HETERODYNE BAT DETECTOR

By

Kyle Jedryszek

Evan McGowan

Bill Waltz

Final Report for ECE 445, Senior Design, Spring 2026

TA: Gayatri Chandran

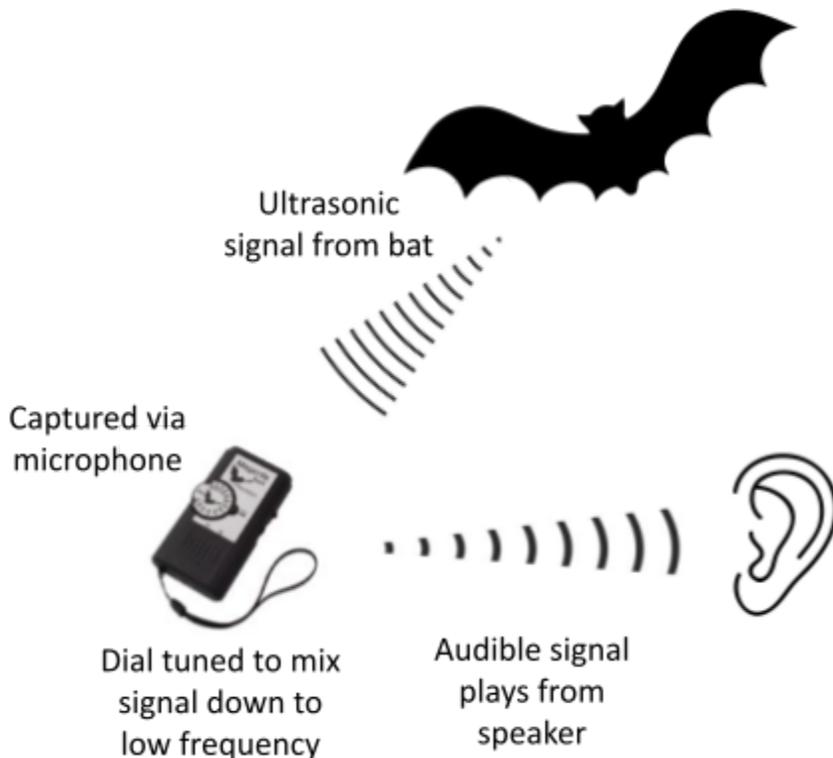13 February 2026

Project No. 3

Contents

1. Introduction

Bat detecting is popular overseas in the United Kingdom and Australia, but lacks the same market share in the United States. As such, many bat detectors used in the United States are imported, incurring additional taxes and higher shipping costs. Domestic options are either too expensive and/or have low audio quality, specifically those that plug into phones and tablets. Our client, Dr. Joy O'Keefe, requires a high-quality, mass-produceable, and domestically made device for the purpose of providing several groups of people with a bat detecting device for Bat Walks at the Central Illinois Bat Festival at a reasonable price.

1.1 Solution

We propose a battery-powered handheld device equipped with a microphone, capable of detecting frequencies between 15kHz and 100kHz to be converted down to a human-audible range. The frequency to be mixed with is controlled by a large dial (with illuminated frequency labels) on the front of the device. The sound will then be amplified and output via quality speakers. This model will also have stored, prerecorded sound bytes that can be played so that first-time users can know what to listen for, a feature our client desires that has not been seen yet. An accessible, inexpensive, and reliable option does not yet exist in the domestic market, and our product fills this niche.

Ultrasonic signal from bat

Captured via microphone

Dial tuned to mix signal down to low frequency

Audible signal plays from speaker

1.2 Requirements for Success

- The device must be tunable between 15kHz and 100kHz frequencies using the onboard tuner, testable using Dr. O'Keefe's Ultrasound Calibrator.
  - The Ultrasound Calibrator is a small device which outputs ultrasonic sound at a known frequency. We can tune our device to the calibrator's output frequency and if we can hear the output, we know it works.
- When an ultrasonic source radiates sound, the device must downconvert it to audible frequencies, playing it through the onboard speaker and filtering out background noise with an SNR of at least 25 dB.
- Battery life (rechargeable or otherwise) lasts the length of at least one bat walk (1-2 hours)

2. Design
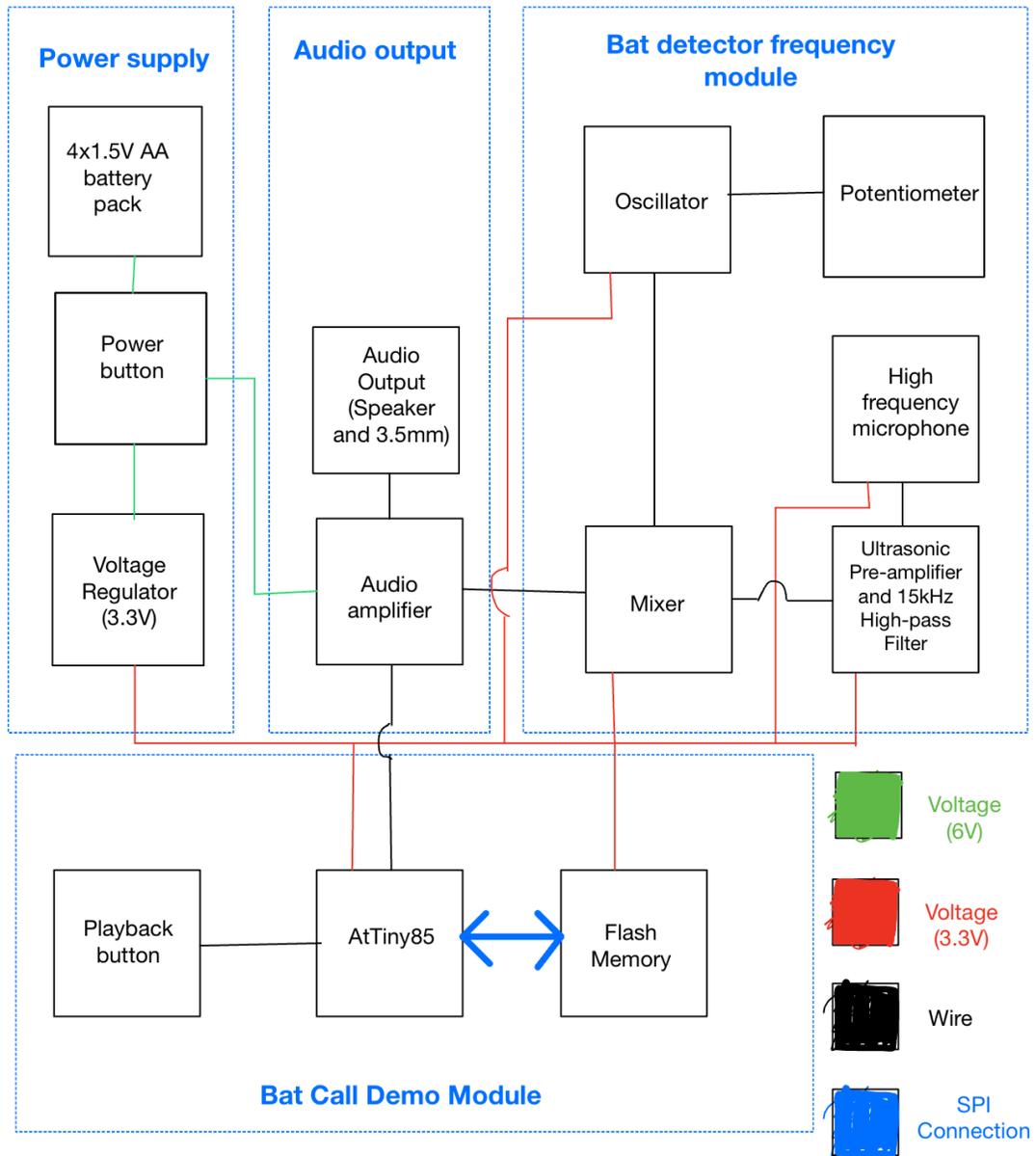
2.1 Onboard Bat Call Audio Demo Module

- The on-board bat call audio demo will allow the user to listen to pre-recorded (and down-converted) bat sounds in order to be able to identify bats detected by the device when used in detector mode.

2.4.1 Playback Button
- The playback button can be pressed by the user to play the pre-recorded audio. When the button is pressed, it will tell the microcontroller to play the audio to the speaker.
- Requirement: Allow for on-demand user input to hear pre-recorded audio through the microcontroller
- Requirement 2: Briefly halt mixer output to the speaker while the pre-recorded audio plays

2.4.2 ATTiny85
- The ATTiny85 is our microcontroller of choice. When prompted through the button, it will read audio data from the flash memory and output it to the speaker.
- Requirement: Interact with the on-board ROM and amplifier to play pre-recorded audio via SPI protocol

2.4.3 On-board Flash Memory
- The on-board flash memory will store pre-recorded bat sounds that will be read by the microcontroller for output to the speaker.
- Requirement: Store pre-recorded sound data to be provided to microcontroller

2.2 Bat Detector Frequency Module
- The bat detector frequency module is the main component of the device. It will receive ultrasonic frequencies from the microphone, mix them down based on the value of the potentiometer dial, and send the output to the audio output subsystem.

2.3.1 Pre-Amplifier & Filter
- The preamp amplifies the input received from the microphone. It is placed before the passive high-pass filter (having a 3dB bandwidth of 15kHz) to ensure that all low-frequency noise is removed.
- Requirement: Amplify the incoming ultrasonic signal and filter out frequencies below 15kHz

2.3.2 Oscillator
- The oscillator will produce a frequency that mixes with the ultrasonic signal, with its frequency being controlled by an onboard potentiometer.
- Requirement: Produce an oscillating signal that can be controlled within the ranges of 15kHz to 100kHz

2.3.3 Mixer
- The mixer will receive amplified ultrasonic waves and the local oscillator signal, and mix them together to bring them down to a frequency that can be heard by the human ear, which is then output to the audio subsystem. The same frequency deviation is present, but now at an audible frequency.
- Requirement: Mix down ultrasonic frequencies provided by the microphone to frequencies audible by the human ear

2.3.4 High-Frequency Microphone
- The high-frequency microphone is the device's input. It will receive ultrasonic audio input from bats to be mixed down by the mixer.
- Requirement: Be able to detect audio frequencies between 15kHz and 100kHz

2.3 Audio Output
- The audio output contains both a 3.5mm auxiliary jack and a built-in speaker to allow for audible audio output from either of the sources. It will receive the audio output from either the mixer or the microcontroller through the playback feature.

2.2.1 3.5mm Auxiliary Jack
- The 3.5mm jack will allow the user to use their own headphones to listen to the device's audio output instead of the built-in speaker.
- Requirement: Allow for the user to plug in and use external headphones and speakers to listen to bat calls
- Requirement 2: Disable use of the speaker while an external output device is plugged into the audio jack

2.2.2 Speaker
- The speaker will be built into the detector, allowing the user to hear bat calls through the device through the mixed-down frequency received from the mixer chip.
- Requirement: Output audible mixed-down ultrasonic signal

2.2.3 Audio Amplifier
- The audio amplifier amplifies audio signals received from the mixer and microcontroller into audible frequencies, while filtering out the higher spurious frequencies. It will then send the amplified sound to the speaker.
- Requirement: Amplify audio received from the mixer and microcontroller

2.4 Power Supply
- The power supply provides power to the necessary components in the other subsystems. It is powered by AA batteries with a 3.3V voltage regulator. It is also equipped with a power switch to allow the user to turn the detector on or off.

2.1.1 AA battery holder
- The battery holder contains AA batteries to provide voltage to the regulator, amplifiers, and input/output.
- Requirement: Provide sufficient power for at least 1-2 hours

2.1.2 Voltage Regulator and Switch/Power Button
- The voltage regulator will maintain and distribute a constant voltage to the required components of the circuit. The switch will control when the device is on or off.
- Requirement: Allow the user to control when the device is powered on or off
- Requirement 2: Provide 3.3V to the microcontroller, flash memory, and microphone

2.5 Tolerance Analysis

Our design contains many components that remain active for the majority of the device's operation. This includes amplifiers, regulators, and the microcontroller. One concern lies with the device's battery life, and whether the goal of 1-2 hours of battery life can be achieved.

Our limiting component in the design is the LM386N-1 audio amplifier, which has an operating range of 4V-12V. Our four AA batteries must thus maintain power draw for two hours such that their individual voltages do not drop below 1.0V. Using the Duracell MN1500 as a benchmark, we can draw more than 500mA during the device's 2-hour operation to stay above this limit.

The ATTiny85 is specified to draw 2mA of current while powered, with up to 40mA per I/O pin, a value which we will not come close to reaching. A maximum of 15mA can be drawn from the flash storage at any given time, as well. Microphone current is negligible, with a supply current of up to 0.2mA.

The AP2210 voltage regulator has a maximum current output of 300mA, which we also will not come close to reaching in standard operation, so our other components will receive adequate power throughout operation. The four op-amps each have a maximum of 50mA for output current. This puts us at an absolute maximum power draw of 500mA, which is adequate for two hours of battery life.

3. Additional Considerations

3.1 Ethics

Our team believes that our product lacks ethical concerns. The only interaction that our product has with the outside world is in amplifying the high-frequency sounds of bats out in the wild through the use of a microphone. Nothing is sent back out to the bat to communicate with it or otherwise interrupt nature. No recording is enabled by the device, eliminating the possibility of recording without the permission of others. This device only amplifies inaudible sound waves, so it cannot be used to listen in on private conversations. Component choices may be obtained via reverse engineering of existing products, such as the Magenta Bat4, but no circuit or intellectual property is to be copied without permission.

3.2 Safety

The device is not believed to harbor any safety concerns. The only moving parts on the device are plastic dials, and the device is not heavy enough to cause unintentional damage from dropping or otherwise. No metal parts of the device are exposed through the chassis, eliminating most chances for an electric shock.

References

[1] *LM386 Low Voltage Audio Power Amplifier Data Sheet*, Texas Instruments, 2023.

[2] *Global Product Technical Data Sheets - Duracell Batteries,* Duracell.com, 2016.

[3] *ATTiny25/45/85 Data Sheet*, Atmel, 2013.

[4] *W25X40CL Data Sheet*, Winbond Electronics, 2014.

[5] *SPVA1A0LR5H-1 Data Sheet*, Syntiant, 2024.

[6] *AP2210 Data Sheet,* Diodes Inc., 2021.

[7] *TLV9054 Op Amp Data Sheet*, Texas Instruments, 2024.