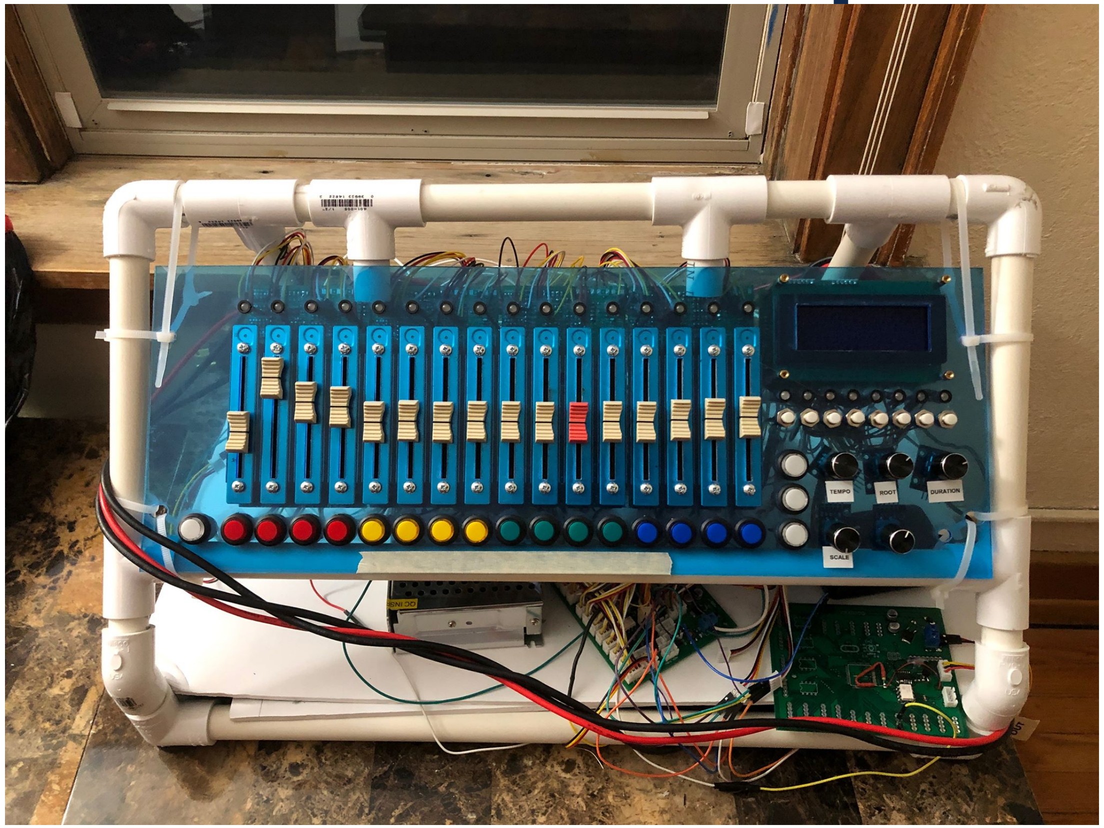
MIDI Controller Sequencer



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Introduction

Problem Statement

- Musical instruments often have a difficult and arduous learning curve.
  - Keeps many participants from ever knowing the joy of musical composition.
- Can a device be made to:
  - Teach the user basic music theory
  - Quickly allow them to compose new melodies

Solution

MIDI Sequencer with Motorized Linear Potentiometers

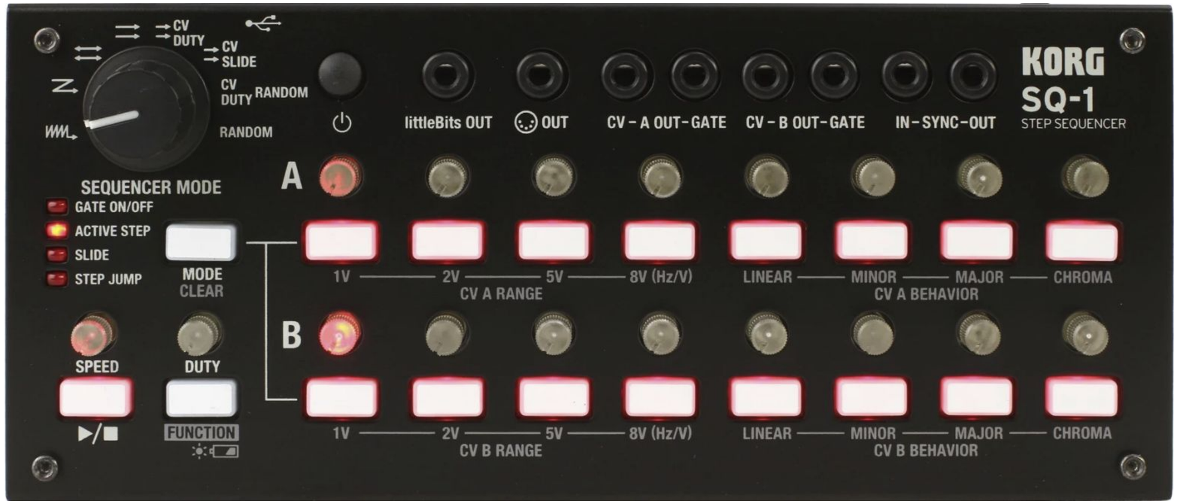
- An easy to use sequencer that allows for creating melodies and music.
- Simplifies learning curve often associated with instruments
- Potential to be used as a teaching tool
- An intuitive and innovative design:
    - Allows for fast switching between musical properties and melodies.
- Portability

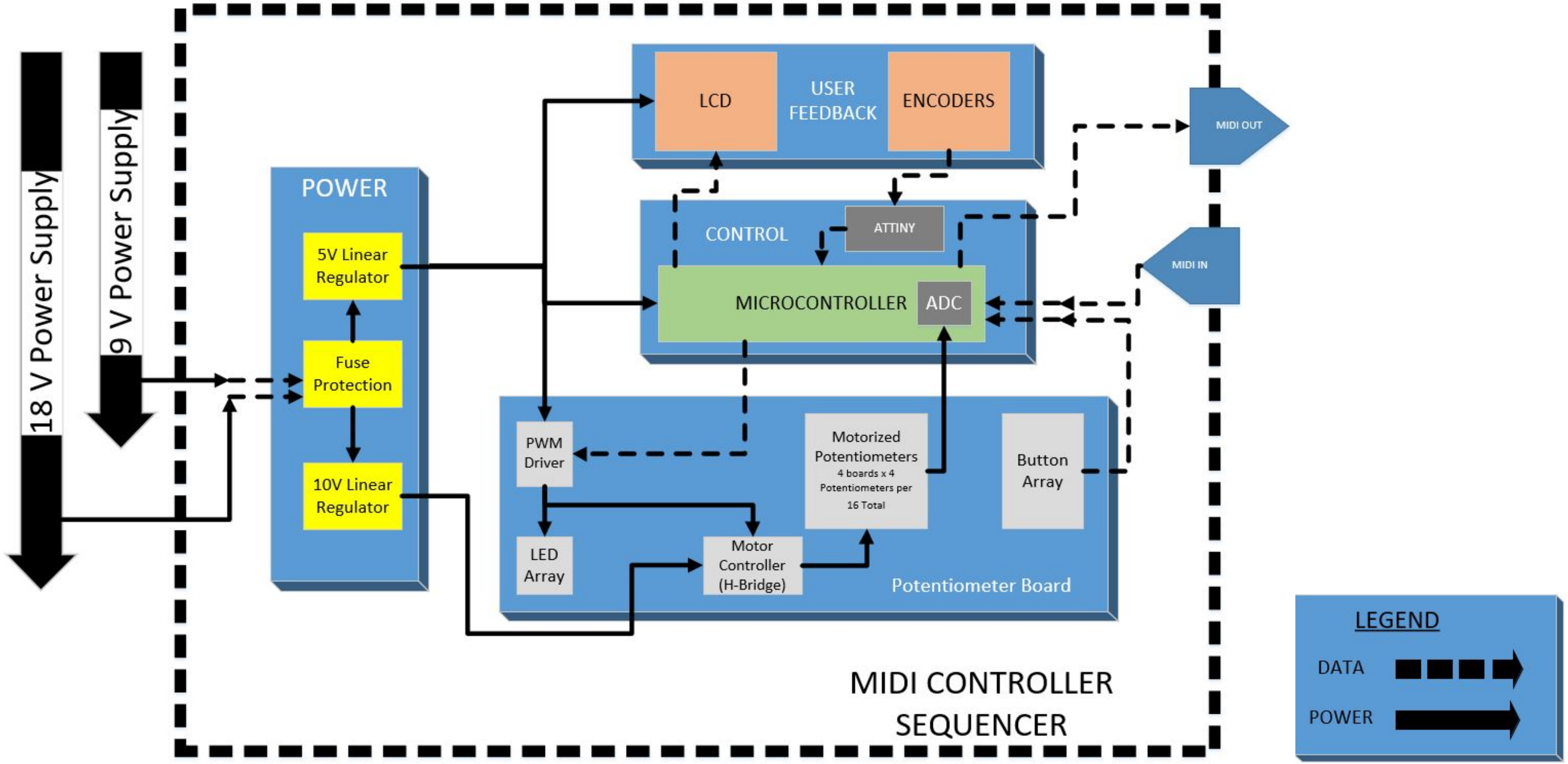
High Level Objectives

- User input data directly affects MIDI OUT data.
- Adaptive potentiometer position: Detents
- LCD screen displays relevant information.
- Potential to be adapted to an easy to build DIY kit
- Capable of fitting into existing rack unit (4U)
- Portability

Current Alternatives

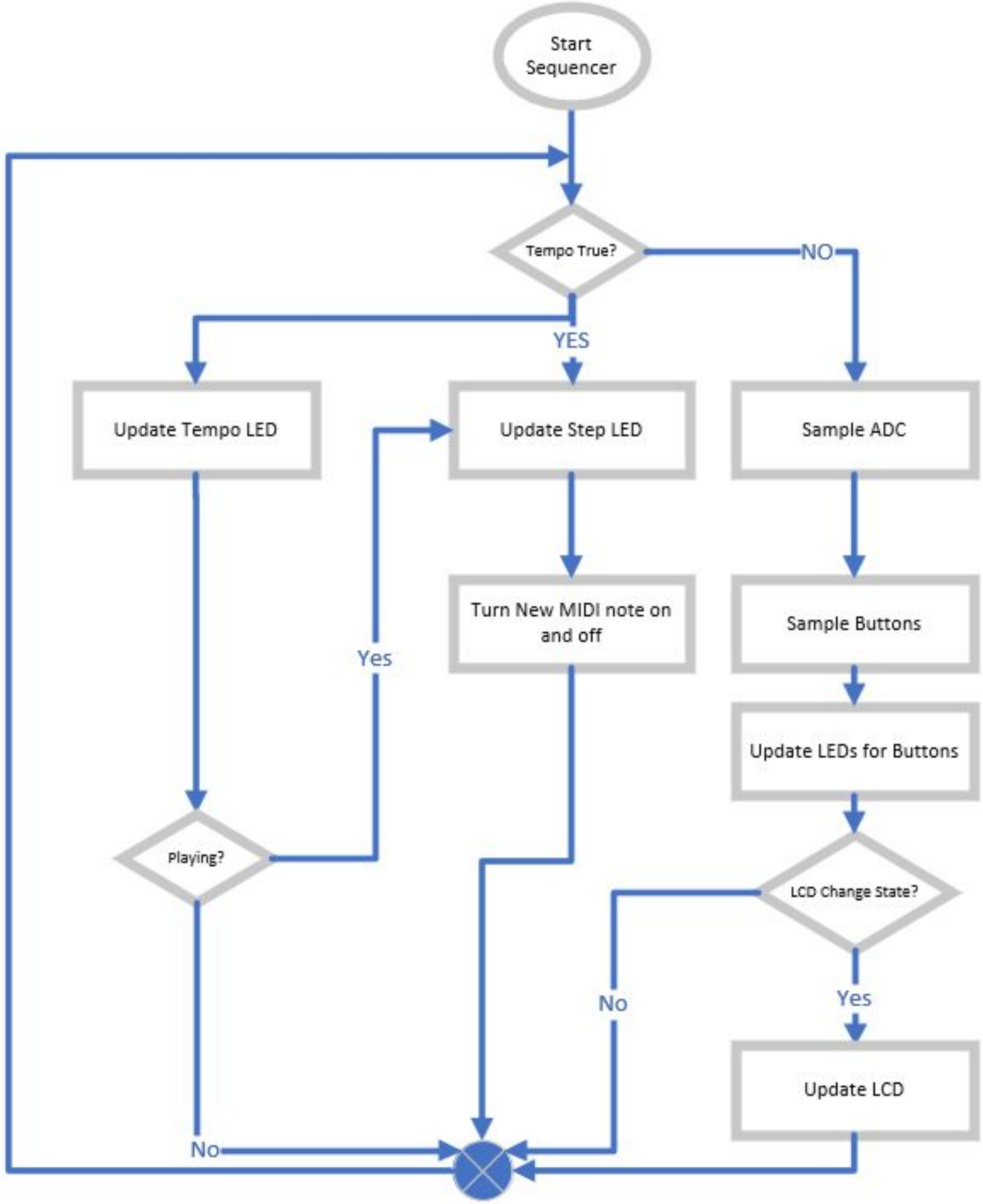
- The market currently offers alternatives with common pitfalls:
  - Difficult to learn
  - Non adaptive user feedback
  - Rarely has a dedicated display
  - Not a useful music theory teaching tool





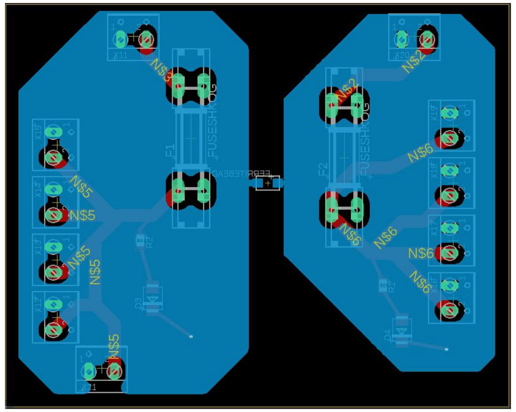
18 V Power Supply
9 V Power Supply
POWER
5V Linear Regulator
Fuse Protection
10V Linear Regulator
LCD
USER FEEDBACK
ENCODERS
CONTROL
ATTINY
MICROCONTROLLER
ADC
MIDI OUT
MIDI IN
PWM Driver
LED Array
Motor Controller (H-Bridge)
Motorized Potentiometers
4 boards x 4 Potentiometers per 16 Total
Button Array
Potentiometer Board
MIDI CONTROLLER SEQUENCER
LEGEND
DATA
POWER

Software Flowchart

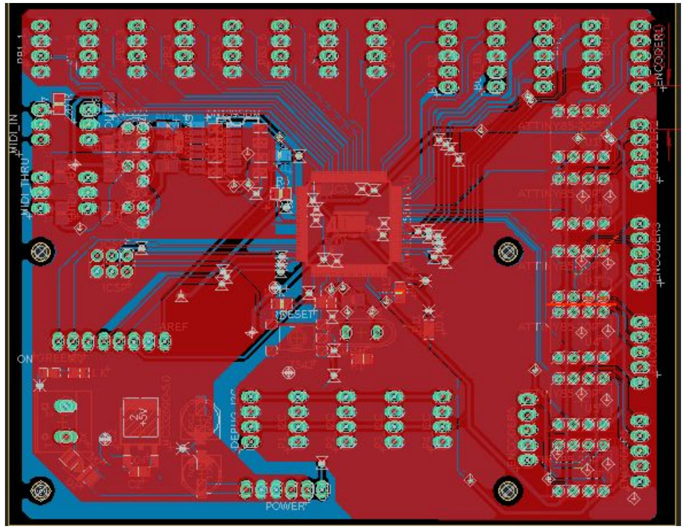


Resulted in 4 PCB Designs

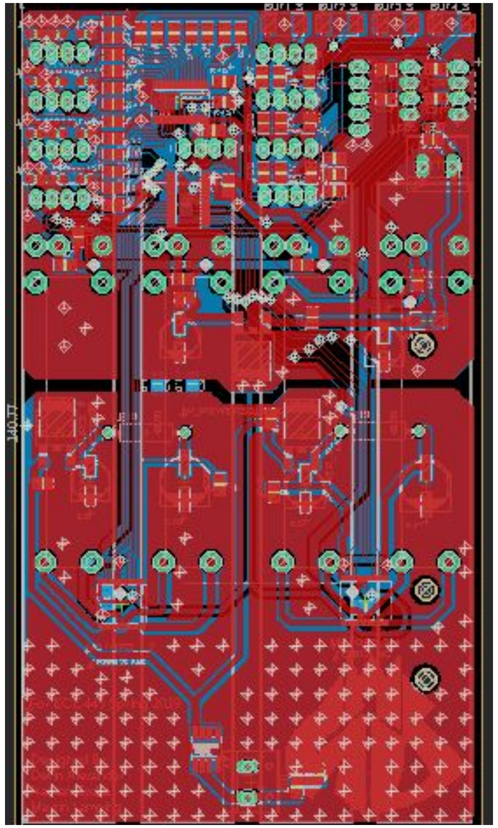
1) Power



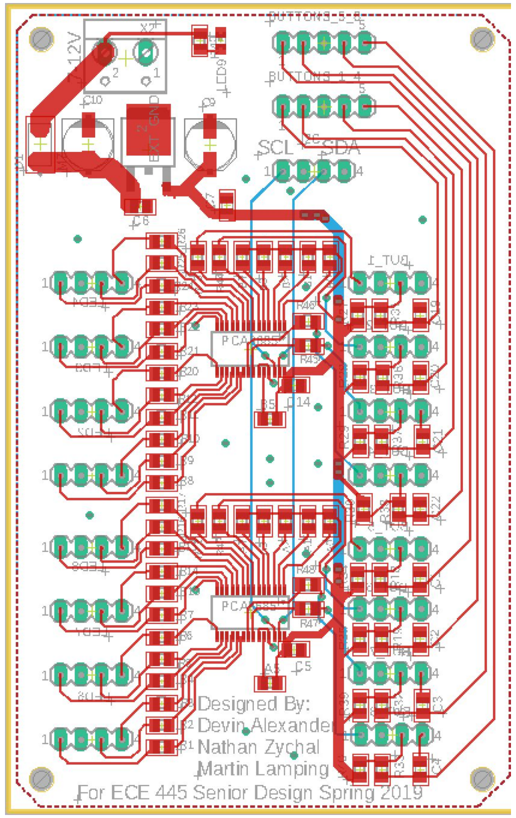
2) Control



3)Potentiometer



4) Auxiliary

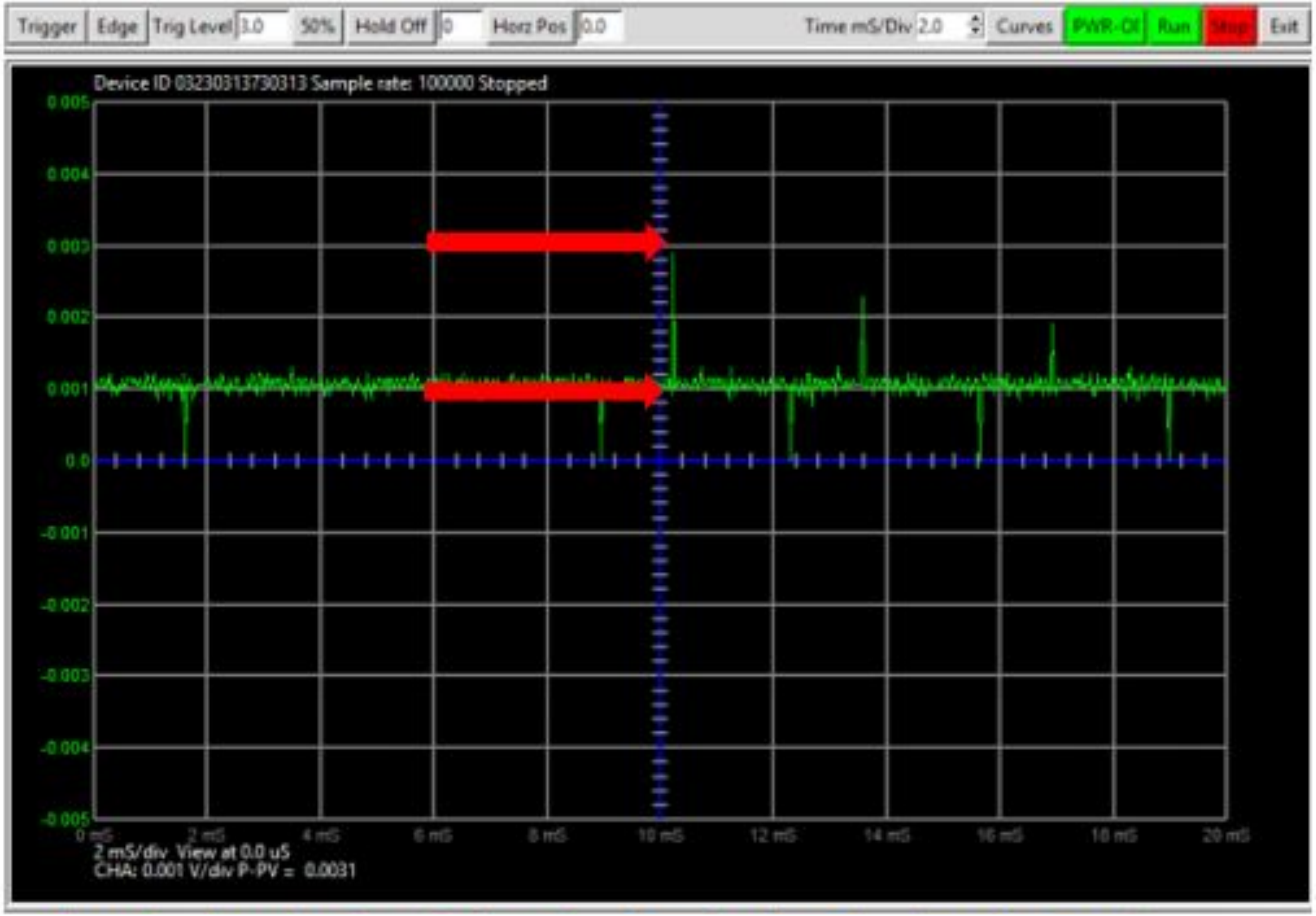


MIDI Background Information

- Musical Instrument Digital Interface (MIDI)
- Common protocol for interacting with multiple musical instruments through one digital interface.
- Popularized in the 1980's
    - First protocol to help connect electronic instruments
    - Still widely used today

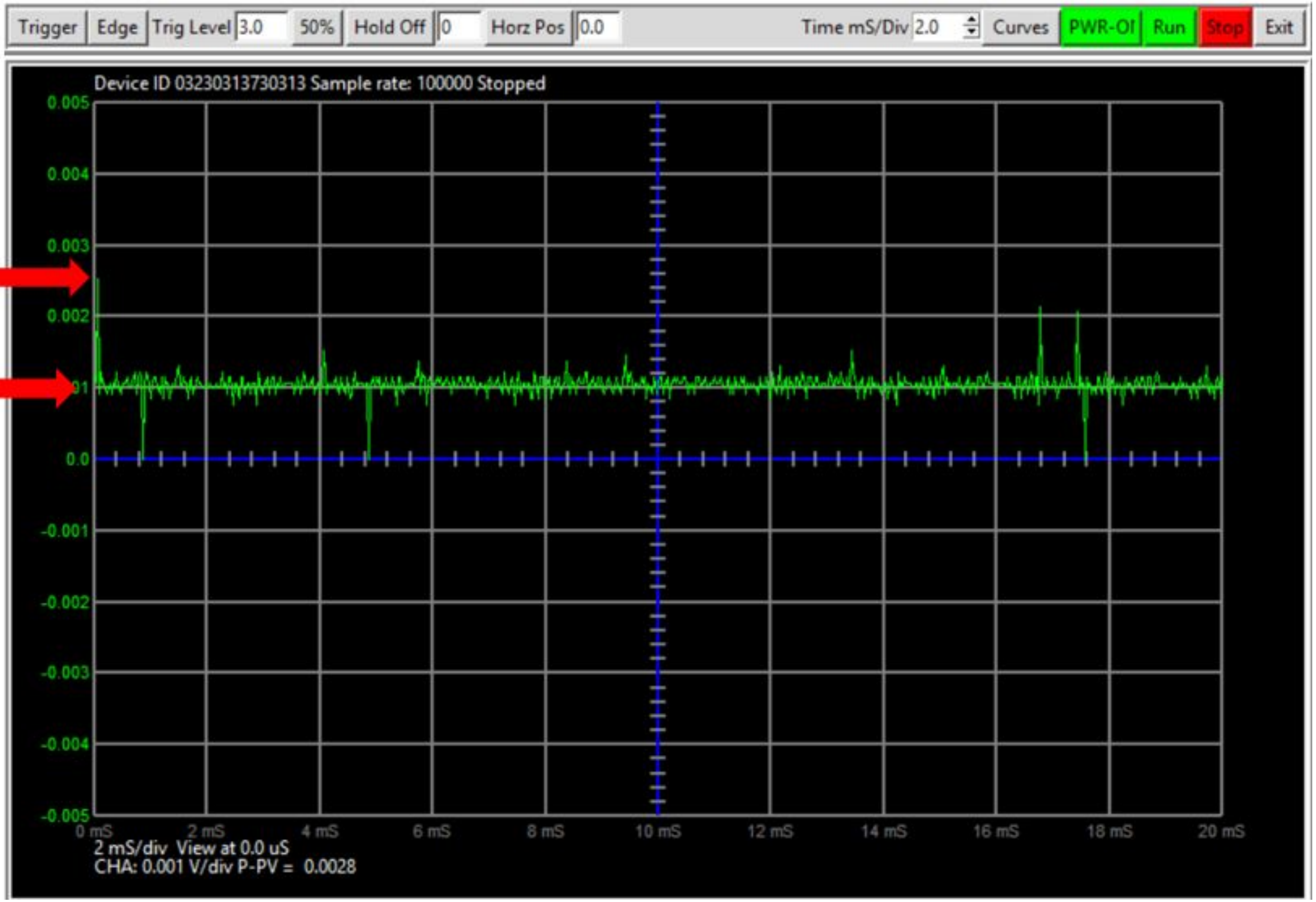
Test/Design Considerations

- EMI Concerns
  - How would 16 motors’ EMI affect readings of nearby potentiometers?
- Timing
  - How would we maintain a constant tempo with other software running?
- Physical dimensions and board spacing
  - How do we make the user interface compact enough to fit standard rack mount?
- Circuit Protection
  - How do we protect components against surge scenarios?



EMI Testing

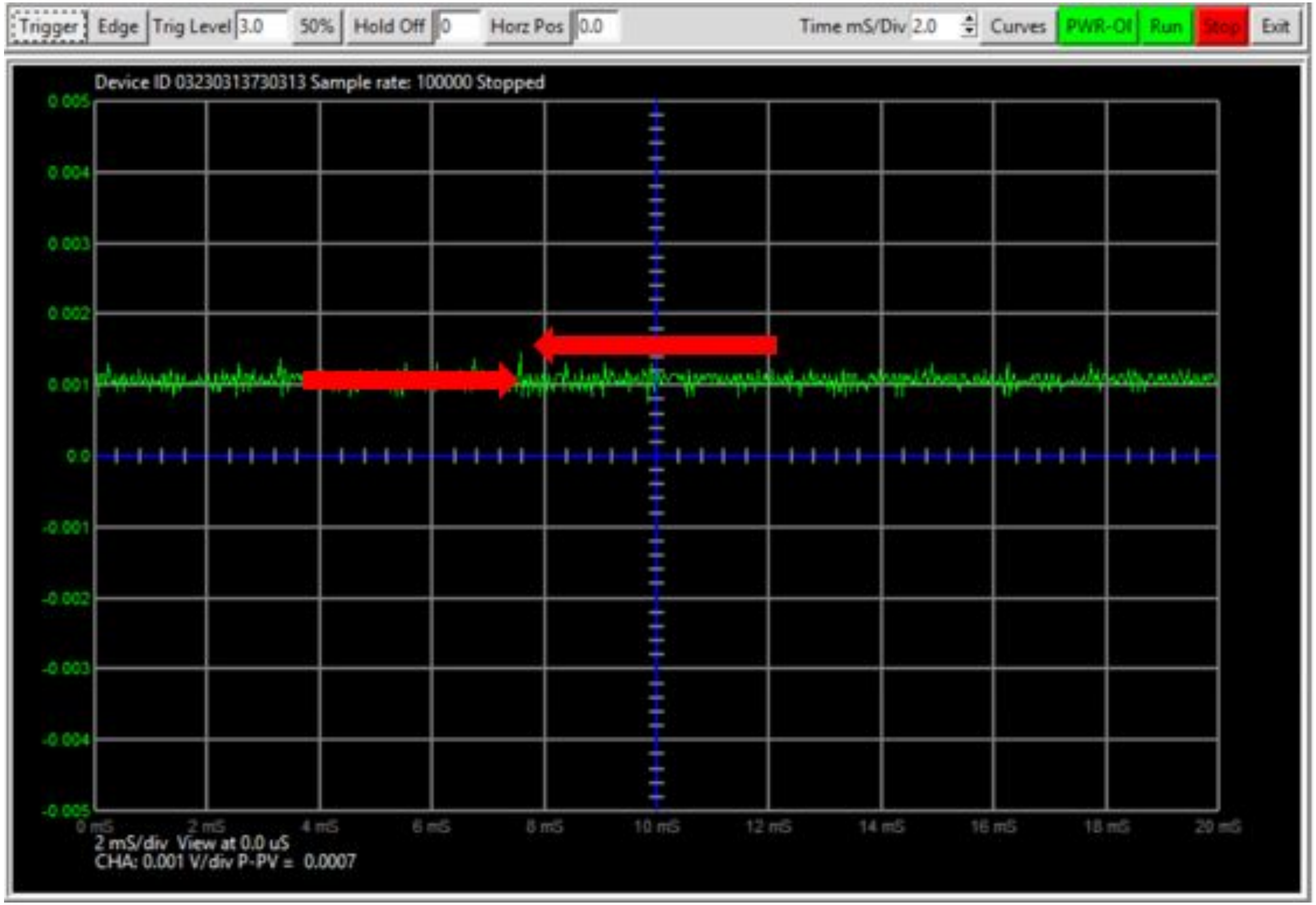
•Test bench description: measured induced voltpikes across 1 KΩ resistor held in worst case scenario below the motor.
•Unshielded PCB test case.
• 2 mV spike in voltage.



EMI Data

- PCB shielded with plastic.
- Result: 1 mV spike in voltage.

EMI Data



- Shielded trial with conductive ground plane.
- Result: There was a complete reduction in induced spike.

Timing Data

- Timing tasks were crucial for successful data handling.

Task	Time (sec)
Sample ADC	108 μs - 1896 μs
Sample Button	108 μs -1896 μs
Change Step LED	3996 μs - 4004 μs
Change Motor	8 ms
Blink Tempo LED	Variable based on BPM
Service Encoders	~ 500 μs
Update LCD Screen	~ 26548 μs

Physical dimensions and board spacing

- User interface
  - We figured out a relative spacing that fits all hardware
  - Space the boards to make it possible to mount in standard form factor
  - Hex standoffs and micro board position was crucial to wiring.

Detents

- Motorized potentiometers provide detent emulation.
- Motors worked successfully with a single potentiometer mock up and single board consisting of four potentiometers.
  - Some of the motors on two boards didn’t work as intended.

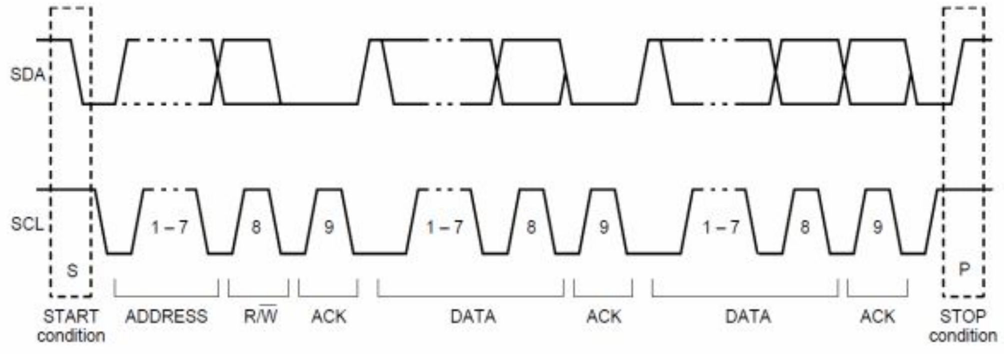
Detent Position Calculation:

Detent spacing = $1024/(Num\ Detents)$

$Num\ Detents$ = 13 for one octave
= 25 for two octaves

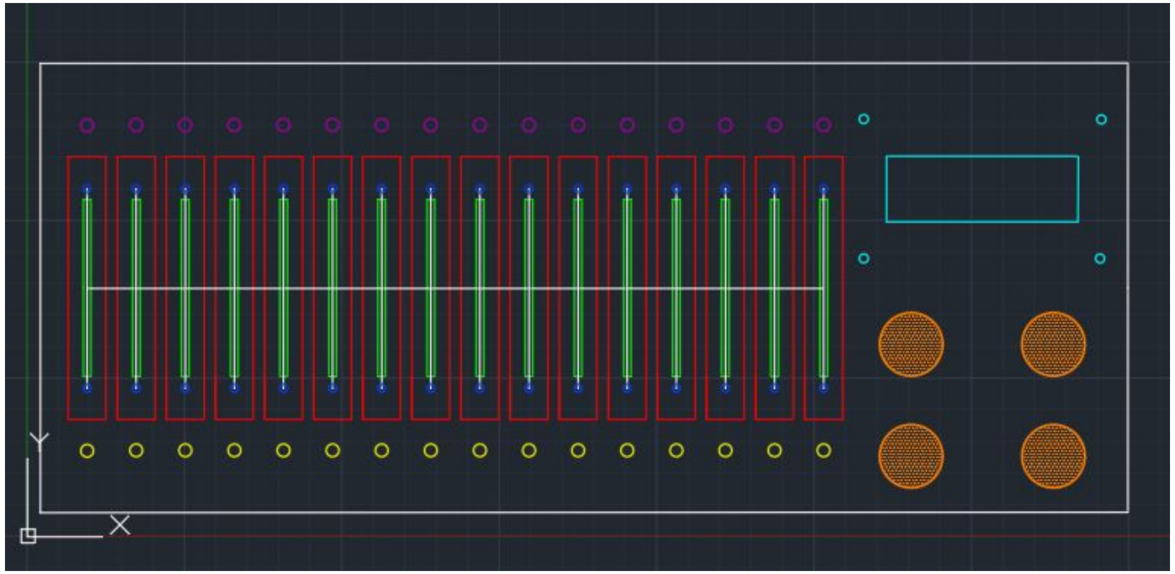
Inter Board Communication (I2C)

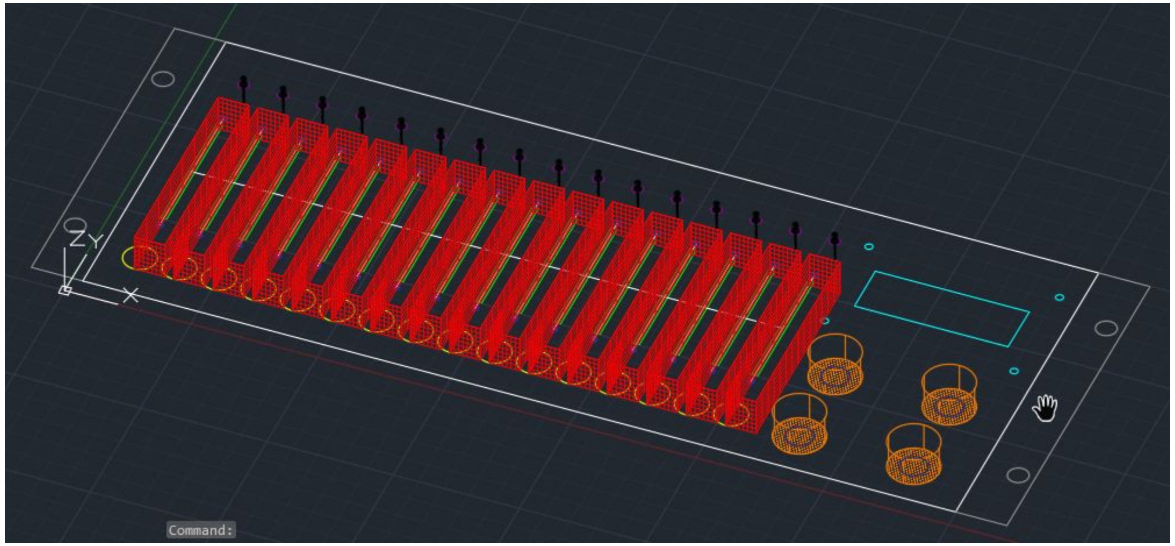
- Addressing is done by soldering shorts to VCC or GND.
- Quick communication between microcontroller board and other boards (non standard use).
- Twisted data with ground lines for equal capacitive loads and no coupling.



Faceplate V1

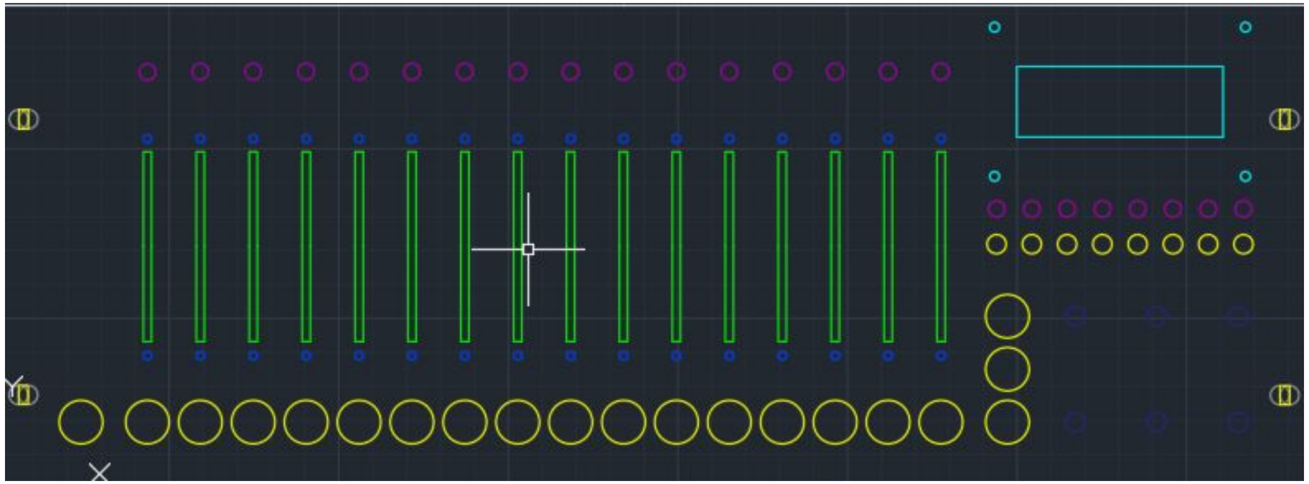
- Initial 2D and 3D model of faceplate.
- This model did not have adequate spacing or sufficient holes for housing all hardware.
- 4U rack unit design.





User Interface

- Fits into 4U rack unit
- User Inputs
    - 16 Motorized Pots
    - Rotary Encoders
    - Buttons
- User Outputs
    - LCD
    - 16 Motorized Pots -> Detents
    - LED Array



Faceplate V2

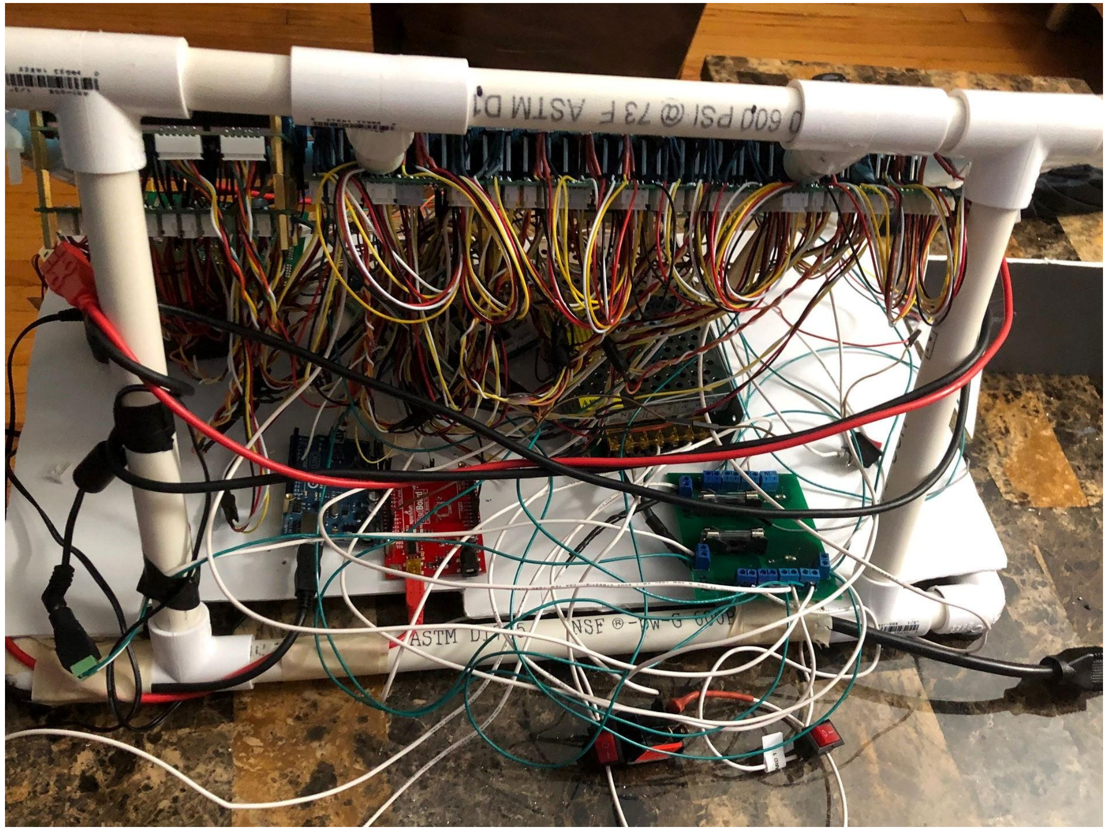
Final Laser Cut Faceplate

Control Module RV

- Supports I2C frequency of 100 KHz
- Sets data on clock rise or fall (due to oscillator).
- digitalread() and digitalwrite() critical for timing.
- Reads interrupts in the form of digital signals.
- Motor logic controlled through analog pins.
- MIDI Circuitry verified

Challenges Encountered

- 1st PCB order delayed
- Soldering by hand
    - ordered stencils for final board run
- Timing
- Software
- Package Identification
- Wiring Complexity
    - High probability for shorting and errant connections



Progress Post Demo

- Fixed timing drift/errors
  - ensured the correct tempo
- Play / Pause
- LED sequence

Conclusions

- **Independently verified and confirmed successful workings of all subsystems:**
  - Microcontroller functionality for LED light up sequence tested and verified.
  - Microcontroller functionality for LED light up button sequence tested and verified.
  - MIDI circuitry tested on separate PCB, tested and verified.
  - Motor controlled via microcontroller tested and verified.
  - LCD fully illuminated and correct display of data tested and verified

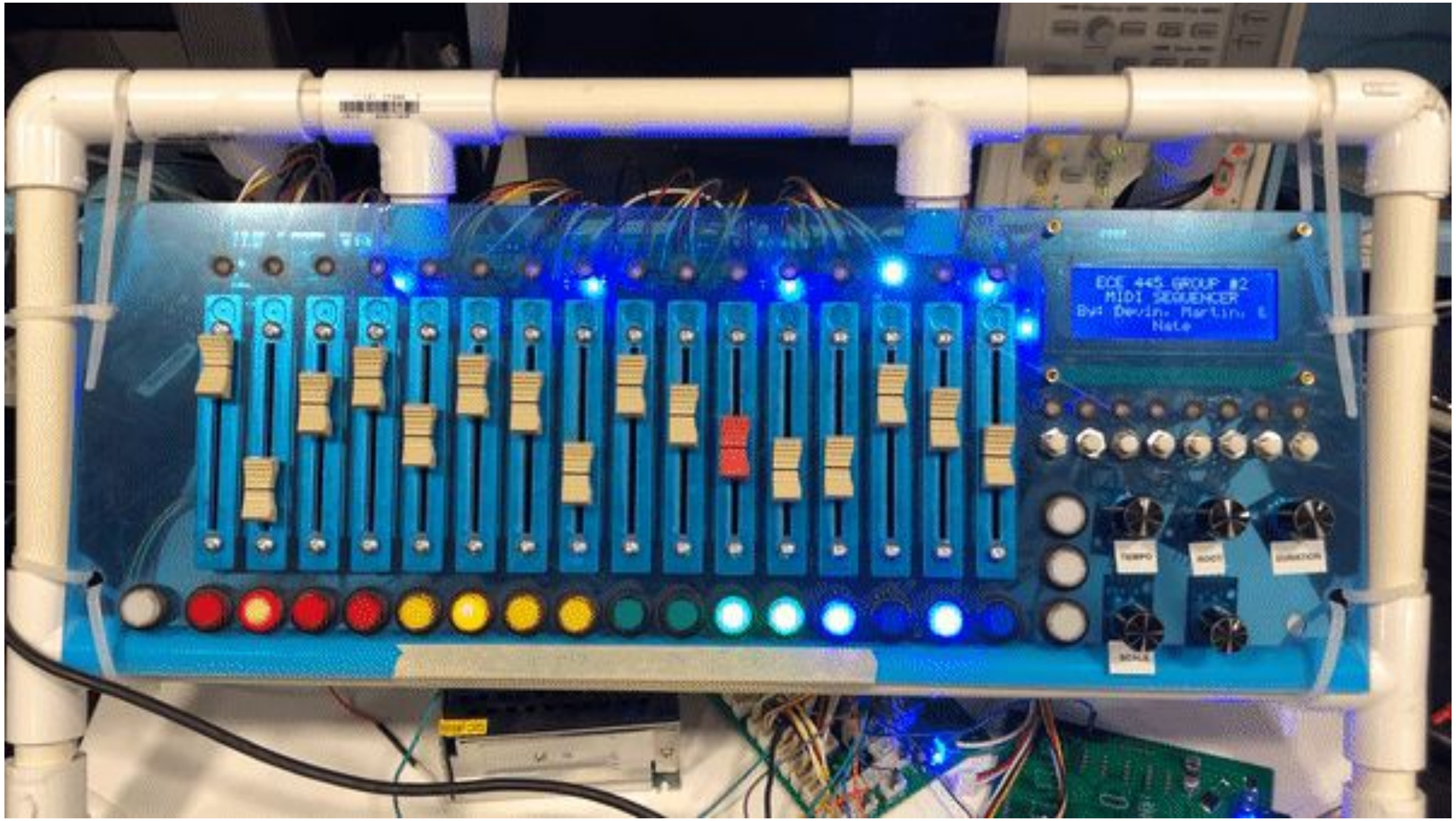
Future Work

- OLED screen
- MIDI circuitry integration with final microcontroller board.
- PID Motor control
- Adaptive potentiometer feedback
- Continuous feedback
- Polyphony
  - Chords
  - Harmonizer

Adaptive Feedback

- This project has the ability to provide continuous feedback
- Generally reserved for analog instruments
- Future project iterations may contain the following :
  - recoil
  - pluck
  - wah

Demo Video



Questions?