A Low-Cost and Portable Apnea Detector for Healthcare System

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Abstract

Objectives: This paper highlights on the development of a simple electronic circuit based low-cost, noninvasive and portable apnea detector for patient care monitoring system. Methods/Statistical Analysis: Apnea indicates the cessation of breathing. In this study, thermistor sensitivity method has been implemented in designing the apnea detector. The resistance of a thermistor changes significantly with temperature. The change of temperature between inhaled and exhaled air (during respiration process) is sensed by the thermistor and corresponding change of thermistor resistance is measured in terms of electrical signal with the help of additional active and passive circuit elements. Findings: The resistance of the thermistor changed by 7 Ohm with increase of temperature of 1 degree centigrade. When the apnea detector is switched on and no exhaled breath is incident on the thermistor, the buzzer associated with the device gives sound to indicate the condition of apnea or absence of breathing. The output voltage of the circuit is found to be 8 Volts at this condition. However, if a subject exhales upon the thermistor, the sound of the buzzers stops to indicate the presence of breathing. During this condition, the output voltage is less than 8 Volts and found to vary from subject to subject. Application/Improvements: The designed apnea detector, being a low-cost and portable device can be implemented in patient care monitoring system.

Keywords: Apnea, Apnea Detector, Health Care System, Patient Care Monitoring System, Respiratory Activity

1. Introduction

The discoveries of oxygen and carbon dioxide led to the theory and practice of closed breathing systems and identified respiration as inspiration of oxygen and expiration of carbon dioxide, which formed the basis of general physiology. The Greek word ‘apnea’ means without breathing. An apnea occurs if someone’s breathing ceases for a certain amount of time i.e., if the magnitude of the respiration movements are decreased for at least 10 sec or drop 4% O₂ saturation in blood of the physiological values. It is a common disorder that occurs in about 7% of the population of which more than 85% remain undiagnosed. During apnea, external breathing is suspended and muscles of inhalation show no movement. Based on the patency of the airways, a flow of gas between the lungs and environment may or may not occur; gas exchange within the lungs and cellular respiration is not affected. Apnea can be voluntarily achieved; drug induced, mechanically induced, or can occur as a consequence of neurological diseases, trauma or sleep (sleep apnea). In different clinical conditions, namely neonatal monitoring, intensive care and sleep diagnostics, monitoring of breathing dynamics is regarded as an important diagnostic tool.

Apnea can occur in premature babies during their first weeks of life because of their immature nervous system. Different apnea monitors already exist, some utilizes electrical leads on the human body to detect breathing and heart beats; if apnea persists for prolonged period, it might cause brain damage. One way of identifying such breathing problem is by using apnea detector.

A plethora of researches has been carried out in detecting apnea. Lee and his coworkers have described an algorithm that can detect central apnea. Andrew et al. proposed fixed formant frequency thresholds for detecting the hypopneic snores which must be higher than that of the typical ones. Among different types of apnea,
sleep apnea is a major risk factor resulting in irritability, sexual dysfunctions, high blood pressure (hypertension), learning and memory difficulties. Another study used snoring sound and oxygen saturation screening for the detection of sleep apnea. Laiali Almazaydeh discovered a way to detect apnea by respiratory signal classification. Hill et al. designed a device which records and analyzes tracheal sound waves to detect apnea. Miwa et al. studied on apnea detection of preterm infants using laser doppler vibrometry. However, most of the above mentioned methods for apnea detection are rarely used in patient care monitoring system either due to the complications of the algorithms used or the expensive and complex natures of the instruments used. This paper presents an innovative idea of noninvasive, cost effective apnea detection tool which can easily be employed in the health care industry.

2. Methodology

In our developed model of apnea detection, the focus is given to detect apnea using thermistor sensitivity method. A thermistor is a type of resistor whose resistance varies significantly with temperature, more so than in standard resistors. In the beginning, when the circuit is switched on, the buzzer produces a sound as no respiration is there. Then, the thermistor is placed in front of the patient's nose so that it can sense the respiration and convert the change in resistance (due to the variation of temperature between the inspired and expired air) into electrical signal. Since, the signal generated is a weak signal, so it needs to be amplified. A high input impedance amplifier is used to convert this signal into a high amplitude signal. Figure 1 illustrates the circuit that has been used to develop our model.

This amplified signal obtained from pin 6 of the 741 op-amp (pin 6 of 741 IC is for the output voltage) after passing through the diode goes up to pin 6 of 555 timer IC (pin 6 of 555 timer IC is for threshold). Also a part of the signal charges the capacitor C, which makes the pin 2 (responsible for trigger) of 555 timers IC high. When pin 2 is high, then pin 3 is low, so in the presence of respiration, the buzzer does not respond and no sound is heard. Now, in the absence of respiration, when no signal comes to the (input) pin 2, the output of pin 3 goes high to indicate apnea and the buzzer responds. The schematic representation of the apnea detector circuit is shown in the next segment.

Figure 1. Circuit diagram of apnea detector.

Figure 2. Apnea detector circuit on Breadboard.

Figure 3. Apnea detector circuit on Veroboard.

Figure 2 and 3 represents the apnea detector circuit on breadboard and veroboard, respectively. The finalized circuit developed on the veroboard was placed in a plastic container as shown in Figure 3. The Complete apnea detector system is shown in Figure 4.

3. Result

At room temperature (30°C), we get the resistance to be 301 Ω and at body temperature (37°C), we get the
resistance as 350 $\Omega$. So, the sensitivity of the thermistor can be calculated by, Difference in temperature = (37-30) $^\circ$C = 7$^\circ$C. Difference in resistance = (350-301) $\Omega$ = 49$\Omega$. Thus, we see that for 7 degree change of temperature, the change in resistance is 49 ohm. Therefore, for 1 degree change in temperature, the difference in resistance is $= \frac{49}{7} = 7\Omega$ and the changes of output voltage is 8 volt and the switching voltage is 1.50-8.00 volt.

The developed model of apnea detector works satisfactorily. When the system is switched on, the buzzer makes sound indicating the absence of breathing air on the sensor (thermistor). This condition corresponds to apnea. When someone breaths over the thermistor, the buzzer sound stops, indicating absence of apnea. Thus the developed system can be used to monitor apnea qualitatively.

4. Conclusion

It is to be mentioned here that the apnea detection circuit designed on the veroboard proved its functioning as desired. One of the major advantages of this detector is its low cost (Approximate cost Rs. 250/-) for which it can be easily used to detect apnea in patients not only medical field but also at home for monitoring purpose. For handling this device, one need not to be strictly from medical background. In future, using microcontroller, this circuit can be used to detect the rate of respiration, pulse rate, body temperature simultaneously$^{15,16}$. The developed model of the apnea detector is still under study and it will be applied to the apnoeic patients in the coming days for quantitative interpretation of data to be collected from them. The developed system, being a portable, low-cost, noninvasive and readily accessible device, can easily find its place in modern patient care monitoring system.

5. References

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