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Design of a MEMS Pressure Sensor for Detecting Apnea Event

Nithya V. K.[*], P.K. Senthil Kumar[**] and A. Vimala Juliet[***]

Abstract: Sleep Apnea is a common breath disordered sleeping condition with reduced breathing amplitude. This disorder if not diagnosed will lead to chronic conditions like Cardiac arrest, Heart attack and even heart failures.

There are many systems available today in the biomedical field for detecting the sleep apnea event. All those systems are much complex and bulky and also it requires a continuous monitoring of the subject's physiological activities. With the emergence of MEMS technology, it became much easier to design and fabricate miniature systems that can be conveniently used for sleep studies. The inhale and exhale activities of the human being under consideration can be effectively monitored by using MEMS sensor. If there is an effective Apnea scoring algorithm and a signal conditioning chip, then the breathing pattern of the person can be detected from the exhaling air pressure of the person.

Index Terms: Sleep Apnea, Apnea Event, MEMS Sensor

1. INTRODUCTION

Sleep Apnea is a disorder that occurs while a person is sleeping. When a person sleeps, if there is some immediate stop in the breath and if it extends for some time, then it can be characterized as an Apnea event.

The persons with Sleep Apnea disorder if not diagnosed properly it might lead to chronic health conditions like stroke, cardiac arrest, heart attack, obesity and even heart failures.

In certain cases even high BP is observed in persons with Sleep Apnea. All these implies the importance of a successful and well designed Apnea detecting method.

This study involves a comparison of different Apnea scoring methods and also the design of a new Sensor module for scoring Apnea event.

2. EXISTING SYSTEMS FOR THE DETECTION OF SLEEP APNEA - A COMPREHENSIVE STUDY

A person with Sleep Apnea will be having one or more halts in the breath during the sleeping hours. This discontinuity in breath can last from few seconds to even minutes. The time duration of the discontinuity will determine the severity of the Apnea event.

Also the occurrence of Sleep Apnea will disrupt the person's deep sleep and the person will enter into a state of light sleep. This will definitely lead to changes in many bio physiological activities of the person. That is the importance of diagnosing Sleep Apnea.

A person who is having sleep apnea if left undiagnosed, might get suffer with high BP, obesity, Arrhythmia, Cardiac arrest and even stroke.

There have been many studies going on for the detection and diagnosis of Sleep Apnea in the recent years. It has been viewed as an important sleep study in different parts of the world.

[*] Dept. of Instrumentation and Control, SRM University, Chennai, India. *Email: nithya.vkarippath@gmail.com*
[**] Asst. Prof., Dept. of Instrumentation and Control, SRM University, Chennai, India. *Email: pksenthil2007@yahoo.co.in*
[***] HOD, Dept. of Instrumentation and Control, SRM University, Chennai, India. *Email: hod.ice@ktr.srmuniv.ac.in*

A. Poly Somno Graphy (PSG)

The golden standard of Sleep Apnea detection is being Poly Somno Graphy. Poly Somno Graphy or PSG is a comprehensive Sleep study that is being used to diagnose the occurrence of Sleep Apnea.

It records many bio physiological parameters of a human during sleep. PSG is an instrument that is very huge , around the size of a room. The person under consideration has to undergo a complete sleep study with the use of PSG, in a dark room. The process will take a minimum of 8 hours.

There are different varieties of the PSG equipment, that are available in the market. A common PSG will be having mostly 32 electrodes, in which 8 electrodes for ECG, 8 for EEG, 8 for thoracic and 8 for abdomen.

PSG is considered as the golden standard of sleep studies.

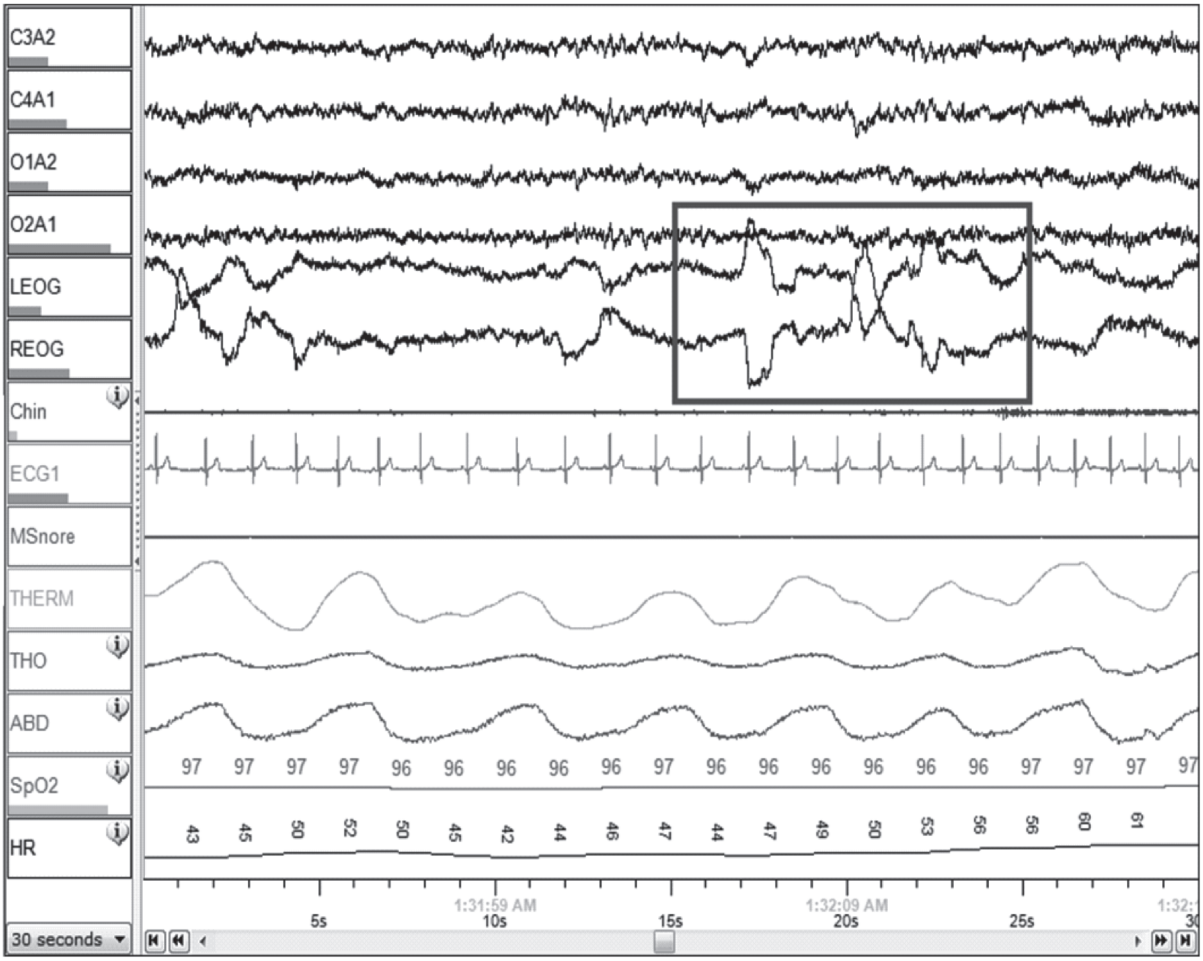

Figure 1: Polysomnographic record of REM sleep. Eye movements highlighted by red rectangle [1]

B. A Wireless Portable System with Micro Sensors

In this study, a wireless portable system is proposed for the monitoring of respiratory activities [2]. It has got two sensor modules, of which one is a Respiratory posture sensor and the other one is an Oximetry sensor module.

The Respiratory posture sensor consists of again two sensors, one a hot film flow sensor and the other one is a tri axial accelerometer. The flow meter is used to measure the flow rate of oxygen during the breathing activities and the accelerometer is used to monitor the position of the peron while sleeping.

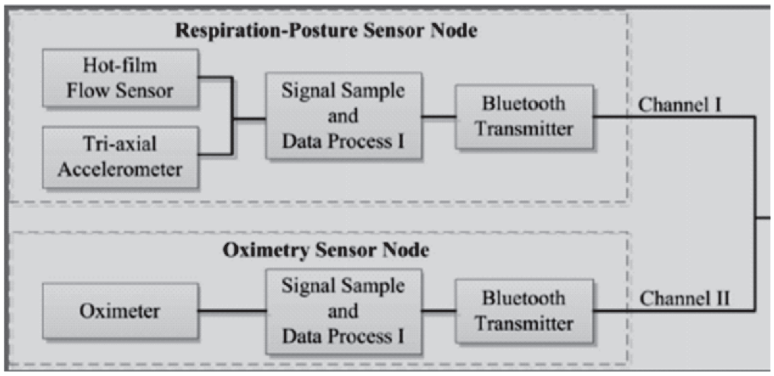

Figure 2: Sensor Modules [2]

The oximeter sensor will monitor the oxygen saturation level in blood as a normal pulse oximeter does.

The person has to wear the respiratory posture sensor on the upper abdominal part and the oximeter on the finger tip.

Then from the study different respitaory parameters as calculated as given in Table 1, which is referred from [2].

Table 1
Respiratory Parameters and Calculation Methods [2]

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

C. Sleep Apnea Detection from Cardiac Interbeat Intervals

In this study proposed in [3] , a new automated method is suggested to diagnose specifically Obstructive Sleep Apnea. It is done from single lead ECG based on the periodicity in the cardiac signals. There will be a distinct difference in the ECG signal for a person with OSA and a normal healthy person.

Here in the proposed system the cardiac interbeat interval signal is monitored and the hilbert's transform is done for the signal. The signals are shown in Figure 5 and Figure 6 [3].

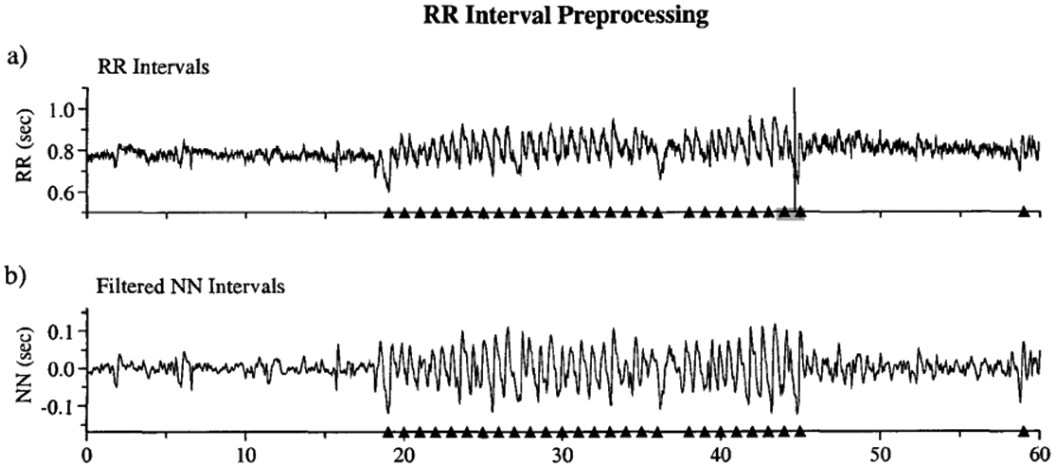

Figure 3: RR Interval preprocessing signals [3]

D. Adjustable Smart Pillow System for Sleep Detection System

In the paper [4], a smart system is proposed which is Smart pillow system associated with a control system. A pictorial representation of the adjustable smart pillow system is as given below:

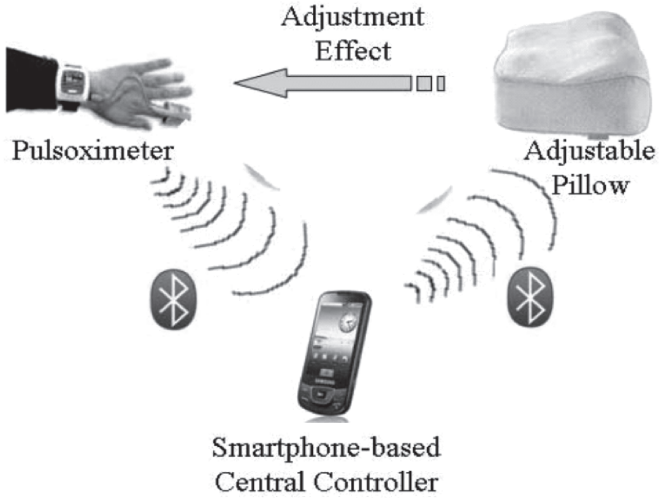

Figure 4: Adjustable smart pillow system [4]

The system given above has a pulsoximeter wore on the subject's finger tip. It will measure the instantaneous oxygen level in the person's blood stream and the signal is being sent to a smart phone, which has the main controller in it.

The controller will generate control signal and this signal is being used for adjusting the bladders in the adjustable pillow. So if the sleep position of the person is disturbed, the position can be adjusted through the smart pillow.

E. A Home Sleep Apnea Screening Device With Time-Domain Signal Processing and Autonomous Scoring Capability

In this proposed study [5] a microsystem is given, with the sensor part being Piezoelectric Pressure Sensor. A Piezoresistive pressure sensor will sense any changes in the pressure input and will output a change in the electrical resistance.

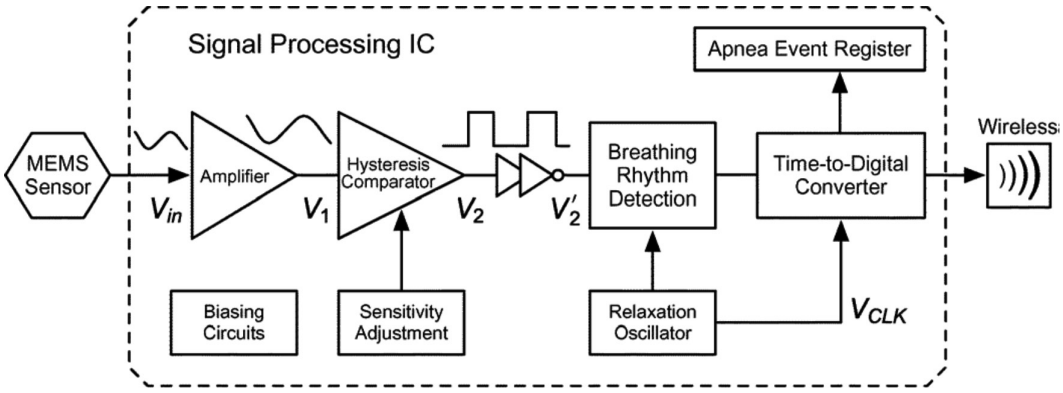

Figure 5: System block diagram including the sensor, the signal processing chip, and wireless module for data transmission [5]

The sensor module will sense the pressure and the piezoelectric material will change its dimensions accordingly. So the resistance of the Piezo resistive material will get changed. This will produce an electrical output.

3. PROPOSED SYSTEM WITH MEMS PRESSURE SENSOR

Micro Electro Mechanical Systems (MEMS) is a newly evolving technology that has very high impact on the current world of electronics. Very small devices can be fabricated using MEMS technology.

A. MEMS Pressure Sensor

MEMS Capacitive pressure sensors are proposed here. The working principle of MEMS Capacitive Pressure Sensor is that whenever there is a pressure change acting on the two plates of the parallel plate capacitor then there will be a change in the capacitance output,provided one plate is fixed and dielectric constant is a fixed one. So according to the change in the applied pressure there will be a change in the thickness of the dielectric medium in between the plates of the capacitor and this will produce a capacitance output.

B. Equation

The equation that governs the study is C = □A/D

where

E : Dielectric constant (fixed one)

A : The cross sectional area of the capacitive sensor (fixed one)

D : The thickness of the dielectric (Variable One)

C. Geometry-MEMS Pressure Sensor

Designed a Capacitive pressure sensor with the following structure using COMSOL software.

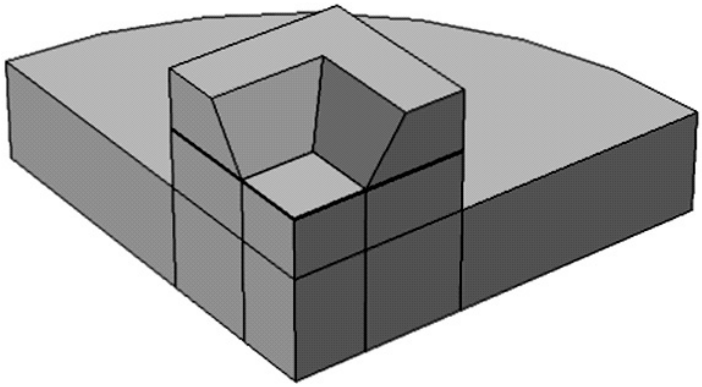

Figure 6: Geometry of the structure

The system will become more compact with the use of the MEMS sensor. Also it will become more easy to use in home atmosphere.

4. CONCLUSIONS

Sleep Apnea is a sleep disorder, not a disease. But this disorder might lead to chronic conditions like cardiac arrest, heart attack, stroke, obesity, high BP and even heart failure. There comes the importance of diagnosis of this disorder.

The studies that were listed above are having many individual drawbacks that is the reason why here a new system is proposed.

The drawbacks of individual systems are listed in the below table.

Table 2
A comparison of different apnea related studies

A. Poly Somno Graphy(PSG)	– The entire system is much complex and costly – It is a bulky system which room size
B. A Wireless Portable System with Micro Sensors	– Many sensor modules are involved that makes the entire system much complex to analyse
C. Sleep Apnea detection from cardiac interbeat intervals	– Many analytical calculations are involved
D. Adjustable Smart Pillow System for Sleep Detection System	– The controller is in the smart phone. So there is a chance for a poor control according to even environment conditions.
E. A Home Sleep Apnea Screening Device With Time-Domain Signal Processing and Autonomous Scoring Capability	– The sensor module will produce erroneous reading if there is much variation in the temperature. – The system will become more temperature dependent.

The proposed system with mems capacitive pressure sensor will better diagnose the event of sleep apnea without the problem of reduced performance because of temperature dependency.

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