Digital Bat Ears

ECE 445 Project Proposal

Paul Logsdon

Ian Bonthron

TA: Kevin Chen

Table of Contents

1.0 Introduction

1.1 Statement of Purpose:

The goal of this project is to develop a full spectrum bat detector at a reasonable cost. This device will record bat calls up to 100 KHz, downshift the calls into the human hearing range (20 Hz-20 KHz), and play the calls back through an audio jack without seriously distorting the signal. Also, the device will store the processed/original data for further processing on an SD card and provide an intuitive interface to the user. Bat detectors currently available on the market which have this functionality range from $500-$1000. We aim to provide similar functionality but only using $50-$100 worth of parts.

1.2 Objectives:

1.2.1 Goals:

1. Characterize a variety of MEMS microphones to determine their sensitivity in the ultrasonic range.
2. Based on the information from (1), design an amplifier/filter stage based on the empirical frequency response of said microphones.
3. Develop algorithms to compress/downshift ultrasonic data into the human hearing range and implement on a DSP.
4. Develop UI to interact with DSP
5. Develop algorithms to store data from DSP to SD card

1.2.2 Functions:

1. Records audio in the ultrasonic range (up to 100 KHz)
2. Downshifts audio and plays it back through the headphone jack.
3. Saves raw and/or downshifted data to the SD card
4. Provides user interface to repeat or delete different recordings

1.2.3 Features:

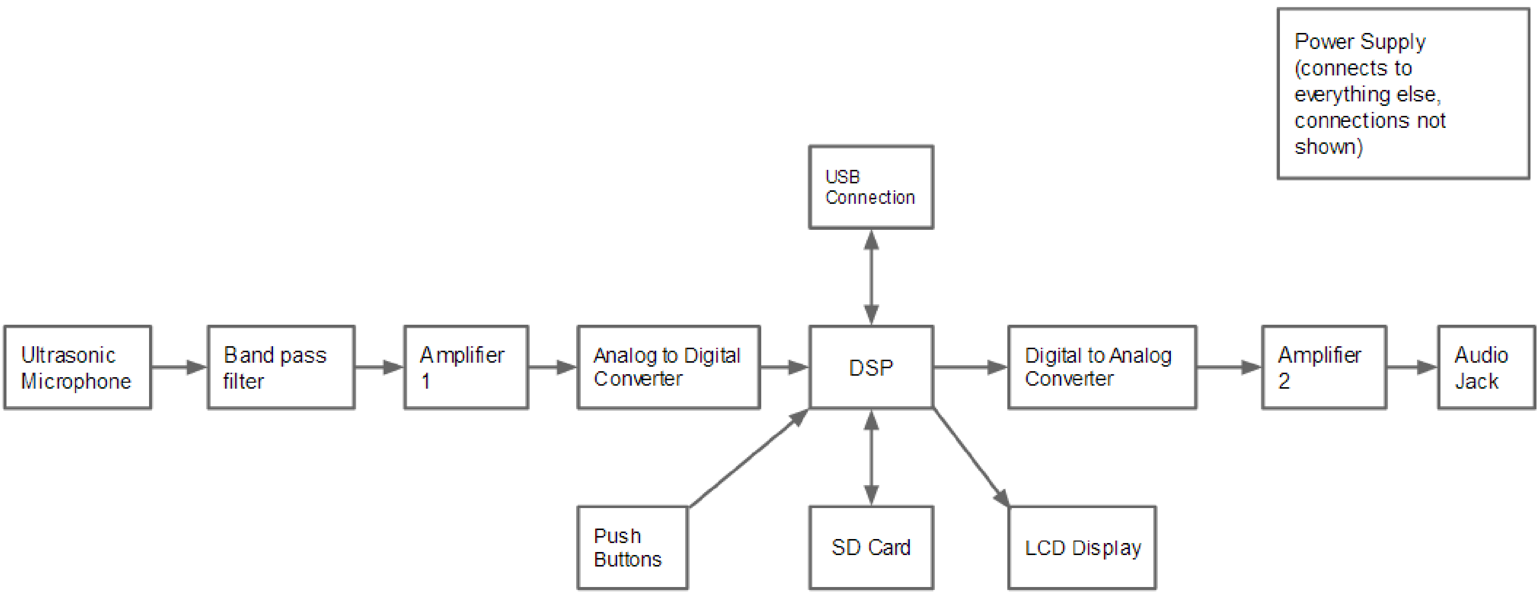
1. Contains a MEMS ultrasonic microphone for low cost, high accuracy recording
2. Contains a low power TI DSP for fast and efficient processing
3. Powered by standard AA batteries
4. Interfaces with standard headphones and SD cards
5. Electronics are stored in a durable case

1.2.4 Benefits:

1. Provides advanced functionality at a low cost
2. Has a friendly and intuitive UI
3. Provides output in a format which can be easily analyzed on a PC
4. Durable and portable

2.0 Design

2.1 Block Diagram:



2.2 Block Descriptions:

1. Ultrasonic Microphone - A MEMS device which has sensitivity in the ultrasonic range up to 100 KHz. This device will serve as the input to the rest of the system. We need to test a couple of MEMS microphones to determine which one is the best, see the cost analysis page for more details.
2. Band pass filter- this device takes input from the microphone and it will filter out any frequencies below 20 KHz (anything in the normal hearing range) as well as any frequencies above 100 KHz (outside of our test range). This serves to limit the input data that the rest of the system will look at, as well as serve as an anti-aliasing filter for the Analog to Digital converter.
3. Amplifier 1 - this device will amplify the signal to the level required for the analog to digital converter. This design will incorporate an operational amplifier, which we have chosen to be the TI OPA830IDBVT. This device is available at a low cost. It can operate

on a 3V power supply, and has a unity gain bandwidth of 250 MHz, which is well beyond what we would need.

4. Analog to Digital Converter - converts analog data into a digital format which can be used by the DSP. The maximum frequency in our signal is 100 KHz, so by the Nyquist criterion we need to have a sample rate at a minimum of 200 KHz. The Analog to Digital Converter we have chosen to use is the ADS8331IPW, which can sample at a maximum of 500 KHz, well beyond what we would need. In addition, it also has a 16 bit resolution, to provide high data accuracy.
5. DSP - the heart of the system. The DSP we have chosen is the TI TM320C553x. The main benefit of this DSP is that it has an architecture similar to the DSP used in ECE 420. In addition to this main benefit, the DSP also has a low power consumption and a low core voltage of 1.7 V. The DSP will have many functions:
    a. Interfacing with the user, via taking input from the push buttons and displaying output on the LCD display
    b. Performing algorithms on the ultrasonic signal to compress and downshift it into the human hearing range
    c. Read/writing data to the SD card
6. USB Connection - needed to program DSP. Thankfully, the DSP we have chosen to use has USB support built in.
7. Digital to Analog Converter - needed for direct audio output. The Digital to Analog converter we have chosen is the TI DAC161S997RGHT. It has a 16 bit resolution, like the ADC, and can operate at a maximum of 10 MHz.
8. Amplifier 2 - This will be needed to amplify the signal and provide enough power to the audio jack. Similar to Amplifier 1, this device will also use the TI OPA830IDBVT operational amplifier.
9. Audio Jack - clearly, this is needed for audio output.
10. SD card - needed to save data. Saved data will be in an uncompressed sound file format, such as raw or wav. Our DSP has a serial SD interface.
11. Push Buttons – needed to interact with the user. They will be basic and inexpensive.
12. LCD Display - A basic black and white LCD display with a resolution of 102x64. The Display we are planning to use is the EA DOGS102W-6. This was chosen over other LCD displays in order to keep the cost down.
13. Power Supply -Serves as the backbone of the system. Uses 3 AA batteries to provide 4.5 maximum to the system volts to the system. It will also contain mechanisms for providing different voltage levels.

Additional Note: The device will also have some kind of durable casing. We have yet to determine what kind of casing and where we would get it from.

3.0 Requirements and Verification

Block From Diagram	***Requirement***	***Verification***
Ultrasonic Microphone	Needs to detect ultrasonic sounds up to 100 KHz. We also need to measure the exact frequency response to adjust for differences in microphone sensitivities to different frequencies.	Using an oscilloscope and an ultrasonic sound generator, test the microphone and measure the exact frequency response by using a sweep of sine frequencies. An ideal microphone will have a flat frequency response across all frequencies up to 100 KHz. The microphone closest to this ideal is the one we should use.
Band pass filter	Ideally, needs to pass frequencies from 20 KHz to 100 KHz and block all other frequencies. However this is not practically feasible, so a transition band of <5 KHz will be allowed.	First, use a simulation program like SPICE to design and test the frequency response of the system. Once we are satisfied with the result, use a function generator to test a physical build of the system by using a sweep of sine frequencies.
Amplifier 1	Based on the signal level from the microphone and the necessary level for the A/D converter, the amplifier needs to amplify the signal.	First we can set up the amplifier in SPICE and simulate the circuit to see if its frequency response is desirable. When the simulation is what we desire, then we can build the circuit on a breadboard and use a function generator to test.
Analog to Digital Converter	Needs to sample data at a minimum of 200 KHz	Set sampling rate and use function generator/oscilloscope to test A/D converter to see if digital data is correctly being sampled

DSP	Needs to perform functions such as interacting with UI, SD card, and performing algorithms to compress frequency range and downshift data	Create test programs and use a function generator in combination with A/D and D/A to see how the downshifting/frequency compression algorithms work. For the other functions, see USB connection, DSP connection, and LCD/push button rows below.
USB connection to DSP	DSP needs to receive program from USB connection.	Use TI IDE and attempt to connect and run program.
DSP connection to SD card	DSP needs to write data to SD card. DSP includes serial SD interface.	Use a test program on DSP to check if SD card can be accessed.
Push buttons	Switches need to create a short circuit when touched and an open circuit when not touched	Use a basic circuit with an LED to test switches
LCD display	Needs to display relevant UI data	Write a UI test program on DSP and interface with LCD
Digital to Analog Converter	Needs to correctly reconstruct digital data	Assuming the A/D converter works, wire A/D converter and D/A converter together and test with function generator and oscilloscope. If the outputs are almost exactly the same, then the D/A converter is working.
Amplifier 2	Based on the voltage level coming out of the A/D converter, amplify to the necessary voltage level for audio output.	Same process as for amplifier 1

Audio Jack	Audio jack needs to transfer power to headphones	Use function generator, amplifier 2, and headphones together and see if sound can be heard.
Power Supply	Needs to deliver steady voltage in order for all other parts to receive the needed power.	Calculate load of all components, and test power supply with load and multimeter. Also, ensure each component is being supplied with correct voltage, within 5%.

4.0 Tolerance Analysis

The two amplifiers stages that we are planning to design are critical for the system's success. They need to amplify the signal to a reasonable level, but not to a level which would exceed the recommended maximum for the A/D converter and the headphone output, which would risk burning out the devices. We will design these amplifier stages to have a maximum voltage of 10% less than the maximum input level of both the A/D converter and the headphone output.

5.0 Cost Analysis and Schedule

5.1 Labor Cost Analysis

Team Member	Hourly Rate	Number of hours	Total Cost x 2.5
Paul Logsdon	$50	200	$25,000
Ian Bonthron	$50	200	$25,000

Total Labor Cost: $50,000

5.2 Parts Cost Analysis

Part	Quantity	Cost
Knowles SPU0410LR5H-QB (Ultrasonic Microphone)	1	$1.36
Knowles SPM0423HE4H-WB (Ultrasonic Microphone)	1	$2.08
Various RLC components	Varied	~$10.00
TI OPA830IDBVT (Op-amp)	2	$2.92
TI TMS320C5532AZHH10 (DSP)	1	$7.35
TI ADS8331IPW (A/D converter)	1	$12.47
TI DAC161S997RGHT (D/A converter)	1	$4.52
EA DOGS102W-6 (LCD display)	1	$12.36
SJ1-3544 (Audio Jack)	1	$1.70
USB-A1HSW6 (USB connection)	1	$0.45
Custom PCB cost	1	~$20.00
Custom casing cost	1	~$20.00
Switches	4 at $0.62/switch	$2.48
SD card connector	1	$2.19

Total Parts Cost: $99.88

Total Cost (Labor and Parts): $50,099.88

5.3 Schedule

Week	Paul's Responsibility	Ian's Responsibility
2/10	Finish Proposal, order microphones and begin microphone characterization	Finish proposal and begin microphone characterization
2/17	Microphone characterization and order additional parts	A/D characterization, D/A characterization and order additional parts
2/24	Design back end amplifier in ADS	Design front end amplifier in ADS
3/3	Breadboard and test back end amplifier. Prepare for design review.	Breadboard and test front end amplifier. Prepare for design review.
3/10	DSP Programming - shift and frequency compression	Design band pass filter in ADS
3/17	DSP Programming - User Interface/SD card	Breadboard and test band pass filter
3/24	Eagle PCB layout	Eagle PCB layout
3/31	DSP integration	Analog Integration
4/7	Full system test in lab	Model casting
4/14	Field Testing and being writing presentation	Field Testing and being writing presentation
4/21	Finish DSP part of presentation	Finish Analog Filter/Amplifier part of presentation
4/28	Demo	Demo