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Development of Wireless Sensing Unit for Environmental Noise Monitoring

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Noise Monitoring Using a Wireless Sensor Network

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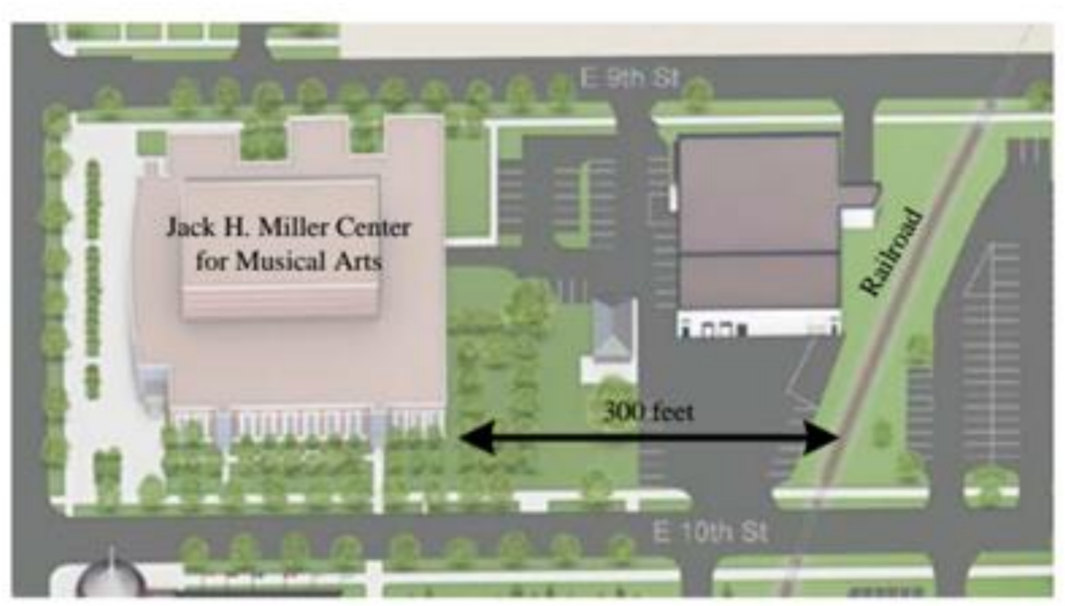
Abstract

Locations with large amounts of environmental noise can raise stress and blood pressure, as well as decrease productivity, for all peoples subjected to it. To better quantify these noise levels, it is important to fully understand the patterns and levels of noise through data collection and analysis. Wireless sensor networks offer one method for autonomously gathering and processing levels of noise pollution in densely populated areas. In this study, a wireless sensing unit (WSU) was developed that was capable of collecting and transmitting noise data. This WSU was comprised of a Teensy microcontroller development system, a sound detecting board, and an XBee wireless transceiver. To capture the auditory range that a human can hear, each WSU had to sample at 20kHz, resulting in a large accumulation of data that must be stored locally and eventually transmitted. Due to the constraints of the system, it was found that nodes would spend approximately eight times longer transmitting data than collecting data, making this not scalable for long time periods or large sensor networks. In order to limit this amount of transmitted data, on-board signal processing techniques of the noise signal were explored.

Application of the Project

Seeing as noise pollution can negatively impact a person's health (high levels of stress, high blood pressure…) our project sought to create a wireless sensor network (WSN) to analyze levels of noise in loud areas. This way, architects would be able to design buildings that cancel out the noise of the surrounding areas, negating the harmful effects of that noise on the persons inside. Once our WSN is fully operational, we will verify the design of the Jack H. Miller Center, which is the Musical Arts building at Hope College. It was designed to negate the sound emitting from the railroad track a mere three-hundred feet away.



Future Work

Integrate the A-weight filter with each WSU

Maximize time efficiency via the correct combination of onboard and post processing calculations

Conduct testing in the Jack Miller Center

Investigate minimizing power consumption of the wireless sensor network

Acknowledgements

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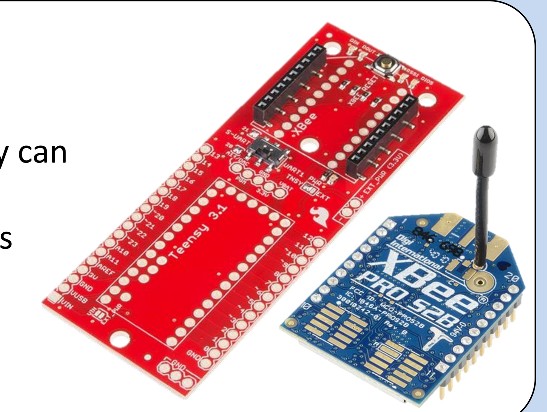
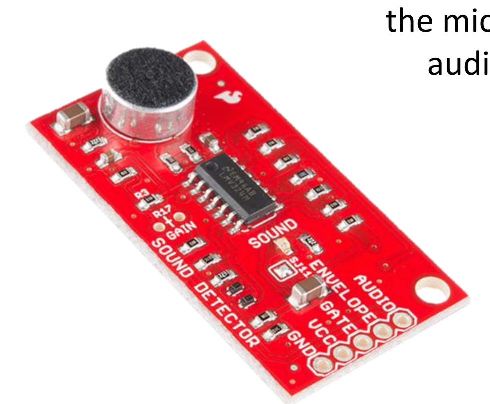
Components of Wireless Sensor Network

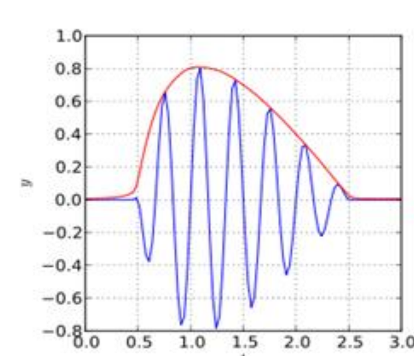
The microcontroller that was chosen to control each WSU was the Teensy 3.2. It can easily sample data at 20 kHz, which is the frequency necessary to properly analyze the range of frequencies the human ear can hear. It also contained 64kB of memory, which allowed for 3.0 seconds of continuous data collection.

The S2 Pro XBee was selected to be the wireless sensor. Not only can they be specifically programmed to either send or receive information, they can also easily send packetized data. XBees gathered data from each Teensy via a Teensy XBee Adapter

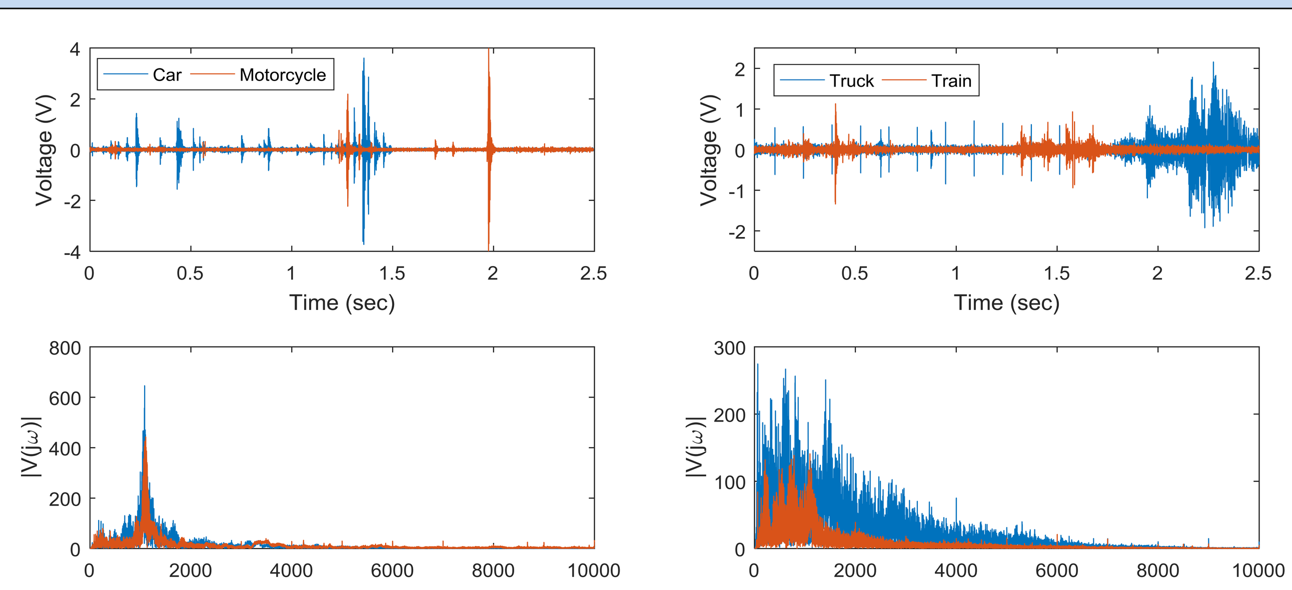




Each WSU also contained a SparkFun Sound Detector, which was where the microphone was contained. It is capable of outputting both the raw audio signal as well as an enveloped audio signal. Both signals are depicted in the image below.



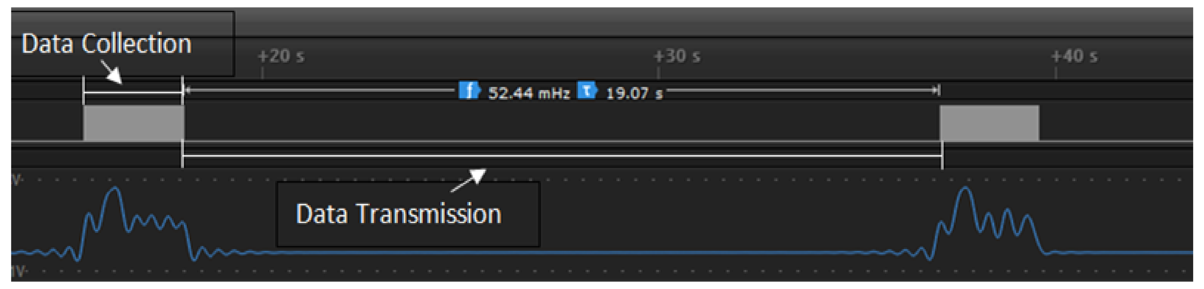
Gathered and Transmitted Signals



The WSU gathered 2.5 to 3.0 seconds worth of data on four different types of moving vehicles. After the data was collected, it was sent to a wireless transmitter connected to a computer. From there, the signals were process in MATLAB.

Problems with First System

Transmitting large quantities of data is not a feasible way for this system to operate. Sending 50,000 – 60,000 data points takes about eight times longer than it does to gather the data.



To combat this issue, each WSU is in the process of implementing onboard data analyzation, so that only processed data will be transmitted. The equation used to calculate decibels from our audio signal is

$$Leq = 10log_{10}(\frac{1}{T}\int_0^T \frac{P(t)^2}{P_o^2}dt)$$

Performing all these calculations on the Teensy took 23.9 seconds. Although the system is not collecting data for a similar amount of time, it is still an improvement from the initial method. The XBee that receives information is significantly less occupied, and thus more Xbees are able to be implemented in the system.

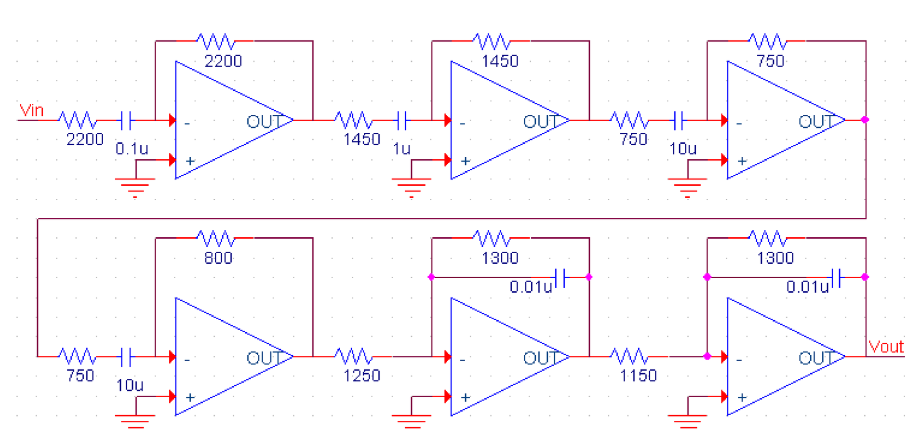
Current Work

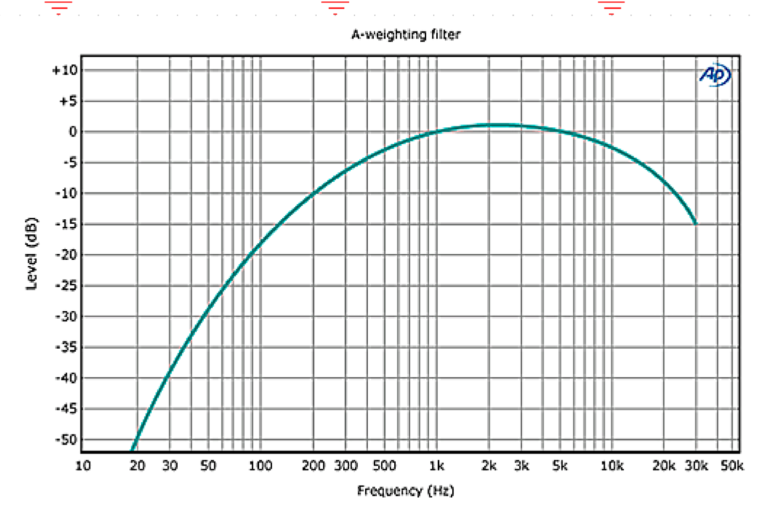
A-Weight Filter

Seeing as the application of the project is to try and minimize noise humans hear in buildings, the next step was to make each WSU "hear" like humans hear. Humans do not hear all frequencies of noise equally. The standard filter applied to an audio signal to emulate a human ear is called an A-weight filter. The transfer function for said filter is:

$$H_A(s) = \frac{5.867 * 10^9 * s^4}{(s+129.4)^2(s+76655)^2(s+676.7)(s+4636)}$$

The transfer function indicates that the circuit can be created using four high-pass filters and two low-pass filters. A circuit was designed which possessed the relationship between gain and frequency that an A-weight filter should have.





Commercial devices used to quantify noise pollution are called Sound Pressure Level (SPL) meters. These devices come preloaded with A-weight filters. Our system will now be able to compare its measurements of noise pollution with an SPL meter to verify that audio signal are being properly processed.