Design And Implemantation of A Programmable Apnea Monitoring System

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ABSTRACT

The monitoring of breathing dynamics is an essential diagnostic tool in various clinical environments, such as sleep diagnostics, intensive care and neonatal monitoring. This paper introduces a noninvasive method for monitoring the respiratory patterns of the patients and the specifications of apnea monitor hardware. The microcontroller based apnea monitor consists of a sensor system interfaced with a microcontroller to detect the apnea from the heat changes in the oro-nazal air flow. The amplified signal obtained from the patient is applied to the microcontroler.After converting the signal into digital form, it is transfered to the computer by using the RS232 serial port to make possible to investigate the relation between the EEG or ECG signals with respiration patterns. The system allows to adjust the apnea period for various applications. In tests, apnea period is selected as 10 sec. Also, an alarm system is available to warn during the sleep apnea. Performance evaluation of the system was complated and satisfactory results were obtained. The requirements for the system reduce cost and discomfort associated with traditional diagnostic prosedures.

I. INTRODUCTION

Sleep is essential for humans although its basic physiological function remains obscure. 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 thus, the detection of various disorders.There are a number of breathing disorders, but *sleep apnea syndrome* (SAS) is probably the most common amongst them. Sleep apnea is defined as cessation of airflow to the lungs during sleep for 10 sec. or more[1],[2]. It normally results from either upper airway collapse [obstructive sleep apnea (OSA)] or lack of neural input from the central nerveous system to the diaphragm [Central sleep apnea (CSA)] [2]. OSA is the more common form of sleep apnea. Common symptoms of OSA are fatigue, daytime sleepiness, heart problems, and systemic hypertension [2],[3]. It is usually associated with loud, heavy snoring[2]. According to a recent study [4], 4% of the man and 2% of the women between 30- to -60 years may meet the minimal diagnostic criteria for the sleep apnea syndrome.. Also, one of the most common respiratory patterns in premature infants is known as periodic breathing, which denotes brief recurring periods of apnea in a sequence of breaths. While no significant changes in heartrate or body temperature occur during periodic breathing, infants with prolonged periods of apnea frequently suffer bradycardia and hypothermia[5]. Apnea can be induced by a number of disorders, though its exact physiological cause is undefined; even the withdrawal of caffeine received in utero from a coffee drinking mother has been implicated[6]. Apnea of greater than 30 seconds duration occurs in about 84% of very low birthweight (under 1000g) infants in the first ten day of life[7] . Bradycardia usually occurs within 30 seconds or less of the onset of apnea[8]. In patients with obstructive sleep apnea, the natural sleep related fall in pharyngeal muscular tone results in collapse of the airway at this level, particularly when the intra-luminal pharyngeal pressure falls during inspiration[9]. Once collapsed, surface tension keeps the airway obstructed until the patient wakens from sleep and pharyngeal muscle tone returns. In patients with severe sleep apnea of either cause, repetitive breath holds occur several times during one night, and a night sleep becomes a series of sleep fragments only lasting about a minute. This renders the sleep process ineffective and leaves the patient grossly sleep deprived during the day. As well as the direct consequences of the airway collapse (snoring and sleep fragmentation), the disease has a number of less direct consequences including respiratory failure, pulmonary hypertension and right heart failure[10] and a possible increase in systemic cardiovascular disease such as stroke, heart failure and sudden death[9]. The blood oxygen saturation falls during apnea, because no gas exchange can take place.

This reaches clinical significance if the blood oxygen saturation decreases below 95% of the saturation level before the episode of apnea and this lasts for more than 10 sec. The desaturation event activates the sympathetic nervous systems. This result in incresing heart rate and blood pressure, which can stress and possibly injure aspects of the cardiovascular system. All these effects may combine and lead to progressive and serious change, even to incurable damage to numerous parts of the human organizm. Because the onset of apnea is so unpredictable, and the result of oxygen deprivation so debilitating, it is essential that potentially apneic patients be monitored continuously**.**

In this study we have developed a new algorithm and implement a non-invasive system for this purpose. 16F877 microcontroller from PIC16F family is used in hardware design and PIC C programming language is used for software development.

II. METHODS

Perceiving the Respiration

Since breathing activity generates no readiliy detectable electronic signal, the monitoring of respiratory function requires the use of a transducer of some sort. Traditionally, this has been accomplished with chest impedance electrodes, ultrasonic motion detectors, pressure sensitiv air-filled matresses, and heart rate monitors[11]. The heart rate may not drop during certain apneic episodes, particularly those of short duration. Apnea monitors dependent solely on a change in heart rate to signal an alarm will be inadequate for some infants. The detection of pressure changes in an air-filled mattress, or movement in an ultrasonic field provide the operating principle of the motion detection tecnique in respiratory monitoring. The frequent incidence of false alarms due to non-respiratory generated body movement in the patient renders these device unreliable. One of the other detection method is chest impedance pneumography that works on the principle with an increase in gas volume of the chest in relation to the extra-cellular fluid volume, conductivity decreases, and lenght of conductance path increases due to expansion. Thus electrical impedance increases[12]. With some ventilatory patterns, such as abdominal ventilation, the impedance path through the chest may not be significantly altered, thus generating a false alarm.

Oro-nazal airflow is defined as the continuity of airflow from the nose and the mouth. The cessation of air flow indicates the existance of apnea. The existance of congestion in the nose reveals that the airflow stops, thus it can be evaluated as an apnea incorrectly. Oro-nazal air flow is measured with heat sensitiv electrodes named as nasal thermistor and located on the both nostril and mouth arc. Thermistor is a semi-conducter device that its resistance changes with temperature. Resistance of thermistor can both increase or decrease with temperature depending upon its inner structure. Because of its stable charachteristics , the NTC type of thermistor is selected in designing apnea monitor. It must be payed attention while placing the thermistor to the patient nose in which it must not touch to the inner nose epitel. Otherwise, the increase of heat can be evaluated as an existance of apnea incorrectly and causes a false alarm. The thermistor and its connection to the patient is shown in Fig.1

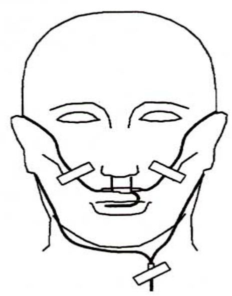

Fig 1. The perceiving of oro-nazal air flow with thermistor

The resistance of thermistor is equal to R=7.63 Ω at the room conditions. The changes in the resistance of thermistor is averagely equal to R= 6.5 Ω during the exhale and R= 7.7 Ω during the inhale depending upon the respiration heat of the patient. When the amplifiers inner current pass through the thermistor, there exists a small voltage on the thermistor.After being amplified, this signal is used to detect the apnea . The signal is applied to the microcontroller and converted into digital form for interpretation whether the apnea exists or not. Then it is transfered to the computer by using the RS-232 serial port. The implemented computer program allows to store and draw the respiration signals for certain patients

III.THERMAL CHANGE IMPULSE IN THE RESPIRATION

Due to the low amplitude of the respiration signal, there exists an amplifier circuit. The operation voltage of the amplifier is selected V_{cc} =9V. The pozitive input resistance of the thermistor is equal to 1 KΩ, and the feedback resistance of the thermistor is equal to 5.1 MΩ. In this way , we are able to process the respiration signal by apmlifiying it 5100 times. The amplitude of the signal is measured -1.5V during the inhale,0.9V during the exhale and -0.2V in the no-respiration condition. The amplified signal is than applied to the ADC pin of the microcontroller and converted into the digital form.The microcontroller also controls the voltage level during the respiration continiously and comments the signal whether the apnea exists or not. The thermal change curve is shown in Fig.2

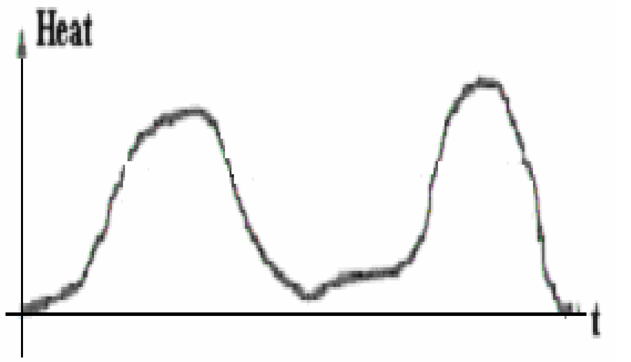

Fig.2. Thermal change curve

IV. IMPLEMENTATION OF SYSTEM

The microcontroller based apnea monitor consists basically of a heat sensitiv sensor, and an amplifier circuit, interfaced with a spesific microcontroller system connected with a computer by using RS-232 serial port. The microcontroller is used for interpretation of the signal to detect the apnea. The system works with two 9V battery and it has a portable property. The LM7805 ragulator is connected to the power supply and the 5V voltage is obtained that is necessary for microcontroller. The aim in this application is not to increase the number of battery. A piezzo sounder and two leds ,one of which is red and the other is green are connected to the microcontroller. The green led is "ON" while the patient continues the normal respiration. During the apnea the green led turns into "OFF", then the red led and the piezzo sounder turns "ON". PIC16F877 isselected for microcontroller which includes an internal ADC(Analog to digital converter) and so there is no need to use an extra ADC.The microcontroller needs a square wave clock signal to operate the program instructions that are available in the memory. It reaches to each instruction in one cycle of the clock signal and loads the instructions to the registers[13]. PIC16F877 has two pins, OSC1 and OSC2 for clock signal inputs. The clock signals that are generated by different ossilators can be applied to these pins. The ossilators with cristal and capasitor is used in the circuits in which the timing is important such as apnea monitor. The apnea period is established averagely 10 sec. The system detects the apnea and provides alert if there is no signal exists after the respiration of the patient stops. The control mechanism of the system resets it self if the patient starts the respiration during these 10 s period. Also there exists a reset button to interfere to the alarm system manually. It is depicted a block diagram of the system in Fig.3

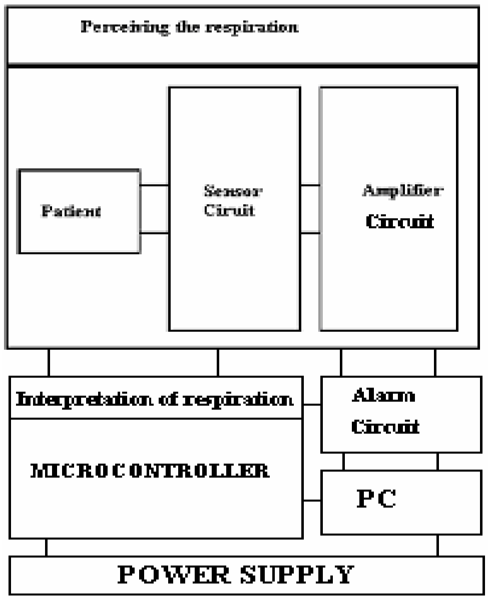

Fig.3.Block diagram of apnea monitor

V. DISCUSSION AND CONCLUSION

A noninvasive method for monitoring the respiratory patterns of the patients and the specifications of apnea monitor and implementation of hardware is described. A heat sensitive thermal sensor is used for detecting the sleep apnea interfaced with PIC16F family 16F877 microcontroller for signal interpretations.

A number of parameters are considered in selecting the microcomputer such as reliability, flexibility, cost and so on. Also, we intend to utilize this system as a research instrument, thus we desired more information and data processing capabilities than simply the detection of apnea. In the present form, the system is capable of detecting apnea, warns during the apnea and transfers the respiration signals to the computer. The final design concept includes the categorization of the apnea intervals, and generate a real-time histogram of their frequency and duration which makes possible to investigate the relations between the EEG, ECG or other physiological signals and the respiratory patterns.

The system also communicates with a computer by using RS-232 serial port to make advanced researchs on respiration signals. The system works with two 9V battery which makes it portable.

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