A REVIEW ON DIFFERENT TECHNICAL SPECIFICATIONS OF RESPIRATORY RATE MONITORS

Karthik Mohan Rao[1], B.G. Sudarshan[2]

[1]*PG Student, Department of Instrumentation Technology, RV College Of Engineering, Bengaluru, India*
[2]*Associate Professor, Department of Instrumentation Technology, RV College Of Engineering, Bengaluru, India*

Abstract

Respiratory Rate (RR) is a very important physiological parameter to be monitored in both healthy and critical condition, as it gives meaningful information regarding their respiratory system performance as well as condition. Respiratory rate is an important vital sign that can indicate progression of illness but to also predict rapid decline in health. For the purpose, non-invasive monitoring systems are becoming more popular due to the self-evident increase in patient comfort. It can be hard to predict respiratory failure as it can lead to life threatening condition within a short span of time. Thus it necessitates continuous monitoring of respiratory activity and suitable monitoring equipment are developed which could be life-saving. The survey incorporates non-obtrusive strategies and gadgets used to give data about respiratory rate. Many types of respiratory rate monitors have been used for the measurement of the Respiration Rate. This review consists of seven types of Respiration Rate monitors with different sensors. Respiration Rate monitor using Ultrasonic Sensor and Respiration Rate monitor using facial tracking method are the non-contact respiration rate monitoring system. Respiration Rate measurement based on Impedance Pneumography and Respiration Rate measurement are based on the Thoracic Expansion measurement include the sensor that are placed on the thorax. Respiration Rate monitor with MEMS based Capacitive Pressure Sensor, Respiration Rate monitor with temperature sensor, Respiration Rate meter–a low–cost design approach uses sensors that are mounted within the oxygen mask. Thus the Respiratory Rate Monitors discussed in this paper provide optimal result to detect changes in the severity of chronic illnesses.

Keywords: *Respiratory Rate, RSA, RSS, Doppler Effect, Movement, Respiratory sensor belt.*

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1. INTRODUCTION

Respiratory Rate (RR) is a very important physiological parameter to be monitored in people both in healthy and critical condition, as it gives meaningful information regarding their respiratory system performance as well as condition. The RR is defined as the number of breaths per minute. A typical RR at resting is 12 and its corresponding frequency is 0.2 Hz. During recovery from surgical anesthesia, a µ-opioid agonists used for pain control can slow down RR leading to bradypnea (RR<12) or even apnea(cessation of respiration for an indeterminate period)[13], while airway obstructions like asthma, emphysema and COPD will increase RR causing tachypnea(RR > 30)[14]. Hence, RR measurement becomes clinically very important.

Changes in the severity of chronic illnesses such as Chronic Obstructive Pulmonary Disease (COPD), Congestive Heart Failure (CHF), Arthritis, Asthma, Cancer, Diabetes and HIV/AIDS can be detected using Respiratory Rate Monitor.

Development of a respiration rate meter, a low-cost design approach uses a displacement transducer with infrared (IR)-transmitter and IR-receiver for sensing the Respiration Rate[1]. Respiration Rate Monitor based on Impedance Pneumography measures changes in the electrical impedance of the person's thorax caused by respiration or breathing[2]. Respiratory Monitoring System Based on the Thoracic Expansion Measurement uses respiratory sensor belt that made up of plastic tube container, Axis, spring, Bumper edge, reflective objective sensor[3]. Temperature sensor based Breath Rate Monitor [4] is a real-time system that computes the respiratory rate of the patient. The system will activate an alarm on crossing the lower or upper respiratory rate limit and simultaneously it will send a SMS to the concerned doctor's cell phone. This system uses a temperature sensor to keep track of the temperature of the respired air[4].

Facial Tracking Method for Noncontact Respiration Rate Monitor involves tracking a facial region of interest (ROI) associated with respiration in thermal images [5]. A new Scheme of Respiration Rate Monitor uses a MEMS based capacitive nasal sensor system for measuring Respiration Rate (RR). Ultrasonic breathing monitor uses ultrasonic source and transducer for the measurement of frequency shift between the exhaled air flow and the ambient environment[10].

2. DIFFERENT TECHNICAL SPECIFICATIONS OF RESPIRATORY RATE MONITORS

2.1 Development of a Respiration Rate Meter–A Low–Cost Design Approach

The Respiration Rate meter uses a displacement transducer in combination with infrared (IR) transmitter and IR – receiver, respectively, for sensing the respiration rate. In the capillary glass tube a thermocol ball moves up and down during Inhaling and exhaling the air. The IR-transmitter and receiver sense the ball movements. These movements are converted into pulses by the pulse generator. A counter counts these pulses for a minute. A 3-digit LED (Light emitting diode) display monitors the respiration rate through a 7-segment driver/decoder. To reset the display to initial state (zero) and activate the counter for 1-minute to count the respiration pulse, switch S1 (the start switch) is used. The gate pulse generator utilises a monostable multivibrator that generates gating pulse of 1-minute duration, when triggered by start switch[1]. Fig -2 shows block diagram of the system.

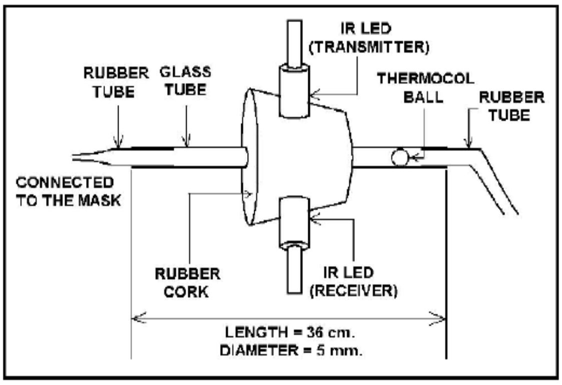


Fig -1: The sensor module [1]

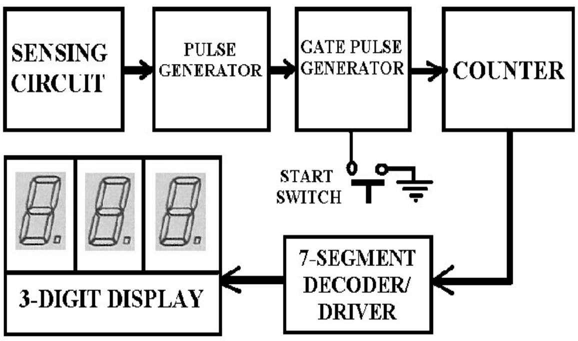


Fig -2 The block diagram of the system [1]

2.2 Respiration Rate Measurement Based on Impedance Pneumography

Impedance pneumography is a regularly utilized method to screen a man's breath rate by housing two electrodes (Fig -3A) or four electrodes (Fig -3B) on individual's thorax. The goal of this approach is to quantify changes in the electrical impedance of the individual's thorax created by breath or relaxing. [2].

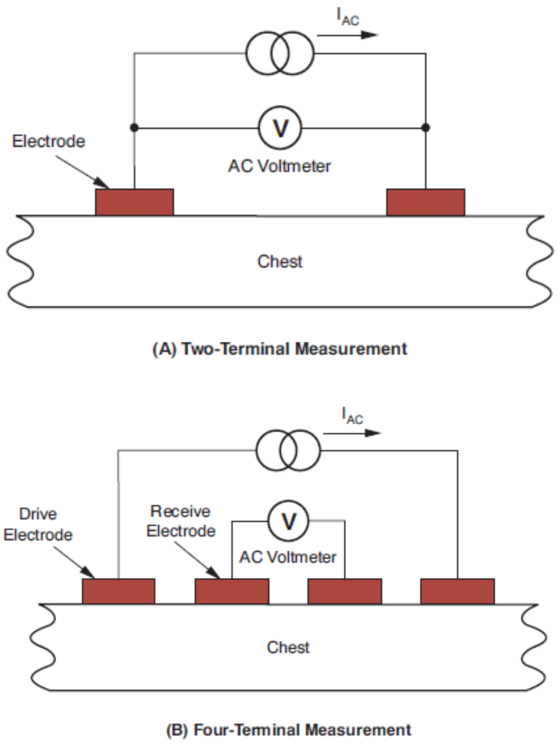


Fig -3: Arrangement of Electrodes for Impedance Pneumography [2]

In both of these techniques, high-frequency ac current is infused into tissue using drive electrodes. Potential difference is produced over any two focuses between the drive terminals because of ac current. Produced potential difference is related to the tissue resistivity between receive electrodes. The ratio of the difference in voltage between the two receives electrodes and the current that permeates the tissue is called equivalent resistance [2].

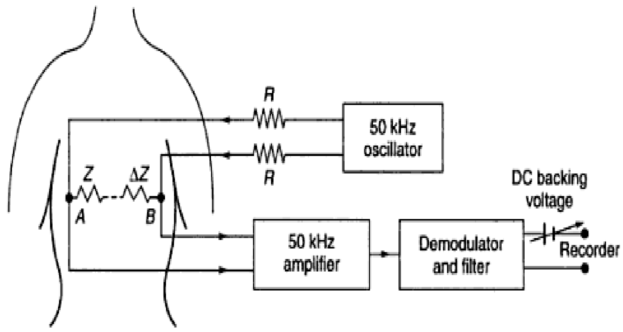
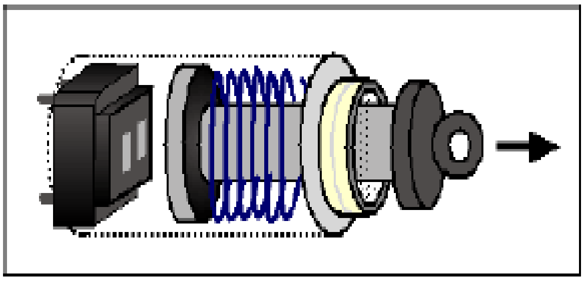


Fig -4: Principle Of Impedance Pneumography (Two-electrode method).

The voltage difference measured across two electrodes in two terminal measurement system generates some errors (shown in Fig -3A) due to the presence of non-linear voltage. The site of current infusion is set physically apart from the potential measurement site in four electrode system. Usage of four electrode system is less than compared to two-electrode system due to the requirement of additional two electrodes.

2.3 Thoracic Expansion Measurement Based Respiration Rate monitoring System

Thoracic Expansion Measurement Based Respiration Rate monitoring System is specially designed for neonatal care unit. The system is designed such that it has to work with both group monitoring mode and individual monitoring mode. The system works with group monitoring mode using wireless transmission and with individual monitoring mode using wired connection. The system needs following specific designs: Respiratory sensor belt design, design of the hardware and software design for the system. The respiratory sensor belt is designed using reflective object sensor. During the respiration, due to inhalation and exhalation the thoracic or abdominal part expands. This expansion results in the variation of output voltage of the reflective object sensor. The Hardware part of the system is designed such that it should allow the connection of the respiration belt to individual monitoring mode or to group monitoring mode. Finally, the software part consists of algorithm that allows the connection of the respiration belt to individual monitoring mode or to group monitoring mode[3].



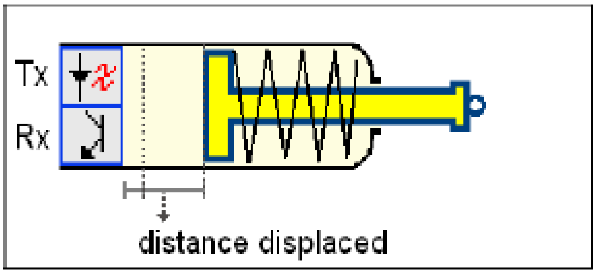


Fig -5: Graphic design and Logic symbol of the displaced respiratory sensor

Graphic design and Logic symbol of the displaced respiratory sensor is shown in the fig -5. The designed respiratory sensor belt is named as PR2012. The respiratory belt unit consists of constructed respiratory sensor. The Respiratory belt is fastened firmly around the chest to monitor the subject's respiration rate[3].

2.4 Breath Rate Monitor using Non-invasive Biosensor

The device is an intelligent system based on microcontroller. The system will keep a nonstop authentic-time trace of the respiratory rate of the patient. The system will give the alarm on exceeding the respiratory rate boundary limit; simultaneously system sends the SMS to the Physician regarding the respiration rate. The system uses temperature sensors to provide non-stop temperature response of the respired air [4].

The framework utilizes LM-35 accuracy incorporated circuit temperature sensors. Its yield voltage is relative to the temperature which is measured in Celsius (Centigrade). The scale component is 0.01 V/°C. The LM-35 has favourable element over straight temperature sensors aligned in °Kelvin, as it is not needed to subtract a vast steady voltage from its yield to acquire advantageous Centigrade scaling. It draws just 60µA from its supply[11]. Fig -6 demonstrates the fundamental circuit of the LM-35.

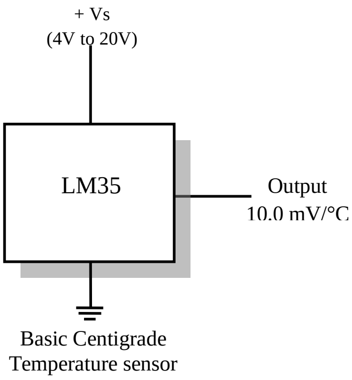


Fig -6: Fundamental circuit of the Temperature sensor LM-35

The microcontroller based framework utilizes brilliant temperature sensor, which is set inside the breathing cover or adjacent the nostrils of the patient concerned. This sensor gives prompt temperature input of the breathed in and breathed out air. To distinguish the maxima(s) and minima(s), the microcontroller runs a calculation in recursive mode, and in this manner concentrates its periodicity. This framework is savvy enough to distinguish false case recognition. The framework keeps a consistent track of the respiratory rate and upgrades the rate for like clockwork. The framework will give a caution, and sends a SMS on the off chance that the respiratory rate surpasses the limits of the lower or upper respiratory rate limit.

2.5 A Noncontact Respiration Rate Monitoring System based on Facial Tracking Method

This method involves tracking a facial region of interest (ROI) associated with respiration in thermal images. To enhance the recorded thermal images and to remove unwanted noise image processing techniques were used. The skin surface area centered on the tip of the nose [fig -7] was specified by a circle that covered the region affected by respiration process. Signal processing and Feature extraction methods were applied to this region to compute the respiration rate[5].

FLIR A40 thermal camera is used to record the thermal images. Thermal videos were recorded for two minutes for each subject. This provided 6000 thermal images per subject. To date, data from 15 subjects have been recorded, but the data recordings are continuing. Following processes are performed to find and track the ROI [7]:
i. Image enhancement
ii. Segmenting the subject face from the image background.
iii. Identification of the ROI
iv. Tracking the ROI

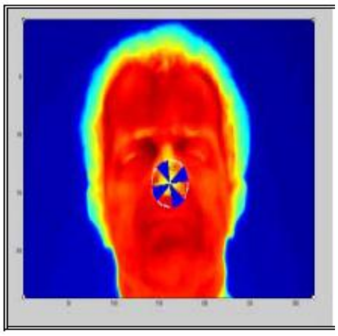


Fig -7: The position of ROI on the tip of the nose [5]

When the subject's face was extricated from the picture foundation, the remaining range was uprooted. A scanning operation was carried out inside the selected boundary. This consisted of starting from the top-left corner of the boundary and averaging the values of the pixels in an area consisting 5 by 5 pixels. This process continued till the scanning operation reached the far right corner of the image. Then, the scanning process was repeated by moving down by 5 pixels and then to the far left corner of the image again until the selected area of the image was completely scanned. During each scan, the most recently calculated average pixel value was compared with the previous largest average pixel value. If the current average value was larger the previous value, it replaced the previous largest average pixel value[5].

2.6 A New Scheme for Determination of Respiration Rate in Human Being using MEMS Based Capacitive Pressure Sensor

The Scheme uses a MEMS based capacitive nasal sensor system for measuring Respiration Rate (RR) of human being. At first two identical diaphragms based MEMS capacitive nasal sensors are designed and virtually fabricated. The system consists of signal conditioning circuitry along with the sensors. In order to measure the respiration rate the sensors are mounted below Right Nostril (RN) and Left Nostril (LN), in such a way that the nasal airflow during inspiration and expiration impinge on the sensor diaphragms as shown in the fig -8. Due to nasal airflow, the designed square diaphragm of the sensor is being deflected and thus induces a corresponding change in the original capacitance value[9]. This change in capacitance worth is to be distinguished by a connected twofold testing (CDS) capacitance-to-voltage converter is intended for an accuracy interface with MEMS capacitive weight sensor, a speaker and a differential cyclic ADC to digitize the weight data. The design of sensors and its characteristics analysis are performed in a FEA/BEA based virtual simulation platform[11]. The designed MEMS based capacitive nasal sensors is capable of identifying normal RR (18.5±1.5 bpm) of human being.

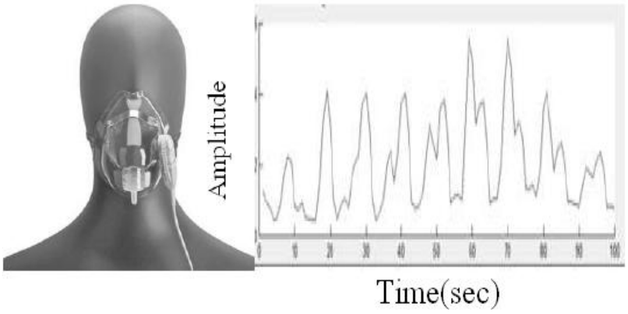


Fig -8: Schematic of the process for the respiration rate (RR) measurement [9]

2.7 Breath Rate Monitoring System using Ultrasonic Contactless Sensor

The system uses a low control ultrasonic dynamic source and transducer. During the respiration there exists a difference in the velocity of the expired air and surrounding environment. This velocity difference will cause the frequency shift. The device measures frequency shift, i.e., the Doppler shift (Doppler Effect). Obtained signal is then digitized. Using a definite signal processing technique effects of subject movements are separated from the breath. The source is kept 50cm away from the sensor, and it uses frequency of 40 kHz, well above audible frequencies[10].

The subject's head is illuminated with an acoustic wave transmitted by a transducer and afterward that reflected wave is recuperated and investigated. The subject's head is to illuminated with an acoustic wave emitted by a transducer and then that reflected wave is recovered and analyzed. A frequency shift induced due to the movement of the subject and also the exhaled air flow is known as Doppler effect[10].

The apparatus permits checking the breathing of a subject in recumbent position. A wide area including the subject's head is illuminated using a 40 kHz ultrasound transmitter. The receiver receives the reflected signal, and is recuperated and investigated. The wave of incidence and movement of neighbouring objects is subjected to different transformations linked to physical and chemical characteristics after the incidence of reflected wave on the local environment of the media. The acquired deciding result is a mixture of frequency shift, level reduction, and a modified spectral energy repartition against time when the subject inhales out. Fig -9 shows the block diagram of the apparatus.

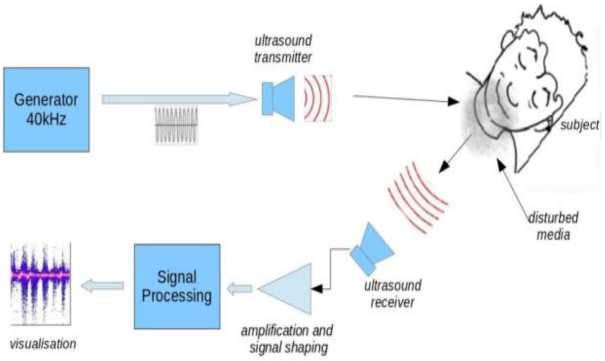


Fig -9: Block diagram of the device [10]

3. COMPARISON BETWEEN TECHNICAL SPECIFICATIONS OF DIFFERENT RESPIRATION RATE MONITORS

Table -1: Comparison between technical specifications of different Respiration Rate monitors

Types	Sensor Module	Methodology
Respiration rate meter–a low–cost design approach	Uses mask fitted with IR LED transmitter-receiver[1] as shown in the fig -1	Movement of thermocol ball between IR transmitter-Receiver produces pulse[1]
Respiration Rate Measurement Based on Impedance Pneumography	Uses electrodes that are placed on the chest, measures electrical impedance changes of thorax[2]	Impedance Pneumography Method[2]
Thoracic Expansion Measurement Based Respiration Rate monitoring System	Uses displacement transducer, constructed using axis, spring, bumper edge, reflective object sensor as shown in the fig -5[3]	Displacement method[3]
Breath Rate Monitor using Non-invasive Biosensor	Uses temperature sensor that measures temperature changes during inhalation-exhalation[4]	Thermistor method[4]
A Noncontact Respiration Rate Monitoring system based on Facial Tracking Method	Uses thermal camera to take the thermal images and movement of ROI can be measured using image processing[5].	Displacement method, Image processing[5].
A New Scheme for Determination of Respiration Rate in Human Being using MEMS Based Capacitive Pressure Sensor	Uses MEMS based capacitive nasal sensors that are mounted below Right Nostril (RN) and Left Nostril[9].	Change of capacitance during the exhalation-inhalation cycle[9].
Breath Rate Monitoring system using Ultrasonic Contactless Sensor	Uses ultrasound transmitter-receiver to measure the subject's head movement and respiration air movement using an ultrasonic wave[10].	Measurement of movement of both Subject and exhaled air using Doppler effect[10].

4. CONCLUSION

Respiratory rate is one of the fundamental signs that are viewed as standard for observing patients on intense clinic wards. An irregular respiratory rate has demonstrated as a critical indicator of genuine clinical occasions, for example, Cardiac capture and admission to an emergency unit. There are varieties of Respiration Rate monitors. In this paper, seven types of Respiration Rate monitors are reviewed. And each Respiration Rate monitor has its own specification with different methodology. The Respiration Rate monitors discussed in this paper uses methods such as Displacement method, Thermistor method, image processing method, capacitance method. All type of monitors discussed will provide optimal result.

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BIOGRAPHIES

Karthik Mohan Rao received the B.E. degree in Electronics and Comunication engineering from Vivekananda college of Engineering Technology, Puttur, India and pursuing M.Tech. degree in Biomedical Signal Processing and Instrumentation engineering in RV College Of Engineering, Bengaluru, India.

Dr. B.G. Sudharshan working as Associate Professor, Department of Biomedical Signal Processing & Instrumentation, RV College Of Engineering, Bengaluru, India