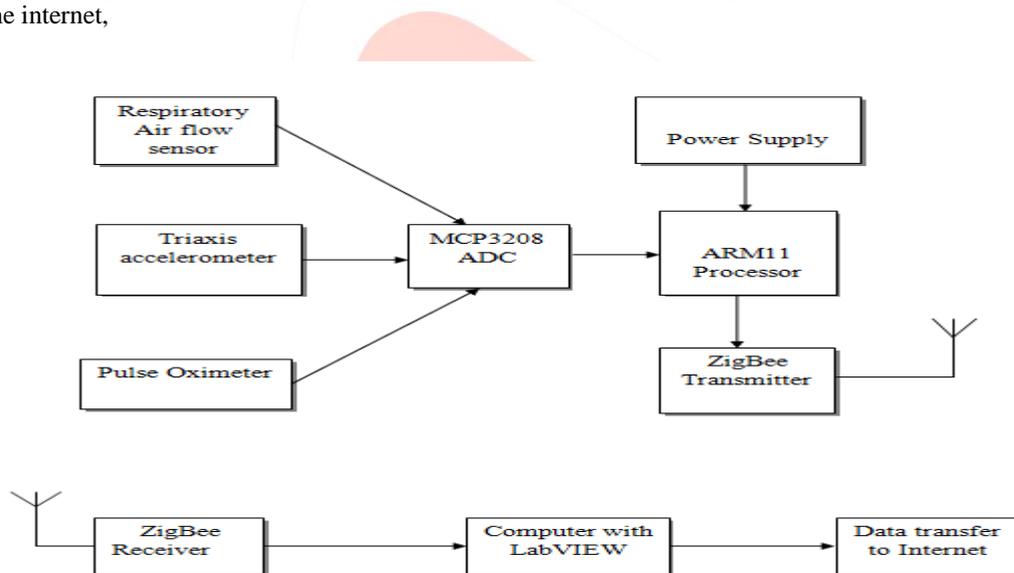


Fig 1. Schematic diagram of monitoring device

creating telemedicine capabilities. The thermal respiration sensor consists of a thermistor to monitor respiratory airflow, and a triaxial accelerometer is applied to detect body posture. The outputs of the thermal respiration air flow sensor, pulse oximeter and the triaxial accelerometer are sampled and processed by a ARM11 processor before transmitted via the ZigBee module. The ZigBee transmitter transmits data to the ZigBee receiver wirelessly. A ZigBee receiver connected with a PC or cell phone receives data from all the sensors including respiratory data, acceleration data, and oximetry data simultaneously. Then, the calculation of respiratory flow rate, triaxial acceleration, and SpO<sub>2</sub> and derivation of respiratory parameters and body posture are conducted. A friendly user interface is designed to display the monitoring results. The monitoring results can also be transmitted to a remote center or person via the Internet. It makes the system capable of remote monitoring and timely risk alarming when severe respiratory distress occurs.

## B. Sensors

### 1) Thermal Flow Sensor for Respiratory Air Flow Measurement:

A thermistor based circuit shown in Fig-2 is designed to monitor respiration. The sensor is placed over the nose/mouth and infers airflow by sensing differences in the temperature of the warmer expired air and cooler inhaled ambient air. The flow signal generated is related directly to the sensor temperature and indirectly to airflow. Thermistor used for the respiration measurement is connected to the resistor bridge network. Under constant current, a thermistor will change its resistance as a function of the temperature. This value is converted as voltage by using voltage divider circuit with 10K resistor. The difference in the voltage is amplified by LM741 op-amp. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals. In order to achieve high input impedance two resistors of 1k $\Omega$  is added to the differential input voltage. A resistor of 10 k $\Omega$  is inserted between the non-inverting input and ground thus reducing the input offset voltage due to different voltage drops due to bias current and may reduce distortion in some op-amps. The feedback resistor value is determined by the impedance levels to be established. The feedback resistance is chosen to be 500K variable one and the input resistance is 1K so it can amplify  $(-500K/1K)$  differential voltage. So the required amplification can be made by adjusting the variable resistor. Next stage the amplification is done with the active low pass filter (integrator). This circuit is used to filter the high frequency in the respiration side. This amplified output is directly given to the comparator circuit. Here two input voltages are compared where one is the reference voltage and another one is from integrator. Here the reference voltage can be varied by adjusting the variable resistor VR2 this voltage varied from -12V to +12V. This voltage is given to non inverting pin so whenever the reference voltage is higher than the respiration voltage the negative voltage (-12V) will be the output and whenever the integrator voltage is greater the positive voltage (+12V) will be the output. This output is directly given to the BC547 Transistor. So when it gets the positive voltage that means respiration voltage high it gives low as output to the LED as well as NOT Gate so the LED lights up and the high output is generated by the NOT gate given to the processor. When the negative voltage is given to the transistor it will be in OFF state and no more conduction between collector through the Transistor Base terminal there is a potential divider by using two 10K resistors. So the half amount of the voltage will be given to the Base. Then the final output voltage is given to the processor.

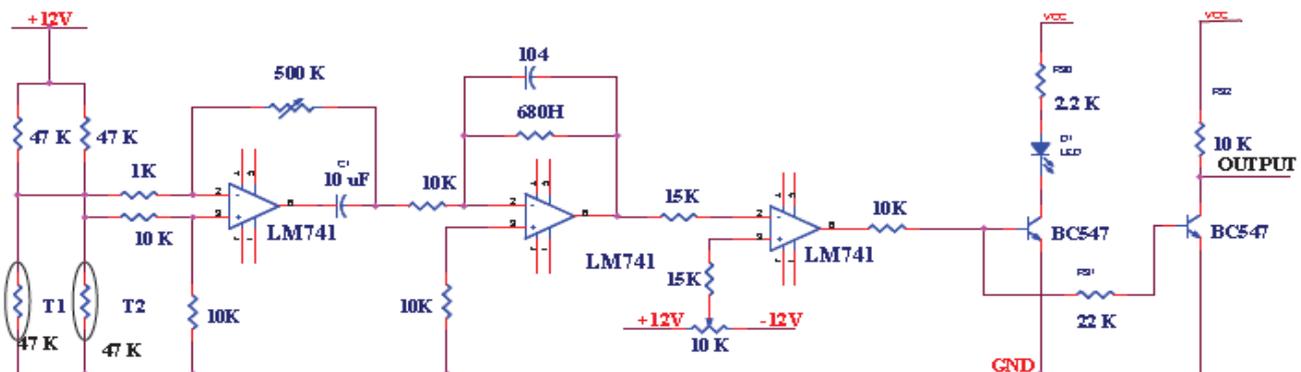


Fig 2. Circuit Diagram of Respiratory thermal air flow sensor

### 2) 3-axis Accelerometer for Body Posture:

A 3-axis MEMS accelerometer is used to recognize the body posture considering that we only need to obtain the gross body posture of the subject. It is worn on the torso of the body with a belt. MPU6050, a triaxis accelerometer with digital outputs is used to detect body posture due to its small size, low power, and high resolution (16-bit) measurement up to  $\pm 16$  g, which makes it suitable to be utilized in portable devices. MPU-6050 3-Axis accelerometer uses separate proof masses for each axis. Acceleration along a particular axis induces displacement on the corresponding proof mass, and capacitive sensors detect the displacement differentially.

### 3) Pulse Oximeter for SpO<sub>2</sub> measurement :

Pulse oximeter device is employed for the estimation of peripheral oxygen saturation (SpO<sub>2</sub>). The detector is placed on subject's finger tip. Oxygen saturation is defined as the measurement of the amount of oxygen dissolved in blood, based on the detection of Hemoglobin and Deoxyhemoglobin. The principle is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated haemoglobin. Oxygenated haemoglobin absorbs more infrared light and allows more red lights to pass through. Deoxygenated (or reduced) haemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band. Infrared light is in the 850-1000 nm wavelength light band. The probe contains a

red light source and a detector. These shine through the tissues of the body and work together to measure the colour difference between oxygenated and deoxygenated blood. The machine detects the pulse from an arterial blood source and is able to calculate the percentage of oxygen saturation by combining the detected colour changes of the blood combined with the detected pulse of the artery.

**III. ALGORITHMS AND SOFTWARE**

1) *Derivation of Respiratory Parameters:*

The output of the thermal flow sensor is calibrated and analyzed. A variety of algorithms to derive related respiratory parameters such as minute ventilation (MV), peak inspiratory flow (PIF), respiratory rate (RR), and tidal volume (TV) are designed. Table I shows the calculation methods for the four respiratory parameters.

Table I  
CALCULATION METHODS OF RESPIRATORY PARAMETERS

Respiration parameters	Calculation Methods
RR	Count the peaks of the respiration waveform in a half minute
MV	Digital integration of respiratory flow rate in a half minute
TV	Minute ventilation divided by respiration rate
PIF	Find the maximum value of the respiratory peak

2) *Estimation of Body Postures:*

The 3-axis accelerometer measures the 3-axis accelerations of the human body along the directions of the three axes .An algorithm is designed to estimate body postures using measured 3-axis accelerations. Body postures are classified into different postures of sit/stand, lie on the back, lie on the face, lie on the right, and lie on the left . The axis position of accelerometer at different postures are shown in fig 3.

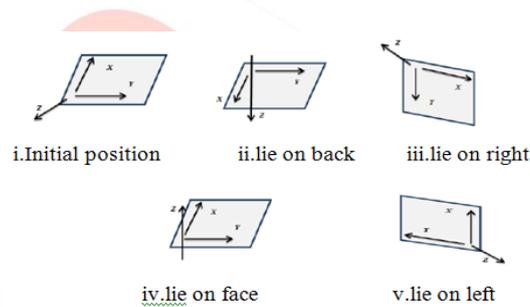


Fig 3. Axis position of accelerometer for different postures

A LabVIEW-based user interface shown in Fig. 4 is designed to display the waveforms of the respiratory airflow and the 3- axis accelerations, respiratory parameters, body posture and the value of SpO<sub>2</sub> .

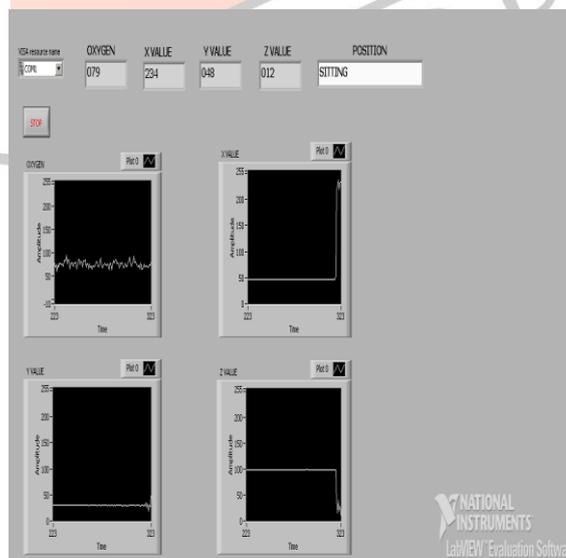


Fig 4. User Interface for body posture and SpO<sub>2</sub>

#### IV. CONCLUSION

A wireless portable system with sensors for monitoring respiratory parameters which is used to diagnose respiratory diseases is presented in this paper. The monitoring system consists of three sensors: the respiration air flow sensor, tri axis accelerometer and the pulse oximeter sensor. The utility respiratory air flow sensor also makes comprehensive respiration parameters acquirable which are important in the diagnosis of OSA, COPD, and asthma. Employing the triaxis accelerometer to detect motion and body posture provides a reference for respiration movement. The ZigBee data transmission makes the monitoring system wireless and mobile so that the user can use it freely. The mobile phone or the computer connected to the Internet as the user interface terminal makes telemedicine achievable. The proposed wireless portable devices with sensors serving as both sleep recorder and spirometer can be applied for remote monitoring and diagnosis of OSA, COPD and asthma.

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