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
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.

<table>
<thead>
<tr>
<th>Task</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ADC</td>
<td>108 μs - 1896 μs</td>
</tr>
<tr>
<td>Sample Button</td>
<td>108 μs - 1896 μs</td>
</tr>
<tr>
<td>Change Step LED</td>
<td>3996 μs - 4004 μs</td>
</tr>
<tr>
<td>Change Motor</td>
<td>8 ms</td>
</tr>
<tr>
<td>Blink Tempo LED</td>
<td>Variable based on BPM</td>
</tr>
<tr>
<td>Service Encoders</td>
<td>~ 500 μs</td>
</tr>
<tr>
<td>Update LCD Screen</td>
<td>~ 26548 μs</td>
</tr>
</tbody>
</table>
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 standoff 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:

\[
\text{Detent spacing} = \frac{1024}{(\text{Num Detents})}
\]

\[
\begin{align*}
\text{Num Detents} &= 13 \quad \text{for one octave} \\
                   &= 25 \quad \text{for two octaves}
\end{align*}
\]
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?