Automatic Piano Tuner

Group 49

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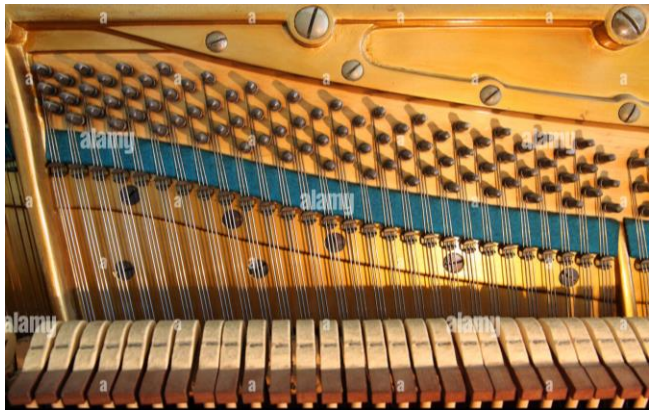
The Problem

Problem

Pianos require periodic tuning to function

- Specialized skills & tools
- High cost, $200
- Time consuming



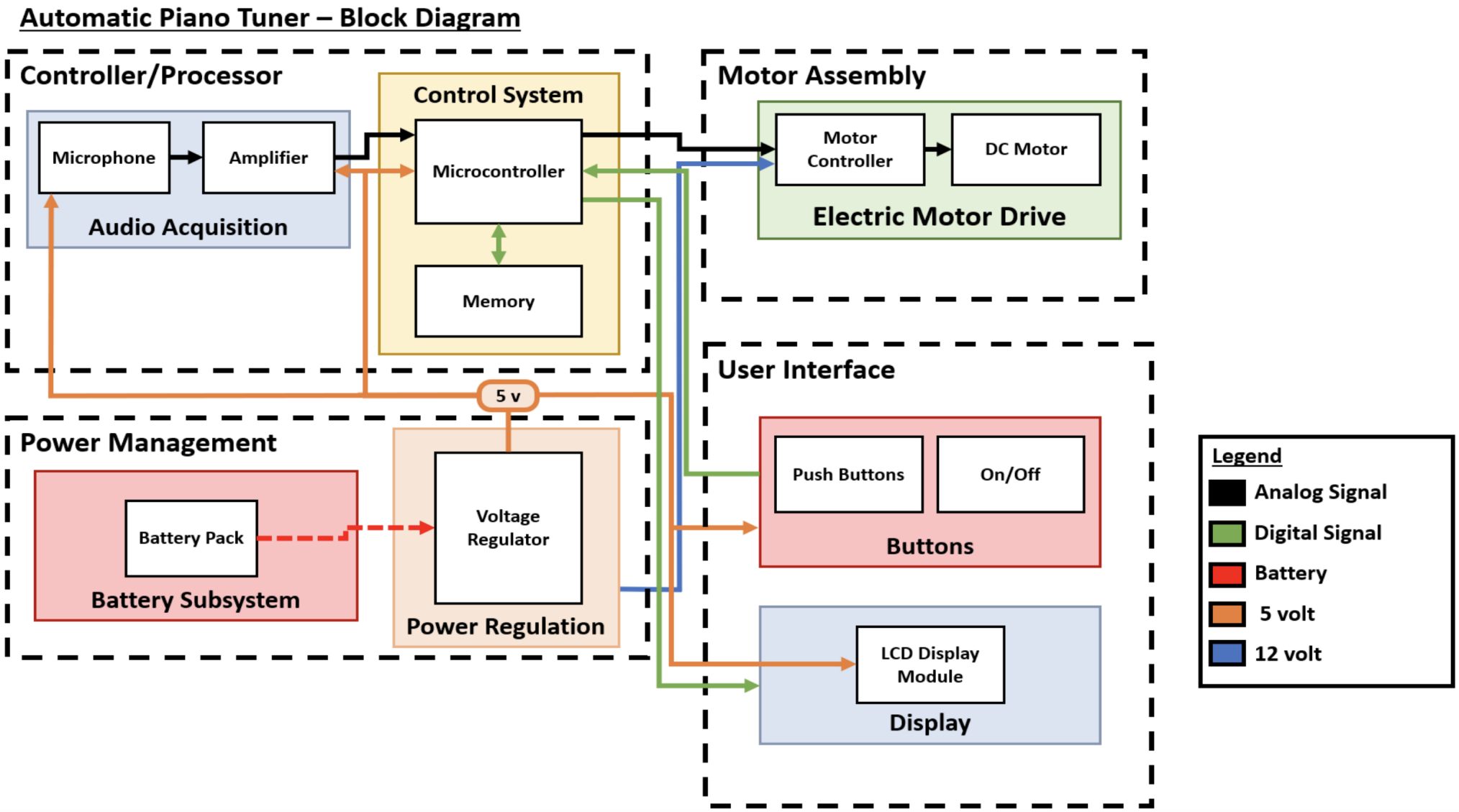
Solution

A device which can automatically detect frequencies and tune piano

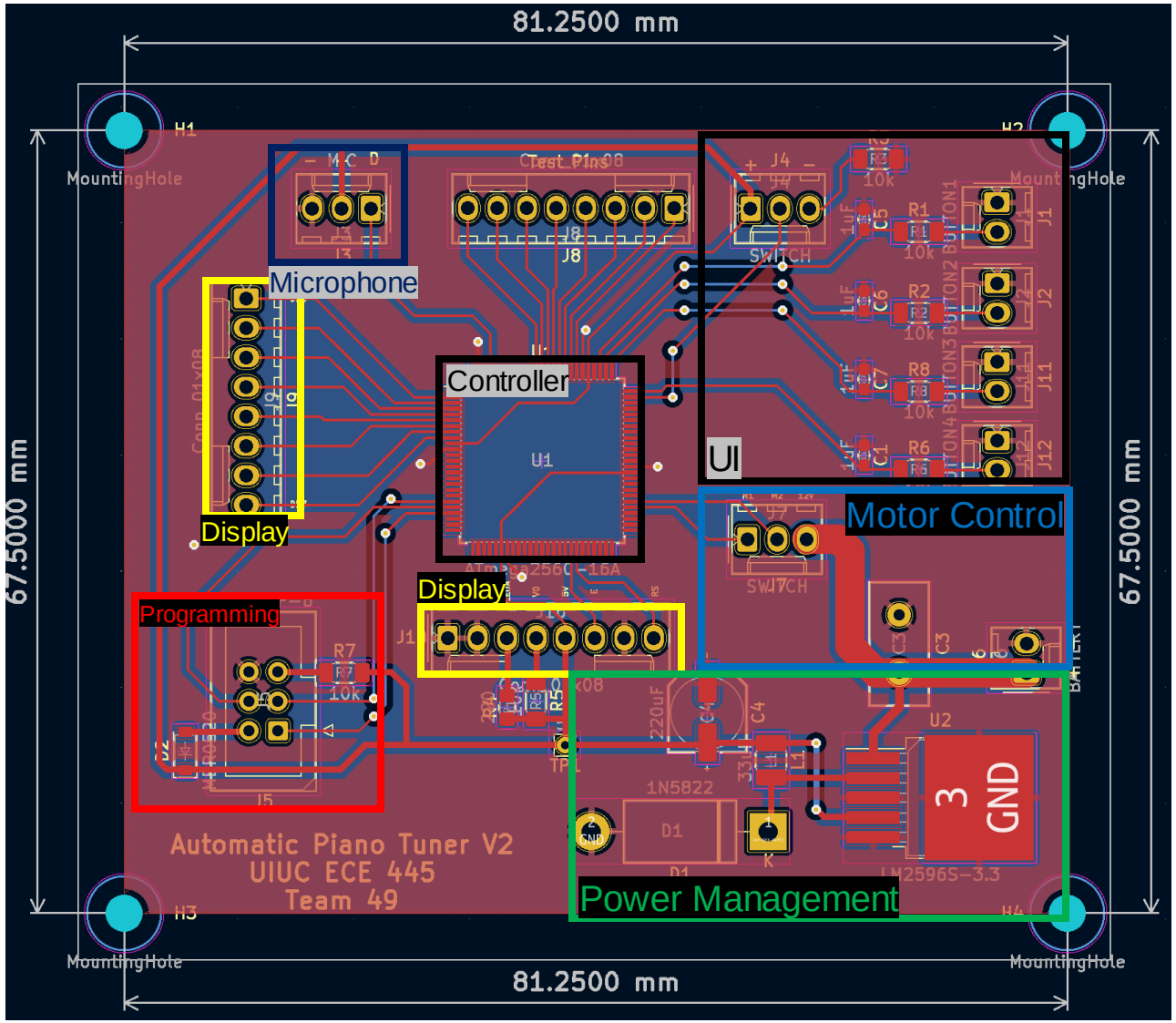
- Low skill requirement
- Cost equal to a single tuning session
- Expedited processes

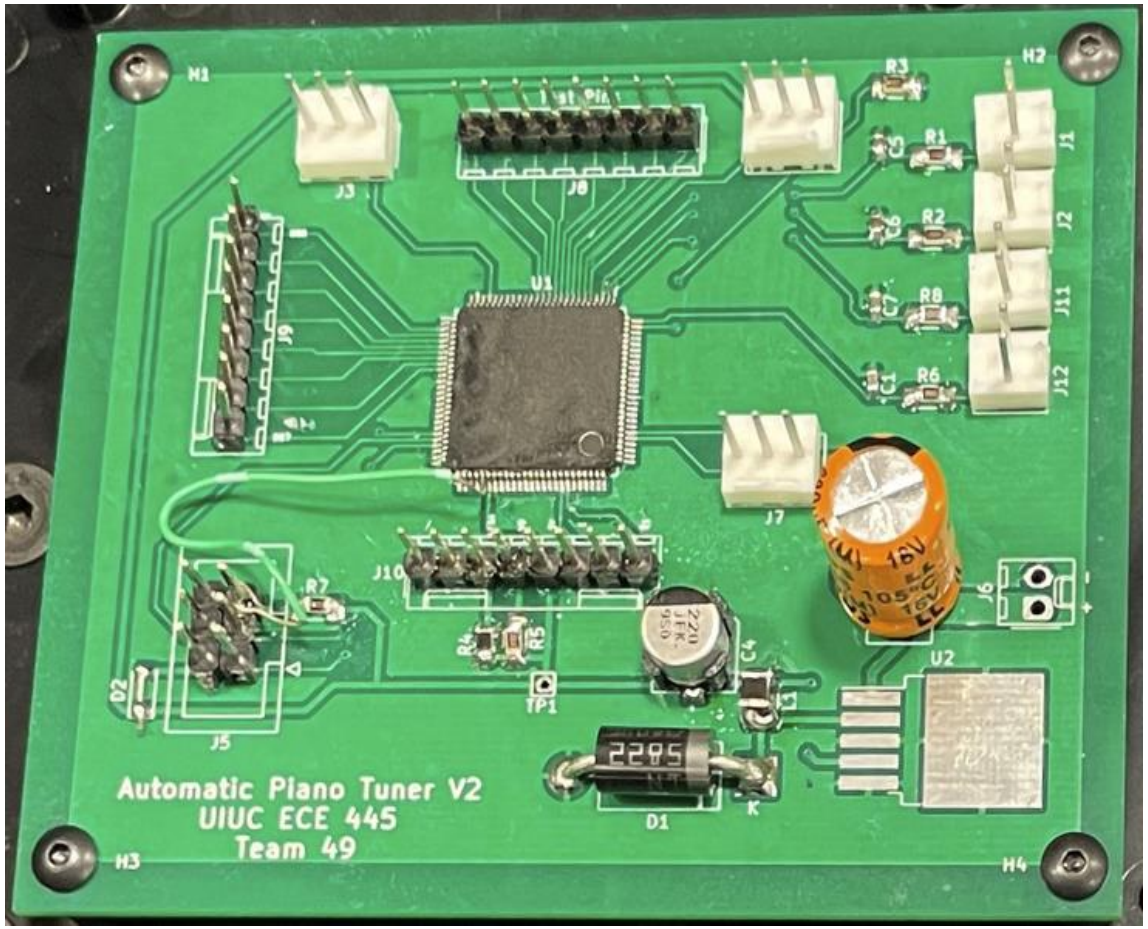
Design

Design – Block Diagram



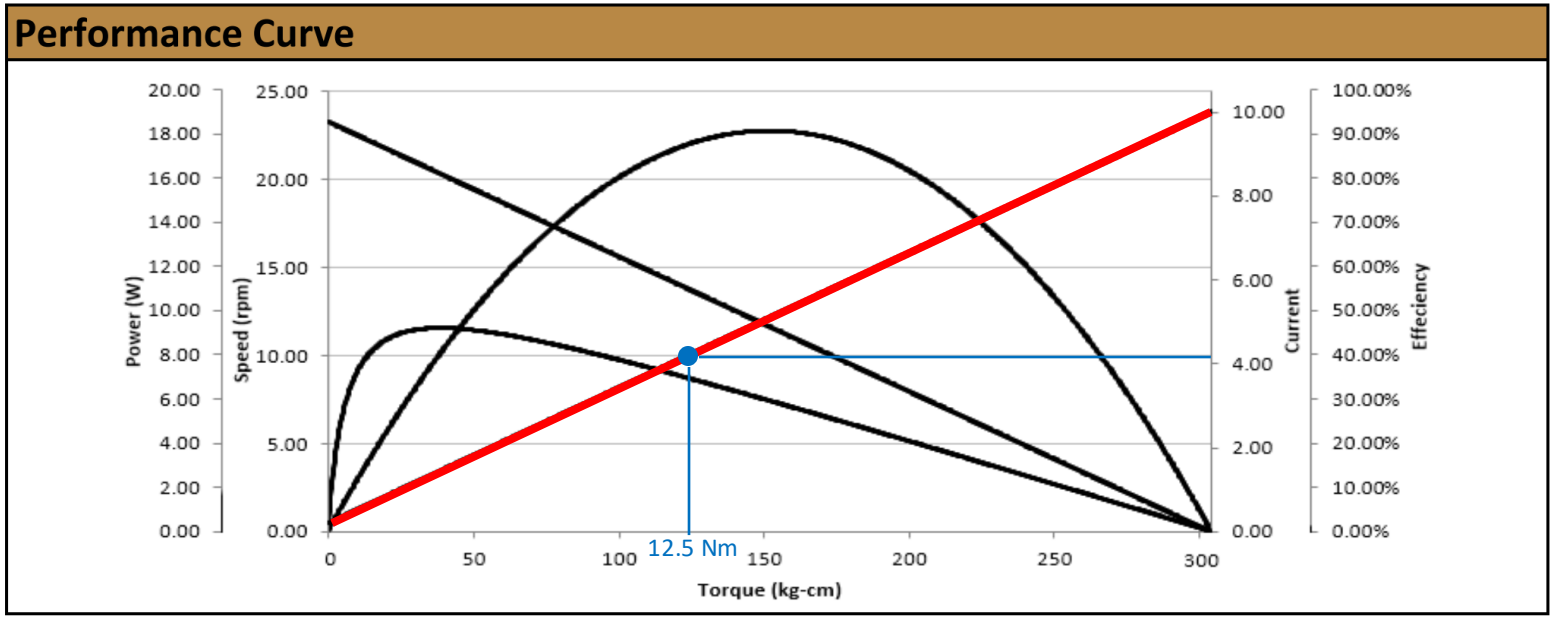
Design - PCB


81.2500 mm
67.5000 mm
Microphone
Controller
Display
Display
Programming
UI
Motor Control
Power Management
Automatic Piano Tuner V2
UIUC ECE 445
Team 49
MountingHole
MountingHole
MountingHole
MountingHole
81.2500 mm


Automatic Piano Tuner V2
UIUC ECE 445
Team 49

Specifications

- 9 – 14 Nm Torque
- 4 A Current
- Motor Controller



https://media.digikey.com/pdf/Data%20Sheets/ISL%20PDFs/MOT-IG32GM-12V-264E.pdf

Design – Software Control Loop

Buttons to set desired frequency

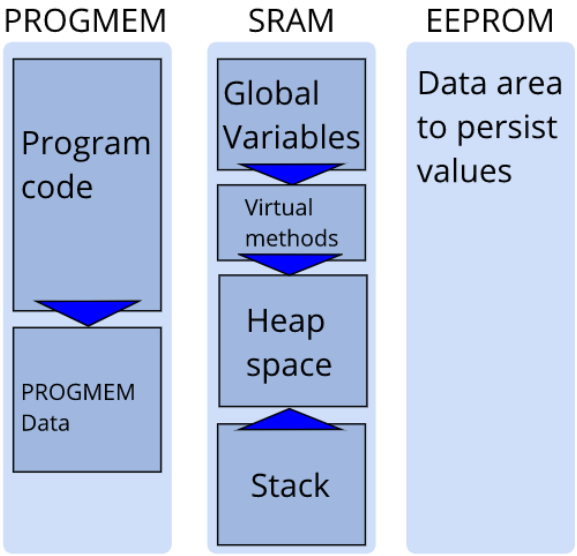
- Save frequencies values in memory to save RAM space

Compare frequency from microphone to desired frequency

- Use rolling average to smooth values

Move motor depending on difference in frequencies

- Greater frequency difference allowance on tightening



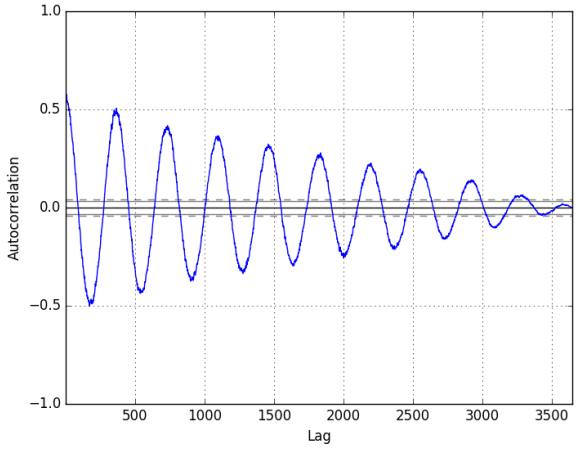
https://www.thecoderscorner.com/electronics/microcontrollers/efficiency/how-arduino-avr-memory-model-works/

Design – Software Frequency Detection

Autocorrelation

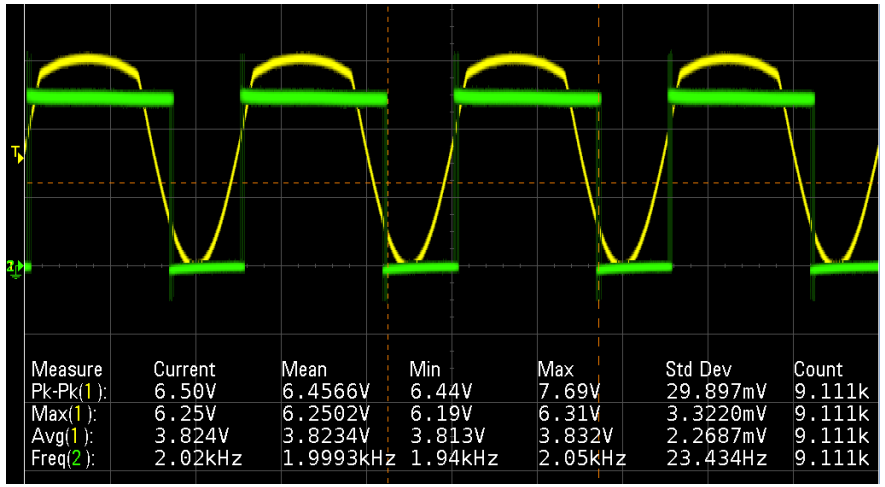
- First implementation of frequency detection algorithm
- Compares lagged signal against original signal to determine period
- Good noise rejection, fast through FFT speed

$$R_{xx}[l] = \frac{\sum_{n=0}^{N-1} x[n]x[n-l]}{\sum_{n=0}^{N-1} x[n]^2}$$

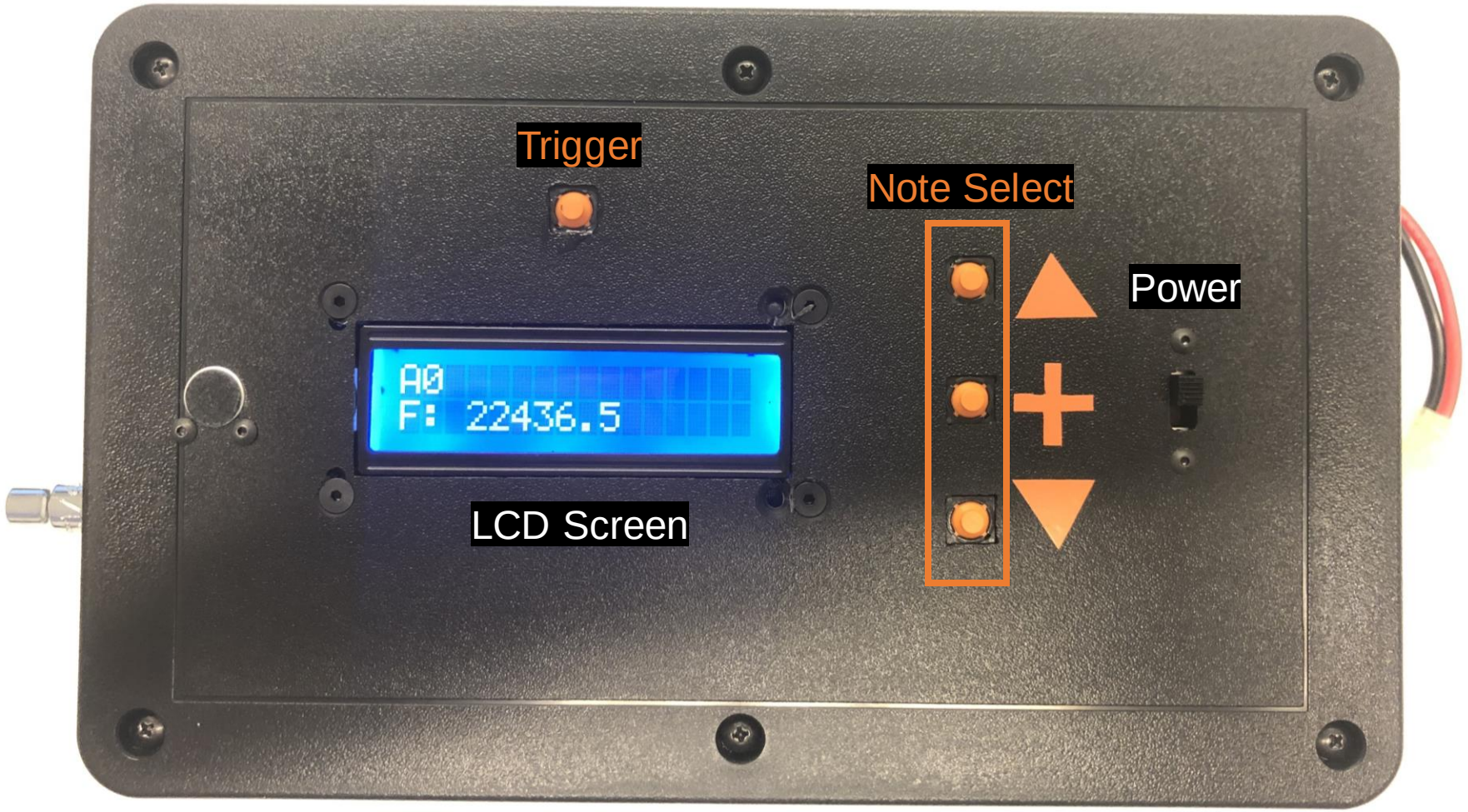


Period Estimation

- Compares two ADC samples to detect positive slope during zero-crossing
- Measures the time passage between positive zero crossings using ADC sample rate to estimate period



Design – User Interface



Note Select

- Up Key

- Up Octave

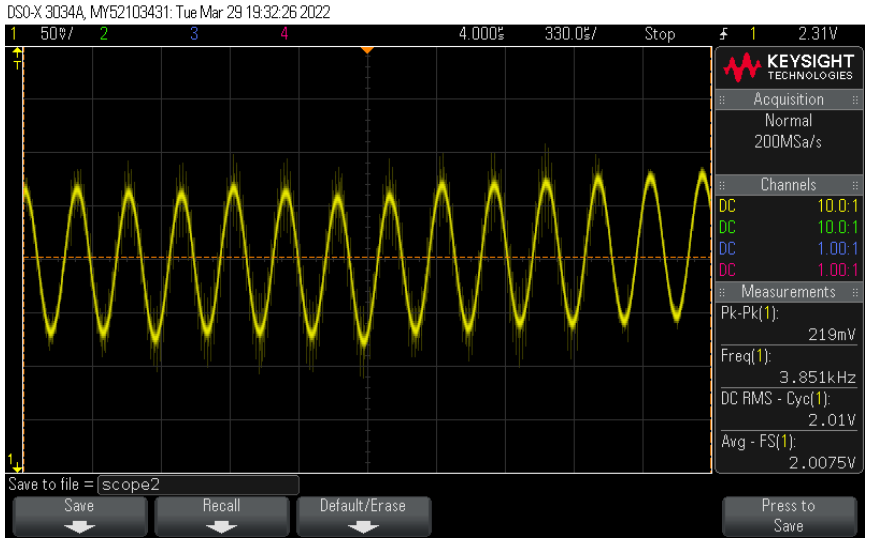
- Down Key

Test Results

Video

Test Results - Audio Acquisition and Control

- Frequency range 27.5 Hz - 4186 Hz
- Differentiate between frequencies 1.6 Hz apart
- Determine frequency in less than 5 sec



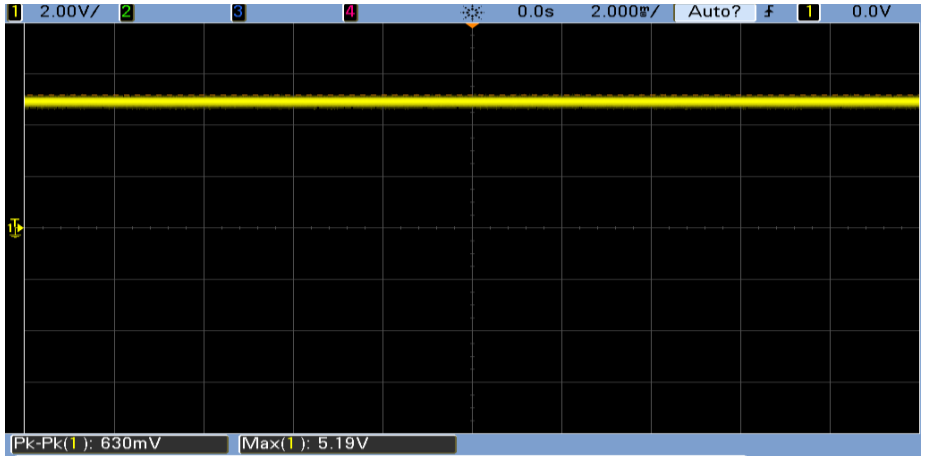
Test Results - Power Regulation, Battery

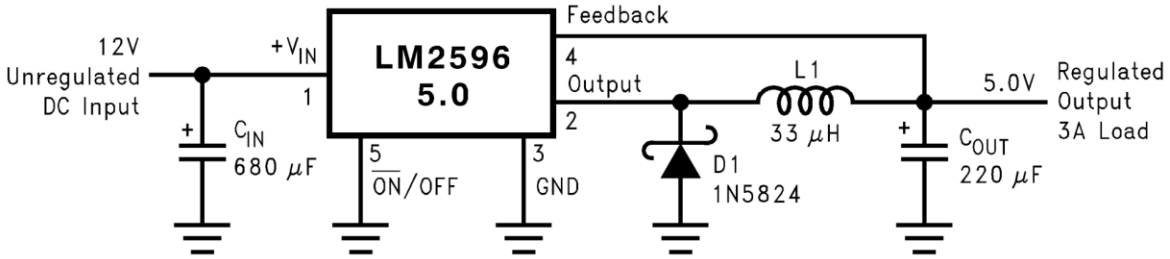
Power Regulation

- Provide 12V to the ‘Motor Assembly’
- Provide 5V to majority subsystems

Battery System

- Rechargeable
- Remain powered for 2 hours at load



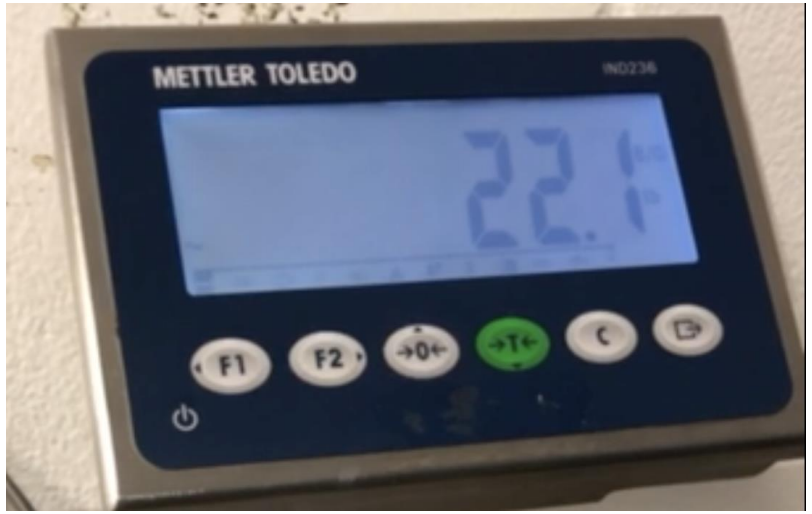


Test Results - Electric Motor Drive

Able to rotate piano tuning pin

Able to produce the required 9-14 Nm

- Provides at least 9.83Nm of torque



$$l = 10cm, f = 22.1lbs$$

$$Torque = force * length = (22.1lbs) * \frac{4.448N}{1lbs} * 0.01m$$

Test Results - Buttons and Display

Display

- Display current note and octave
- Update display after button press < 1sec

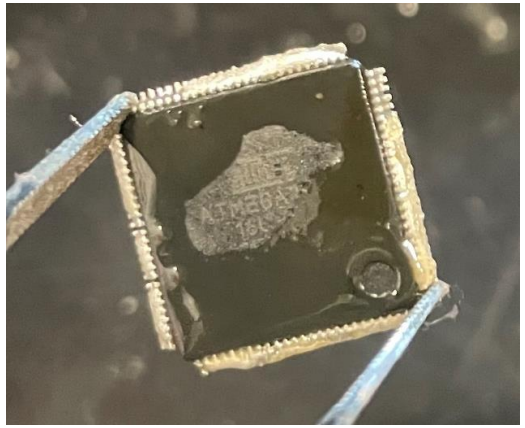
Buttons

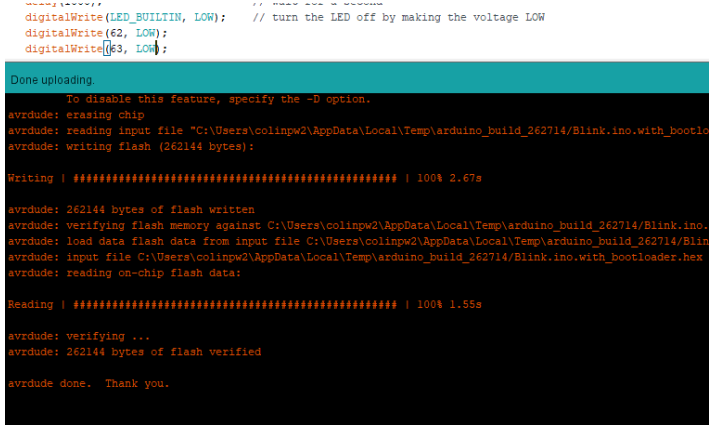
- Pressing note select buttons updates desired frequency < 1sec
- Disable dual up/down button press

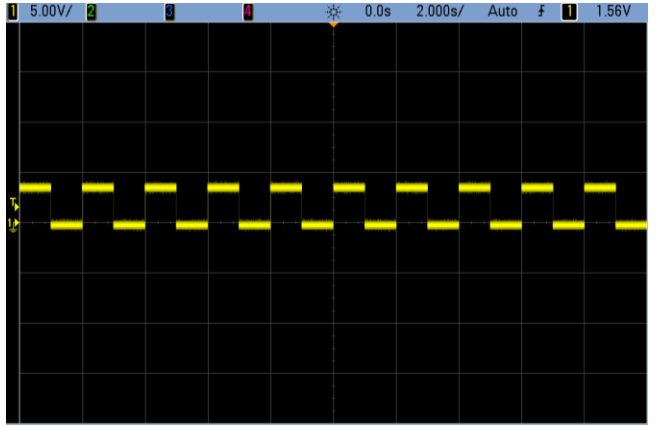
Challenges

Challenge – Microcontroller

- Shortage of components, especially microcontrollers limited us to purchasing an Arduino Mega and desoldering
- Migrated chip from Arduino board to PCB, would not program with the standard ICSP header
- Zero information online indicating the source of the problem
  - AVR uses internal oscillator, Arduino reprograms to use external oscillator
  - Used a signal generator to simulate oscillator and burn new bootloader

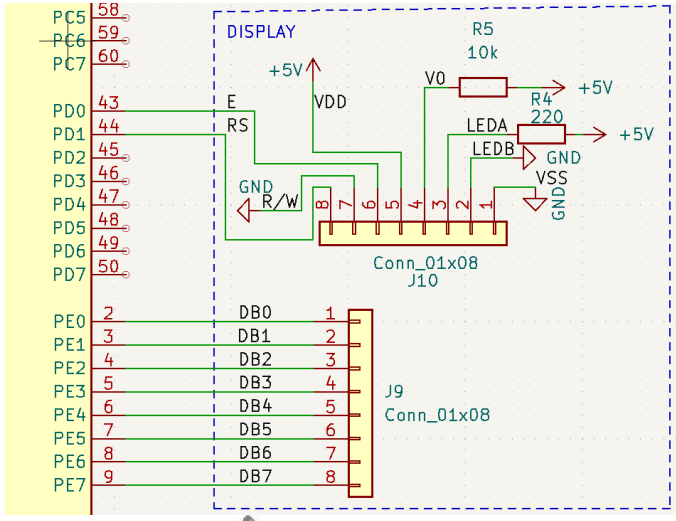


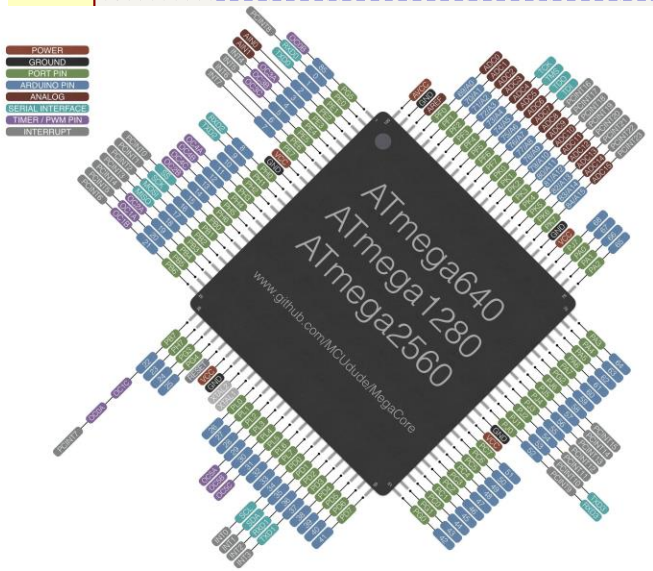




Challenge – Display

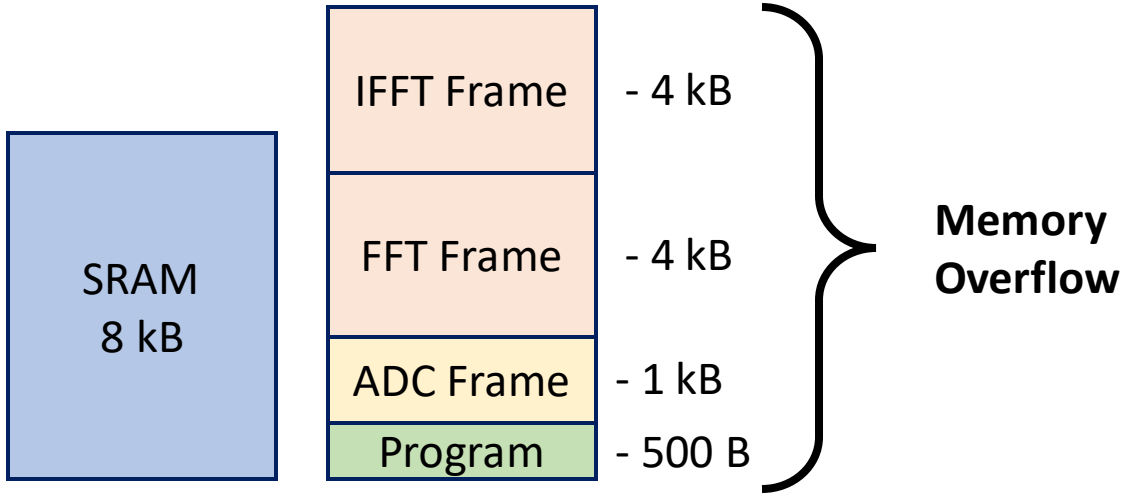
- LCD display VO pin required voltage divider
- LCD display LEDA pin required smaller resistor
- Using MegaCore AVR pinouts





Challenge – Frequency Detection

- Project was designed around frequency detection scheme using autocorrelation. Worked independently on computer
- KISS FFT library uses large data structures for storing real and imaginary information
- Arduino has no clear way of indicating what error is occurring




```
for(int i = 0; i < FRAME; i++){
   output[i] = fft_real[i];
   Serial.println(i);
}

#######Serial Monitor #######
% 0
% 1
% 45684294
```

Take Away

Conclusion – What We Learned

- Technical Skills – Soldering, PCB fabrication, full system design
- Engineering team project experience
- Professional presentations of results

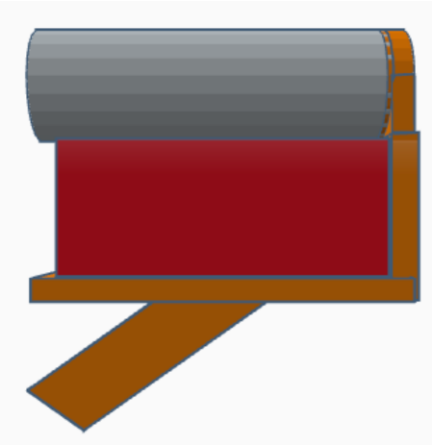
Further Work

Further Work

Project can be further enhanced by improvements to

Useability

- Smaller box
- Arm to hold device by



Frequency Detection Accuracy

- Better microphone
- Autocorrelation frequency detection

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