Handheld Heart Sound Monitoring Device

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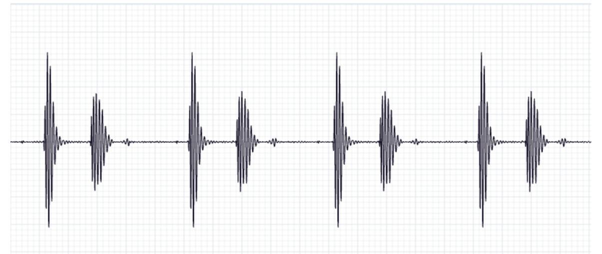
Problem Definition and Background

Heart disease is the leading cause of death for men and women in the United States according to the CDC. Physicians rely on stethoscopes to listen for heart murmurs and abnormalities. Hearing is extremely subjective even for well-trained physicians who can reach an accuracy of 70-98% detection rate.

To combat this, we designed and built a handheld device using a stethoscope/microphone head to measure heart sound (phonocardiogram) signals and display them on a screen in order to aid in the detection of heart murmurs.



Design

This project aimed to design a portable, user-friendly device that used a modified stethoscope head with precise microphone positioning, a signal conditioning circuit to enhance signal quality, microprocessor integration for real-time analog to digital conversion, and an LCD screen to display the heart sounds. The first goal was to find a microphone sensitive enough to pick up the sound of heart murmurs, which usually occur from 40 Hz to 530 Hz. Two different microphones were acquired and then tested using a function generator and an oscilloscope.

	Pro	Con
Electret Microphone	• Inexpensive • Fit the dimensions for stethoscope tubing	• Required amplification • Required a RC circuit to power • Less sensitive • Frequency range not provided in the datasheet
MAX9814	• Picks up frequency from 20Hz-20Khz • Built in and adjustable amplifier • Arduino compatible	• Slightly more expensive • More fragile

After testing, the MAX 9814 was chosen due to its superior capabilities.

The project also required a bandpass filter. Two design alternatives were considered: a passive RC bandpass filter or an active op-amp bandpass filter.

	Pro	Con
Resistor Capacitor Filter	• Inexpensive • Prior experience with RC filters	• No gain • Less drop off at cutoff frequencies
Op-Amp Filter	• Provides gain and sharper drop off at cutoff frequencies • Inexpensive	• Hard to manipulate the null balance

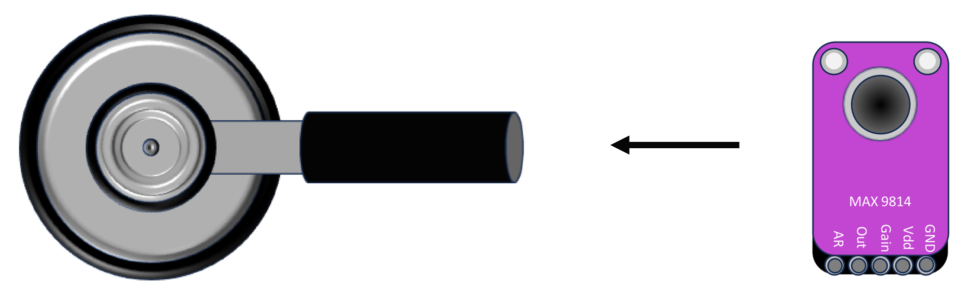
The Op-Amp design was chosen due to its sharper cutoffs, which aid in reducing noise. There is a gain, but the signals are also amplified using a built-in amplifier inside the MAX 9814 microphone.

Methods

The fabrication of the device is as follows:

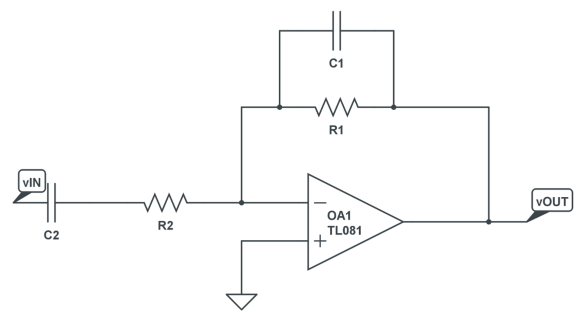
Stethoscope and Microphone

The tubing of a Littman stethoscope was cut close to the head. A MAX 9814 microphone was then inserted into the end of the tubing.



Op-Amp Bandpass Filter

$$Voltage\ Gain = -\frac{R_2}{R_1}, \quad fc_1 = \frac{1}{2\pi R_1 C_1}, \quad fc_2 = \frac{1}{2\pi R_2 C_2}$$



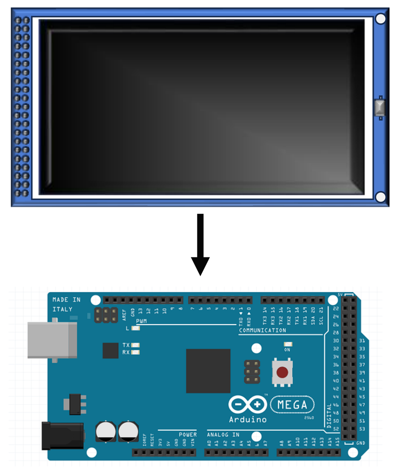
- R1 = 3000 Ω
- R2 = 40,000 Ω
- C1 = 0.1 μF
- C2 = 0.1 μF
- Fc1 = 530 Hz
- Fc2 = 40 Hz

Arduino Code

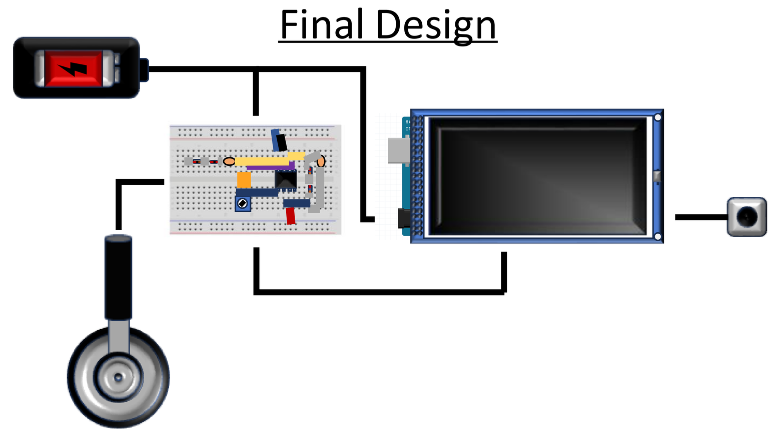
The microprocessor chosen for this project was the Arduino Mega 2560 Rev 3. A 3.5-inch LCD screen was then placed onto the Arduino.

The code developed for the Arduino is as follows:

- Analog to digital conversion
- Signal filtering
- A function that outputs the measured signals to the display
- A debounce loop for the external pushbutton that freezes the screen when pushed



Final Design



The final design consists of a stethoscope head and a microphone which get filtered through an Op-Amp bandpass filter. The result is sent into the Arduino which processes it and displays it on the LCD screen. The system is powered by battery to make it handheld, and the pushbutton freezes the screen.

Testing

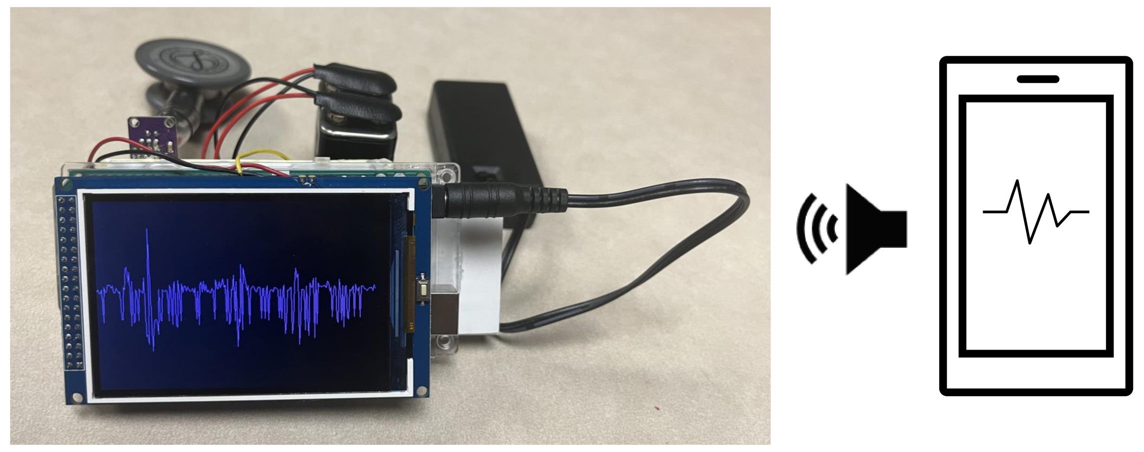


Figure 1. Image of fully constructed device

The device was tested by playing recordings of heart sounds both with and without pathological conditions. The measured signals would appear on the device screen and the pushbutton was used to freeze the screen for analysis.

The recordings were collected by the University of Michigan Medical School.

Results

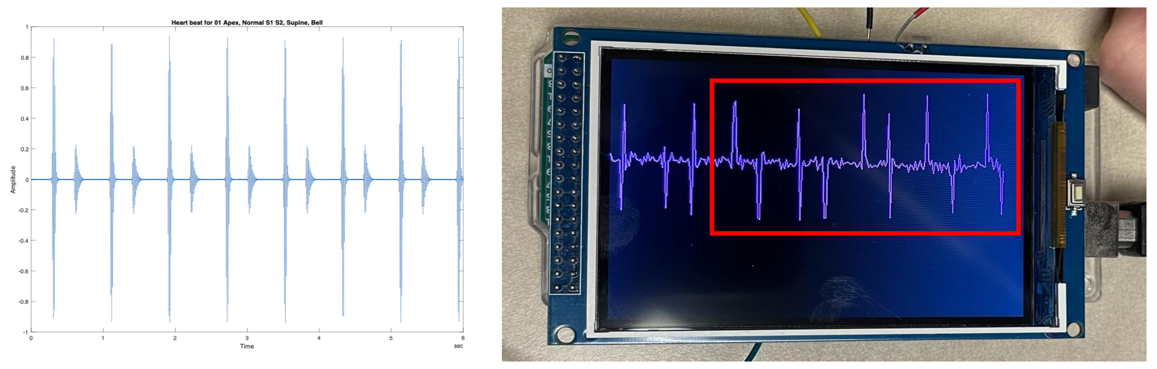


Figure 2. Plot of normal heart sound on MATLAB (left) and the results displayed on the LCD (right) when the sound was played

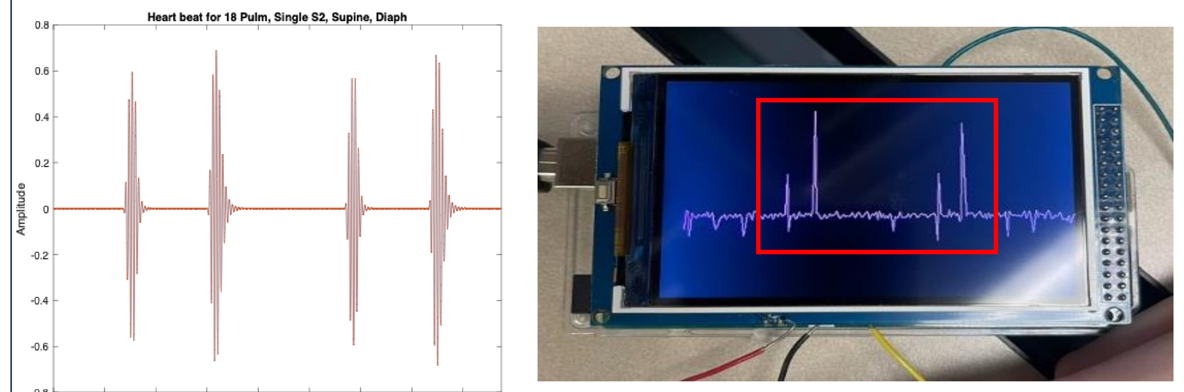


Figure 3. Plot of heart sound containing a pulmonary murmur on MATLAB (left) and the results displayed on the LCD (right) when the sound was played

To validate the functionality of our device, we tested approximately 10 to 15 different established heart murmur recordings from the University of Michigan. The top two plots represent measurements taken from normal heart sounds, while the bottom two depict measurements obtained from known heart murmur recordings, specifically referencing recording #18 from Michigan Heart Sounds. Using a simple MATLAB code, we plotted heart waveforms to compare against those measured by our device.

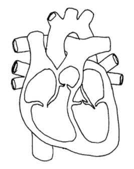
As shown in the above figures, our device captures waveforms remarkably similar to those generated by MATLAB, despite the device's lower resolution.

Conclusion

The goal of our project was to create a device that could aid in the ability to detect heart sounds, specifically abnormal ones like murmurs. Typical heart sound detection can be costly and inaccessible. Through iterative design and eventual implementation, we successfully created a portable cost-effective solution that offers real time visualization of heart waveforms.

Although our project successfully achieved our goal there are still limiting factors. The resolution of the LCD is one of these factors. The LCD is unable to display all the fine details of sound waveforms due to the limited number of pixels. Another factor that is limiting the ability of the display is prevalence of outside noise. With continued refinement and iterations in the future the device could provide an even more meaningful impact.

In conclusion, while acknowledging the inherent limitations of the LCD and filters used, our handheld heart sound visualization device remains a promising tool to improve cardiovascular diagnostics.



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Engineering Standards

- Electromagnetic Compatibility (EMC) standard IEC60601
- Human Factors Engineering ISO 62366
- Biocompatibility ISO 10993

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