Crystal Breath

High Level Design

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1 Introduction

During a surgery, the only resource for surgeons and anesthesiologists to confirm that their patient is still breathing is to use a stethoscope. The stethoscope is pressed up against the patient's neck and the doctor listens for the sound of air moving in and out of the throat. The problem with this process is that it is not a *continuous* method of determining whether or not a patient is breathing. Even though heart rate monitor is used in operating room, it does not detect breathing. Thus, a patient could theoretically stop breathing for a period of time while the heart rate monitor still detects pulses. By the time the heart rate monitor signals that the patient's heart has stopped, it may be too late, whereas a continuous breath monitor could sense a problem much sooner. Our goal is to develop a device that continuously monitors a patient's breathing throughout surgery.

2 Problem Statement and Proposed Solution

2.1 The Problem:

Monitoring the status of the patient during surgery is crucial. However, when a patient's breathing becomes shallow, it is harder to notice the rise and fall of the chest, and to hear inhalation and exhalation. To indicate that the patient is still breathing, surgeons often hold a stethoscope to the patient's neck and listen for the air rushing through the larynx.

This common procedure is burdensome. First, this takes valuable time from the doctors; one of them must occasionally locate a good measurement spot and hold the stethoscope in place for a few good seconds. Second, the doctor may interfere with the many cords and instruments surrounding the patient when he/she tries to get near the patient to measure the breathing rate.

Our "better" solution to this problem is to develop a device that can continuously measure the air level rushing through the patient's neck, process the sound and visually display the breathing level on a monitor. This way the information is readily available to all staff in the operating room.

2.2 Proposed Solution:

We want to create a breath monitor that will measure the strength of the patient's breath by placing it on the patient's neck. The device will ideally record nothing but the patient's breathing sound, which is then processed and display visually via a monitor.

With the amount of medical equipment already present in the operating room, the ideal breath monitor will be wireless. However, first and foremost, we want to focus on making the device workable. If we achieve that goal, we will then modify the device to become wireless. Also, the device can hopefully be placed on the patient's chest if he/she is having a neck surgery. The breath monitor will give the surgeon more time and space to perform surgery.

3 System Requirements

In order for our device to be an effective alternative to measuring breath with a stethoscope, a number of requirements must be fulfilled from both an engineering perspective and a medical perspective. The most important requirement that must be achieved is safety and reliability. The goal for this device is that it is used in operating rooms, so it must provide surgeons with reliable, consistent, and continuous performance throughout the duration of an operation. The device must be easily sterilized in preparation for surgery. It is also important that the device gives a warning (either in the form of lights flashing or an audio signal) when the device malfunctions so the doctor knows to revert back to using the stethoscope to measure breath.

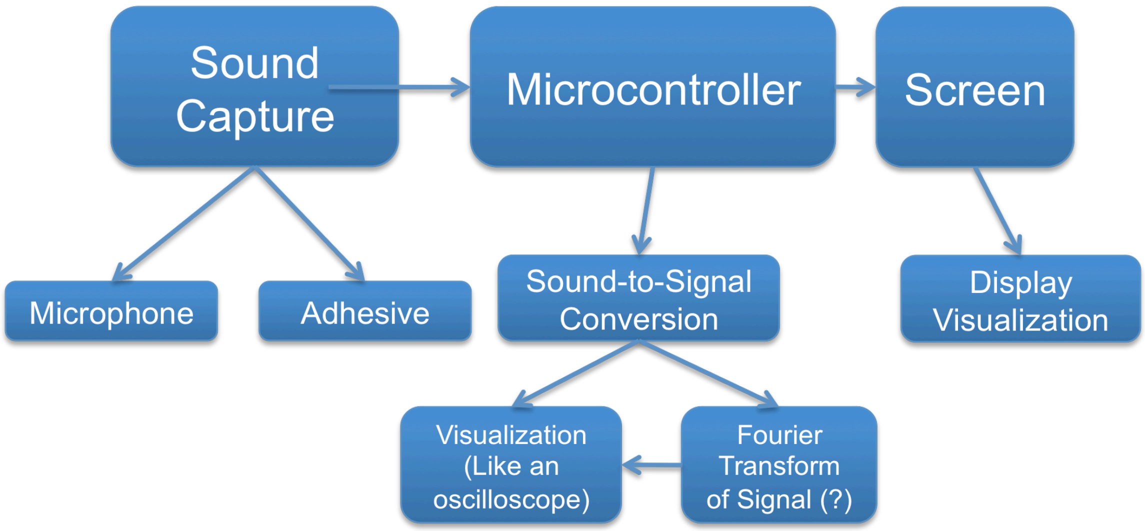
From an engineering perspective, the most important requirement that must be fulfilled is sounding an alarm when the device recognizes when the patient's breath has become dangerously shallow or the patient has stopped breathing entirely. This entails determining a threshold of safe breathing and programming the microcontroller to recognize when the patient's breathing has dropped below the threshold. The microphone part of the device should readily attach to and detach from the patient's neck in, similar to the way a bandage is applied to the skin. The microphone should also provide a sound proof seal around the application area such that the microphone is only picking up the sound of air moving in and out of the throat and not any of the surrounding sounds in the operating room.

The sound that is picked up by the microphone must be processed and displayed using LEDs. As of now, the idea is to use our microcontroller as a sort of oscilloscope to output the sound picked up by the microphone to a series of LEDs which will light on the basis of frequency and intensity of the sound. This means that the microcontroller must be able to process the analog signal input from the microphone, compute a Fourier transform to identify the frequency of the sound peaks, and be able to turn on the correct number of LEDs.

Because the device must work continuously and consistently throughout a surgery, we will most likely have to power it through a wall outlet or use batteries and connect the microphone directly to the microcontroller, rather than transmitting the signal wirelessly. Using a direct connection from microphone to microcontroller will ensure that the signal does not pick up any noise or interference during transmission.

4 System Block Diagram

4.1 Overall System:



4.2 Subsystem and Interface Requirements:

The sound capture subsystem is comprised of a microphone and adhesive. The adhesive must be comfortable for the patient, does not shift laterally; and it should be small enough so that surgeons can have plenty of room to perform the surgery. Ideally, the microphone will not pick up any noise or ambient sound. To insure no extra sound is picked up, we require a unidirectional microphone, which will come into contact with the patient's neck. In addition, we will insulate the back of the microphone with sound absorbent material such as studio foam or soft silicone pad.

The microcontroller system is the most flexible of the subsystems. It must convert sound to an electrical signal, then, like an oscilloscope, represent the signal visually. One possible method is to take a Fourier Transform of the resultant electrical signal.

The final, and simplest subsystem, is the screen. We simply need a screen to visually display the sound coming from the microcontroller, possibly via a VGA cable.

4.3 Future Enhancement Requirements

Our group wants to create a working device, thus we simplify the interface. Ideally, the breath monitor would be wireless, but first we are going to build a wired prototype. If we succeed, we will attempt to make the breath monitor wireless. Doing so would require a wireless transmitter from the microphone and a wireless receiver on the microcontroller.

5 High Level Design Decisions

The entire system will be powered using a 9V battery and should be able to continuously run for 10 hours to accommodate long surgery procedures. To capture the breath, a unidirectional microphone will be secured to the neck of the patient. The strength of the microphone connection to the neck is very important. Primarily, the microphone needs to remain fastened throughout surgery. Also, a high quality connection will insulate the microphone from ambient noise. Thus, we will try using double-sided medical tape since it is widely used in the medical field.

The microphone will send the signal to the circuit board. The circuit board will contain the power supply connection, a bandpass filter to isolate the breath signal, and a microcontroller with analog-to-digital conversion potential. The microcontroller will be similar to the PIC32 microcontroller used in the design assignments throughout the semester. The microphone will pick up some noise that interferes with the breath signal. A filter consisting of resistive and capacitive components will cut off the frequencies outside of the breath frequencies, leaving behind a signal that contains the breath.

The microcontroller will take this filtered signal as an input and perform an analog-to-digital conversion. This will allow the sound signal to be processed and eventually be displayed graphically. Fourier transform can be performed to analyze the signal with regards to its frequency components, so the exact frequency and amplitude of the breath can be identified.

The system will communicate to the user the strength of the breath in two ways. The first way will be applying the filtered analog signal to a group of red LEDs, which will light when a large enough signal is present. The brightness of the LEDs will correspond to the relative strength of the breath signal. A visual display will communicate more precisely to the user the strength of the breath signal by displaying the digital signal on a graphic display. The graphic display will receive its input from the microcontroller. Surgeons can make their own judgment whether or not the breathing level is dangerously low. The microcontroller will be programmed to signal a visual and audio warning if the patient's breathing level is dangerously low, or the batteries are running low on energy.

6 Open Questions

One of the pressing questions we have going into the low-level design is whether or not we can connect a unidirectional microphone to the circuit and if the microphone works with a digital signal processing microcontroller. If not, then we have to consider other possibility and we then have to consider how to eliminate sounds that are picked up from other sources. If we have time to modify the device to work wirelessly, then a MEMS microphone is a possible option.

We are also unsure how we would analyze the signal. We would like to display the signal on a monitor. However, we question if this requires the analog signal to be sampled and replicated in digital form in order to be displayed on a monitor, or if we should filter the signal and perform Fourier transform so that it may be displayed on an oscilloscope or monitor. In your feedback, it seemed that you wanted our group to pursue the former option, but is the latter option also a possibility for this project? Would our option still require an analog to digital conversion regardless of whether or not we filter and perform a transform on the signal?

If we do pursue some of the ideas you recommended in your feedback, then we will have some extensive research, review, and testing to do in the way of signal analysis. With either option, we would all have to become even more thoroughly acquainted with the microcontroller, which each of us individually has a rudimentary understanding of at best. There are too many questions regarding the microcontroller to list in this section, but we will have to assess our knowledge and answer them soon.

7 Major Component Costs

Major Component	**Cost**
Unidirectional Microphone	$30
Studio Foam (insulator)	$5
Medical Double Sided Tape	$5
Microcontroller	$30
Velleman Sound-to-Light Kit (for testing)	$30
Cables	$20
Battery	$6
Total	$126

8 Conclusions

The development of an effective, and perhaps wireless, breath monitor will give surgeons more time focusing on saving lives in the operating room. Their time should not be wasted by activity such as checking the patient's breath. To accomplish this goal, our group will need to do extensive research in both the electrical engineering field as well as the medical field. From an engineering standpoint, we must develop a deep understanding of certain aspects such as what is the best breathing to background noise frequency, how to program an analog-to-digital converter, how to output a sound input visually, etc. From the medical perspective, we must make sure that the breath monitor is sterile and easily cleaned, does not interfere with other devices in the operating room, and works consistently throughout an operation. The breath monitor must also be easy to use, because the objective is to give doctors one less thing to worry about during a surgery. This means that microphone should attach to and detach from a patient's neck effortlessly. Thus, a simple, yet effective, user interface must be developed.