Mobile Wireless Health Monitoring: Implementation of a Miniaturized Programmable System-on-a-Chip

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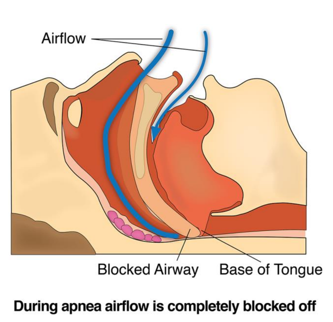
Abstract/ Introduction

As technological advancements have progressed, exploration in miniature transducer use for biosensors and wearable electronics for health monitoring medical applications have emerged as well. Examples of this include electroencephalographs (EEGs), electrocardiograms (EKGs), accelerometers, and other types of analog data sensors [1]. Data transmission and microcontroller technologies have advanced synergistically along with sensor technologies, allowing for wireless mobile heath monitoring [2]. With leading industry standards for transferring data through ad-hoc wireless sensor networks, such as Bluetooth® communication, it has become increasingly easier to implement the wireless transfer and synchronization of large data between patient and observer [1]=[3]. Currently, open areas of research that need to be addressed in wireless sensor network technology are (a) user interface, (b) wireless connectivity reliability, [1], [4], (c) energy consumption [5]–[6], and (d) size [4]. Here, we present a novel approach to these bottlenecks by using PSoC® 4 BLE (Programmable System on Chip, Bluetooth® Low Energy). Using this technology, we were able to wirelessly transmit data from a wearable respiration sensor to a smartphone and display said data on a smartphone application for a user to view. However, given that PSoC® 4 directly addressed our bottlenecks of concern, many specific details still need to be addressed including; (i) making sure all our pieces of hardware (firmware, sensor, and smart phone) in our wireless sensor network are synchronized in communication between each other, and (ii) using programming applications to develop better interfaces between user and hardware for real-time applications.

Objective

Sleep apnea is a serious sleep disorder in which a patient repeatedly stops breathing often for a minute or longer. This is due to improper functioning of their breathing muscles during sleep. Sleep apnea affects more than 18 million Americans of all ages which can cause high blood pressure, memory problems, weight gain, and headaches as well as other health complications. Fortunately, sleep apnea is treatable as long as it is diagnosed, but It is estimated that about 10 million Americans with this disorder are undiagnosed [7].

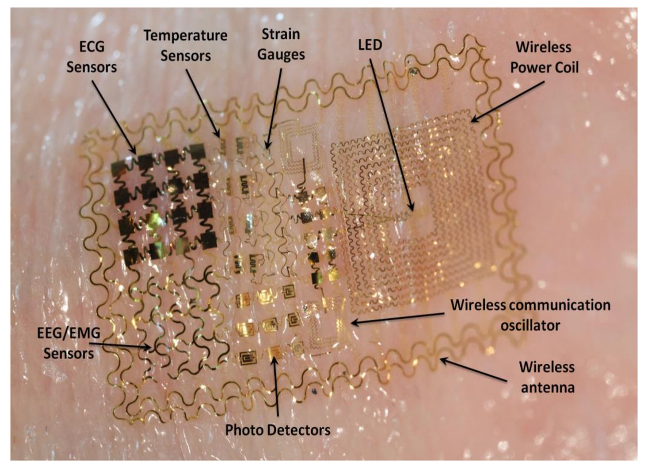
We want to develop a noninvasive system to: (i) wirelessly monitor a patient's apnetic episodes and (ii) develop useful statistical information that can assist physicians in the diagnosis and treatment of sleep apnea.



Flexible Epidermal Electronics

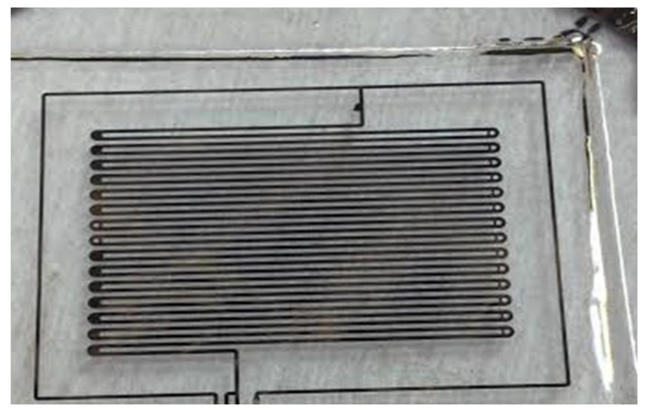
Flexible epidermal electronics allow us to collect important data about the body without disturbing the subject. After stretching and compressing, these electronics still retain their performance just as well as rigid electronics [8].

On the right is an epidermal sensor that can be used to detect electrical activity from the brain, heart, and skeletal muscles.



Flexible Epidermal Sensor on Skin [8]

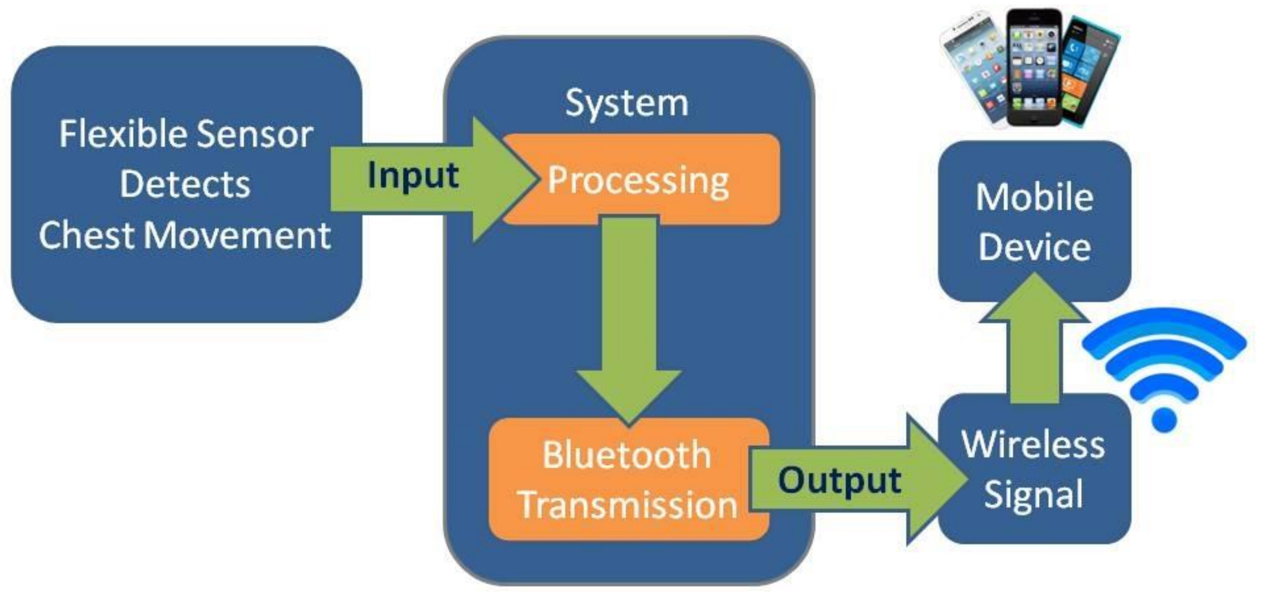
A strain gauge is a flexible electrical component that changes its resistance when stretched. We place the strain gauge on the chest of the patient. So, the strain gauge stretches when the patient inhales and compresses when the patient exhales. Consequently, the resistance of the strain gauge changes depending on whether the patient is inhaling and exhaling.



Flexible Strain Gauge Resistor

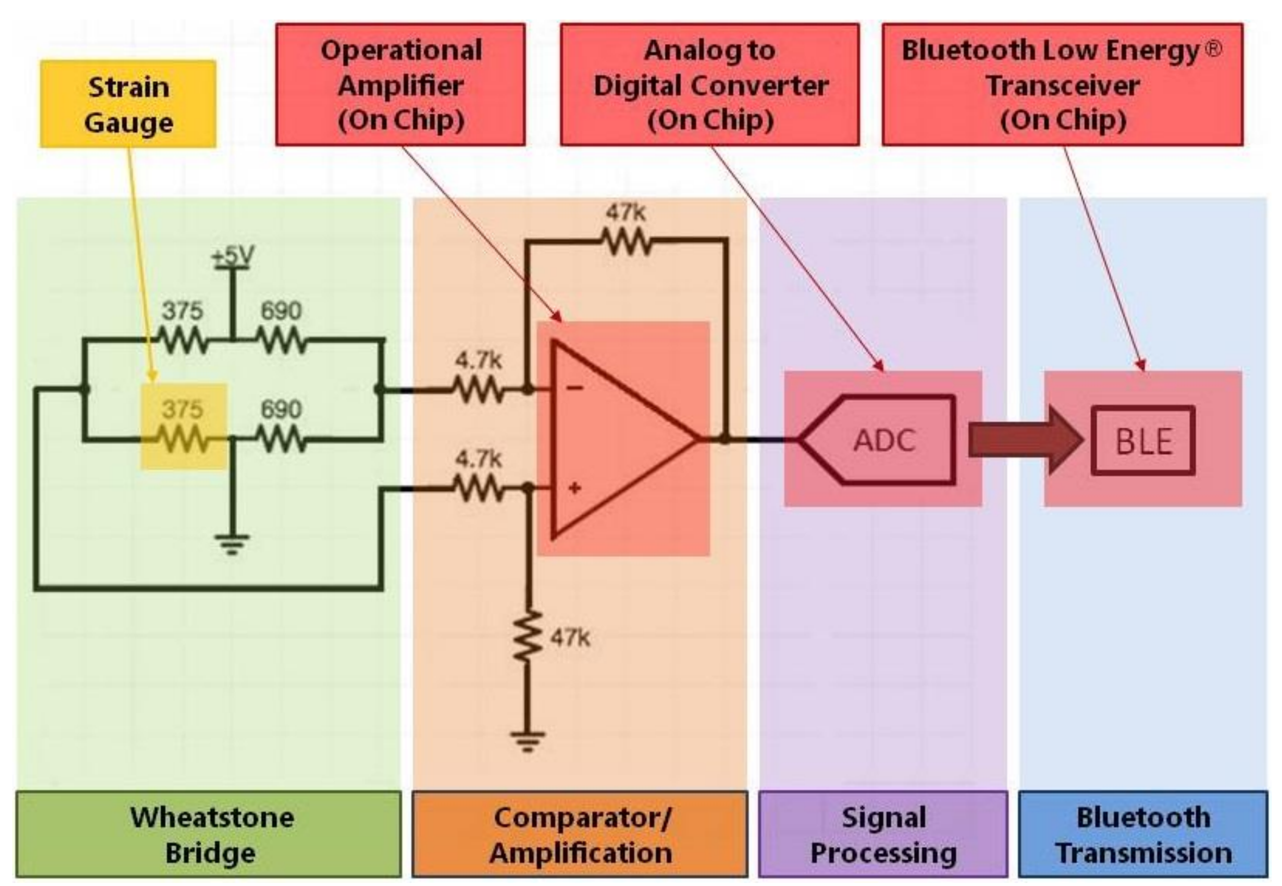
Methodology

Wireless Sensor Network Topology



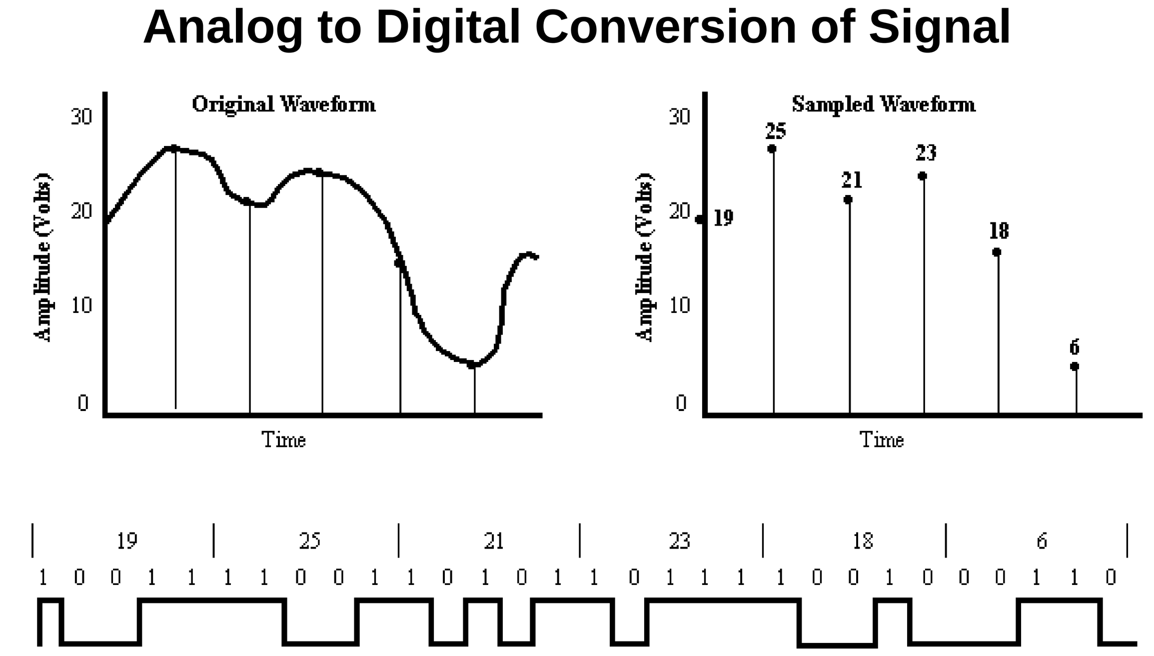
In order to monitor a patient's apnetic attacks, we observe their chest movement during sleep. We thus design a flexible sensor that incorporates the strain gauge in order to detect a patient's chest movement. This detected signal is the input to our system-on-a-chip. The system-on-a-chip then converts the signal to digital data, which is transmitted via Bluetooth® Low Energy to a mobile device or computer for a physician to analyze. Thus, the physician can monitor a patient's apnetic attack trends in real time.

Diagram of System



In the diagram above, the strain gauge is represented as a resistor with variable resistance. When stretched, its resistance increases and creates an imbalance of voltages within the Wheatstone bridge. The comparator outputs an amplified signal of this imbalance. The amplified signal is then digitized by the Analog-to-Digital Converter (ADC) and wirelessly transmitted by the Bluetooth® Low Energy transceiver.

Analog to Digital Conversion of Signal



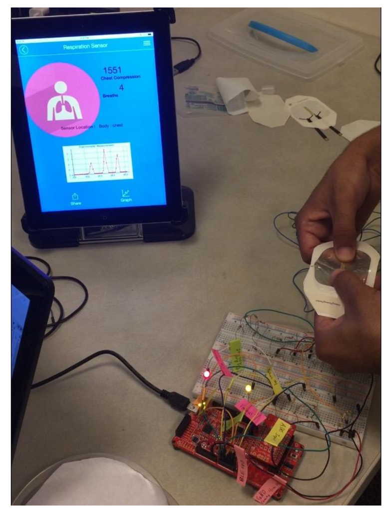
During analog-to-digital conversion, a signal is sampled at a consistent frequency. The values at each of those sampling times is rounded a discrete value. Once the data is converted, it is then possible for us to record and analyze the data using various software tools.

Results and Discussion

- •Respiration sensor network records status of patient's chest compression
- •Took signal from analog respiration and transmitted data to smartphone
- •Phone application updates sensor data in real time
- •Phone application experienced some update latency after 1 minute
- •PSoC® 4 BLE can read sensor output voltages within 0 Volts to 1 volts

We must address the delay of the phone application. It is possible that the delay is caused because smartphones do not have the processing power required of a wireless senor network. An alternative method may be to wirelessly transmit data to a computer and have the computer send the information to an online cloud database. We can then build a smartphone application to reach the data from the cloud, reducing the computational strain on the smartphone.

On the right is our wireless respiration sensor network. The respiration sensor system outputs an analogous signal corresponding to the compression of the patients chest. PSoC® 4 BLE takes in the analog signal, converts it to a digital signal and broadcasts that signal via Bluetooth. The phones Bluetooth capabilities allowed the phone to wirelessly connect to our respiration sensor's broadcasted data. The data is then read and displayed on a smartphone application.



Wireless Sensor Network

Conclusion

The preliminary results show that it is possible to observe biosensor data for health monitoring in a wireless setting. Further advancements in this technology will allow physicians to observe patient health characteristics from a distant location. This collected information will give physicians a better understanding of patients health trends Other implications of this technology advancement will be in medical research. Wireless sensor networks will allow medical researchers to monitor a subject's health during tasks that require free-range motion of the patient.

Future Work

- Fabricate miniature scale System-on-a-Chip
- Build cloud platform to record respiration sensor data to online database
- Build preliminary algorithm to analyze data collection
- Collect data from respiration sensor
- Test and refine algorithm
- Build interface software for both physician and patient

Acknowledgments

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