Wireless Midi Controller Glove

Team 57 – Michael Brady, Sarah Palecki, and Allan Belfort
ECE 445 Project Proposal – Spring 2018

1 Introduction

1.1 Objective

There are many musicians and DJs who create and perform music for a living or as a hobby all over the world, but many of these artists are restricted to creating and performing through the usual routine: pick up an instrument, play a tune, set down the instrument when finished playing, and then head over to the sound board to create effects. This is a process that takes time, and can seem boring to an audience who is watching a musician or DJ play music live. Nobody wants to watch a performer leaned over a soundboard for most of a performance! One of the most necessary uses for a soundboard arises in live mixing from DJs or artists, specifically in the electronic music category. Currently, the dance/electronic music genre is booming, with the genre rising to be the fifth most popular genre in the United States in 2016 [1]. According to the International Music Summit Business Report 2017, over "sixteen percent of people in the USA attended a club event with DJs in 2016" [1]. Clearly, the shows which DJs are playing are in high demand, but what if we can make these performances better?

Our goal is to mitigate the need for putting down an instrument, walking over to the soundboard, and hunching over it to create effects. Instead, we propose to streamline the process above by using a wearable, wireless Midi Controller glove which could integrate effects such as volume control or panning position, all without pausing to put down an instrument and move to a soundboard. This way, with the flex of a finger or the flick of a wrist, effects can be added without the extra hassle of turning knobs and switches on a soundboard. Using flex sensors in the fingers and an accelerometer in the wrist, each gesture can be processed to create a different effect.

1.2 Background

There have been several attempts to make wireless Midi controllers marketable in the past. Currently, they are priced at several hundred dollars, with one brand costing $300 [2], and another brand which is being launched on Kickstarter for a $199 pledge [3]. Before these two models, there was an unsuccessful Kickstarter campaign in 2014 called the "Mi.Mu Glove" which was backed by the artist Imogen Heap [4]. We envision that many artists who wish to use our gloves are performers who are starting out and will not be able to afford several hundred dollars worth of equipment.

Our glove is special for three reasons: it will be made cheaper than $199, it will achieve low latency while using Bluetooth, and it will be able to detect the flexing of the fingers. While the "Mi.Mu" glove was proposed to be made with flex sensors as well, the glove never reached the production phase. Thus, our glove will be the first of its kind to be produced with flex sensors and allow for finger movements to dictate desired effects.

1.3 High-Level Requirements

- Our gloves must be affordable compared to the gloves already on the market, ideally under $100
- Gloves must be able to be control Midi signals through the flex of a finger or the tilt of the wrist
- Gloves must be compatible with a computer DAW (Digital Audio Workstation) or a sequencer

2 Design

Our design is composed of three separate blocks that will achieve successful functionality of the glove: the sensors on the glove, the control and communications block, and the power supply. The user will be able to send information to the DAW by performing different hand gestures. These will be recognized by the flex sensors on the glove's fingers or the accelerometer on the back of the hand which will be outputting readings into a microcontroller attached to the wrist of the glove. This module, in turn, will be processing these values and transmitting digital signals through the Bluetooth module attached to it. Other modules in this block include a power button, which will turn our system on or off, an LED that shows the power status of the system, and a button that starts a Bluetooth connection between the transmitter in the glove and the receiver connected to the DAW. Once these Bluetooth signals are received by the audio workstation, they are interpreted as modifications to a MIDI audio track, and will achieve variations in different audio parameters that can be controlled with this audio protocol. Finally, the power supply block will be in charge of delivering the necessary power to the modules in the processing and communications block of our glove, to ensure a proper and consistent functionality of our product.

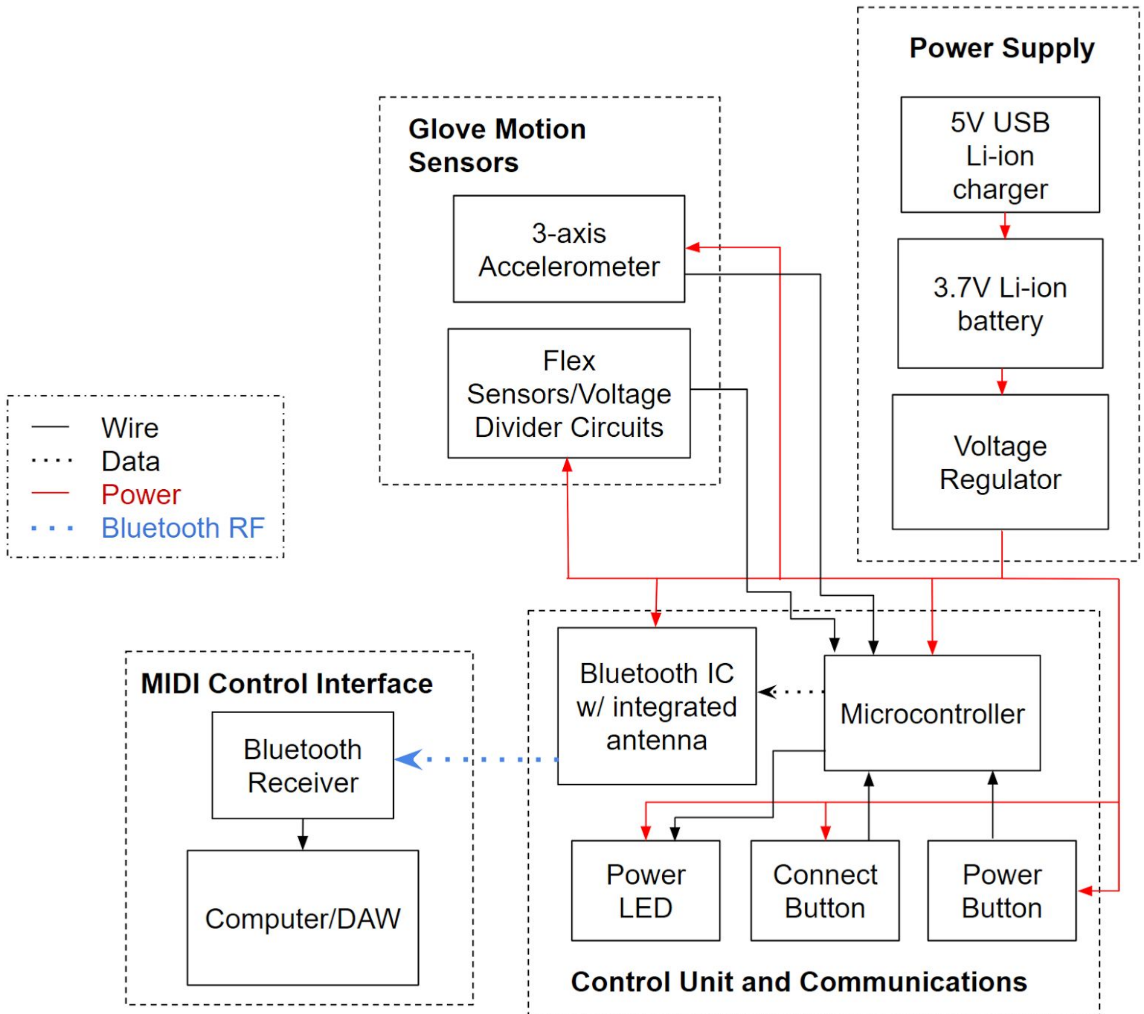


Figure 1. High Level Block Diagram

2.1 Glove Motion Sensors

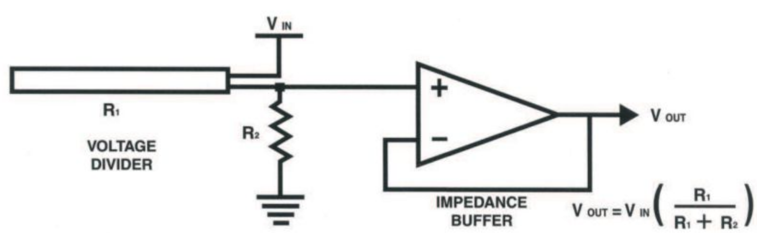
This block modifies the signals sent to the control unit based on the gestures performed by the user wearing the glove. These gestures are recognized both by four individual flex sensors placed on the knuckles of the glove in all fingers excluding the thumb, as well as a three-axis accelerometer located on the back of the hand of the glove. These sensors communicate with the control unit and communications block, and are powered by the power supply block.

2.1.1 Three-Axis Accelerometer

This device will measure the 3-D tilt of the glove and the acceleration with which the glove is moved in any direction, and will be located on the back of the hand. It will send data to the microcontroller to be interpreted as information on the movements performed by the user.

Requirement: Must be able to detect acceleration at a minimum of ±1.5g on each of the three axes.
Requirement: Accelerometer must be able to reliably detect orientation when relatively stable.

2.1.2 Flex Sensors / Voltage Divider Circuits



Shown above is the voltage divider circuit that is employed by the flex sensors. This block interprets the bend of the finger via a flex sensor over the knuckle and, using the above voltage divider circuit, changes the voltages being output to the microcontroller.

Requirement: Resistance level to be found upon testing, but must be able to change resistance by 2x original flat resistance upon bending
Requirement: Must be at least 1.5" in order to fit completely over knuckle

2.2 Control Unit and Communications

This block interprets the readings given by the sensors in the previous block and maps them to predetermined numerical values that will be digitally transmitted to the DAW through the Bluetooth interface. The modules in this block are powered by the power supply block, and information is transmitted wirelessly to the MIDI control interface block. The power LED and control buttons are also included in this block, which show the status of the system and control its operation.

2.2.1 Microcontroller

The microcontroller interprets the readings given by the motion sensors, and represents them as values that will serve as inputs to the MIDI interface. The information on these values and the functions they are meant to modify are then passed to the Bluetooth module.

Requirement: The microcontroller must be able to map the sensor readings into integer values to be processed digitally.
Requirement: Must be able to communicate with UART at rates greater than 50 kbps.

2.2.2 Bluetooth IC with Integrated Antenna

This chip must be both a bluetooth transmitter and have an integrated antenna. It will read the information supplied by the microcontroller and generate a bluetooth signal that will be interpreted by the bluetooth receiver connected to the DAW.

Requirement: Must provide connectivity over a 3 meter range.
Requirement: Must have an operating frequency range of 2402-2480 MHz, at rates greater than 50 kbps.
Requirement: Must be able to receive information for transmission via a UART connection.

2.2.3 Power Button

This button will power the system on or off, and signal the microcontroller to begin reading values from the sensors and sending them to the bluetooth module.

Requirement: Button must be easily pressible, and must not present mechanical malfunctions.

2.2.4 Power LED

The power LED will inform the user on whether the system is on or off.

Requirement: The LED should be clearly visible to the user from at least 1 meter away, a distance longer than an extended arm.

2.2.5 Connect Button

This button on the glove will make the bluetooth module enter pairing mode, where it will look for a bluetooth receiver to transmit its data to.

Requirement: Button must be easily pressible, and must not present mechanical malfunctions.

2.3 Power Supply

A power supply is necessary for our sensors to be giving relevant values, and for both our microcontroller and bluetooth IC to be performing their required functions. A battery will be the source of power, and its output voltage will be regulated to ensure consistency in the functioning of our system.

2.3.1 USB Li-ion Charger

This charger must be able to charge the Li-ion battery via USB port. The maximum output voltage of the charger must be less than the supplied 5V by the USB. This maximum output voltage will depend upon the maximum voltage of the Li-ion battery that is used. Two possibilities are a 3.7/4.2V battery charger or a 3.6/4.1 charger.

Requirement: Must charge batteries via 5V USB port.
Requirement: Must have maximum output voltage less than or equal to maximum battery output

2.3.2 Li-ion Battery

The Lithium Ion battery must be able to provide power to all of the components so that the glove can operate wirelessly, without needing a power cable. It must also be small enough to not be an obstruction for the user wearing the glove.

Requirement: The battery must operate in the range of 3.6-4.3V and last over 2 hours.

2.3.3 Voltage Regulator

This linear voltage regulator chip supplies the required voltage to the blocks shown above in the block diagram. It must be capable of having the capacity to output at least the upper bound of the li-ion battery (about 4.3V) and regulate the chosen battery output voltage +/- 5% from the source voltage.

Requirement: The voltage regulator must provide chosen battery output voltage +/- 5% from a source voltage.

2.4 MIDI Control Interface

This block represents the receiving end of the data that will be sent from the glove. After data from the sensors has been collected, processed and transmitted, the MIDI control interface will receive the bluetooth signals and input them to the DAW.

2.4.1 Bluetooth Receiver

This module will be a bluetooth receiver with an antenna to receive signals coming from the glove's bluetooth transmitter. It will output the signal via USB to the DAW.

Requirement: Must be able to operate within the range of the transmitter and receive signals from it without loss of information.
Requirement: Must be able to send out information to the DAW via a USB connection.

2.4.2 Computer/DAW

At this stage, the signals received from the glove will be interpreted as modifiers of sound parameters of a MIDI signal. This will be done in a Digital Audio Workstation (DAW) software running on a commercial computer equipped with the required input ports.

Requirement: Must be equipped with 1GB of RAM and MIDI interface.
Requirement: Must be able to run Symbolic Sound's Kyma DAW software.

2.5 Risk Analysis

The biggest threat to a consistent functionality of our system is the accuracy of the three-axis accelerometer that will be attached to the glove. This component is meant to output a reading proportional to the acceleration of the hand, and the direction in which it is being moved. The greatest challenge in implementing it into our design is in getting the correct readings for how the hand is being moved, as such a small component is hard to calibrate and consequently hard to ensure that the values it outputs are consistent. This is a critical item in our design, as it will be the measurement device for multiple of the gestures we want to detect with the glove. The flex sensors are only able to detect the curl of the fingers, while the three-axis accelerometer will be able to measure the direction of the hand in two different axis and how much it moves in each direction. It is therefore important to focus on getting this component to work properly, but its functionality goes beyond our implementation of it in our system and has us relying on the chip manufacturer's design of the piece.

Much of the task of interpreting the motion of the hand also falls on the microcontroller block, which maps the accelerometer readings into data that can be processed by the DAW. The microcontroller can be made to counter some inconsistencies on behalf of the accelerometer, and cut off some of the error from the gesture recognition portion before it is sent to the DAW through a bluetooth signal. In other words, there is *some* ameliorating that can be done in the microcontroller if the accelerometer does not meet the requirements detailed previously in this section. This would mean, however, that the mapping performed by the microcontroller would not be able to be as sensitive with respect to the degree at which the hand is moved, and might mean that some sensitivity in gesture reading will be lost in this regard.

If the accelerometer gives inaccurate or imprecise readings, we can resort to calibrating other parts of our system to counter any errors from the component, but will come at a loss to the sensitivity of the gesture recognition and its effects on how much the MIDI parameters are modified.

2.6 Physical Design

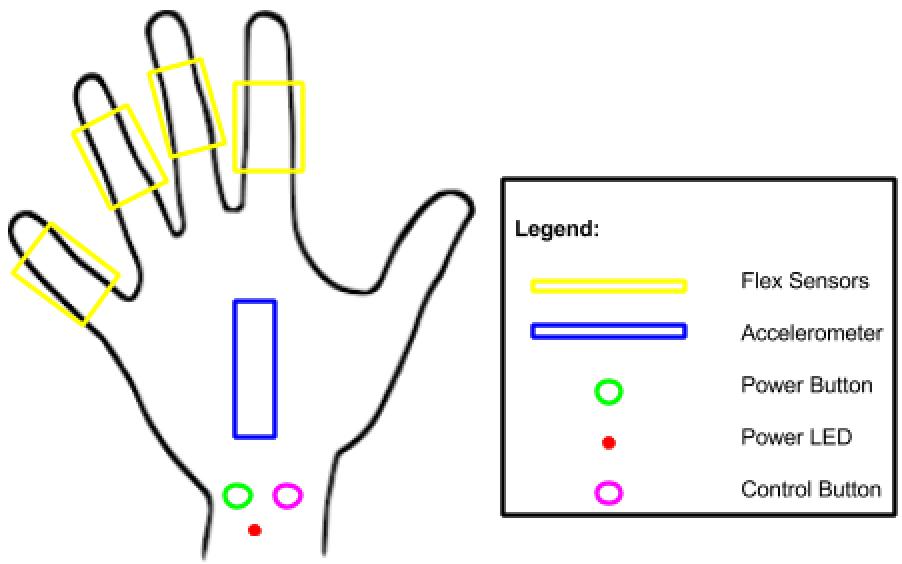


Figure 2. Physical device layout

Above we have shown a physical picture of what we propose our glove to look like. Our diagram shows the glove as it would appear when on a hand that is pressed flat. As can be seen from the yellow rectangles in the picture, we propose to implement four separate flex sensors on each of the fingers of the hand (not including the thumb). These flex sensors will be put over the knuckles of each finger on the back of the hand. Next, it can be seen from the diagram that we propose to implement an accelerometer on the back of the hand, as indicated by the blue rectangle. Additionally, there will be two separate buttons near the wrist of the glove: one power button as well as one control button. These are represented by the green and pink circles on the diagram. Finally, we would like to include one LED so that the user can tell if the glove has been powered on or off. We will be using a flexible yet sturdy fabric that allows the user's hand to breathe and comfortably make several different gestures without creating moisture inside the glove. We are proposing to use biking gloves, or another glove where the fabric does not cover the fingertips. This is so that the user can still use touchscreens and easily grip items without the concern of slip due to fabric.

3 Safety and Ethics

Within our proposed design, there are several safety concerns. One of the necessary implementations of the project is to have the glove be rechargeable when being used wirelessly. Thus, it will require rechargeable batteries. We propose to use Li-Ion rechargeable batteries for this glove, which can create certain concerns as they may explode or burn if misused or mishandled. It is important to ensure that there is no internal short circuit, as this leads to increased heat within the battery and an exothermic reaction, increasing the risk of additional combustion [5]. To ensure this is not the case, we will test the batteries thoroughly before using in the glove. Another concern with these batteries possible explosion upon overcharging. In order to ensure this will not be the case, we will test the batteries thoroughly by charging them ourselves before implementing them within the glove. It is also important to stress that high quality and reliable charging systems must be used to charge the batteries.

Another safety concern is the glove coming into contact with moisture. We propose to use a moisture resistant fabric as well as use rubber coatings on any wires or electrical contact that is being made in order to prevent the user from experiencing any shock. Along these same lines, it is important to store the glove in a cool, covered area so that the glove does not overheat.

One ethical concern is the use of the gloves to create and copyright music which has already been made. This follows the IEE Code of Ethics 7.8.2 [6]. It is important to ensure that artists are not copying previously made works and the violation of interests do not occur. This follows along the line of modifying music and sounds that are under copyright. It is not our intention to make a product which enables the infringement of musical property. Thus, it is up to the user to make these types of ethical decisions.

We believe that this product falls within the lines of IEEE ethics 7.8.1 [6], and it is our goal to comply with ethical design and sustainable development practices for this project. Thus, we will disclose any and all possible safety and ethical issues to the user, so that we may fully disclose any limitations our product has in order to adhere to IEEE ethics 7.8.6 [6].

References

[1]Watson, 'IMS Business Report 2017', 2017. [Online]. Available: http://www.internationalmusicsummit.com/wp-content/uploads/2017/09/IMS-Business-Report-2017-vFinal3.pdf [Accessed: 2- Feb- 2018].

[2] Global DJ, 'Tornado A1 | MIDI Controller Wireless 3D-Gloves', 2018. [Online]. Available: http://global-dj.com/product/tornado-a1-midi-controller-wireless-3d-gloves/ [Accessed: 2- Feb - 2018].

[3]B. Rogerson, 'The gloves are in on the wireless MIDI control battle', 2016. [Online]. Available: http://www.musicradar.com/news/tech/the-gloves-are-on-in-the-wireless-midi-controller-battle-635024 [Accessed: 2- Feb- 2018].

[4] M. Mu, 'Mi. Mu Gloves for music', 2014. [Online]. Available: https://www.kickstarter.com/projects/mimu/mimu-glove-for-music [Accessed: 2- Feb- 2018].

[5]L. Florence, 'Safety Issues for Lithium Ion Batteries', 2012. [Online]. Available: https://www.ul.com/global/documents/newscience/whitepapers/firesafety/FS_Safety%20Issues%20for%20Lithium-Ion%20Batteries_10-12.pdf [Accessed: 3- Feb- 2018].

[6] Ieee.org, "IEEE IEEE Code of Ethics", 2018. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html [Accessed: 3- Feb- 2018].