Dwight Look College of
ENGINEERING
TEXAS A&M UNIVERSITY

Team 28: Guitar Entertainment System

ECEN 404 Final Presentation

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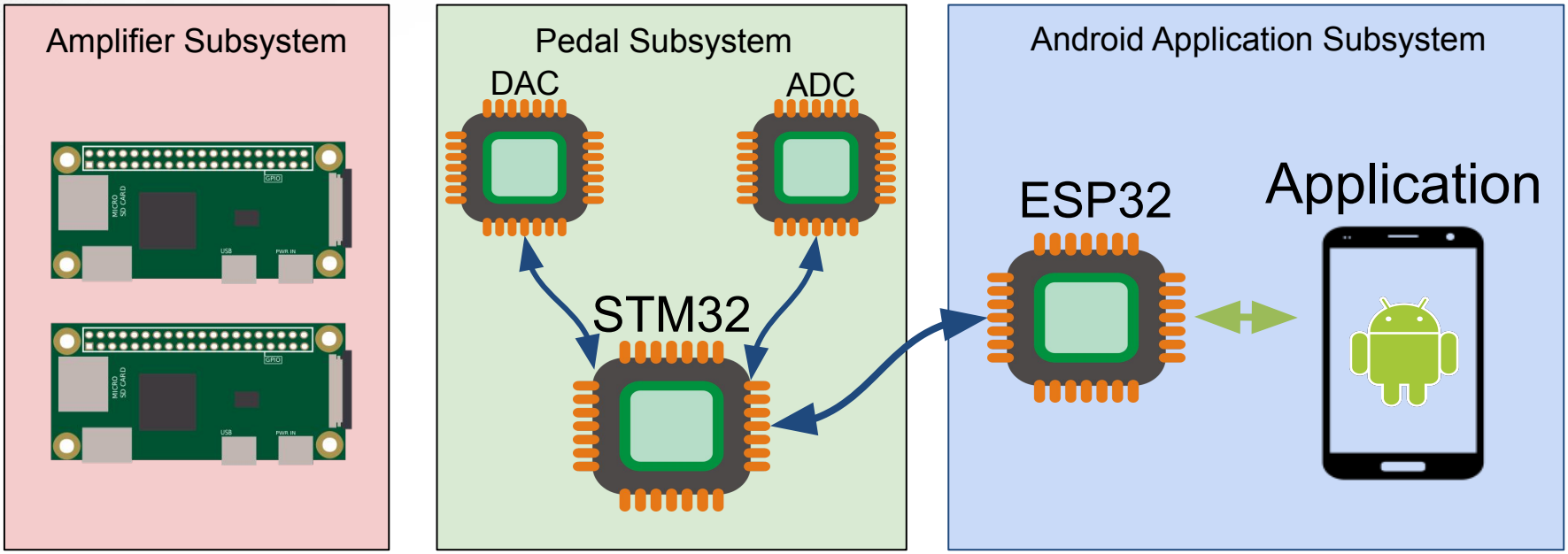
Problem Overview

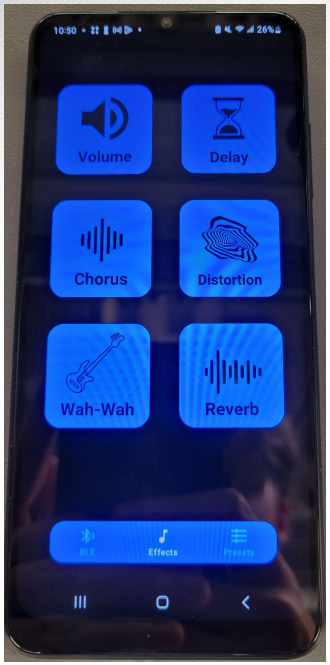
- Problem Statement: Current guitar amplifiers and effects systems often present a steep learning curve, deterring those with limited technical experience from fully exploring their sound potential.

- Solution Proposal: Developing a user-centric guitar sound system, combining an amp, pedals, and a Bluetooth-connected app. This system simplifies sound customization through intuitive controls and presets, making advanced sound manipulation accessible to all skill levels.

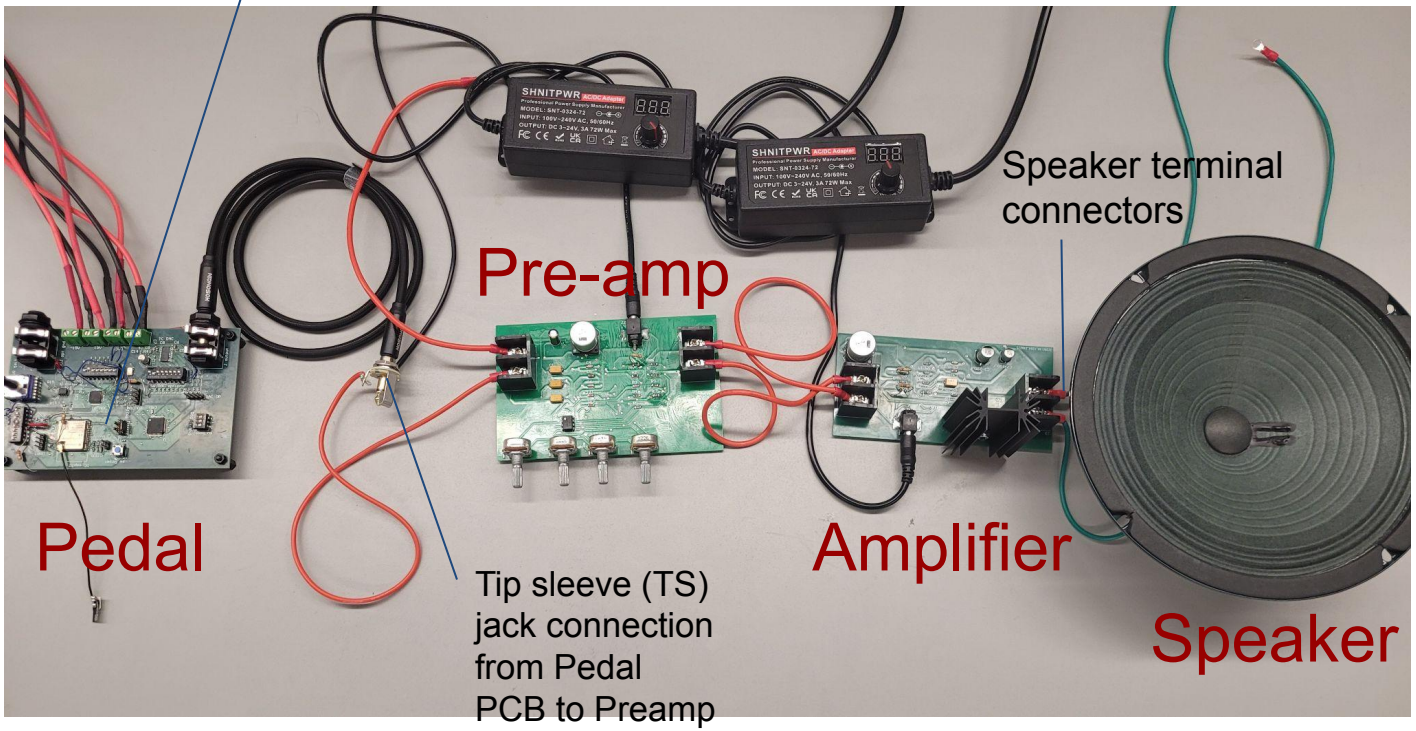
Integrated Project Diagram



Integrated Project Diagram



UART transmission of sound effect commands to DSP



Engineering Design
Amplifier

Preamplifier

- **TL072 Op-amp:** Chosen due to its low noise and high input impedance for high-quality lossless audio output.
- **Potentiometers for tonal enhancement:**
  - **10k Gain:** allows precise volume adjustment
  - **50k Bass and Treble:** gives extensive range for shaping low and high frequencies
  - **10k Mid:** balances tonal spectrum, enhancing guitar's presence in a mix

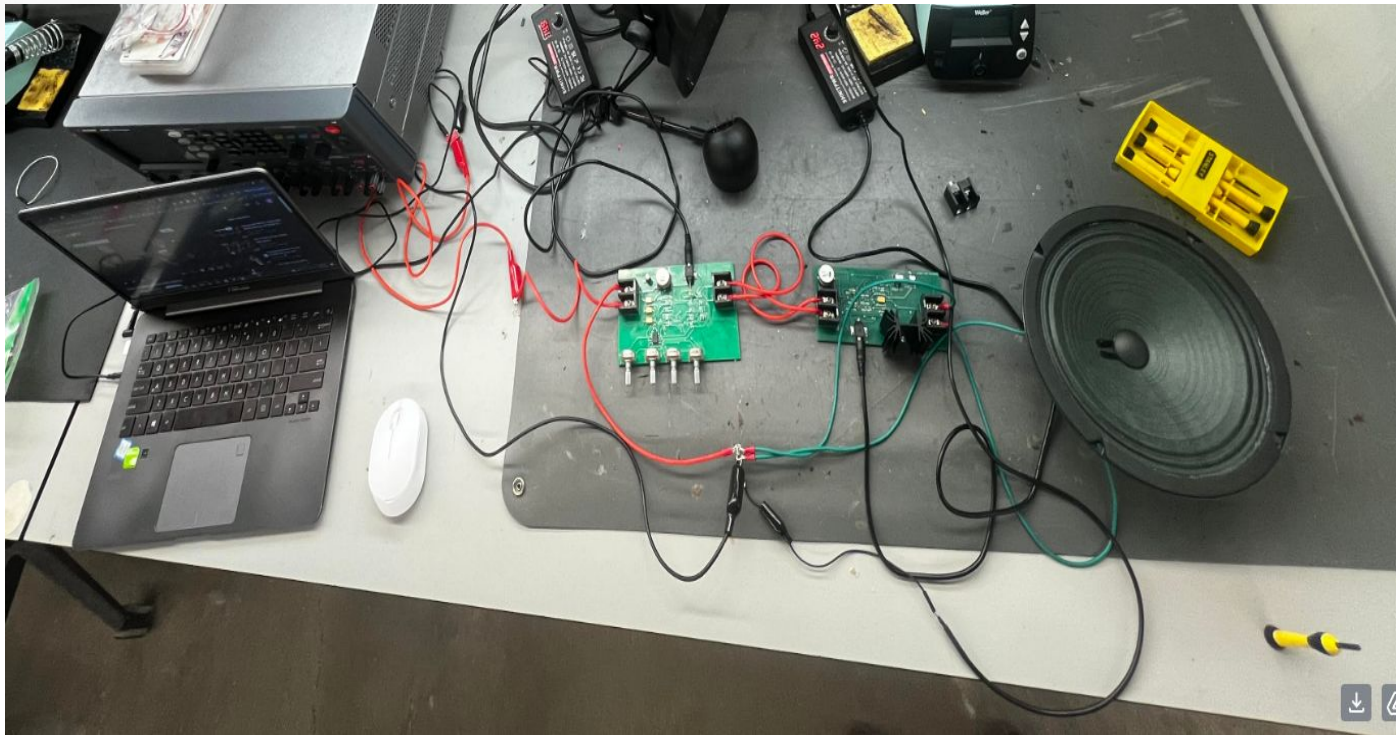
Amplifier

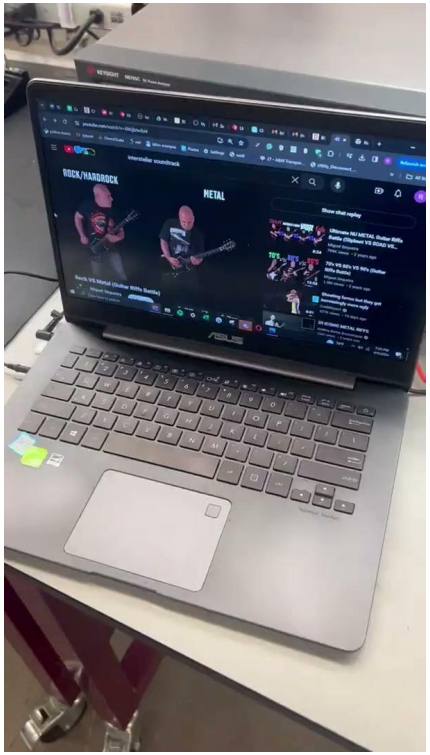
- **LM1875** ideal due to its low THD at less than 0.04%, preserving original tone
- High power output
- Maintains stability with capacitive and inductive loads

Engineering Accomplishments

Amplifier

- In place of the pedal system, an audio jack breakout board was used to convert digital to analog; amplifier is *fully functional*
  - Variety of sounds were tested i.e. pure tones, complex tones, range sweep





Amplifier Validation

Test Type	Test Method	Result
Validate the frequency response curve and aim for a flat response within ±0.5 dB across 20 Hz to 20 kHz	Sent complex audio signals via an audio breakout board	Amplifier is able to output lossless sound at specified frequency; potentiometers are also able to manipulate this signal
Aim for a dynamic range of over 120 dB to capture the full spectrum of audio without distortion or noise intrusion	Full volume complex-signal audio was sent to amplifier	Lossless sound was outputted and went through *no* distortion or noise
Ensure the amplifier maintains operational temperatures below 100°C under full load conditions to guarantee long-term stability.	Send high gain audio signal to the amp and kept constant for 30 mins	Amp chip did not exceed temperature threshold, and kept cool

Engineering Design
Pedal System

Digital to Analog Converter

- **PCM5142**
  - 32 bit DAC, accepts 16, 20, and 24 bit as well
  - Supports a sample rates up to 384-kHz

Analog to Digital Converter

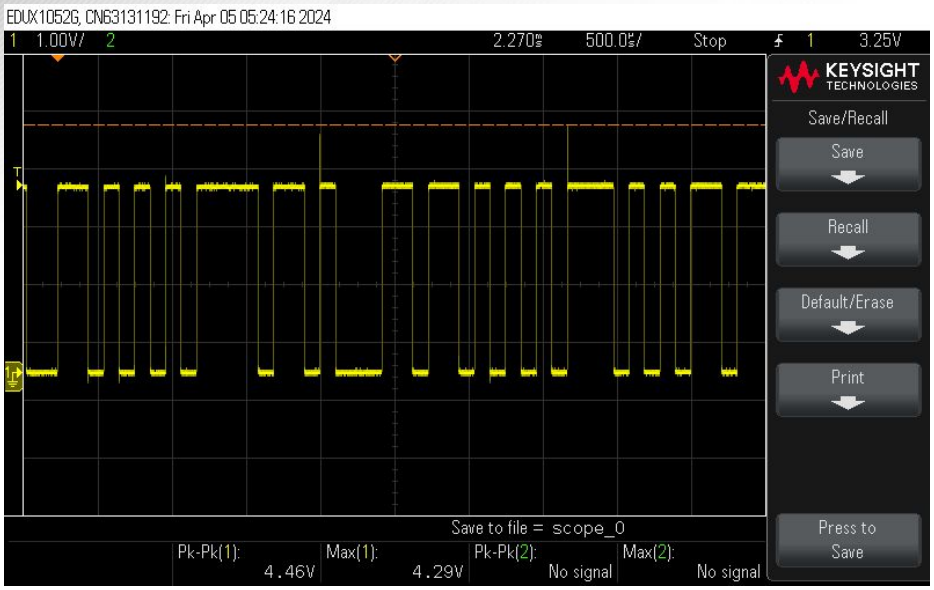
- **PCM4222**
  - 24 bit ADC, can change to 16 bit
  - Supports sample rates from 8-kHz to 216-kHz

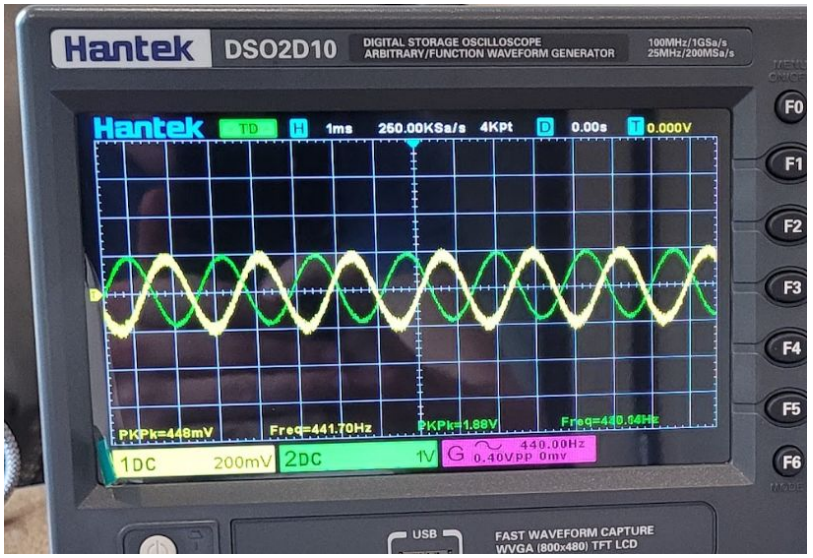
Digital Signal Processor and Microcontroller

- **STM32F446**
  - 32 bit, 180 MHz microprocessor, built in DSP instructions
  - 2 serial audio interfaces that support full duplex I2S
- **ESP32-S3-Wroom-1U**
  - 32 bit, 240 Mhz microprocessor
  - up to 16 MB flash size

Engineering Accomplishments

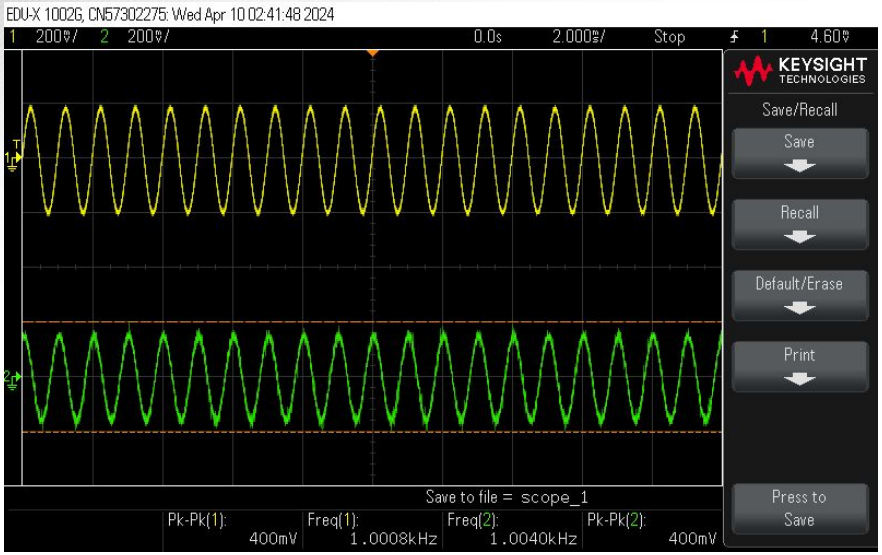
Pedal System





Data out from the ESP32 acting as the DSP, originating from the ADC, being sent to the DAC to be converted to Analog

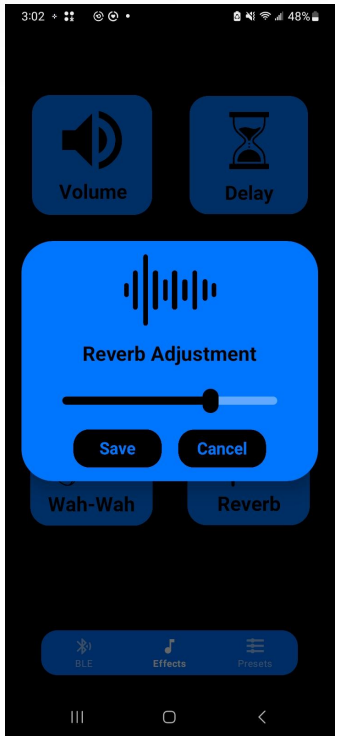
Engineering Accomplishments
Pedal System



Input and output of system using the ESP32 as the DSP

- Frame select 96-kHz
- Bit select 6.21-MHz
- Able to reproduce the input at the output

Engineering Design
Bluetooth App

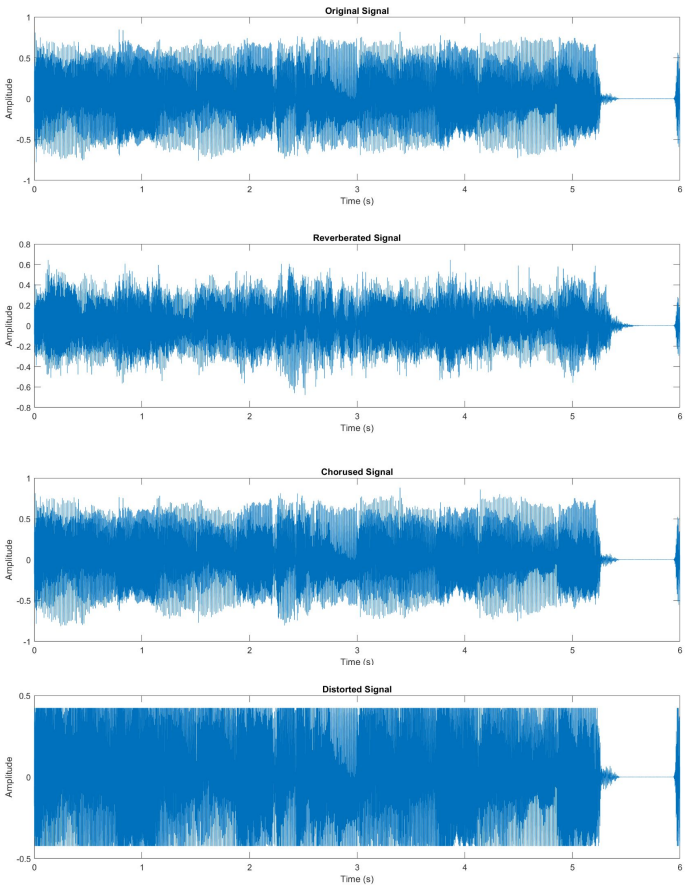


User connects to ESP32 titled “Guitar Sound Effects” and then presses on the effect they want to adjust which is sent through Bluetooth Low Energy (BLE)

- Mobile application runs on an Android device and developed in Android Studio.
- Application contains a page to connect to device, a page to update effects, and a page to save and recall sound effects.
- ESP32 processes the incoming data and transmits the received commands to the STM32 through UART.

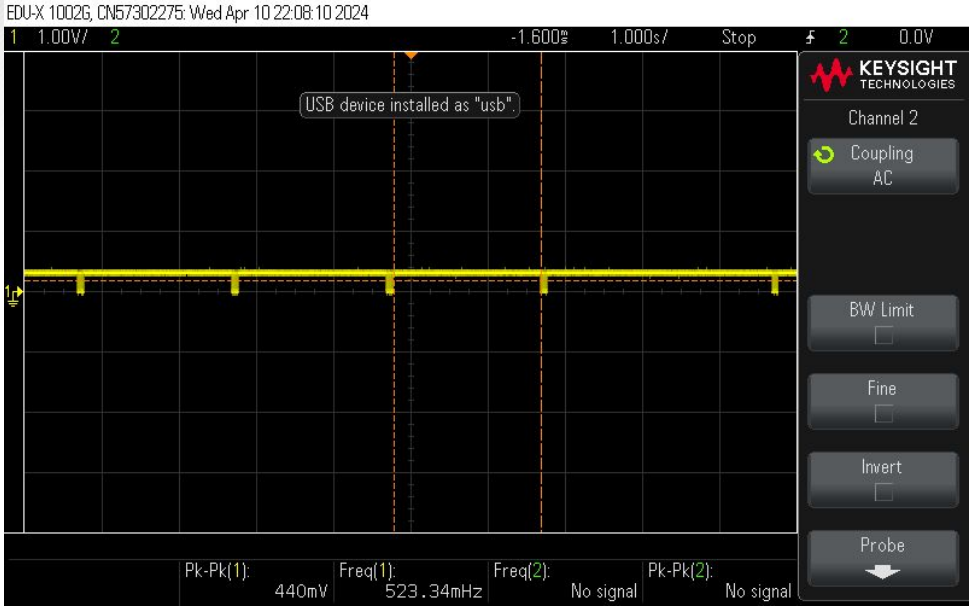
Engineering Design
MCU & DSP Programming

- Volume adjustment adjusts the amplitude of the signal
- Reverb and delay adjustment introduce a delay that is added to the original signal
- Chorus adds the same sound with an adjusted pitches
- Distortion decreases the range of amplitudes
- The wah-wah effect is a band pass filter that allows frequencies within a certain range



Engineering Accomplishments

Bluetooth App, MCU & DSP Programming



UART transmission of sound effect updates from ESP32 to STM32. The user can change the sound effects multiple times within 1 second.

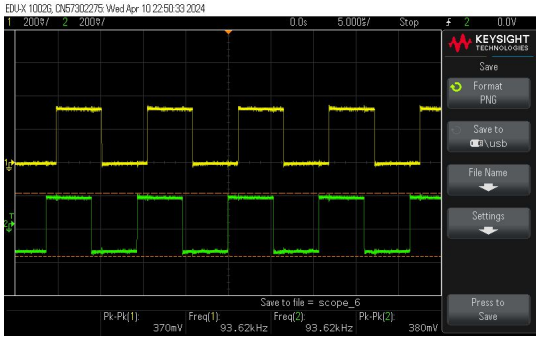
```
--- Quit: Ctrl+C | Menu: Ctrl+T | Help: Ctrl+
T followed by Ctrl+H
Starting BLE work!
Starting Monitor...
Connected
Volume: 15
Distortion: 28
Volume: 59
Chorus: 32
Reverb: 30
Distortion: 54
Delay: 27
Chorus: 70
Reverb: 60
Wah-wah: 28
Chorus: 46
Delay: 53
```

Terminal output of user adjusting sound effects through Bluetooth application.

Engineering Accomplishments

Bluetooth App, MCU & DSP Programming

Bit Clock



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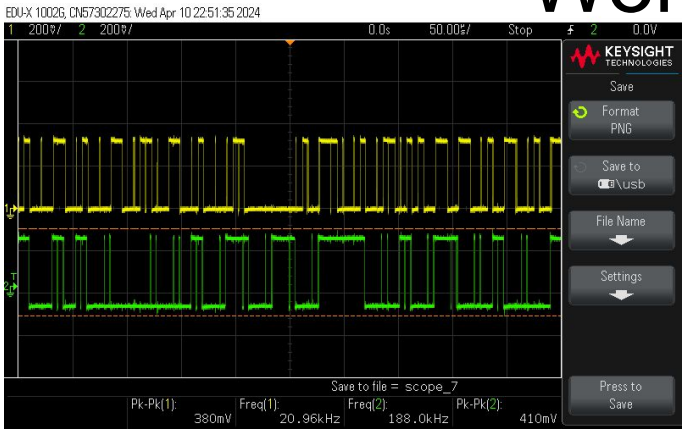
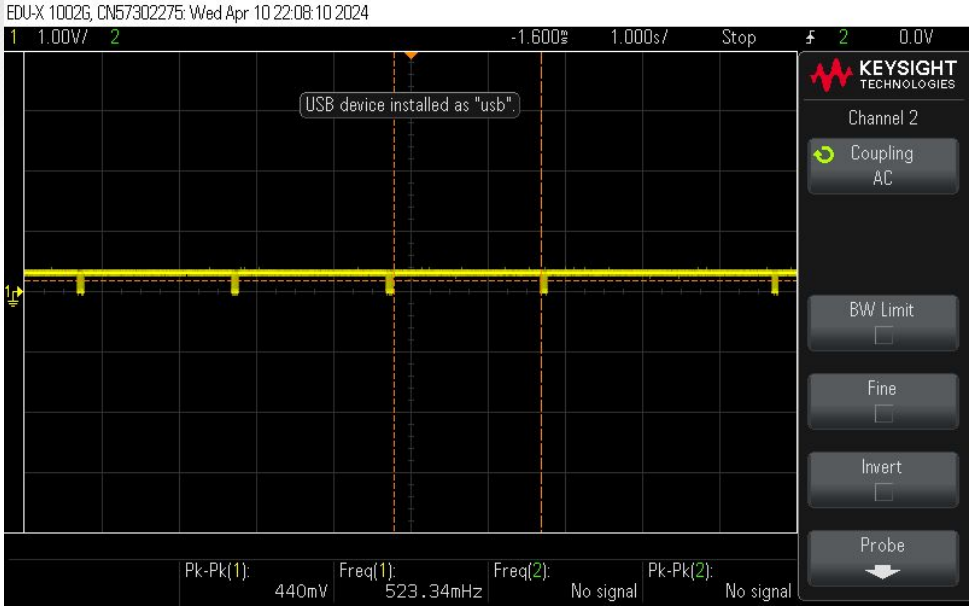


Data

Engineering Accomplishments

Bluetooth App, MCU & DSP Programming



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Terminal output of user adjusting sound effects through Bluetooth application.

Conclusions

- App - Initially unable to get the DSP functionality working on the STM32, switched to doing DSP functions on ESP32.
- Preamp/Amp - Reduced size of amp PCB, and increased trace widths on both PCBs. In addition, reversed the polarity on the preamp PCB. Status - fully functional.
- Pedal - Added optional routing of digital signals to headers and to the ESP32 for testing and as a backup to the STM32. It is fully functional operating as intended.

Current Status

75% complete

- Amplifier has been tested and validated
- Pedal PCB and App still need to iron out DSP issues

Thank you for listening.