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Wireless pulmonary disease prediction system

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ABSTRACT

Many chronic acute diseases affect the respiration of the patients. The monitoring of vital body signs such as respiration is becoming increasingly important, especially in view of the general aging of the population and the associated increase in chronic diseases. A quantitative, semi quantitative or even qualitative monitoring of respiration may help to detect pulmonary disorders such as apnea, Cheyne – stokes or Biot's respiration. When used in a home setting, respiratory monitoring should be easy to use and not constrictive to for the patient. Moreover, because longtime monitoring entails direct connection between the patient and the system, the integration of such systems into clothing is desirable. A novel approach is presented for non constrictive long term – monitoring of respiration, which could particularly become suitable for home care applications. The system is based on textile integrated force sensors, which detect expansion of the thorax during respiration and allow wireless data transmission for maximum mobility. Possible application include long - term monitoring of patients with chronic pulmonary diseases, early recognition of disease and the performance measurement of athletes during excise. Results from performance tests under various conditions are presented. In addition, long – term respiratory monitoring systems could be used to monitor the performance of athletes and to optimize their training. Many qualitative, quantitative and semi – quantitative methods that are integrated in clothing for respiratory monitoring are available.

Introduction

Many chronic and acute diseases affect the respiration of patients. The monitoring of vital body signs, such as respiration, is becoming increasingly important, especially in view of the general aging of the population and the associated increase in chronic diseases. When used in a home setting, respiratory monitoring should be easy to use and not constrictive for the patient. Moreover, because long-term monitoring entails direct connection between the patient and the system In addition, long-term respiratory monitoring systems could be used to monitor the performance of athletes and to optimize their training. Many qualitative, quantitative and semi-quantitative methods that are integrated in clothing for respiratory monitoring are available [3] the most promising technique that allows estimating breathing frequency and tidal volume is respiratory inductive plethysmography ([4], [5], [8]). With this tech- nique, however, the accuracy of estimates of tidal volume is affected by the current body posture of the subject. An approach currently being investigated is electrical transthoracic impedance measurement ([2], [6]). This method not only documents breathing frequency and depth but is also able to capture developing bronchial obstruction and cough manoeuvres ([10], [11]). However, since impedance of the thorax is influenced not only by breathing, but also by temperature and the amount of water in the body, etc., this method is currently unsuitable for respiration monitoring. Cheng *et al.* attempted to detect respiration by means of two metal plates on the chest and back, but the signal was affected by heart beat and other changes within the body [11]. As none of these latter techniques fulfils all the requirements for no constricting, accurate and reliable long-term monitoring, a new approach for respiratory monitoring is presented here using textile pressure sensors; these sensors are known to be effective in the detection of muscle contractions [1].

Methods and material

Measuring principle

The textile pressure sensors aim to detect the expansion of the thorax during respiration. Placed between the thorax and a belt, which acts as a counter force, the resulting pressure on the sensors change synchronously with €€respiration. Four of these pressure sensors are attached to a belt which surrounds the upper body at predefined positions

The sensor is based on the principle of a plate capacitor. Forming the capacitor areas by two opposed conductive textiles, these are kept apart by a layer of 3D textile. Exerting force on the so-formed capacitor causes a change of the thickness of the 3D textile. This deformation can be measured as a change in the capacitance value of the sensor according to (1)

C=€0€rA/d (1)

Where is the permeability in vacuum, the relative permittivity and the area of the capacitor? Applying this approach to the thoracic expansion during respiration allows detecting different respiratory patterns.

Capacitive Sensors

Capacitive sensors are noncontact devices capable of high-resolution measurement of the position and/or change of position of any conductive target. The nanometer resolution of high-performance capacitive sensors makes them indispensable in today's nanotechnology world. They can also be used to

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measure the position or other properties of nonconductive targets

Capacitive sensors use the electrical property of "capacitance" to make measurements. Capacitance is a property that exists between any two conductive surfaces within some reasonable proximity. Changes in the distance between the surfaces change the capacitance. It is this change of capacitance that capacitive sensors use to indicate changes in position of a target. High-performance displacement sensors use small sensing surfaces and as result are positioned close to the targets (0.25-2 mm).

Compared to other noncontact sensing technologies such as optical, laser, eddy-current, and inductive, high-performance capacitive sensors have some distinct advantages.

- Higher resolutions including sub nanometer resolutions
- Not sensitive to material changes: Capacitive sensors respond equally to all conductors
- Less expensive and much smaller than laser interferometers.

Capacitive sensors are basically position measuring devices. Their outputs always indicate the size of the gap between the sensor's sensing surface and the target.

Methodology

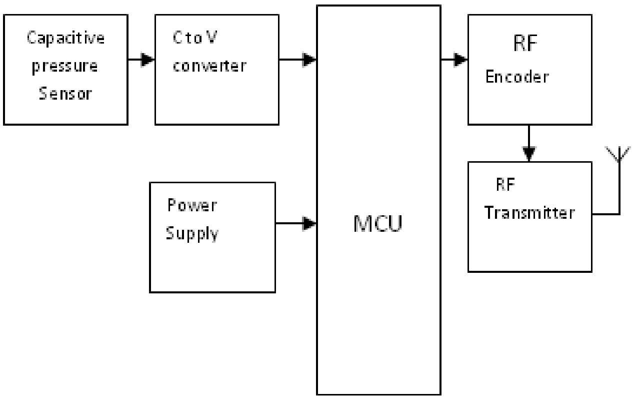

Fig 1 Respiratory signal Transmitter

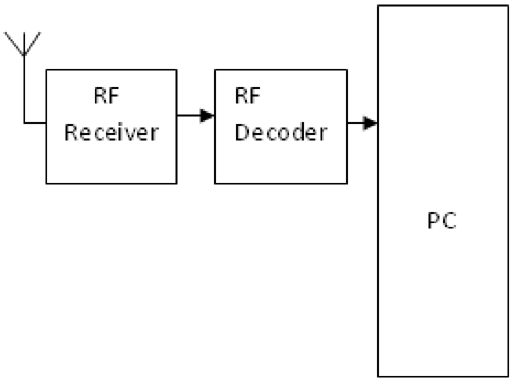

Fig – 2 Respiratory signal Receiver

This system consists of PIC 16F458A, Capacitive sensors, current to voltage converter, RF encoder, RF transmitter, RF receiver, RF decoder, etc…

The capacitance value which is received from the capacitive sensor is converted to voltage using the capacitance to voltage converter. These samples are acquired by the PIC 16F458A micro controller this analog value is converted into digital value. These data are packetized and transmitted through RF transmitter.

The RF receiver receives this data and the encrypted data is decoded by the decoder. This will be given to PC.

Act. Frequency = 200hz

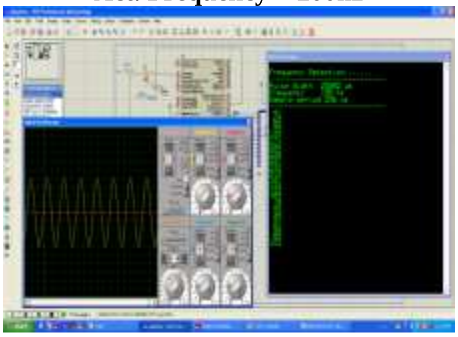

Fig – 3

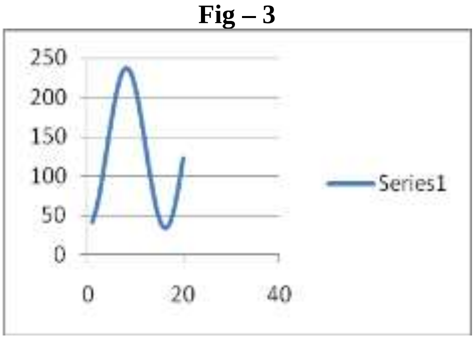

Fig – 4

Act.Frequency = 300hz

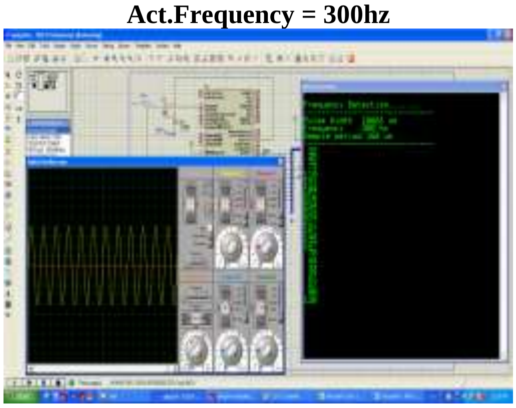

Fig - 5

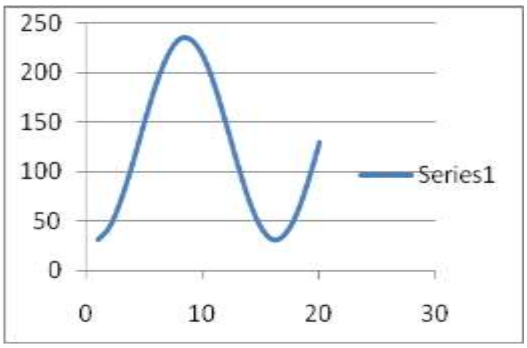

Fig - 6

The above figures are shows the different input samples that are given as input and corresponding digital value is obtained. The graph shows the analog value for the respective digital value.

Measurements

To determine the performance of the system, different tests were carried out. As the tightness of the counter-force belt, and consequently the pressure between the sensors and the body, is essential for signal quality, an electronic spring scale was integrated between both ends of the belt. To assess the ability of the system to detect different breathing patterns, measurements were made following a predefined respiration protocol. The protocol divided the measurement into phases of breathing with high and low frequency, high and low inspiration volume, and phases of apnea (expired breath hold) and breath-hold (inspired breath hold). Synchronous to the measurements with the device, reference measurements were made with the above-mentioned pneumotachograph for comparison purposes.

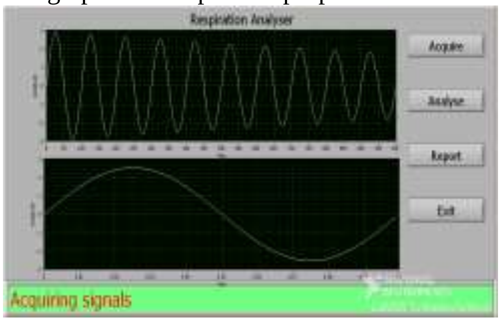

Fig - 7

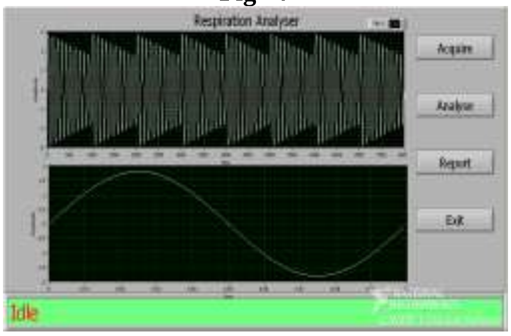

Fig - 8

Fig.11 shows the breathing protocol with the details of segmentation into the different phases; the overall duration was about 130 s with a slight individual variation. The test persons were standing during the entire measurement. To examine the performance of the device during sports, measurements were made on a treadmill Again; respiration was measured by the system and with the pneumotachograph as gold standard. In addition, the activity according to the running program was registered. Fig.9 presents the measurement procedure. After a 30 s walking phase at 4 km/h the subject was asked to run about 50 s at a speed of 7 km/h followed by a 30 s walking period. In order to show applicability of the device for the detection of sleep disorders, the system was also tested on one volunteer during sleep

Results

The preliminary tests with a standard pressure sensor between the belt and on the skin at 18 positions on the upper body show that positioning at the height of the fifth or sixth rib is the most suitable. In these positions the transfer of mechanical power is best because of a high percentage of bone around the thorax. Two sensors were placed under the armpits at the height of the fifth rib and another two sensors under the acromastiums of the subjects, using a total of four sensors for the system.

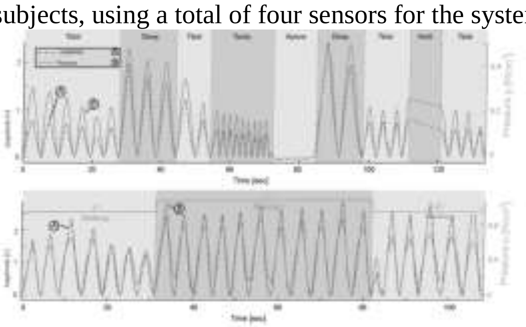

Fig - 9

Even during the running conditions, the results still conform to the reference measurements. During sleep measurements it was possible to record the respiration rate of the volunteer with the system. The depth of the single breaths could not be determined reliably because the contact pressure between the counter-force belt and the body is low and changes very little during respiration. The low contact pressure and small pressure variations are mainly caused by a generally shallow and a predominantly abdominal breathing during sleep as well as belt displacements due to changes in posture. However, phases of non breathing could be distinguished from breathing phases so that detection of apnea is possible. The breathing frequency can be measured in various body postures since four sensors are used at different positions. If one sensor is located between the body and the bed, then the others still measure the movements of the thorax.

Discussion

This study shows that noninvasive respiration measurements can be performed using textile-based pressure sensors. Thus, it is possible to integrate this system into clothing and provide a basis for an easily applied, continuous respiration monitoring system. The system has shown good signal quality, not only during a dynamically changing respiration maneuver but also in Extreme situations such as running on a treadmill or during sleep measurements. It allows for a semi-quantitative detection of the respiration state in many situations, which means that it is able to detect respiration patterns. Therefore, this device has great potential for continuous respiration monitoring in the home care situation, or for applications in sports. The capacitive textile pressure sensors are designed to be sensitive in the pressure range which occurs between the body and a counter-force belt during respiration. Nevertheless, a new wearable noninvasive respiratory measurement system has been developed which shows good results, especially for semi-quantitative evaluation of the respiratory state of the patient. It is robust, simple to produce, and can be made with textile material. Thus, a mobile respiration monitoring system, using this technique, could be produced and applied in daily practice.

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