HEART AND BREATH SOUND AMPLIFICATION FOR DIAGNOSTIC PURPOSES

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ABSTRACT

The standard acoustic stethoscope has become the hallmark of the medical profession. In recent years, electronic stethoscopes have entered the market for prices roughly two times as much as standard stethoscopes. Our client, Dr. Scott Springman, an anesthesiologist at the UW-Hospital, requested that we design an electronic stethoscope that increases the functionality of the standard stethoscope three fold while maintaining the fidelity of a standard, acoustic stethoscope. The three areas of increased functionality are: converting the acoustic sound waves from the stethoscope into a filterable, amplifiable electronic signal, increasing the length of the stethoscope so the heart beat can be heard from farther away, and allowing for both headphone and speaker listening capabilities.

BACKGROUND

- Medical stethoscope was first invented in 1816 by French Physician René Théophile Hyacinthe Laennec in order to hear the sounds of the heart and other organs in the chest (Bause 2010).
- Relies on a diaphragm that when pressed up against the chest of a patient, vibrates in response to the natural vibrations of the body (Rappaport and Sprague 1941).
- Sounds created by the diaphragm's vibration travel into the bell of the stethoscope and pass through a rubber tube that acts as a low pass filter
- Final step is the passage of the sound through binaural ear pieces for the listener to hear (Rappaport and Sprague 1941) (Figure 1).

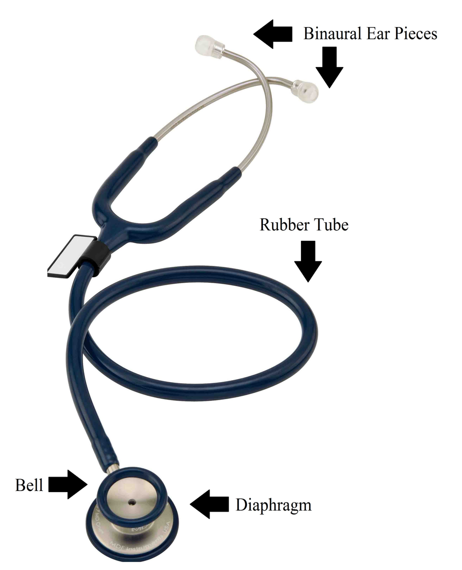

Figure 1: Diagram of a standard acoustic stethoscope including labels for different stethoscope elements. (Alibaba.com 2011)

Figure 2: 3M Littman 3100 Electronic Stethoscope (Medisave 2011).

- Standard acoustic stethoscope is still the most widely used
- Littman 3100 is one of the most popular electronic stethoscopes on the market (3M Corporation 2011) (Figure 2).

MOTIVATION

- Current devices on the market are very expensive
- No device on the market that has speaker playback capabilities
- Current devices on the market limit freedom of movement due to short reach between ear buds and diaphragm

References
[1] Altrabsheh, B. Measurement and classification of heart and lung sounds by using Labview for educational use. *Journal of Medical Engineering and Technology* 35: 340-349.
[2] Rappaport, M.B., Sprague, H.B. 1941. Physiological and Physical Laws That Govern Auscultation and Their Clinical Application: The Acoustic Stethoscope and the Electrical Amplifying Stethoscope and Stethograph. *The American Heart Journal* 21(3) 257-318.
[3] Medisave. 2011. "Tytan Stethoscope." http://www.medisave.co.uk (accessed March 2, 2011).
[4] 3M. 2011. "3M Littmann Electronic Stethscope Model 3200." http://www.shop3m.com/3m-littmann-electronic-stethoscope-model-3200.html?WT.mc_ev=clickthrough&WT.mc_id=shop3m-AtoZ-Littmann-Stethoscopes (accessed March 2, 2011).
[5]Jin, F., Satter, F., Goh, D.Y.T. 2009. A filter bank-based source extraction algorithm for heart sound removal in respiratory sounds. *Computers in Biology and Medicine* 39: 768-777.
[6]Electronics-Tutorials. 2011. "Butterworth Low Pass Filter." http://www.electronics-tutorials.ws/filter/filter_8.html (accessed March 2, 2011.)

DESIGN CRITERIA

CLIENT SPECIFICATIONS

- Electronic signal must be filterable, and amplifiable, to maintain high fidelity for diagnostic purposes
- Device must be portable, allowing client to move freely from room to room without the restriction of a wall outlet
- Increase freedom of movement by providing ample length between headphones and diaphragm
- Incorporate the use of speakers for teaching purposes
- Microphone must not come into direct contact with the patient due to potential disruptions with medical implants

PRELIMARY RESEARCH

INITIAL PROTOTYPE

- Primary design utilized an active condenser microphone, which was fastened to the stethoscope tubing and diaphragm
- Used for initial heart and breath sou recording and signal analysis in MATLAB

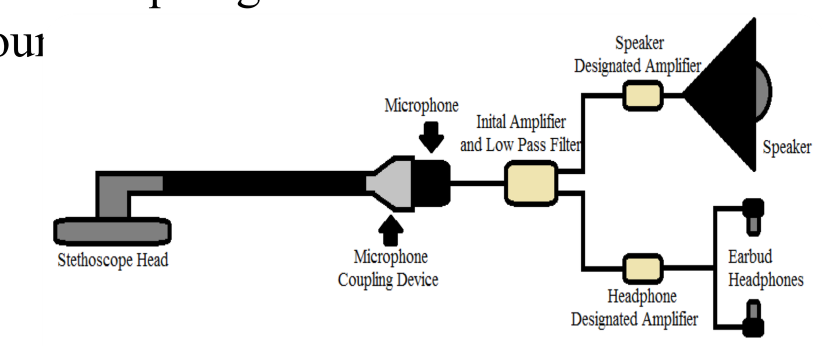

Figure 4: Device block diagram

SIGNAL AND ANALYSIS

- Heart and breath samples were taken using the primary prototype in order to determine amplification and filter details
- A Discrete Fast-Fourier-Transform (FFT) was used to obtain a plot of the frequency spectrum vs. amplitude
- Initial research indicated that the sound of the heart beat resided around 300Hz and below (Figure 3)
- Coroner frequency was determined to be 800Hz and below [1]
- An active, low-pass, third order, Butterworth filter with a cutoff frequency of 800Hz was designed to eliminate as much background noise as possible

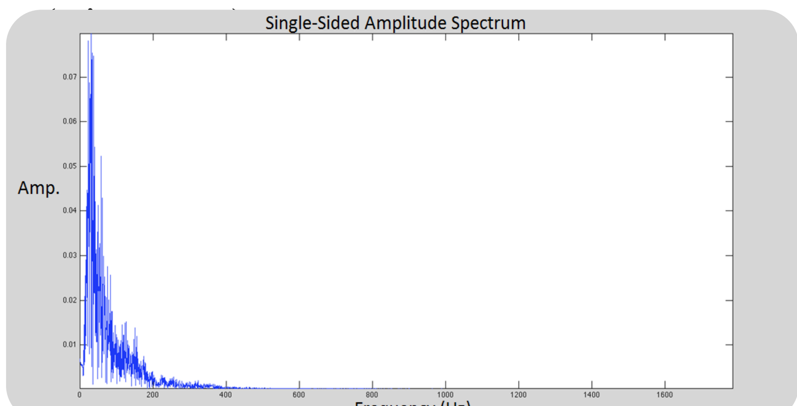

Figure 3: Fast-fourier-transform plot (MATLAB)

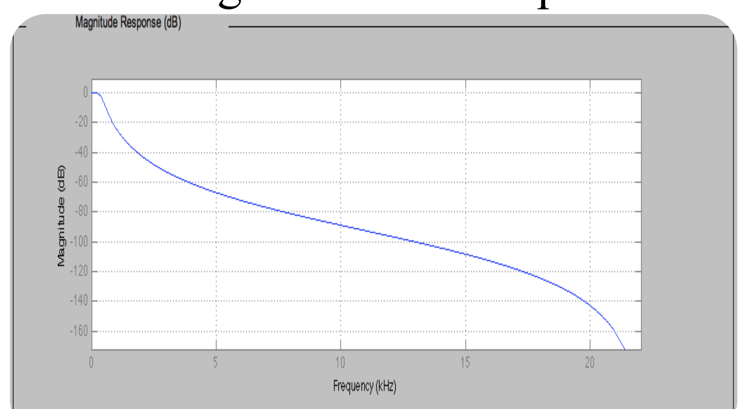

Figure 4: Low pass filter

The final design consists of a physical and electrical component. Moving in a linear fashion from the stethoscope head to the output of the signal (Figure 4):

- Standard stethoscope head from which 0.25m of tubing extends, also acting as a low-pass filter
- Female microphone coupling engulfs the male microphone coupling that houses the microphone, which is all held together by means of an interior rubber gasket. Parts were created using SolidWorks and a 3D-Printer
- Circuit box houses two speakers, bread boarded circuit, and in the future a power source (Figure 5)

FINAL DESIGN

Electrical Design

Electrical segment can be broken down into four main parts

- Microphone Pick up
- Power Management
    - 12 Volts – All Op Amps
    - 6 Volts – Virtual Ground
    - 3 Volts – Microphone power
- Filtering and Amplifying (Figure 6)
    - Signal is transported through a series of four amplifiers
    - Second and third amplifiers filter of the circuit with a 2nd order sallen-key filter and a corner frequency of 800Hz adding up to a single 4th order filter giving us steeper cutoff with a longer passband
- The last amplifier in this circuit gains our circuit by 10 through a non-inverting sequence
- A switch is used at the output to vary between the usage of the speakers and headphones
- Headphone Output
    - The headphones run off of a LM386N amplifier
    - A 10k rotary potentiometer is used at the beginning of the circuit to allow for volume control based on the users preference
- Speaker Output
    - The two 4ohm speakers use a TDA2003 power amp that boost the current so that the signal can be audibly heard through the speakers
    - A 10k rotary potentiometer is used at the beginning of the circuit to allow for volume control

Figure 5: Top view of circuit box

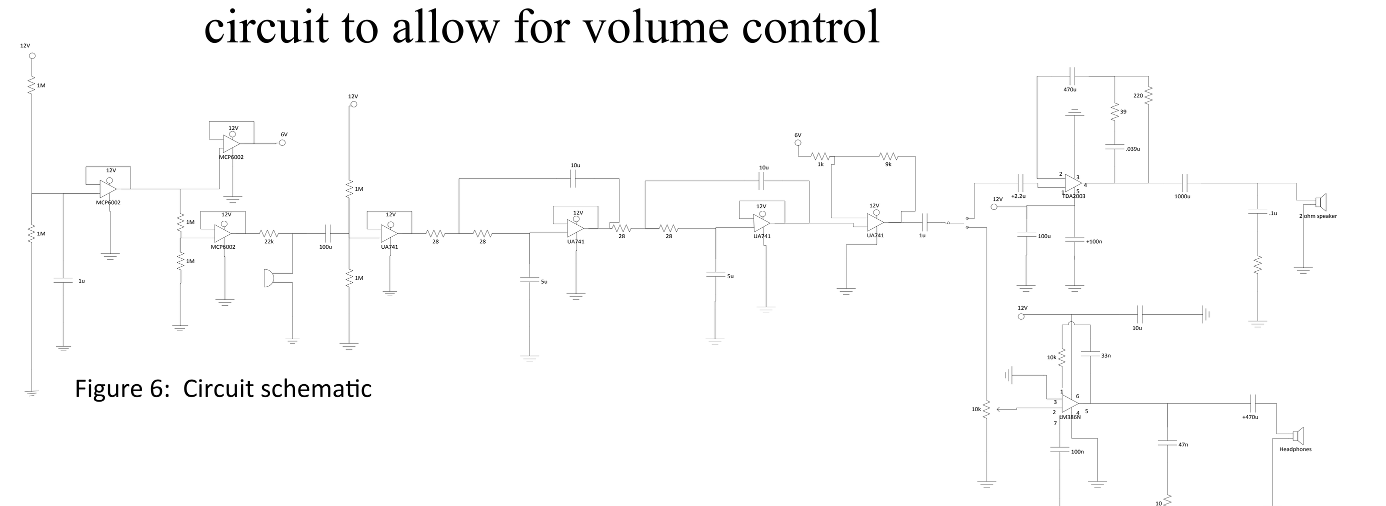

Figure 6: Circuit schematic

FUTURE WORK

- Determine optimal amplification to improve signal to noise ratio
- Make the device fully functional under the power of batteries with a long life expectancy
- Implement a printed circuit board to replace the current bread boarded prototype
- Amplify and filter the signal digitally with use of a microcontroller
- Make the device wireless with respect to the headphones via bluetooth
- Increase portability by downsizing circuit housing
- Test on patients with heartbeat irregularities

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