Synchronized Intermittent Mandatory Ventilation Mode Control Using Pulse Oximeter

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Abstract—**Breathing is the sign of life, the human body is fueled by a proper combination of food and oxygen. The accurate amount of oxygen is a vital factor for health and even survival of life in some cases. Mechanical ventilators are the machines which are commonly used in hospitals, Intensive Care Unit (ICU) and prolonged treatment centers for assistive or complete breathing. Mechanical ventilators work in four modes, Control Volume Cycled Ventilation, Assisted Pressure Controlled Ventilation, Pressure Support Ventilation and Synchronized Intermittent Mandatory Ventilation. Out of which, Synchronized Intermittent Mandatory Ventilation (SIMV) is an important and frequently used mode. This mode is controlled with knob dial provided on customary ventilators after adjusting pre required settings according to physician prescription. Dialing up and down the knob requires a trained operator which not only involves human interference that may cause a human error but also time delay. These risking factors are life-threatening and unavoidable as breathing is vital for life. In this work, we propose Synchronized Intermittent Mandatory Ventilation mode control using Pulse Oximeter that is cheap, accurate and easy to use. It checks blood saturation level with the help of Pulse Oximeter sensor placed on a finger or earlobe, provide this signal to the main architectural unit which rotates knob as per requirement of oxygen. The proposed Pulse Oximeter controlled SIMV mode of ventilator is a useful apparatus for under developing countries where there is a lack of trained operators. By designing Pulse Oximeter based SIMV of ventilator the existing ventilator units in hospitals can be updated from manual to automatic state in a reasonable budget improving health facilities in poor countries like Pakistan.**

Keywords—Ventilator, Pulse Oximeter, Oxygen saturation, Critical care units, surgical theatres.

I. INTRODUCTION

The human body is made-up of the proper combination of elements balanced by an accurate intake and draw out of substances from the body. Oxygen is a basic component for living and proper functioning of human cells. As human body aerobically respires, oxygen is needed for survival. It is used in respiration which converts sugar (glucose) into carbon dioxide, and water. This reaction gives the needed energy for cells to operate properly. The body requests a critical quantity of oxygen in the blood at all times to efficiently feed the cells, tissues, and organs.

Harmful cells due to improper metabolism dissipate their natural protection and are therefore sensitive to viruses. When blood oxygen levels drop below standard, a state identified as hypoxemia can happen. Hypoxemia can be dangerous, suddenly happened because of an accident situation or chronic disease, crawling over time because of a long-term health condition likes chronic obstructive pulmonary disease (COPD). Hypoxemia compared with chronic obstructive pulmonary disease (COPD) generates a shortened life, diminished skeletal muscle function, limited exercise tolerance and an increased risk of death.

Mechanical ventilation is an important tool which is in use for the management of respiratory failure in the critical patients. Mechanical ventilation is required to manage respiratory failure due to various clinical conditions including Acute Respiratory Distress Syndrome (ARDS), Pneumonia, Sepsis, Chronic Obstructive Pulmonary Disease (COPD), and Asthma. Mechanical ventilation can be a life saving facility, providing enough oxygenation is one of the primary goals of mechanical ventilation. If the patient is hypoxemic then ventilator is used for the lung therapy. Ventilator is a machine that supports breathing. Ventilators are supposed to perform following functions: (1) Get oxygen into the lungs, (2) Remove carbon dioxide from the body, (3) Help people breathe easier, (4) Breathe for people who have lost all ability to breathe on their own.

The mechanical ventilators work in four modes; (1) Assisted/Control Volume Cycled Ventilation, (2) Assisted/Controlled Pressure Controlled Ventilation (time cycled), (3) Synchronized Intermittent Mandatory Ventilation, and (4) Pressure Support Ventilation. Synchronized Intermittent Mandatory Ventilation mode is an important and frequently used mode. This mode requires some initial settings of the pressure depending upon the condition and age group (child, adult, old age) of the patient, which is done according to the prescription of the physician. Afterwards volume of oxygen is controlled with a knob by the healthcare staff according to the blood saturation level of the patient.

In this paper, we purpose design which reads biological signal using optoelectronic devices and deliver oxygen to the patient without human involvement. Pulse Oximeter uses an optical sensor technology. Optical sensors provide maximum safety to the patient as there is no central contact. Signal conditioning is also a part of a design so that the received signal in an adequate form can be sent for post-processing and used for analysis. After the post processing the biological signal is being converted into an AC signal that actuates servo motors, which in response rotates the dial knob to provide required amount of oxygen to balance the oxygen saturation of the patient.

II. Related Work

Healthcare has been an important and prior field since mankind came into being. Great scientists and scholars have added tremendous and remarkable achievements in the field of health. Respiratory and oxygen absorption always stood in one of the foremost important health issues. Many researchers have been taken in this accord.

Sangeeta Bagha et al. [1] have added their contribution by designing a SPO2 prob. They have developed a probe which is economical and small in size. This probe works on very small voltage. This small probe was compared with the existing default probes and satisfactory results were obtained.Jean-Paul et al. [2] have observed the short comings of customarily used noninvasive ventilators and have proposed that some simple techniques can be used to monitor and record patients data which can be used to reduce NIVs short comings.John Allen and et al. [3] 6 July said that the OPADs should be monitored continuously and accurately otherwise they can be dangerous. Comparison between healthy people and patients has shown the accuracy and fruitfulness of SPO2 for OPADs.

Shamali Moreand et al. [4] Discusses different types of plethysmography signal, characteristic features of PPG waveform, and algorithm to denoise the signal, and proposes algorithm to develop indexes to diagnose diseases using PPG signal.Amal jubran, et al. [5] have reviewed the latest advancement and discoveries in the field of pulse oximetry. They have observed the accuracy and faults of the latest and customary Pulse Oximeter applications.Taxes instruments [6] have discussed that how to increase the accuracy of a PPG signal. Light passing through the human finger and its characteristics have been discussed in the research work.

Tassadaq et al. [7][8] has developed an medical image processing toolkit and hardware architecture for biomedical applications. The proposed system stores and processes complex and multidimensional medical imaging application.

III. Architecture of SIMV Mode Control Using Pulse Oximeter

This section describes the architecture of SIMV mode control using Pulse Oximeter. The section is further divided into four sub-sections.

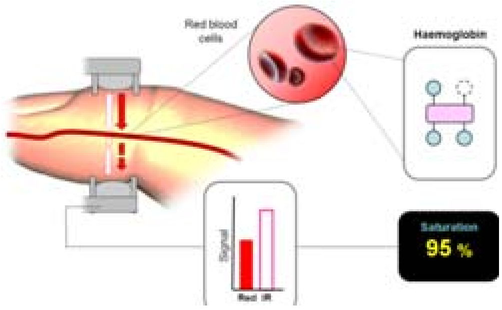

Fig. 1: Working Principal of SPO2 LED

A. *Pulse Oximeter Probe*

The Pulse-oximeter uses Light Emitting diodes (LEDs) and Light Detector. The LED is an optoelectronic device that converts electrical energy into light. The LED emits light, proportional to the amount of current applied to it. Their miniature size, excellent drive properties and large light output over a very narrow bandwidth make them the ideal choice as the light source. They reduce the risk of overheating the tissues. Given is the LEDs used of the different wavelength. The working principal of SPO2 LED is shown in Figure 1. Oxy-hemoglobin (HbO2) and hemoglobin (Hb) have exceptionally different optical spectra in the wavelength go from 600 nm to 950nm. Under typical physiological conditions blood vessel is 97% soaked, while venous blood is 75% immersed. The distinction in retention spectra of HbO2 and Hb is utilized for the estimation of blood vessel oxygen immersion in light of the fact that the wavelength extend between 600 nm and 960 nm is additionally the run for which there is minimum constriction of light by body tissues. Figure 2 shows the spectral response of LEDs.

When light falls on the base of the transistor actuates a current. This current is then enhanced by the transistor, bringing about the increment in gatherer current. Size, cost, and flag to-commotion proportion of a phototransistor are proportionate, to that of a photodiode. The signal level of received light is not too much to achieve the required signal phototransistor, is used which receives the signal and amplifies it which is know enough strong to process with different filters. The spectral response of phototransistor is shown in Figure 3.

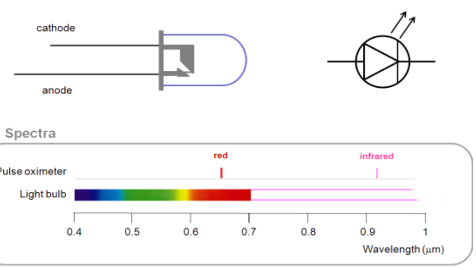

Fig. 2: Spectral response of LEDs

The normalized R ratio can then be calculated based on empirical data as follow. It is done through microcontroller.

$$R = \frac{(AC/(DC)|red}{(AC/(DC)|ir} \quad (1)$$

Equation (1) shows the Absorption Ratio R for normalized red and infra-red. This Normalized R ratio represents the ratio of oxygenated hemoglobin to un-oxygenated hemoglobin as shown follow.

$$SPO_2 = 110 - 25\ (R) \quad (2)$$

B. Processing Unit

The Processing Unit [7][8] is the main unit of the SIMV mode controlled by using Pulse Oximeter system. It analyzes and processes the data and takes decisions. The Processing Unit uses two types of processing core which are general purpose processor scalar core and application-specific processor cores. We can add more functions and programs in the Processing Unit which makes the system more intelligence and make it possible execute more medical applications. The Processing Unit reads the data from a Pulse Oximeter probe and diagnoses the physiological state of the patient by comparing oxygen saturation values. Then it sent a command to servo motors which rotate the knob to permit the required amount of oxygen.

C. Memory System

The storage unit is used to store the patient's information and Pulse-Oximeter data. The patient's medical profile is stored in a storage unit with the assistance of medical professionals. The patient's data is diagnosed by using medical information. The diagnosis process is based on stored patient data and the processing unit. The System uses a memory controller [9][10][11] that controls the on-chip and off-chip memory interface standards such as SDRAM and SRAM.

D. Mechanical System

The mechanical unit contains motors that invert digital pulses into mechanical cylinder rotation. It takes signals from the processing system and operates motors. The mechanical unit uses a stepper or servo motors controller. The mechanical unit stepper controller is used to control the stepper motors. The stepper driver sends pulses to each stepper motor causes the motor to rotate a precise angle; the motor's position can be monitored without any feedback mechanism. The speed of the stepper motor can be increased with increasing frequency. The servo motors are used where much faster and more accurate positioning than universal motors are desire.

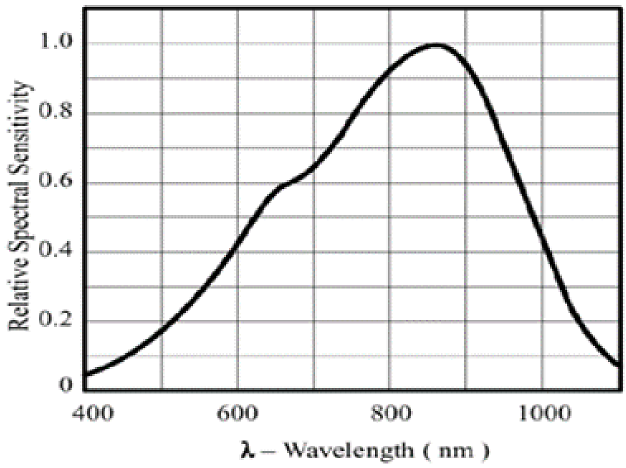

Fig. 3: Spectral response of phototransistor

IV. RESULTS AND DISCUSSION

We executed and tested our Pulse Oximeter system architectures and tested by using real-time and non-real time environments. The section is divided into further three sub-sections.

A. System Architecture

The Pulse Oximeter based SIMV system is tested and evaluated on heterogeneous multi-core system architecture .The system architecture uses a new generation of heterogeneous multi-core computing devices with powerful and energy-efficient hardware. The processing architecture includes Samsung Exynos5422 Cortex-A15 octa-core processor with 2 MB cache and Cortex-A7 Octa core processor with 512 MB cache and Mali-T628 Graphical Processing Unit. The architecture uses high speed 2Gbyte LPDDR3 RAM and 32 GB ROM. The architecture supports open source support; the board can run various flavors of Linux, including the latest Ubuntu 16.04 and Android 4.4 KitKat. The system has General Purpose Input Outputs (GPIO)s to transfer data. The Processing Unit is programmable for general purpose application which allows the Pulse Oximeter system to integrate more features. The Figure 4 shows the hardware components Image of pulse Oximter System Architecture

B. Real-time Performance

A photoplethysmography (PPG) application is used by using Pulse Oximeter in real-time that optically obtained plethysmogram. The application measures the oxygen saturation (SpO2) and blood pressure. While measuring the SpO2, the Pulse Oximeter System takes 10.5 microseconds. The result confirms that Pulse Oximeter System gathers data without losing information and stores it in local memory. The real-time application performs signal filtering in software, processing, stepper motor controlling, and storage.

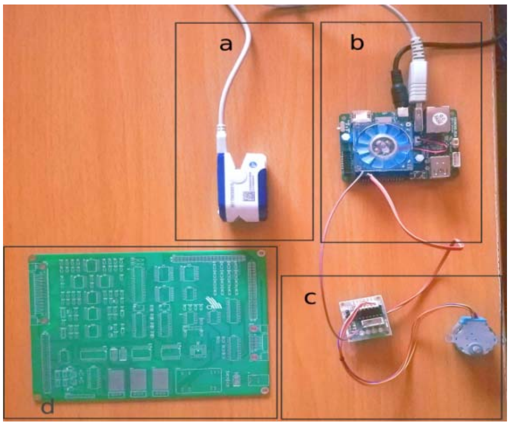

Fig. 4: (a) Pulse Oximeter Sensor (b) Hetrogrnious Multi-core system(c) Stepper Motor & Controller (d) Printed Circuit Board of the Design Architecture

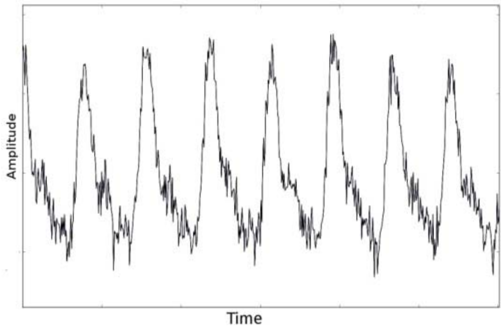

Fig. 5: Noisy image of photo receiver

The waveform of PPG is shown in Figure 5, its input signal has noisy data so filtration is required for noise removal. After filtration, we get the pure PPG signal that we use to calculate the SPO2 and control the ventilator on base of SPO2 value. The noise removal pure PPG signal is shown in Figure 6.

C. Non Real-time Performance

During Non Real-time processing, we acquire 1 GByte of patient data from permanent memory and then perform signal processing. Results show that while performing PPG application on 1 GByte of data the Pulse Oximeter system takes 40.2 seconds.

V. CONCLUSIONS AND FUTURE WORK

Oxygen is the basic need for living. In prolonging absence of oxygen our cells may die. Especially in a Critical patient, if they are on ventilators. Hence oxygen delivery to the cell is one of the vital sign of patient's health. To measure this vital sign and to control the amount of oxygen-delivering to the patient, an instrument is needed that will provide continuous and immediate available data for the monitoring individuals oxygen saturation level.

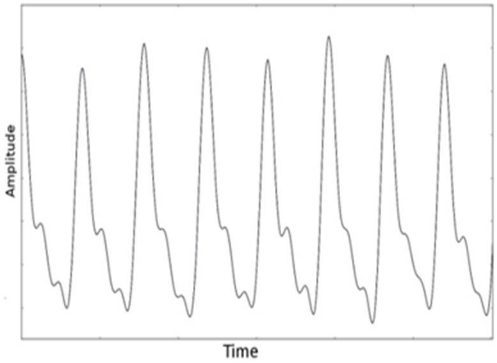

Fig. 6: After noise removal pure PPG signal

By measuring the amount of oxygen critical medical information can be obtained for respiratory disorders. In this work, a Pulse-Oximeter based SIMV mode is proposed and developed. The Pulse-Oximeter based SIMV mode provides a real-time, noninvasive oxygen saturation and control to the amount of oxygen delivered to the patient through the ventilator.

VI. ACKNOWLEDGMENT

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