Haptic Piano Instructional Gloves

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Megan Mileski
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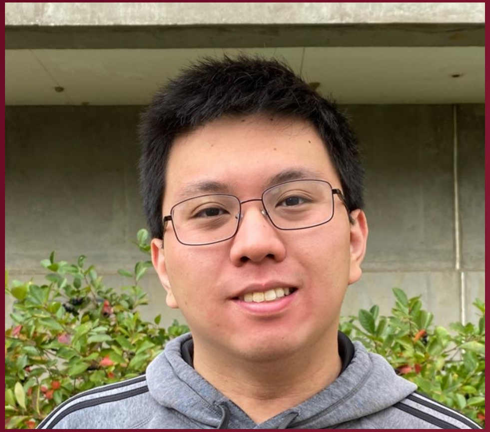
BE REVOLUTIONARY™

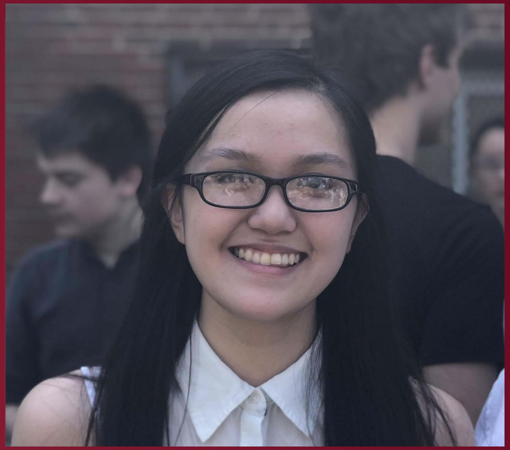
Team 11



Neil Guan
Electrical Engineer

Megan Mileski
Electrical Engineer

Prepsa Ghimire
Electrical Engineer



Paulina Vu
Computer Engineer

Professor Anderson
Advisor

Problem Statement

Piano is notoriously difficult to learn for several reasons:

- Sheet music does not show the correct fingerings corresponding to which keys to press.
- Sheet music also requires a large amount of memorization and music theory background.
- A great deal of time, effort, and patience is required

Especially for beginners, piano can be a daunting instrument to learn. The mental processing between knowing which keys to press and in what order requires intuition. The memorization, music theory knowledge, and time commitment to learn piano can be discouraging to those wanting to learn the instrument.

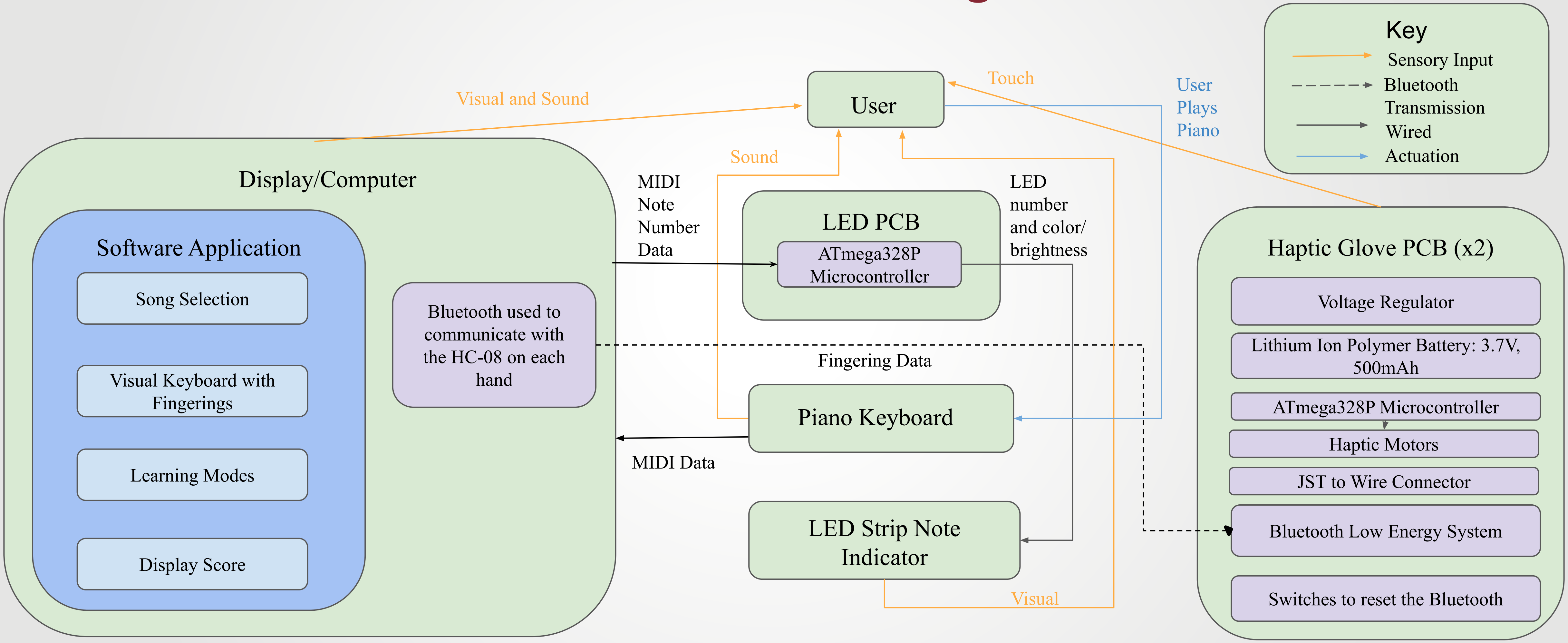
Our Solution: Haptic Piano Instructional Glove

Solution Explanation

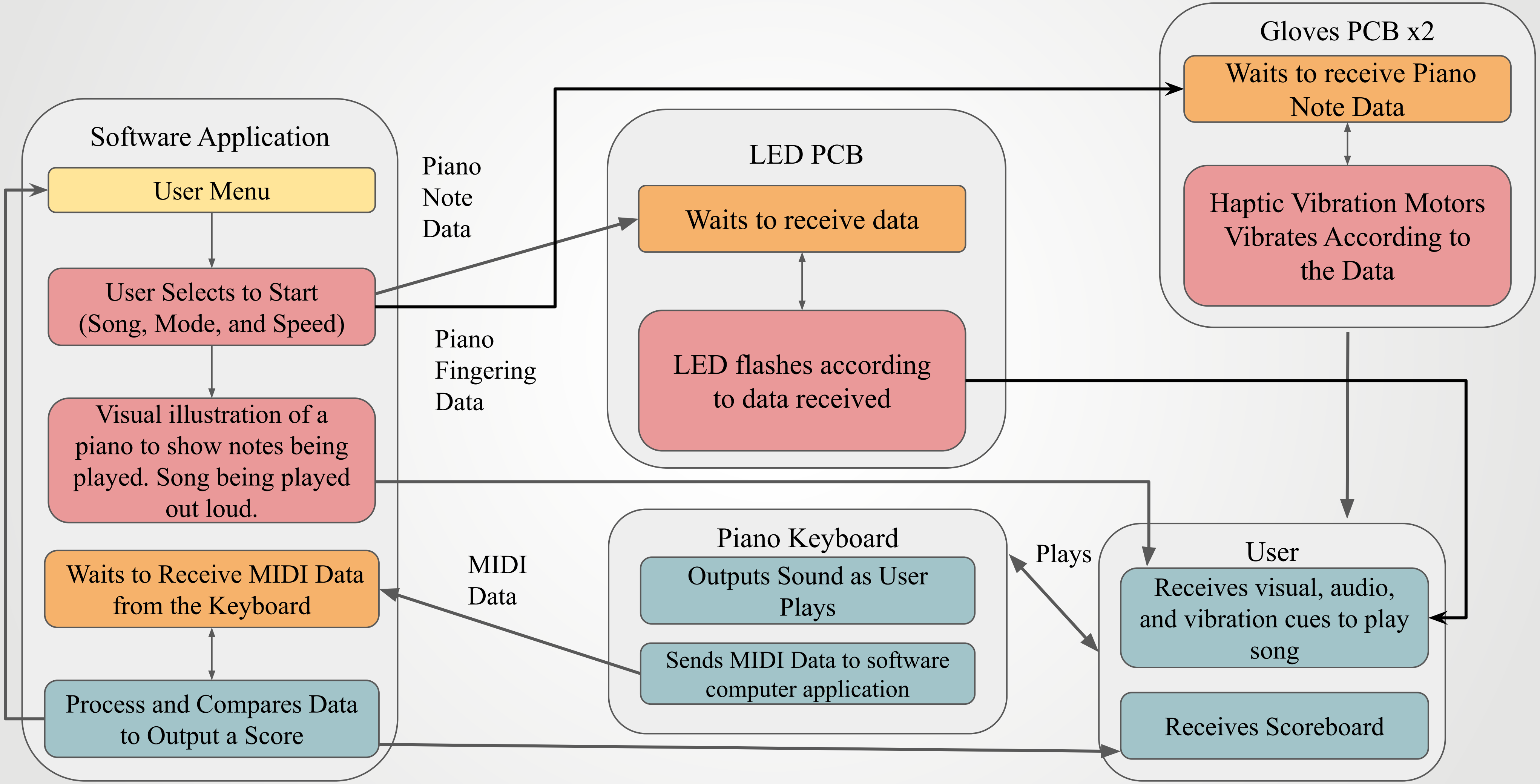
Haptic Piano Instructional Glove addresses issues that come with learning how to the piano by:

- Teaching the pianist to play the piano without sheet music
- Providing the pianist feedback on his/her playing
- Helping the user learn while not actively playing the piano
- Engaging multiple of the pianists' senses in real time whilst playing a song--namely touch, vision and sound for active learning

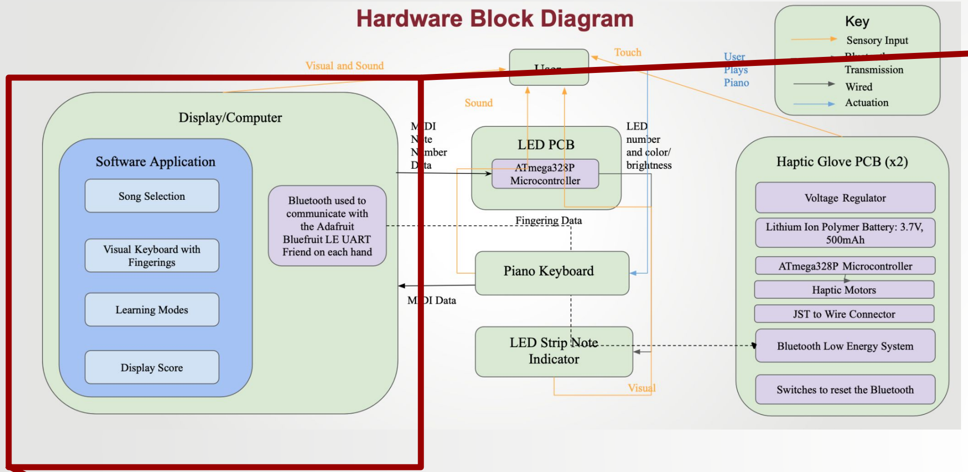
Hardware Block Diagram

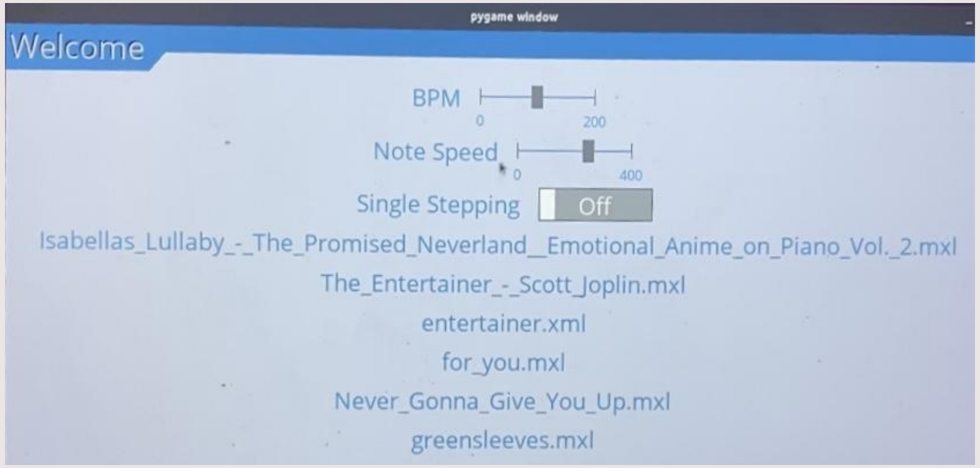


Software Block Diagram



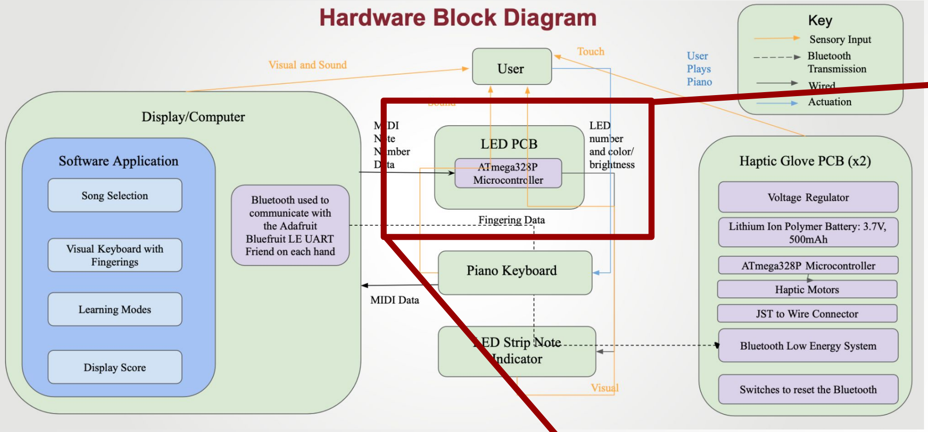
Display/Computer

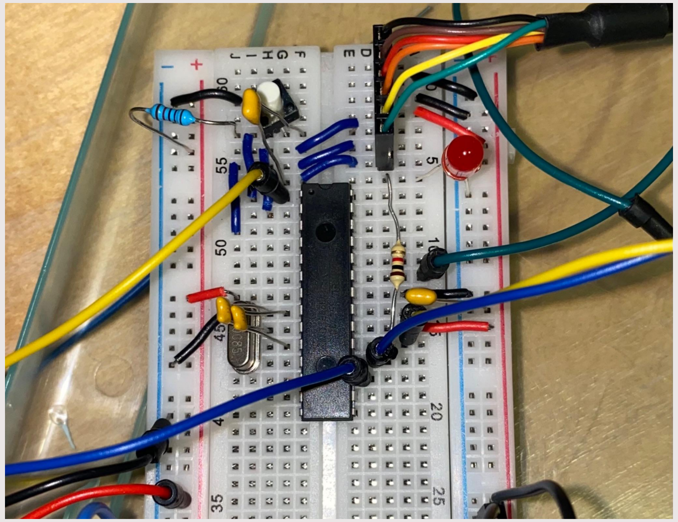




- Selection menu using pygame
- Sends Fingering Data via Bluetooth and MIDI note number data via FTDI Converter Cable
- Allows player to control:
  - Beats Per Minute
  - Note Speed
  - Single Stepping
  - Song Selection

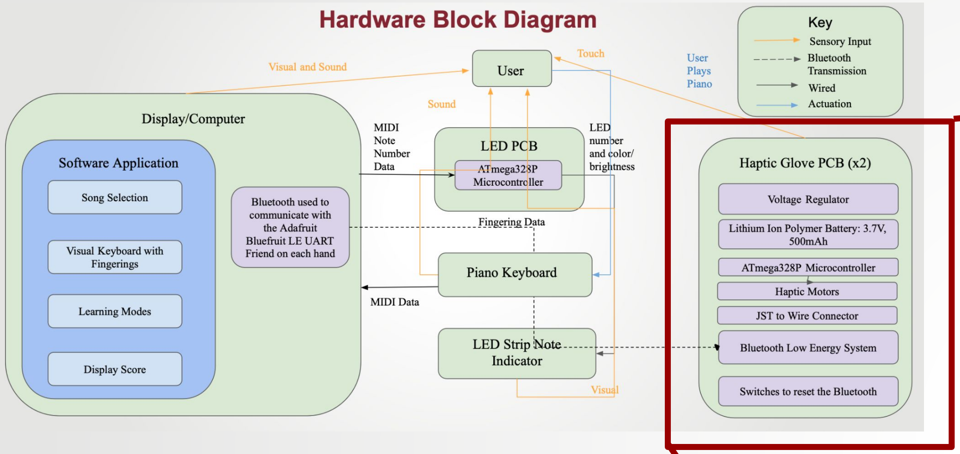
LED PCB

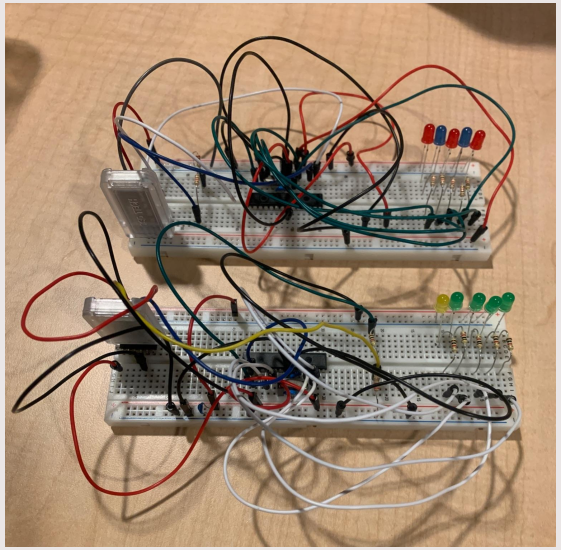




- Atmega328p Microcontroller
- USB to Serial Cable
- Functions:
  - Receives converted Note Numbers (36 - 96) (from pitch (A0 - C8) values) from python via serial communication
  - C++ code receives ASCII value then turns on LED number accordingly

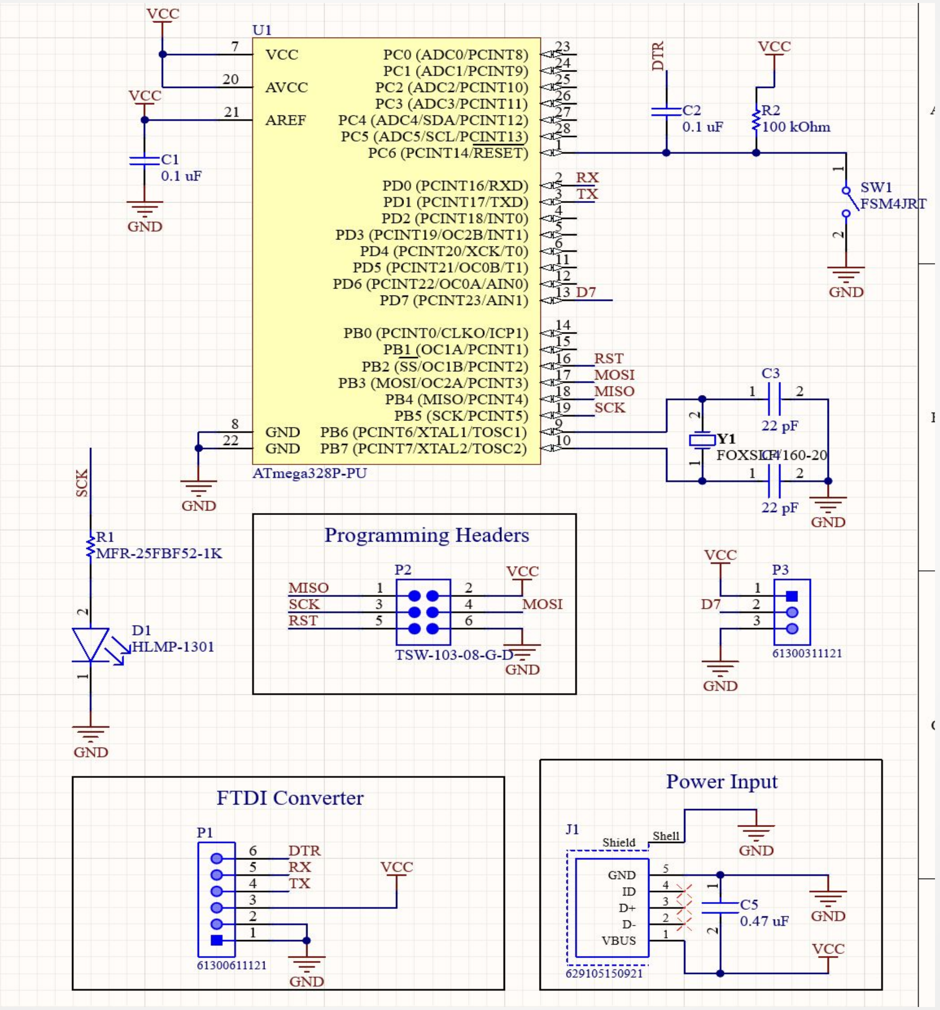
Hand PCB(s)



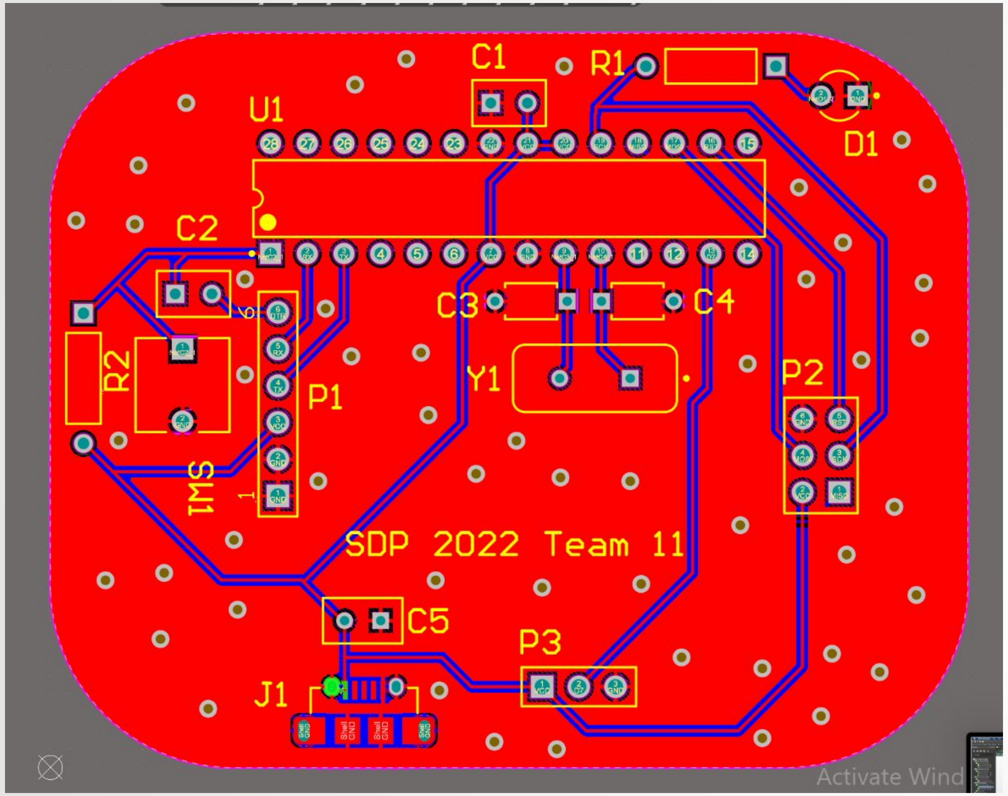


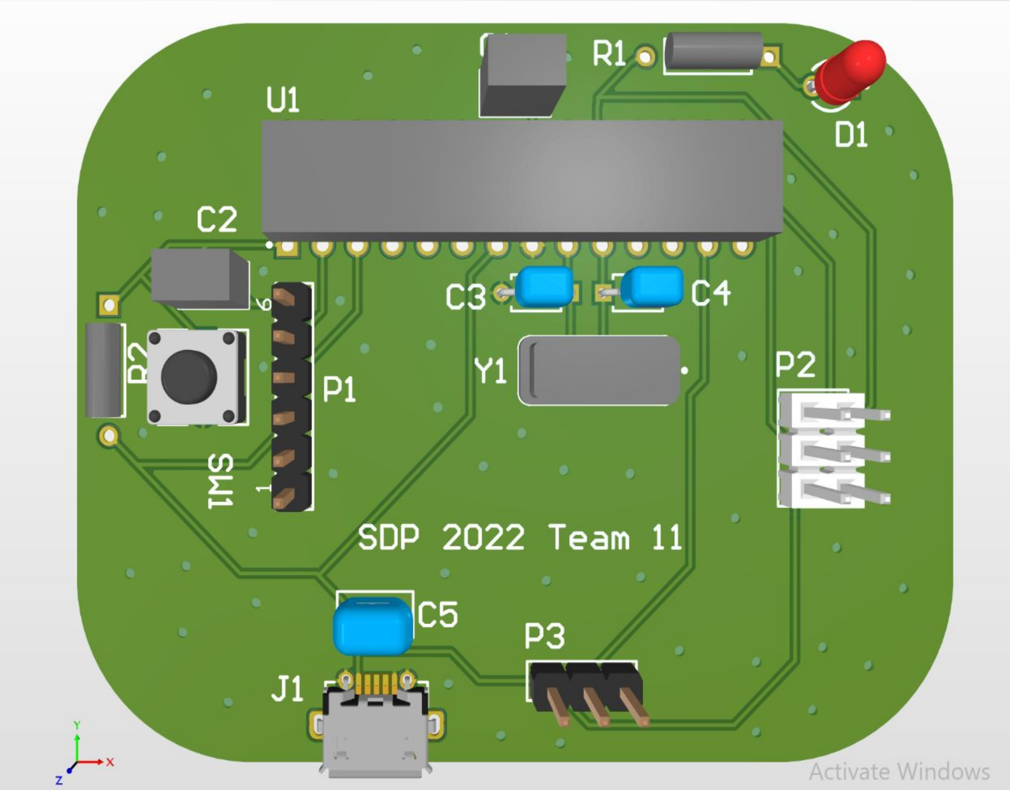
- Atmega328P Microprocessor
- HC-08 Bluetooth Component
- Voltage Divider (1KΩ and 2.2KΩ)
- Haptic Motors (LEDs used here for Demo)
- Functions:
  - ATmega328P receives transmitted data over bluetooth and drives the corresponding GPIO pin(s)

LED PCB Schematic

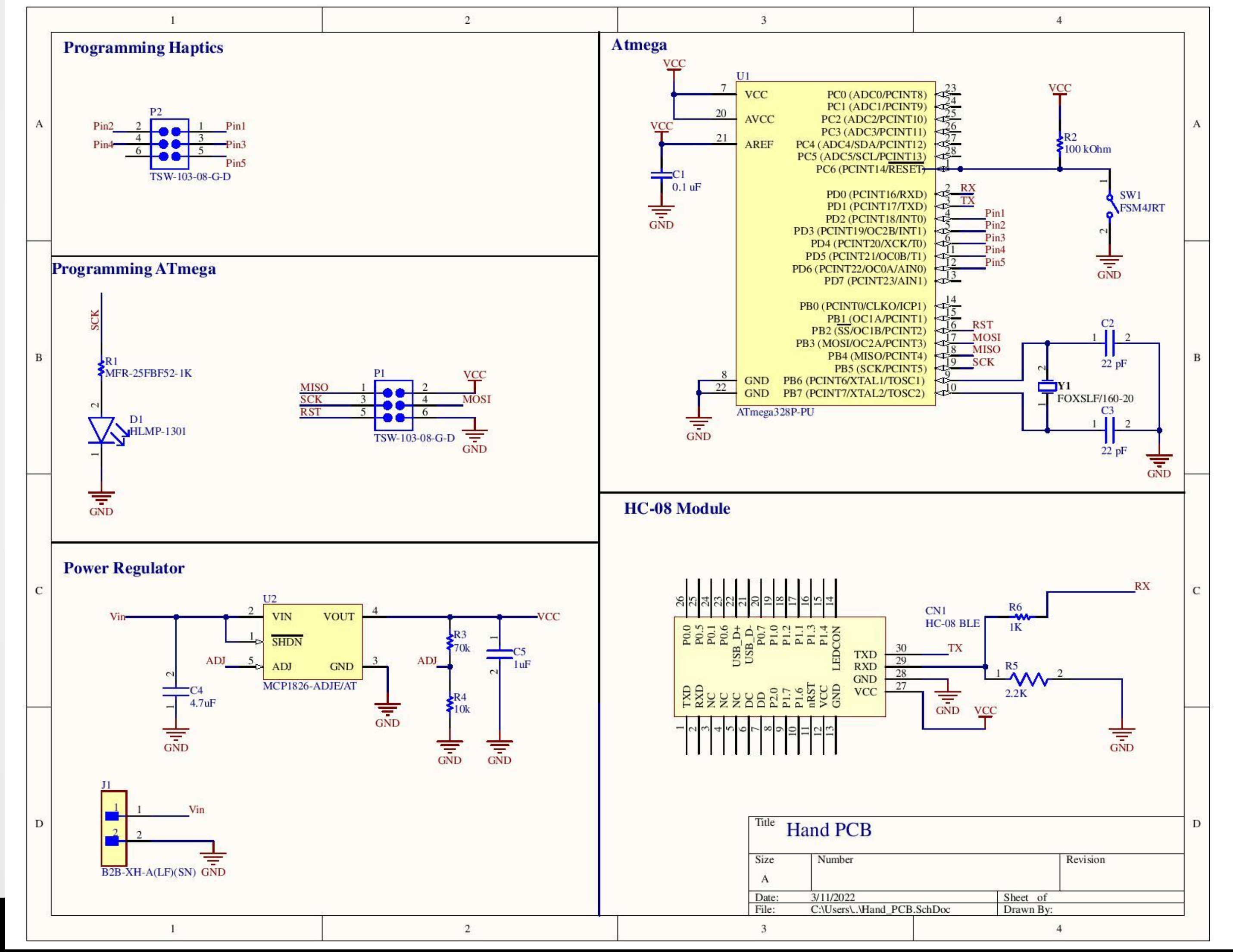


LED PCB

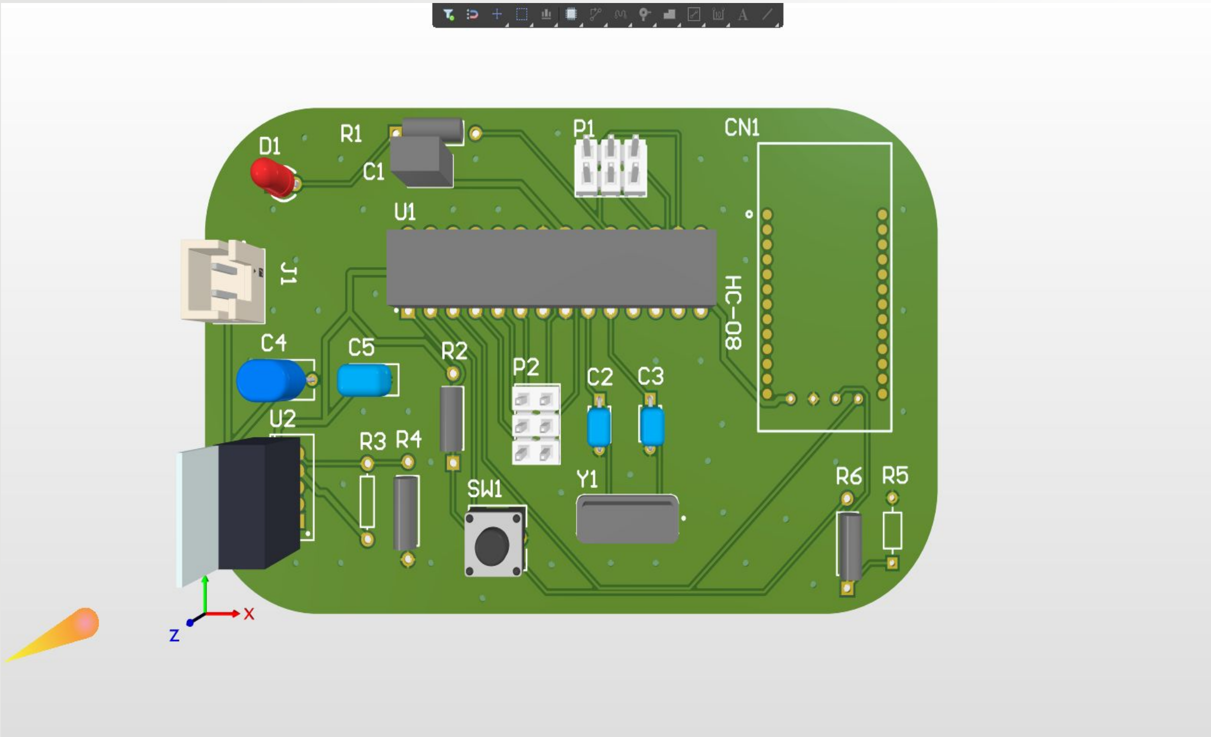

C1
R1
U1
D1
C2
C3
C4
R2
P1
Y1
P2
SW1
SDP 2022 Team 11
C5
P3
J1
Activate Wind

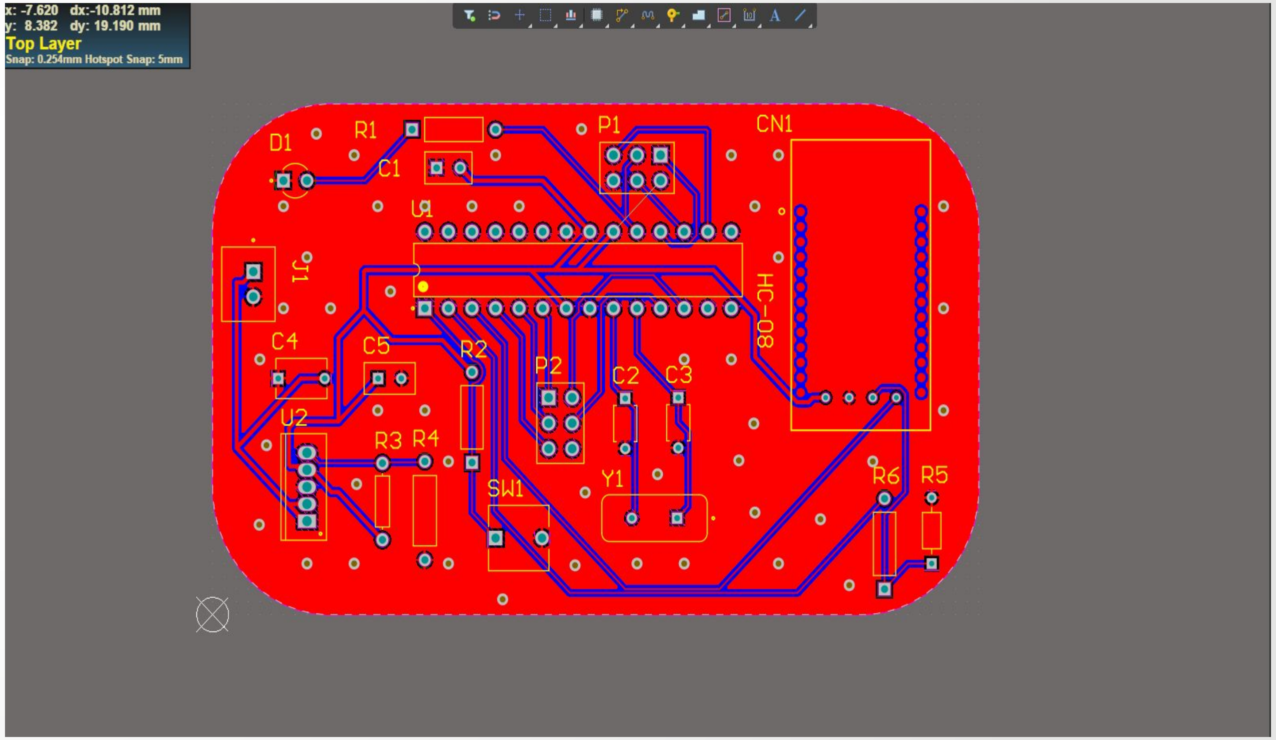

R1
U1
D1
C2
C3
C4
P1
Y1
P2
SW1
SDP 2022 Team 11
C5
P3
J1
Activate Windows

Hand PCB Schematic



Hand PCB


D1
R1
C1
P1
CN1
U1
J1
HC-08
C4
C5
R2
P2
C2
C3
U2
R3 R4
SW1
Y1
R6 R5


x: -7.620 dx:-10.812 mm
y: 8.382 dy: 19.190 mm
Top Layer
Snap: 0.254mm Hotspot Snap: 5mm
D1
R1
C1
P1
CN1
U1
J1
HC-08
C4
C5
R2
P2
C2
C3
U2
R3 R4
SW1
Y1
R6 R5

HC-05 vs. HC-08 Bluetooth Component

HC-05

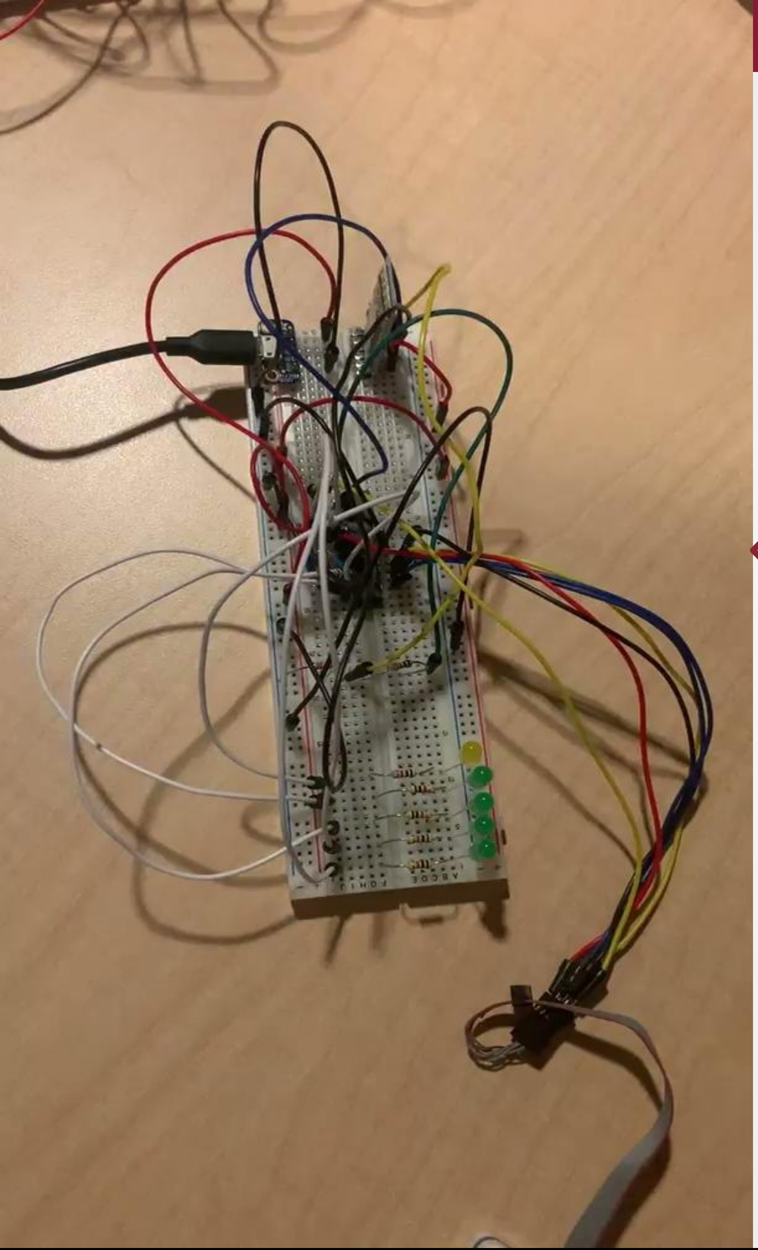
HC-08

- Previously used Adafruit Bluetooth LE Friend
- Needed to find an SMD Bluetooth package
- Needed to decide between bluetooth 2.0 and BLE(Bluetooth Low Energy)/Bluetooth 4.0
- HC-05 uses bluetooth 2.0 protocol
- HC-08 uses bluetooth 4.0 (BLE) Protocol

Results from Prototyping

- **HC-05 with Bluetooth 2.0 protocol:**
  - Had unpredictable transmission delay between bytes
  - The more complex and fast a song became the more packets were getting dropped and then the program would fail

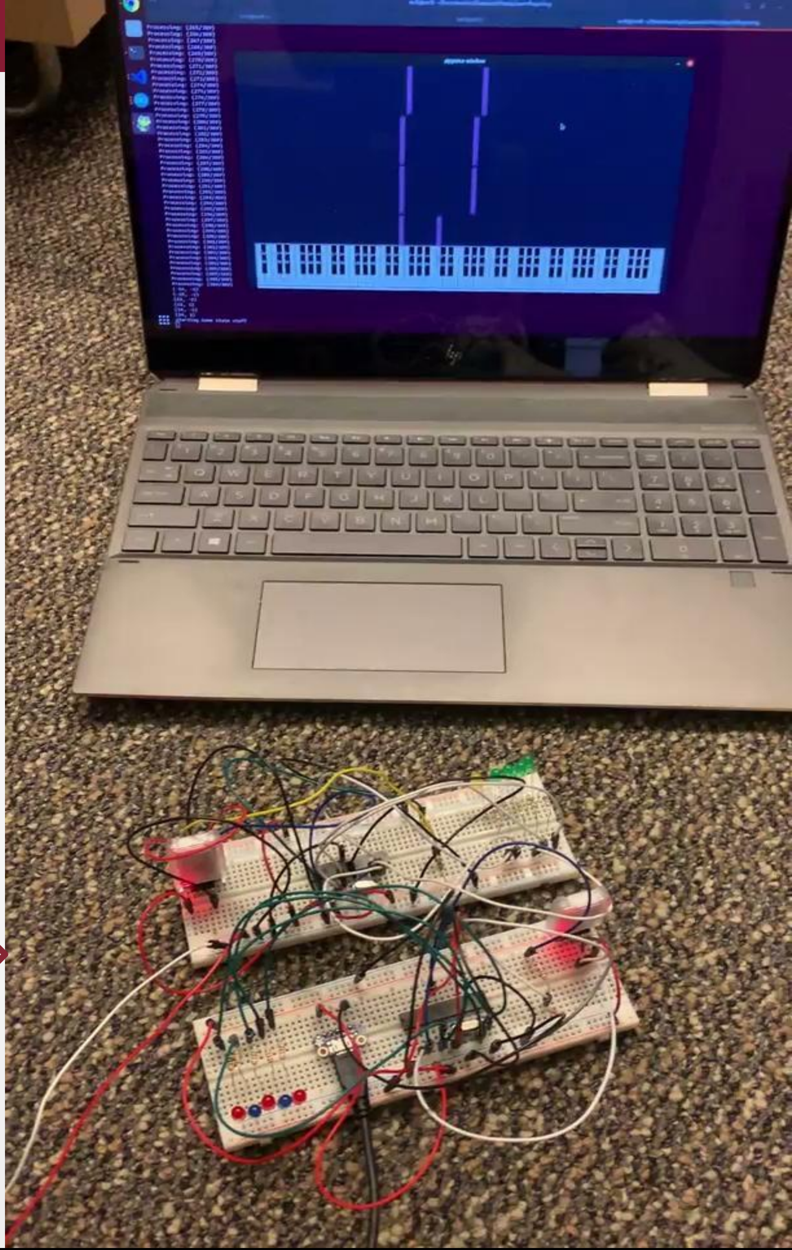
- **HC-08 with BLE/Bluetooth 4.0 protocol:**
  - No observable transmission delays
  - No packet dropping even with the fastest and most complex songs tested



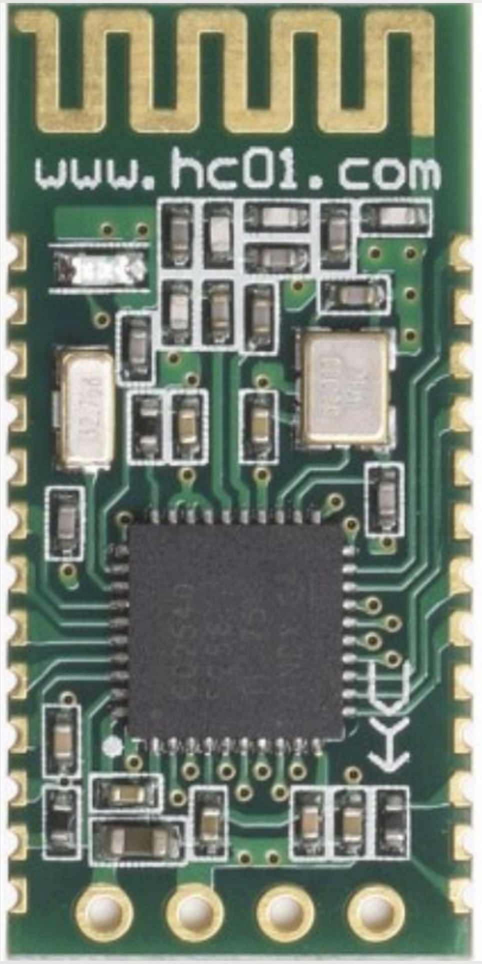
Video Comparison of HC-05 vs. HC-08

Bluetooth: HC-05
Protocol: Bluetooth 2.0

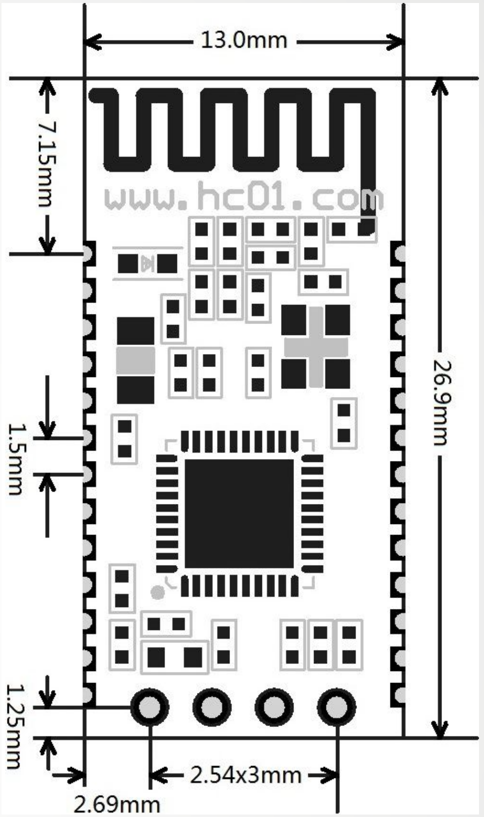
Bluetooth: HC-08
Protocol: BLE 4.0

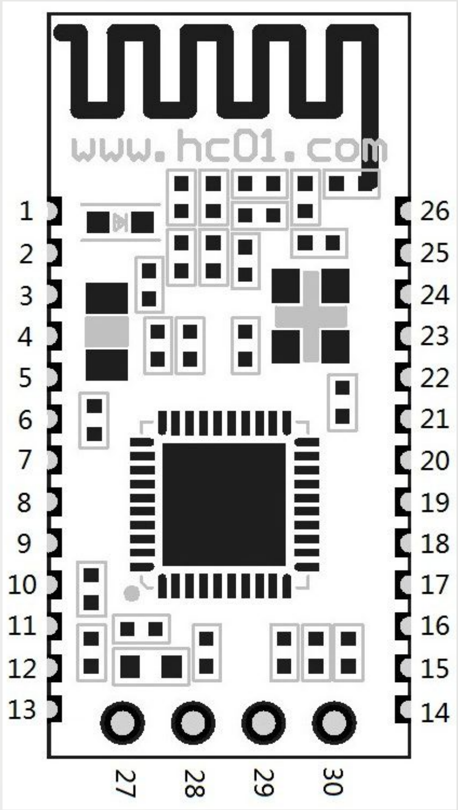


HC-08 SMD



- Surface Mount Device
- 30 pin component
- CC2540 MCU by Texas Instruments
- small size convenient for mounting on glove
- 3.3V voltage across pins RXD and TXD
- Voltage divider required to change 5V to 3.3V
    - 1KΩ
    - 2.2KΩ





Small in size: longest edge is 26.9mm = 1.1 inches

Pin 27: VCC
Pin 28: GND
Pin 29: RXD
Pin 30: TXD

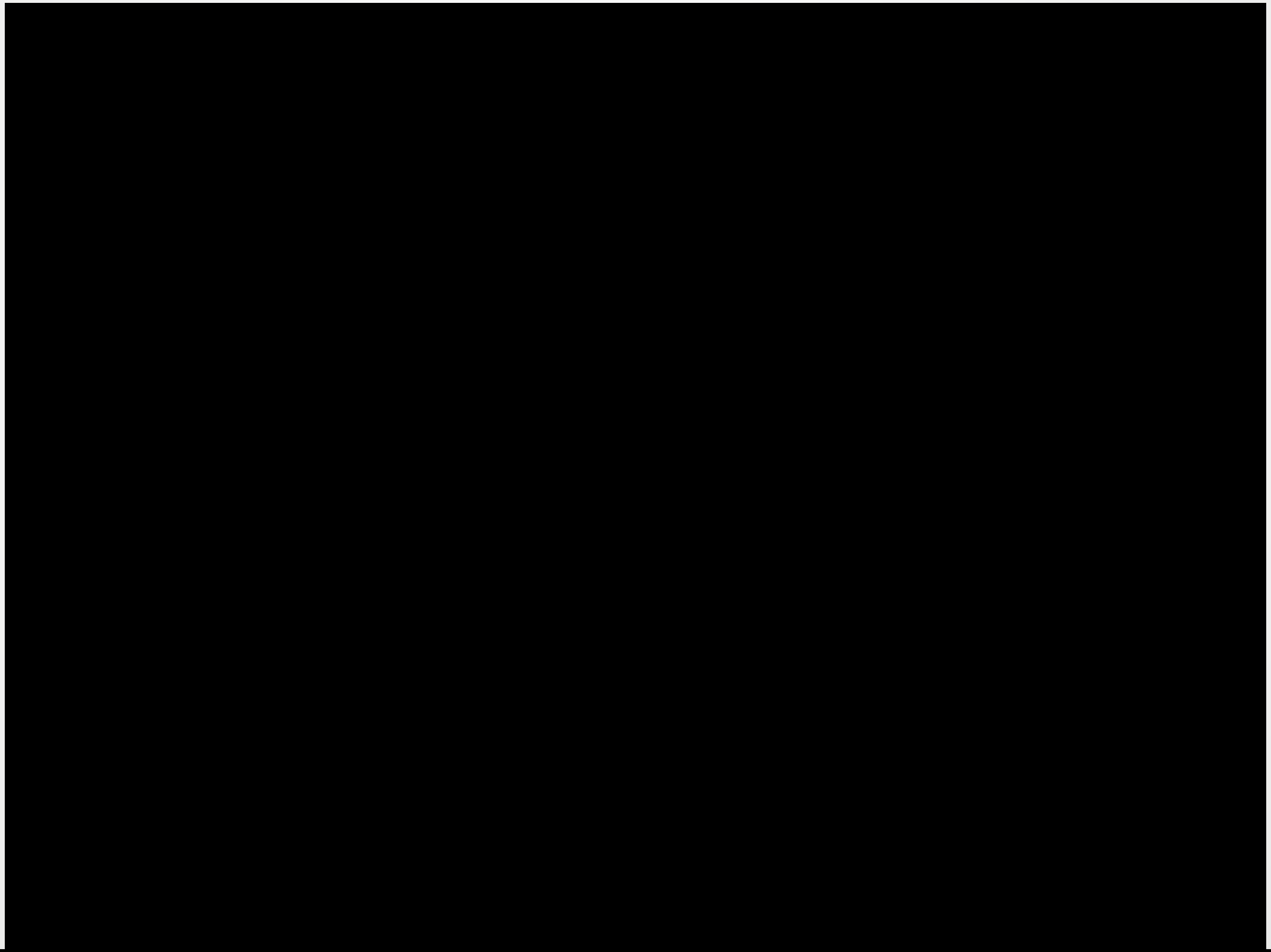
System Specifications + Verification

The gloves are fashioned to be secure and doesn't hinder the player's ability to bend his/her joints.	Players will be able play the piano without any hindrance or discomfort. ● Inspection: Surveys will be conducted to gather user experience on comfort and mobility while playing the piano.
The system is designed to be replicable for a piano with different key sizes.	The system is currently built to create a piano with 61 keys. This system can be modified to fit a different number of keys. ● Demonstration: Alterations of the code and LED strip will allow system to fit any keyboard size.
The system provides the pianist with haptic feedback indicating which finger the pianist must use within 100 ms.	Players will be able to use the glove and feel the haptic vibrations. which indicates what finger they should use to play the notes. ● Inspection: Surveys will be conducted to gather user experience on the strength, timing, and effectiveness of the motors.
The system provides the pianist with visual feedback indicating which keys to press within 100 ms.	The user will have a visual illustrations that will indicated to them what keys they should press and for how long. ● Demonstration: Surveys will be conducted to gather information on how effective the GUI is at helping learn how to play.

System Specifications + Verification

The system provides the pianist with auditory assistance on his/her playing within 100 ms.	Players will hear the song selected play while they are practicing the piano. This vocal cue allows for the users to "hear" if they are playing the notes on beat. ● Analysis: A timer will be used to compare the length of how long the song was playing with the length of the actual song.
The system is designed to have less than 100 ms of latency between the user and the system.	Players will be able to view/play/feel/listen to all of the systems synchronously. ● Inspection: Surveys will be conducted to gather user experience on the latency between the systems.
The gloves have a range of at least 5m.	After choosing all the setting on the user menu, the player will be able to move at least 5 meters away from the computer with the gloves and will still be able to play the piano. ● Demonstration: Each member will test the maximum distance they can move away from the computer to gather average maximum distance.
The gloves have a battery life of at least 1 hour.	The system will be able to continuously play for roughly 60 minutes without issues. ● Inspection: Variety of songs will be played for an hour to see if the battery is still powered.

Video of Integration of GUI, LED Strip & Haptic Circuit



Systems Specifications Met/To Be Met

The gloves are fashioned to be secure and doesn’t hinder the player’s ability to bend his/her joints.
The system is designed to be replicable for a piano with different key sizes.
The system provides the pianist with haptic feedback indicating which finger the pianist must use within 100 ms.
The system provides the pianist with visual feedback indicating which keys to press within 100 ms.
The system provides the pianist with auditory assistance on his/her playing within 100 ms.
The system is designed to have less than 100 ms of latency between the user and the system.
The gloves have a range of at least 5m.
The gloves have a battery life of at least 1 hour.

FPR Plan: Planned FPR Version of the System

- Perfected glove construction that is light and allows for joint mobility
- Synchronization of all the subsystems without noticeable delay
- User performance report display
- Large song selection
- Custom PCBs implemented

Changes from current prototype to FPR version:

- We haven’t committed to a specific glove design
- We haven’t finished implementing the custom PCBs
- We haven’t integrated the scoring
- We will add more songs to the selection menu

FPR Plan: Plan for FPR Demonstration

On the table will be:

1. The keyboard piano with the LED strip on it
2. A laptop that will be doing the bulk of the data processing
3. 2 gloves with the haptic motors and custom PCB driving them
4. LED strip custom PCB

The demonstration will consist of a team member wearing the gloves and playing along to a song to show the complete system effectiveness and robustness. The user will navigate the selection menu and play the song on the piano keyboard. The user will receive guidance from haptic vibrations for the piano fingerings, the LED strip (indicating the location of the note that should be played) and the GUI that allows the user to prepare for upcoming notes and shows the note durations. In addition, the user will be aided by the main python program that generates the correct song audio. At the end of the song the user will see their earned score.

CDR Hardware Components Costs

Component	Quantity	Cost
Haptic Vibration Actuators	10 (1 for each finger)	$21.50
HC-05 Bluetooth Components	2	$15.00
SH-HC-08	2	$20.00
HC-08	2	$20.00
JST to Wire Cable	1	$10.00
Voltage Regulator	10	$10.00
16 MHz Crystal Oscillator	20	$7.00
Total		$103.50

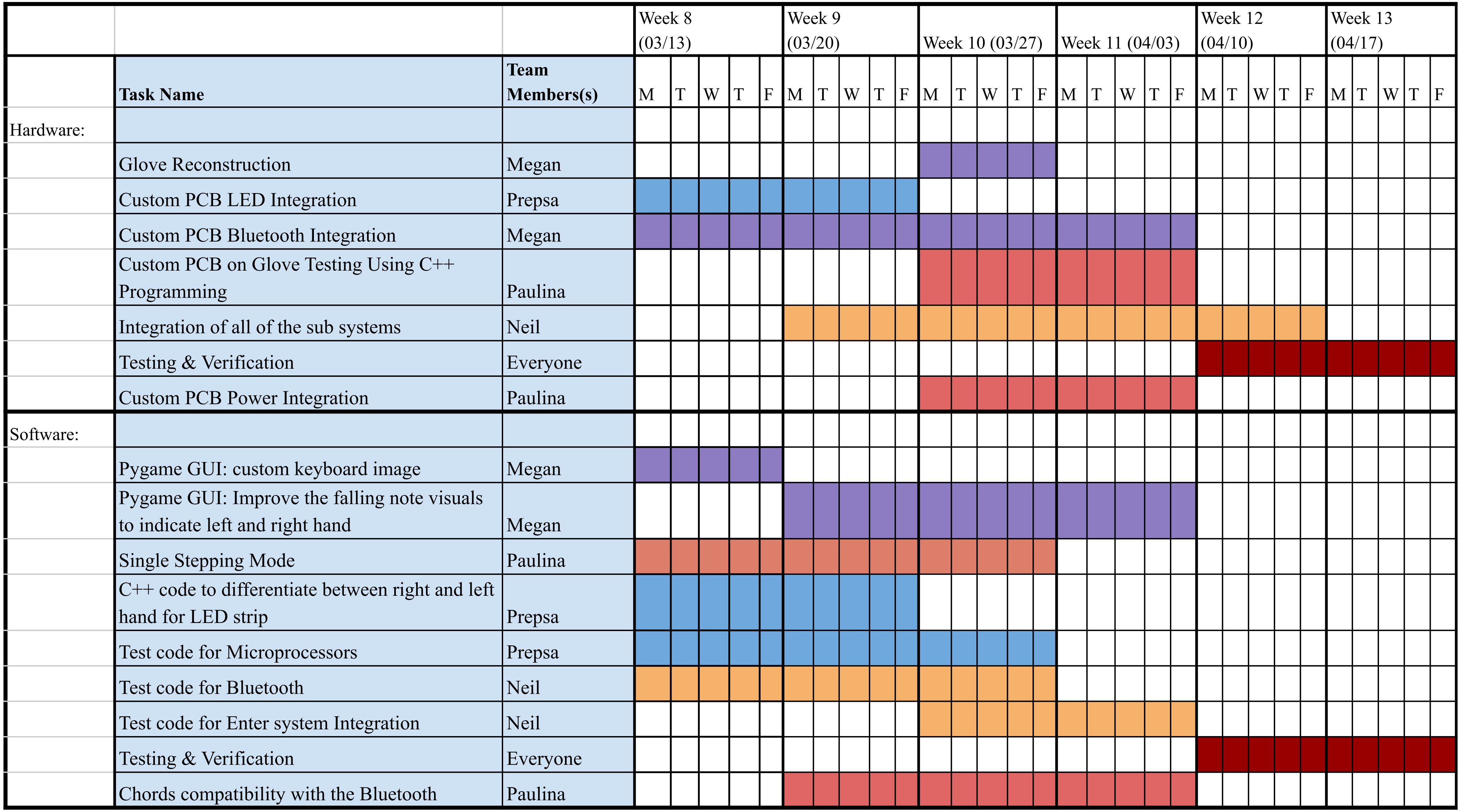
Estimated FPR Costs

Component	Quantity	Cost
Gloves	1 New Set of Gloves	Estimated $15.00
LED PCB (2 Renditions to account for errors)	2 JLC PCBs	Estimated JLC PCB cost: $35.00 $35.00 ✕ 2 = $70.00
Haptic PCB (2 Renditions to account for errors)	3 JLC PCBs: • 1 preliminary test PCB • 2 modified PCBs (1 for each glove)	Estimated JLC PCB cost: $35.00 $35.00 ✕ 3 = $105.00
Total		$190.00

Total Cost Spent as of CDR: 274.57

Estimated Total Cost by FPR: 464.57

Gantt Chart


Week 8 (03/13)
Week 9 (03/20)
Week 10 (03/27)
Week 11 (04/03)
Week 12 (04/10)
Week 13 (04/17)
Task Name
Team Members(s)
M T W T F
Hardware:
Glove Reconstruction
Megan
Custom PCB LED Integration
Prepsa
Custom PCB Bluetooth Integration
Megan
Custom PCB on Glove Testing Using C++ Programming
Paulina
Integration of all of the sub systems
Neil
Testing & Verification
Everyone
Custom PCB Power Integration
Paulina
Software:
Pygame GUI: custom keyboard image
Megan
Pygame GUI: Improve the falling note visuals to indicate left and right hand
Megan
Single Stepping Mode
Paulina
C++ code to differentiate between right and left hand for LED strip
Prepsa
Test code for Microprocessors
Prepsa
Test code for Bluetooth
Neil
Test code for Enter system Integration
Neil
Testing & Verification
Everyone
Chords compatibility with the Bluetooth
Paulina

Team Responsibilities for FPR

Prepsa	Neil
• Budget Lead • KiCad/Altium Lead • 3D Printing • Embedded Code for the LED strip in C/C++ • Custom PCB to control LED strip	• PCB lead • Custom PCB with Power Regulator Design Integration • Bluetooth System • Team Website
Paulina • Display Application • Feedback with user information • Optimizing Code • Custom PCB to control Haptic Motors Integration • Song and speed selection option	**Megan** • Team Coordinator • Embedded Code for the Haptic Motors in C/C++ • Pygame GUI • Custom PCB Bluetooth Integration Design • Glove Reconstruction

Citations

K. Huang, E. Y. Do and T. Starner, "PianoTouch: A wearable haptic piano instruction system for passive learning of piano skills," *2008 12th IEEE International Symposium on Wearable Computers*, 2008, pp. 41-44, doi: 10.1109/ISWC.2008.4911582.

C. Seim, T. Estes and T. Starner, "Towards Passive Haptic Learning of piano songs," *2015 IEEE World Haptics Conference (WHC)*, 2015, pp. 445-450, doi: 10.1109/WHC.2015.7177752.

Evening, Aleksander. "Piano LED Visualizer." *YouTube*, YouTube, 9 Apr. 2019, https://www.youtube.com/watch?v=IZgYViHcXdM.

https://github.com/thegreatkwanghyeon/autofingering

Nakamura, E., Saito, Y., & Yoshii, K. (2020). Statistical learning and estimation of piano fingering. Information Sciences, 517, 68-85.

Live Demo!

Questions?