“Extended Reach” Echolocation Sensor

Senior Design Project Proposal

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1. Introduction

1.1 Project Statement

We have chosen to develop a way for a person to sense their surroundings using sonar by analyzing the reflected signals of ultrasonic chirps we send out and then outputting its characteristics. This project is a modular design, which works with our sister project the “Extended Reach” Haptic Array. We chose this project because it has the possibility to lead to some groundbreaking studies, and can be a prototype for an invisible cane for blind people. Not only will it aid people in way a variety of applications, it provides unique signal processing challenges as well as circuit design experience.

1.2 Objectives

The “Extended Reach” Echolocation Sensor will be able to send out a chirp at ultrasonic frequencies and receive ultrasonic signals reflected off objects in the vicinity of the device. The device will then be able to filter the signal and pull out characteristics of the signal that will be able to indicate distance, shape and other properties of objects that reflected the signals. These characteristics will then be exported so that they can be used by the “Extended Reach” Haptic Array project.

Benefits to the Customer

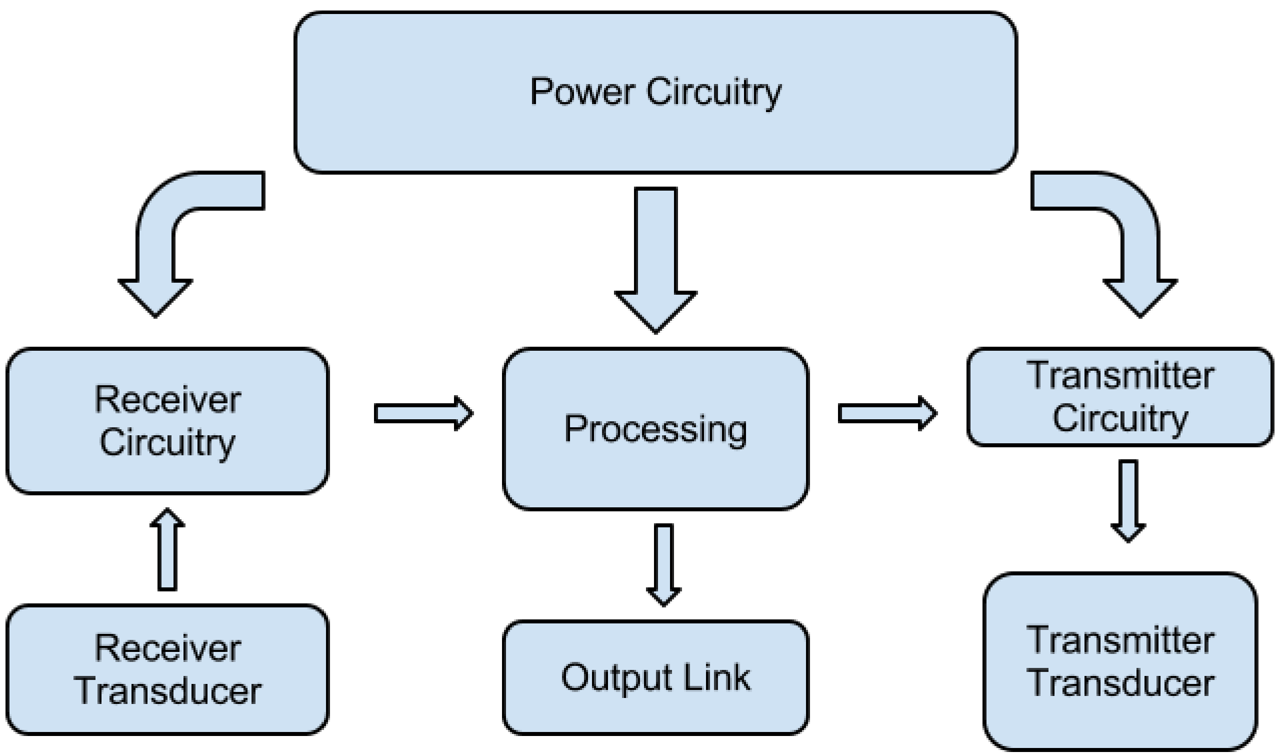
- It may be used to sense the surrounding environment without the need of light or without the use of sight.
- It will be a virtually weightless alternative to a cane
- Can be used in applications where people need to reach something that is out of eyesight
- Reasonably priced
- User friendly, and fun to learn

Product Features

- Ability to sense distance to an object within a minimum distance
- Ability to process multiple characteristics of reflected audio signal
- Ultrasonic frequency transmission from 22kHz – 40kHz
- Fast processing speed allowing continuous updates of sensing feedback
- Safe and reliable design

2. Design

2.1 Block Diagram



2.2 Block Descriptions

Processing:

The processing block is the heart and soul of the echolocation sensor. For the sensor processing, we will be using an ST Discovery DSP board. The Discovery board will do three main things: send out the chirp waveform, process the incoming reflected signal, and output the signal characteristics to the output serial link. The chirp waveform will linear with a frequency bandwidth from around 22kHz to around 40kHz. The incoming reflected signal will be analyzed using cross-correlation. The reflected signal will be cross-correlated with the outputted chirp waveform. Times (and therefore places) where the cross-correlation leads to larger values can be interpreted as important. We will utilize one of the programmable push-buttons on the Discovery board to yield two different output characteristic patterns. The first pattern will be in the time-domain, and the second pattern will be an FFT of the time-domain output pattern.

Transmitter Circuitry:

The transmitter circuitry will mainly handle amplification of the emitted chirp signal from the Discovery board. We want the signal to be amplified enough that the outgoing chirp will have a sound intensity of around 100-120dB (SPL). The reason for this is that this is the range that bats use in their echolocation and also the range that most ultrasonic rangefinders use.

Transmitter Transducer:

The transmitter transducer will send out the ultrasonic chirp. Since the chirp will have a bandwidth of about 22kHz to 40kHz, it would be nice if the transducer had a flat frequency response up to about 60kHz. We are trying not to use specially-built ultrasonic transducers because they can cost between $100 and $500. Cheaper ultrasonic transducers have too narrow of a bandwidth for our application. Instead we will be using audio transducers that have shown to have a flat response higher than their rated 20kHz. One transducer that we are currently looking at using is the Panasonic WM61A.

Receiver Transducer:

The receiver transducer will receive the reflected ultrasonic signal. The specifications of the receiver transducer will be the same as the transmitter transducer.

Receiver Circuitry:

Once the emitted chirp is reflected and received by the receiver transducer, it needs to be modified for proper use with the Discovery board. Specifically, it needs to be lowpass filtered in order to prevent aliasing, it needs to be highpass filtered in order to remove frequencies in the audio range, and it needs to be biased and scaled in order to fit the specifications of the ADC on the Discovery board.

Output Link:

Packets of information regarding the characteristics of the room will be sent through UART. The Discovery board has pins that can be specially assigned for UART capabilities.

Power Circuitry:

The power circuitry will supply power to the transmitter circuitry, the receiver circuitry, and the processing unit. Power will mainly come from a wall to mini-USB adapter. The mini-USB will power the ST Discovery board and the rest of the circuitry will draw power from the necessary pins on the board. Voltage regulators will be used to make sure the necessary power gets to each component.

3. Verification

3.1 Requirements

Power Circuitry:

The power circuitry should be able to regulate the power at steady DC voltages to power the board, receiver and transmitter. The power source must be reliable and may not exceed current limits.

Receiver Circuitry:

The receiver circuitry will need to remove noise below 22kHz and the high pass filtering will be done on the ST board through programming and will remove any frequencies above 40kHz.

Transmitter Circuitry:

The sound will need to be amplified to above 100db (SPL).

Processing:

Must perform FFT, Cross correlation, and Signal processing calculations in between sending chirps to the transmitter. This must happen in milliseconds.

Transmitter Transducer:

Must be able to produce a response from 20kHz to 40kHz. Must be reasonable in pricing.

Receiver Transducer:

Must be able to receive and transduce signals from 20kHz to 40kHz. Also must be reasonable in pricing.

Output Link:

The speed of the data transfer must be fast enough to happen between chirps, and must interface with an arduino chip.

3.2 Verification

Power Circuitry:

We will also use Pspice to characterize the response of the circuit to make sure the system is stable. Once we have verified the design and have built it, we will make sure that the voltages and currents are constant and correct using a multimeter.

Receiver Circuitry:

We will use Pspice to make sure we are getting the correct response from the circuit. Once we have verified the design and have built it, we will send test signals below 20kHz through the circuit and check the response through the circuit to see if the low pass filter is working.

Transmitter Circuitry:

We will do a Pspice analysis of the circuit before we design it, and to verify it is correct once it is built, we will send out a signal through the circuit and check it against the response we want at the output of the circuit using an oscilloscope. We want to be able to send a chirp, so the test signal will be sweep of frequencies between 20kHz and 40kHz, at the output of the circuit it should be a flat band signal with some gain across all frequencies.

Processing:

We will be using debugging tools in Keil. It will be able to output discrete values of calculations happening in real time. We will be able to send in a signal and check through the debugger if the calculations it would output is correct. Any wrong values will indicate issues, and we will be able to set test cases to debug any problems.

Transmitter Transducer:

We will be able to test the signal by first verifying the receiver works and then outputting a chirp through the transducer and checking to see if the signal received is the same or if the transducer filters out some of the signal.

Receiver Transducer:

We will use audio equipment in the lab to produce a signal that is known and that tests the range of the transducer (20kHz - 60kHz). Then using an oscilloscope we will check to see if it is transduced to an acceptable electronic signal.

Output Link:

We will have the output connected to a device which will be able to display the output. If we can see the output it will be working correctly.

3.3 Tolerance Analysis

The functionality of this sensor is dependent on the transducers' abilities to send and receive signals accurately in the ultrasonic frequency range. If this device does not function properly, the chirps will not be sent out and received accurately, and the determined characteristics of the room might be false. The transducers need to be able to send and receive signals within the 22kHz to 40kHz bandwidth. We will test the frequency response of our chosen transducer at the limits of this bandwidth and make sure that has a relatively flat frequency response.

4. Costs and Schedule

4.1 Cost Analysis

Labor:

Employee	Labor Costs
Matthew Lurie	$35/hr * 15 hrs/week * 12 weeks * 2.5 = $15,750
Kyle Spesard	$35/hr * 15 hrs/week * 12 weeks * 2.5 = $15,750
Total	**$31,500**

Parts:

Item	Quantity	Cost
STM32F4 Discovery Microcontroller	1	$20.00
Ultrasonic Transducer	2	$10.00
PCB	1	$20.00
Resistors, Inductors, Capacitors, Op-Amps, etc.	N/A	$20.00
Wall Power to Mini USB Converter	1	$10.00
Total		**$80.00**

Total: $31,500 (Labor) + $80.00 (Parts) = **$31,580**

4.2 Schedule

Week	Task	Person
9/16 *Proposal due 9/19, 4pm*	● Finalize and submit proposal ● Research and order transducers ● Start researching power circuit requirements	Matthew Lurie Matthew Lurie Kyle Spesard
9/23	● Circuit design ● Coding simulation ● Start writing design review	Kyle Spesard Matthew Lurie Kyle, Matt
9/30 *Design Review*	● Finalize design review ● Start PCB design	Kyle Spesard Matthew Lurie
10/7	● Finish and submit PCB order ● Put together parts list ● Program input output buffers	Matthew Lurie Kyle Spesard Kyle Spesard
10/14	● Program highpass filter ● Program cross-correlation	Matthew Lurie Kyle Spesard
10/21 *Individual Progress Reports due 10/24, 4pm*	● Program frequency-domain mode ● Create mock-up	Matthew Lurie Kyle Spesard
10/28	● Tolerance analysis ● Debugging	Matthew Lurie Kyle Spesard
11/4 *Mock-up Demos*	● Get base features running ● Debugging	Kyle Spesard Matthew Lurie
11/11 *Mock-up Presentations*	● Start coordinating with Haptic Array group ● Debugging	Kyle Spesard Matthew Lurie
11/18 *Thanksgiving Break*	● Enjoy Thanksgiving!	
11/25	● Verifications of specs ● Debug with other project	Matthew Lurie Kyle Spesard
12/2 *Demos/Presentations*	● Prepare presentation ● Prepare demo ● Final paper	Matthew Lurie Matthew Lurie Kyle Spesard
12/9 *Presentations, Final Papers due, Lab Notebooks due, Checkout*	● Finalize final paper	Kyle Spesard