Remote-Controlled DJ

ECE445 Design Document

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Draft

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1. Introduction

1.1 Objective

The objective of this project is to deliver a remote-controlled DJ package. The problem we address is that by moving the wrist, the DJ will be able to remotely change the song and manipulate it with various DSP functions. We want to make the resulting music interesting. Our design will comprise a hardware component of wrist-strapped gesture sensor and a software component of motion analysis algorithms and signal processing algorithms. And all these interactions will happen over a Bluetooth connection, feeing the DJ from his station.

1.2 Background

In a party, the DJ is the guy responsible for supplying everyone an endless stream of entertaining music. But we all know he deeply wants to join the party! So we will build a remote gesture controlled DJ console that every DJ can take into the action. Due to the incorporation of physical turntables and hardware implementation of signal processing functions, DJ stations often cost upwards of $1000 dollars [7], and are very heavy and cumbersome to transport. We want to miniaturize the DJ for the average user, and at the same time add creative ways to interact with the sound. The primary uses of DJ has been to stream through prepared playlists. Therefore having a phone app provides the reasonable convenience of accessing the user's existing playlists. Through the gesture control offered by our wrist-strapped device, we achieve multiple dimensions of interaction that will be more intuitive and direct than the myriad of buttons and sliders on a DJ station.

1.3 High-level requirements

- Requirement 1: The device will detect the orientation of the hand with an accuracy of +/- 10 degrees.
- Requirement 2: The device will detect "one-shot" gesture events e.g. skipping songs by horizontally throwing the wrist outwards with a success rate greater than 90% and less than two false positives in ten minutes.
- Requirement 3: The device will measure the relative change in height with an accuracy of +/- 20 centimeters.

2. Design

Our system comprises two parts:

1. **A compact device** that straps to one's wrist and collects gesture information. The gesture can be used to navigate a playlist, change various effects, manipulate voice recorded from a microphone etc. It will also sample the onboard inertial measurement units at a rate of 500Hz, estimate orientation from the measurements, and send over the processed result at a lower rate of 20Hz.

2. **A phone app** that implements the various signal processing functions and outputs the music. The app is driven by gesture data from the embedded device.

Details

To send gesture data from the device to the app, we use the Bluetooth Low Energy protocol. The embedded device will contain a power module, a bluetooth module,sensors (IMU and barometer), a microcontroller and a few buttons and LEDs. The microcontroller mounted on the device fuses sensor data (using Kalman filters) to estimate the pose of the hand, in the form of orientation and change in height. We will define a custom protocol to stream these events along with continuously changing gesture data to the phone, which will make use of these data to perform signal processing tasks. In addition, the phone will record the user's voice through a microphone and mix it into the final audio. The microchip on the embedded device will need to be reasonably powerful to perform sensor fusion.

Specifically, we have three modes to control the phone app. Different hand motions are mapped to different musical effects. The mapping is as follows:

All modes: Turning of wrist maps to texture change. (Like turning the texture knob on a guitar amp). Slicing your hand horizontally outwards through air moves to the next song. Slicing inwards goes to the previous song.

Mode 1: Height maps to pitch. Up/down rotation of palm maps to reverb.

Mode 2: Sudden upwards rotation of palm maps to activating looping, sudden downwards rotation maps to stopping the looping.

Mode 3: Height maps to wah-wah effect.

We'll use buttons for switching between modes, and for on/off.

2.1 Block Diagram

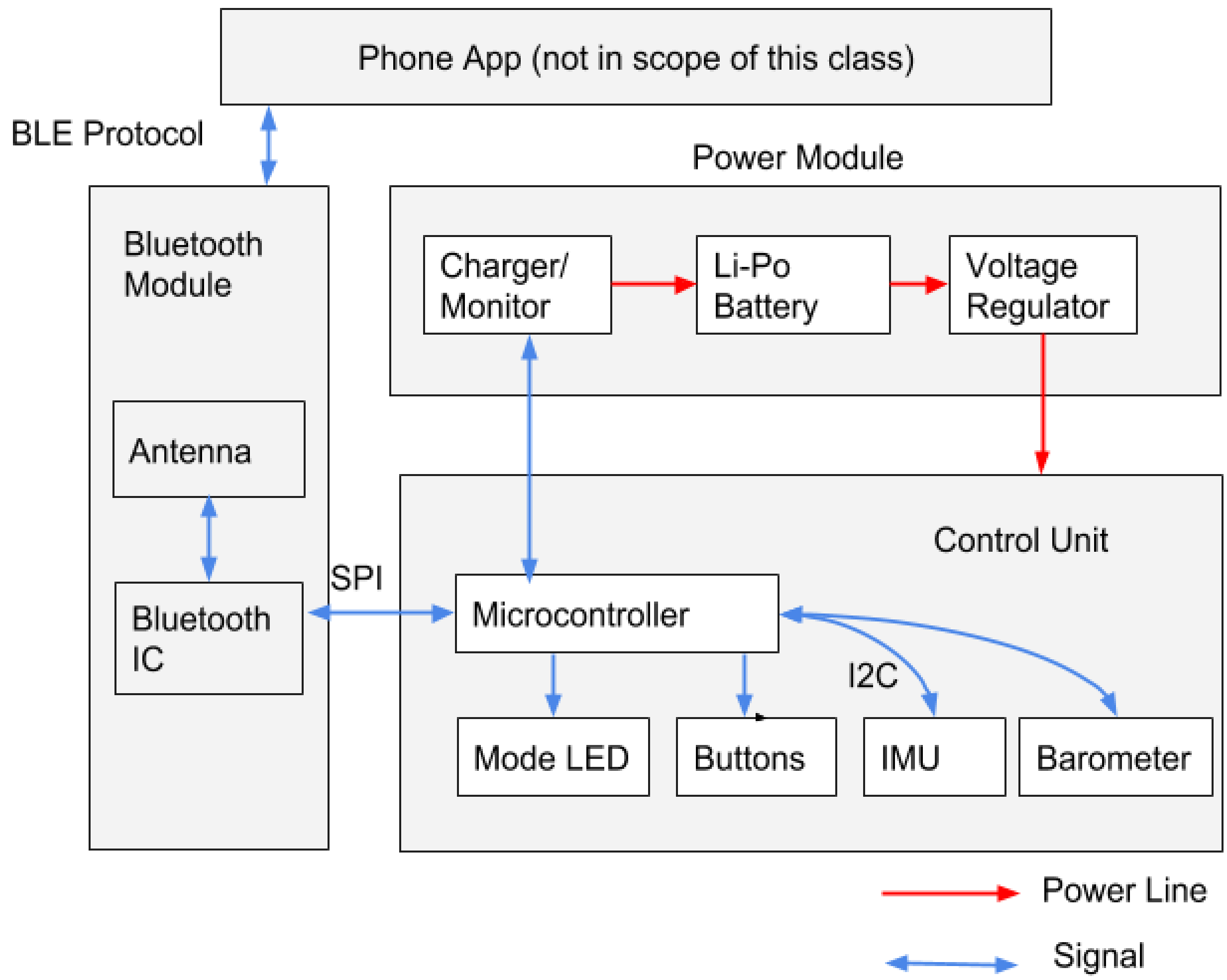

Fig 1. Block Diagram

2.2 Physical Design

The device should comfortably strap onto the user's wrist. We will design a casing for our electronics that partially matches the shape of an iPod nano, so it fits in one of the off-the-shelf exercise phone holder wristbands (Fig. 2). The design consists of two halves, each of which will be 3D printed and pieced together to form the casing.

Referring to Fig. 3, we plan to place the battery in between the two M3 nut holders, glued to the bottom part of the casing. The PCB will be mounted on top of the M3 holders using screws. Holes will be carved out of the front panel as needed to expose buttons and LEDs.

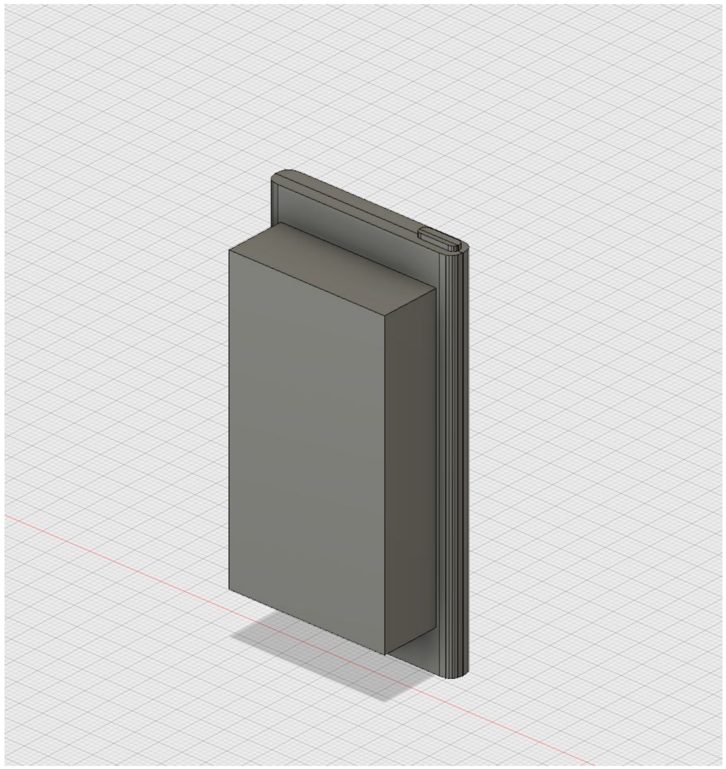

Fig 2. 3D External View of Physical Design

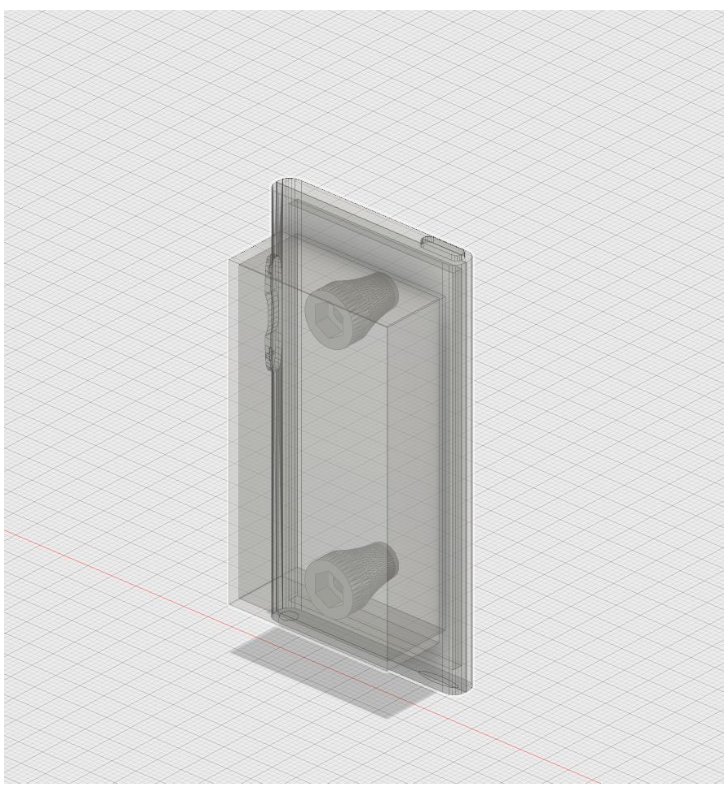

Fig 3. 3D Internal View of Physical Design


Fig 4. Side View **Fig 5. Front View**

We intend to place the battery pack and the charging module inside the iPod-shaped body, while placing the main PCB in the rectangular extrusion.

Now we will discuss the functional overviews and block requirements of each element in our block diagram.

2.3 Power Module

Power module includes battery charger and monitor, Li-Po battery, and a voltage regulator.
Li-Po battery will be used as a power source to keep the communication network up continually, and it is regulated to 3.3V by a voltage regulator to power the control unit. We can charge Li-Po battery and monitor state-of-charge and remaining capacity.

2.3.1 Charger/Monitor

We plan to incorporate a charging circuit into our main PCB to charge and monitor our Li-Po Battery.

Requirement 1: The charging circuit can charge battery with power supply between 4.35 and 6.4V.
Requirement 2: It can measure battery's voltage and state-of-charging, and estimate remaining capacity.

2.3.2 Li-Po Battery
The lithium-Polymer battery is used to power control unit..

Requirement 1: The battery must be able to store enough charge to provide at 3.3-4.2V for current draw about 150mA at least five hours continuously.

2.3.3 Voltage Regulator
Voltage regulator supplies 3.3V to the control unit. This chip must be able to handle the peak input from the battery (4.2V) at the peak current draw (500mA).

Requirement 1: The voltage regulator must provide 3.3V +/- 5% from a 3.5-4.2V source.
Requirement 2: Must maintain thermal stability below 125°C at a peak current draw of 500mA.

2.4 Control Unit
The control unit is responsible of reading accelerometer, gyroscope, and magnetometer values from the Inertial Measurement Unit. It performs sensor fusion to estimate the orientation of the hand.

2.4.1 Inertial Measurement Unit
We plan to design a similar circuit to [8], which internally uses the MPU-9250 chip.

Requirement 1: The device will detect the orientation of the hand with an accuracy of +/- 10 degrees.

2.4.2 Altimeter/Barometer
We plan to use the MS5611-01BA barometer[9], which claims to have a high-resolution module of 10 cm and fast conversion down to 1 ms.

Requirement 1: The device will measure the relative change in height with an accuracy of +/- 20 centimeters.

2.4.3 Microcontroller
The microcontroller we plan to use is NXP1768. It is a Cortex-M3 processor powerful enough to perform sensor fusion while handling Bluetooth data transmission. We plan to implement a Kalman filter on the IMU data to update orientation continuously. Since the MPU-9250 is capable of sampling at a maximum rate of 500 Hz, we plan to run the algorithm at this rate.

Requirement 1: The orientation estimation algorithm must be accurate within 5 degrees after stabilizing for 10 seconds.

Requirement 2: The drift in orientation must be less than 15 degrees after 5 minutes of active use.
Requirement 3: The microcontroller must detect gestures as indicated by a particular pattern in the change in orientation, and report to the phone app with a latency less than 1 second.
Requirement 4: The microcontroller must detect changes in height with an accuracy better than 15cm.

2.4.4 Buttons

We need four buttons in total. Three of them are used for mode switch and the fourth one is used for on/off.

Requirement 1: The buttons are required to be robust and persistent with a success rate greater than 90%. Success means our microcontroller is be able to detect it and change modes accordingly if any button is pressed.

2.4.5 Mode LED

We need three LEDs to represents three different modes. Each LED is responsible for one mode. If our device is off, all LEDs are supposed to be turned off.

Requirement 1: The LEDs are required to be able to last for at least five hours.
Requirement 2: The LEDs are required to be visible to indicate which mode is currently on.

2.5 Bluetooth Module

The Bluetooth module we plan to use is Adafruit Bluefruit LE SPI Friend - Bluetooth Low Energy (BLE). Data from the control module is sent to the module via data bus and then received by phone app via BLE protocol.

Requirement 1: The Bluetooth module is required to be able to send data to phone within 10 meters.
Requirement 2: The Bluetooth module is required to be able to send data to phone within 0.5 second.

2.6 Risk Analysis

Our project integrates both IMU and barometer/altimeter sensor values to determine the movement of one hand. Therefore, the greatest risk in our project is whether our sensors are able to provide precise values, e.g. hand orientation and its change in height. At the meantime, these sensors need to respond fast enough if user moves hand fast. If the movement is determined correctly, then the rest of design is straightforward.

3. Cost and Schedule

3.1 Labor Cost

Circuit/ PCB Design	PCB soldering	Data Fusion code	Phone App Design	Integration	Debug	Salary	Total Hour	Total Cost
10hr	12hr	20hr	20hr	10hr	20hr	$30	92hr	$2760

3.2 Parts

#	Description	Manufacturer	Quantity	Cost($)
1	Bluefruit LE SPI Friend - Bluetooth Low Energy (BLE)	Adafruit	1	17.5
2	0.8A Fast Ultra Low Dropout Linear Regulators	TI	1	2.8
3	Lithium Ion Polymer Battery - 3.7v 500mAh	Adafruit	3	7.95
4	3.7V to 5.0V Voltage Booster	Banggood	1	6.45
5	Charging Circuit	ECE Shop	1	30
6	NXP1768 Microcontroller	Sparkfun	1	54.95
7	MPU9250 IMU	Sparkfun	1	14.95
8	MS5611 altimeter sensor	Amazon	1	13.99
9	Surface Push Button	ECE Shop	5	0.4
10	Yellow LED	ECE Shop	5	0.2
11	iPod Case	Amazon	1	8.59
12	3D Printing	Shapeways	1	16.07
Total Cost: $192.15				

GRAND TOTAL = LABOR + PARTS = $2760 + $192.15 = $2952.15

3.3 Schedule

Task	Deadline	Assigned To
Order Parts	2/19	All
3D Printing Design	2/19	Yifei Teng
Microcontroller Circuit Design	2/22	Ningkai Wu
Voltage Regulator Circuit Design	2/22	Yifei Teng
Charging Circuit Design	2/22	Jie Du
General Circuit/PCB Design	2/26	All
Data Fusion code	3/19	All
Bluetooth Code	3/26	Jie Du
Phone App Design	3/26	Ningkai Wu, Yifei Teng
PCB soldering	4/9	All
Integrate prototype	4/16	All
Test integrated System	4/30	All

4. Safety and Ethics

For the safety concerns, we will follow safe battery usage listed in the course website since our project utilizes Li-Po battery and a charge for it. Our charger is an industry made IC device and it shuts charge controller off when charging input is higher than required voltage range, which will reduce the likelihood of hazards while charging. We will also check our circuit before connecting it to battery in order to prevent short circuit which may lead to electric shock. Moreover, in order to make device comfortably strap onto the user's wrist and doesn't fall off when user moves, we will use 3D printing to make a mold to hold our device tightly, and then use armband from the market to attach device to user's wrist.

For the ethical issues, we will be guided by IEEE and ACM code of ethics. We may encounter many problems in the project. When the problems occur, we will not try to pretend the problems are not there and move on to the next task. Based on #5 of IEEE Code of Ethics, "to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors" [1]. Therefore, when we encounter hard problems, we will first discuss in the group and think about the strategies to solve the problem. If we can't solve the problem ourselves, we will talk with our TA for the solution.

We will do a lot of research on the project, and there might be some brilliant ideas from a paper or our classmates that help us with the project. We need to respect ideas of others and cite them in our project report. Based on #1.6 of AMC Code of Ethics, it is very important to“ Give proper credit for intellectual property” [2].

5. Citations

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[9] Digikey MS5611-01BA Barometric Pressure Sensor. Available at: https://www.digikey.com/en/product-highlight/t/te-connectivity-measurement-specialties/ms5611-01ba-barometric-pressure-sensor.

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