4D Media Jacket

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1. INTRODUCTION

1.1 PROBLEM

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According to TIME, people are playing video games more than ever. Gaming increased by 75% in the first week of quarantine itself [1]. Verizon has stated that each week since the pandemic has hit there has been a 23% increase in gaming. In addition, popular consoles such as a Nintendo Switch are not keeping up with its demand [2]. In regards to the movie industry, Netflix gained 16 million subscriptions within the first month of lockdown according to BBC [3]. The average weekly Netflix usage rose 72% since the COVID-19 pandemic began [4]. Thus, media has become an integral and pervasive part of the pandemic life.

Thus, amid the COVID-19 pandemic we rely more than ever on media forms to keep us entertained. Movies, music, and video game technology sales are at a peak now and new innovations are needed to keep up with the amount that we have come to rely on these media forms. The status quo of these media forms rely on a very 2D experience which after about a year of quarantining has become boring, as well as the fact that this 2D experience is not indicative of the technological innovations of our time today.

1.2 SOLUTION OVERVIEW

Our solution to create a jacket that provides a 4D experience for various media forms. Specifically, we will focus on movies, music, and video games. Instead of just being able to hear sound and see visuals, we plan to develop a more engaging media experience by enabling users to actually feel these media forms through vibrations and shocks from our jacket. For example, in movies users should be able to feel the vibrations of sitcom audience laughter or explosions, in music users should be able to feel the vibrations of the beats, and in video games users should be able to feel the shock of a gunshot and hits. Thus, we plan to successfully devise a more engaging media experience through this jacket by upgrading from our current 2D experience to a 4D experience. In addition, our objective is to make this jacket inexpensive, and therefore purchasable for more consumers.

Currently there are a few similar concept jackets in the market. The problem with these jackets, however, is that they are only built and supported by VR based video games. They do not have the ability to utilize haptic feedback for other forms of media such as music and movies. These jackets are expensive as well.

1.3 VISUAL AID

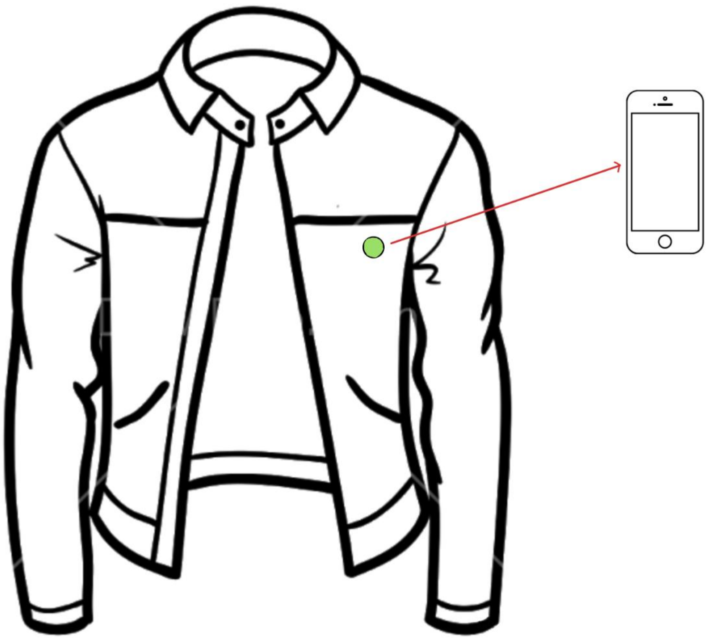


Fig. 1: A basic visual representation of what the prototype would look like and its functionality

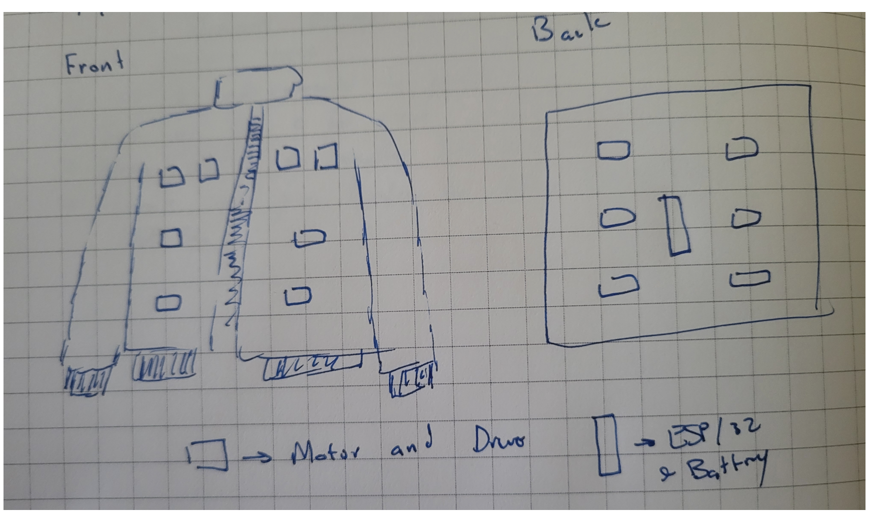


Fig. 2: Locations of motors in jacket

1.4 HIGH-LEVEL REQUIREMENTS

- ➢ Jacket must be able to create different patterns of haptic feedback based on inputs from the microcontroller over Bluetooth
- ➢ Jacket must be able to last over 4 hours of use on a single charge.
- ➢ The app interface should be able to activate the jacket and simulate haptic feedback patterns.
- ➢ The Bluetooth module attached to the microcontroller must have a maximum latency of ~70 ms.

2. DESIGN

2.1 BLOCK DIAGRAM

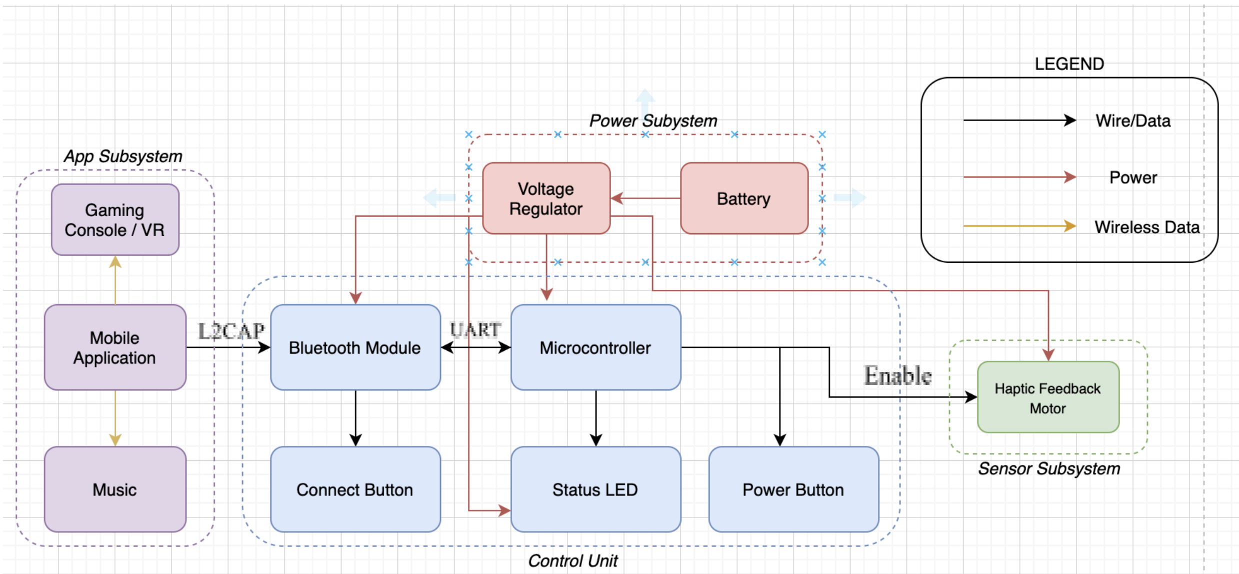


Fig. 3: Block Diagram displaying the required interconnected subcomponents

2.2 PHYSICAL DESIGN

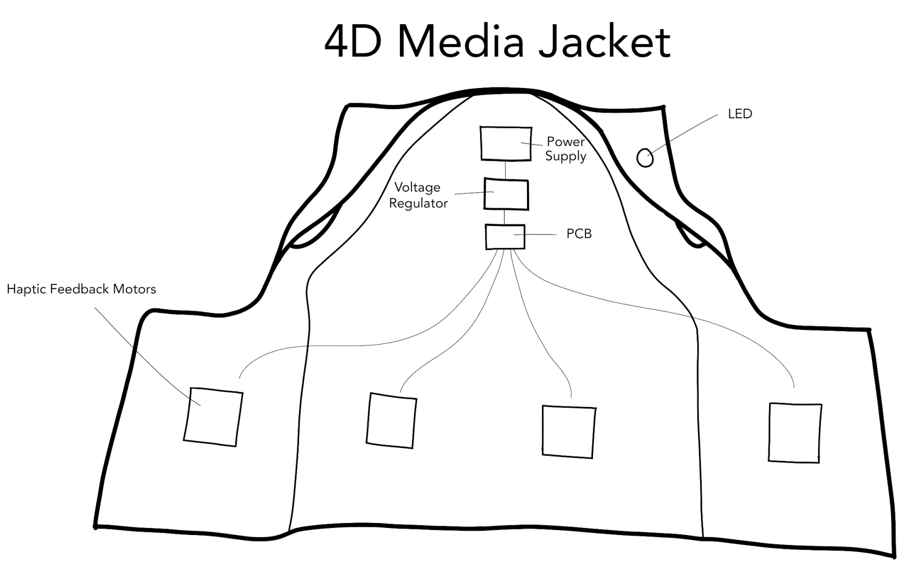


Fig. 4: A more in depth physical design showing the placements on the jacket of various parts

2.3 REQUIREMENTS AND VERIFICATION TABLES

The main risks for this project are latency and power. The Bluetooth module we have chosen is not the fastest way of communication, but it is more energy efficient than a WiFi module. Thus, latency will play a major factor in user experience. The second risk is power. We need a reasonably small and relatively lightweight power supply, but the haptic feedback motors have significant energy consumption in large numbers. Thus, we need to balance the power consumption of the feedback motors against their effectiveness.

2.3.1 Power Subsystem

The power supply will supply power to all components of the jacket. The power supply must be able to power the suit for over 4 hours on a single charge and has a voltage regulator attached to it to prevent damage to the circuit.

2.3.1.1 Li-Ion Battery

Requirement	Verification
1. Must store more than 6Ah in charge	1. Connect a fully charged battery (6 V) Li-ion battery with positive terminal at Vdd and negative terminal at GND. 2. Discharge at a rate of 350 mA for 20 hours. 3. Connect a voltmeter in parallel to the battery and ensure the voltage is greater than 5.25 V

2.3.2 Control Unit Subsystem

The control unit subsystem will consist of a PIC microcontroller and a Bluetooth module. This microcontroller will interact with the haptic feedback motors in order to create around different haptic feedback patterns, with each pattern corresponding to a different stimulus. The control unit will interface with the game/audio and send signals to the haptic feedback motors to generate a “4D” experience.

2.3.2.1 Status LED

Requirement	Verification
1. LED light is visible to user while wearing the jacket	1. Connect the LED to PCB 2. Supply LED with 10 mA of current 3. Wear the jacket and turn the jacket on by pressing the ON switch 4. The user should be able to see a green light emanating from the LED

2.3.2.2 Power Button

Requirement	Verification
1. Must be easily accessible and pressable	1. Wear the jacket 2. Try to press the power button 3. Ensure this can be done without significant stress

2.3.2.3 Connect Button

Requirement	Verification
1. Must be easily accessible and pressable	1. Wear the jacket 2. Try to press the power button 3. Ensure this can be done without significant stress

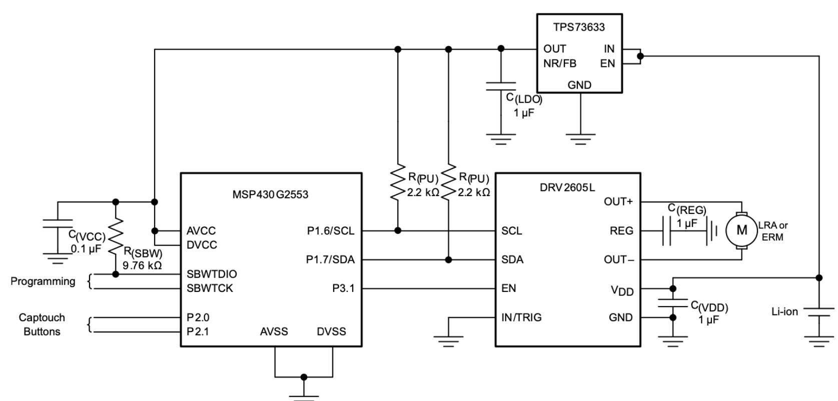
2.3.2.4 Microcontroller

Requirement	**Verification**
1. When the device is in standby mode, i.e it hasn't been used for over 10 minutes and it does not have any active bluetooth connections, the microcontroller puts it in standby mode. 2. Jacket to consume under 50mW of power in standby mode	1. Disconnect any bluetooth devices from the jacket. 2. Wait for 10 minutes 3. Check if the LED is showing a yellow light 4. Measure the power consumption and verify if it meets our requirement

2.3.3 Sensor Subsystem

Our sensor subsystem consists of haptic feedback motors. This motor will be used to generate the vibrations needed to create the "4D" experience for our jacket. For example, in video games the sensation of shots will be implemented by the haptic feedback motor generating very high impact vibrations.

2.3.3.1 Haptic Feedback Motor



Requirement	Verification
1. Different vibration patterns should be created in the haptic feedback motor through the driver chip	1. Connect power source to DRV2605 with capacitors and NFP-7C-FS0725 haptic feedback motor as shown in diagram 2. Use the provided library code for the haptic driver to program two patterns to the captouch buttons.

	3. Both buttons should produce different feedback patterns

2.3.4 App Subsystem

Our mobile application subsystem consists of a native iOS app that can communicate with the ESP32 bluetooth module. This app will be used to link with music streaming apps and playback the songs with haptic feedback on the jacket. It will also let users control the feedback patterns of the haptic motors for demonstrative purposes.

2.3.4.1 iOS App

Requirement	Verification
1. App must be able to connect to ESP32 bluetooth module and produce different haptic feedback patterns in the jacket	1. Power on the jacket 2. Press the connect button on the jacket to establish a connection with Bluetooth 3. Connect to the ESP32 module on the mobile phone settings screen 4. Navigate to the app and press the buttons corresponding to feedback patterns 5. Verify that the patterns are being simulated on the jacket, and that all motors are responding in the same amount of time.

2.4 PLOT

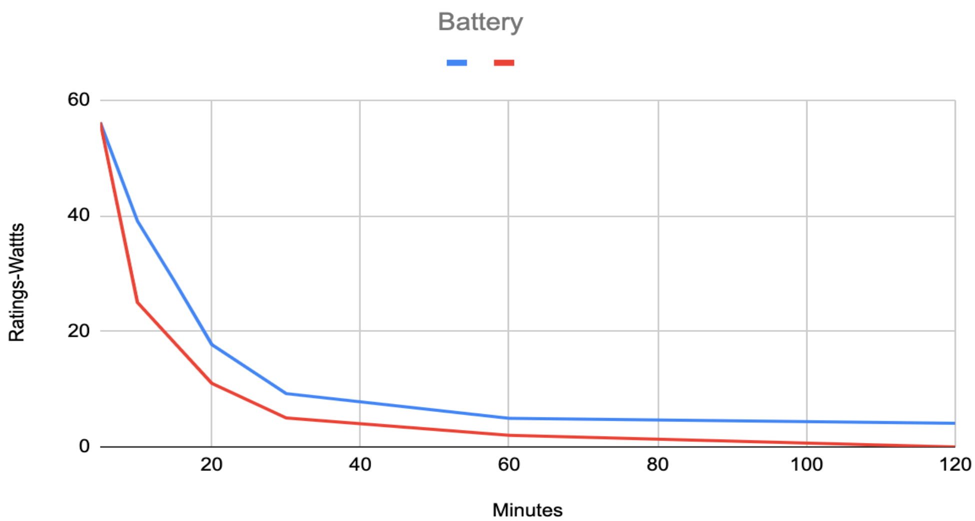
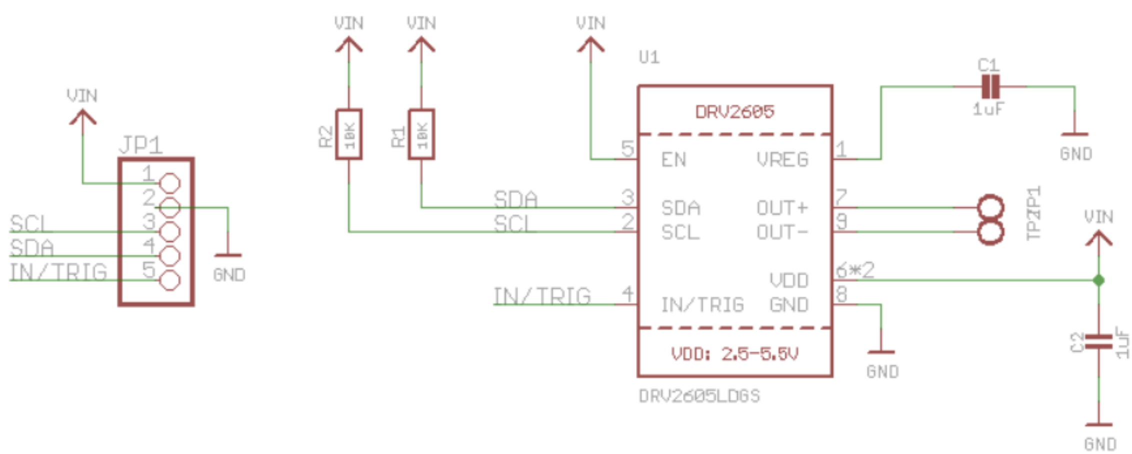
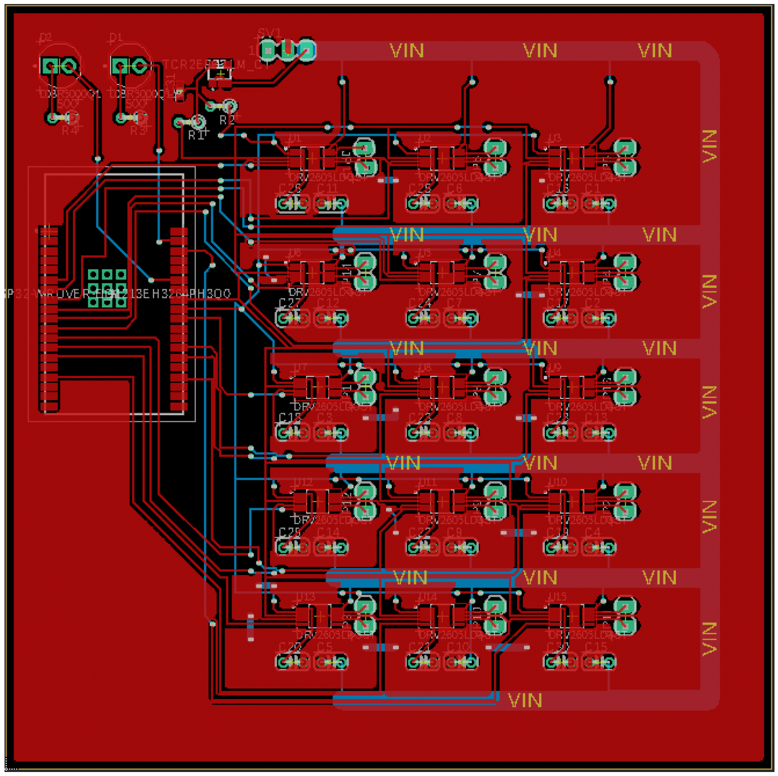


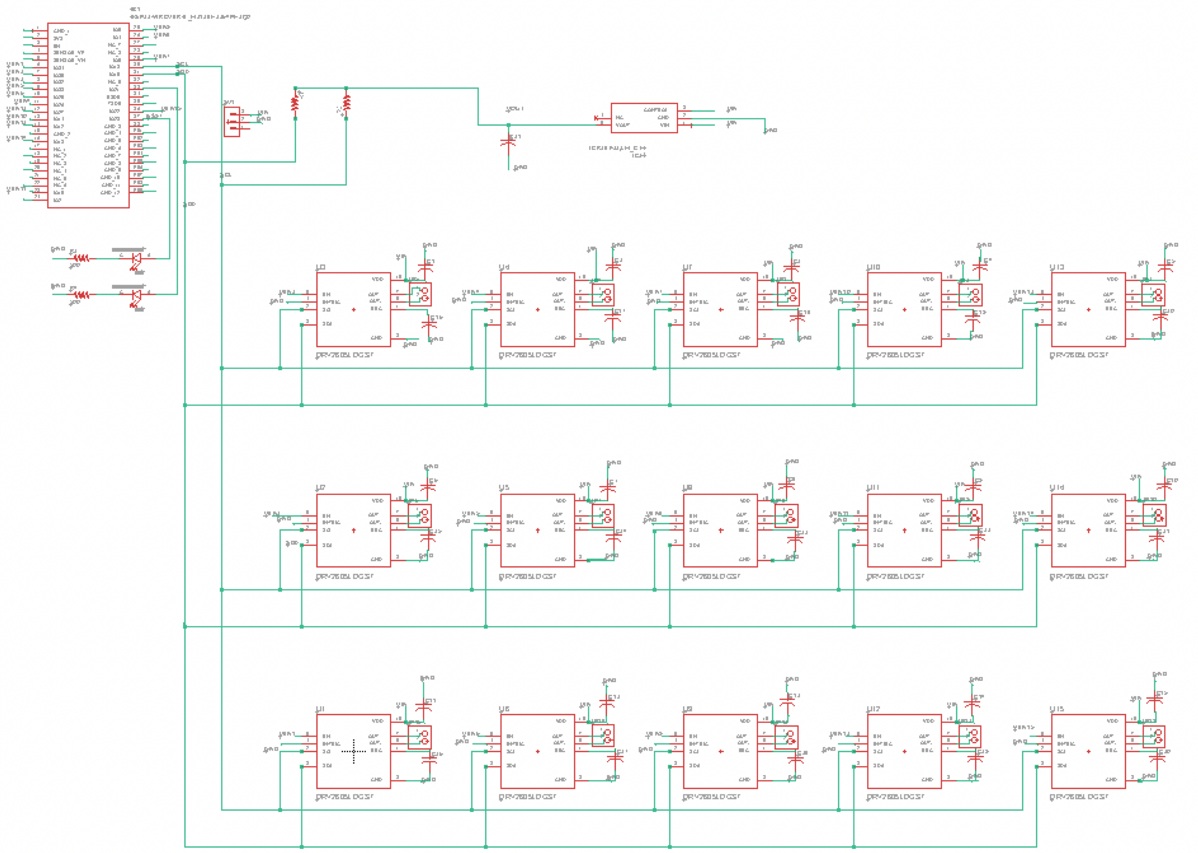
Fig. 4: Chart displaying the battery drain over time of two possible haptic motors, 7G NFP-E1015 (red) and a coin motor (blue). This chart was made with the assumption of 15 motors being used

2.5 SCHEMATIC

Haptic Motor Driver (built on adafruit design)







2.6 TOLERANCE ANALYSIS

One important tolerance we must maintain is determining how much vibrational frequency we need for the desired amount of haptic feedback we want to incorporate in our jacket. Since our jacket will be a wearable device, we need to study where human skin is most sensitive to the mechanical pressure that will emit from haptic feedback.

There are four different sensory receptors in our skin that respond to mechanical pressure. These four types include Merkel’s Cells, Ruffini Ending, Meissner’s Corpuscle, and Pacinian Corpuscle. The former two are best at sensing slower movements and the latter two are best at sensing faster movements such as vibrations. The frequency range for these different sensory receptors vary. Upon research, we have found that most devices that utilize haptic feedback motors aim to be sensed by the Pacinian Corpuscle receptors in our skin due to both its effectiveness and safety [5].

The Pacinian Corpuscle sensory receptors operate at a frequency range of 125 Hz to 300 Hz, peaking at about 250 Hz. Thus, we had to find a haptic feedback motor that stays within this range. Ideally, we wanted to find a motor that is as close to the 250 peak as possible because this is the median value between the 125 Hz and 300 Hz range mentioned above.

There is, however, one caveat to this range. One is that as the frequency of the haptic feedback motor (or essentially any motor) increases, the overall distance-based displacement of the motor increases as well. Velocity (v) is a vector quantity that measures displacement (or change in position, Δs) over change in time (Δt).

$$v = \frac{displacement\ (\Delta s)}{change\ in\ time\ (\Delta t)}$$

Thus, when deciphering the exact frequency of the haptic feedback motor for our jacket, we have to consider what part of the range we would like to aim for. As mentioned above, the ideal frequency range for the Pacinian Corpuscle sensory receptors is between 125 Hz and 300 Hz - resulting in a 250 Hz ideal peak (median). However, considering issues such as the increased displacement of the motor as a result of a higher frequency, we want to find a motor that is slightly lower than the ideal 250 Hz frequency. This is because in our project, since the jacket is a wearable item, it is important that the motors do not move out of place too much. This could defeat the purpose of the jacket if the vibrations are emitted at incorrect locations. Ideally this would mean we want to find any haptic feedback motor would be in the range of 200 Hz to 250 Hz.

Upon further research, we found the NFP-7C-FS0725 haptic feedback motor which has a rated speed of about 14,000 ± 15%rpm.

$$1\ \text{rad/s} = \frac{1}{2\pi}\text{Hz} = \frac{60}{2\pi}\text{rpm}$$

Using the equation above we see that this rated speed converts to 233.33 Hz, which is very close to the ideal range we came up with considering the ideal frequency range for the Pacinian Corpuscle sensory receptors as well as the drawback of increased displacement due to increased speed. This is the mathematical reasoning for why we have decided to use the NFP-7C-FS0725 haptic feedback motor.

3. COST AND SCHEDULE

COST ANALYSIS

- Labor:
  - According to statistics from the Electrical and Computer Engineering Department at UIUC [6], the average salary of Computer Engineer graduates is 84,000 dollars. All 3 of our team members are computer engineers so we will use that to estimate the average hourly salary. Workers in the US average 260 days of work per year as well. So:

    84000 / 260 = 323 dollars/day / 8 hours/day = ~40 dollars/hour * 3 = ~120 dollars/hour
    120 * 2.5 (overhead multiplier) = 300 dollars/hour

    So, to employ our team, it would cost an employer approximately 300 dollars per hour. Estimating 15 hours per week of work and 16 weeks in the semester, the total would come out to $72,000 to provide the average cost to employ a team of engineers of our caliber.
- Parts:

Parts	**Cost (Prototype)**	**Cost (Bulk)**
Haptic Motor (NFP-7C-FS0725)	$5.00	$3.00
Haptic Driver (MAX1749EUK+T)	$2.85	$2.55
Microcontroller + Bluetooth Module (ESP32-WROVER-E)	$3.90	$3.90
Battery (L37A78-3-2-2WX)	$14.99	N/A
Miscellaneous (Wires, Connectors, Cloth/Stitching, Casing)	$25	N/A
Total:	**~$52**	**$9.45**

- Total
  - The prototype will cost around 52 dollars, for the actual jacket, we only need to order extra motors/drivers and one extra microcontroller in case there is a problem, or we burn out the other one. For the motors and drivers at 5.50 bulk cost at 15 pieces each will come to around 75 dollars of expense plus 4 dollars for the ESP, bringing it to approximately 80 dollars. So the total cost of the project should be around $130, plus $72000 of salary.

SCHEDULE

Week	Saksham	Hritik	Anushi
3/8	Finish deciding parts, place orders	Designing PCB	Designing PCB
3/15	Finalize PCB Version 1	Start designing physical prototype	Finalize PCB Version 1
3/22	Start microcontroller programming	Start application programming	Work on physical prototyping, finalize prototype
3/29	Continue physical prototype, continue programming	Continue physical prototype, continue programming	Continue physical prototype, continue programming
4/5	Finalize physical prototype, continue programming	Finalize physical prototype, continue programming, Finalize PCB Version 2	Finalize physical prototyping, continue programming, finalize PCB Version 2
4/12	Finish microcontroller programming, create final project	Finish application Programming, create final project	Finish application programming, create final project
4/19	Begin testing, fix errors	Begin testing, fix errors	Begin testing, fix errors
4/26	Finalize project, begin final report, continue debugging code	Begin final report, continue debugging code	Begin final report, enhance any needed physical components
5/3	Finish final report	Finish final report	Finish final report

4. SAFETY AND ETHICS

For our power supply unit we are using a 7 Ah lithium-ion battery to keep all 15 haptic feedback motors running for a period of 4 hours. The problem with these batteries is that they can easily overheat. This can happen either by overcharging the battery, overusing the battery, or bringing the batteries to extreme temperatures. This is especially risky in our project because the batteries are placed inside of the jacket which will actually be worn by a person. To mitigate this, we will make sure to not overcharge, overuse, and bring the jacket/battery to extreme temperatures. In addition, we will replace the batteries every couple weeks to make sure that the batteries are not being overused.

Another possible concern for this project is that the haptic feedback for certain video games (particularly those where we will be simulating gunshot hits) may be too upsetting for certain people, especially those with pre existing heart conditions. To resolve this, we will conduct a lot of research regarding how much stimulation is safe over the parts of the body that the jacket covers, and pay close attention to the rules and regulations of other high stimulation activities such as roller coasters to ensure that the ride is safe for everyone. This aligns with the IEEE Code of Ethics, #9, which states that technologies should not injure people [7].

It is evident that the media plays a large role in our society today. It is responsible for not only learning but also the mental well-being of many young people. Status quo is that there is concern that violence from video games make young people more prone to violence in real life. Questions may arise regarding whether enhancing the video game experience from 2D to 4D will make matters worse. Although these concerns exist, there is no scientific evidence correlating video games to someone becoming more violence prone. Facts are based on quantitative methods and scientific calculations, and not opinions or anecdotes. This aligns with IEEE Code of Ethics, #5. In order to be “honest” and “realistic” in stating claims and concerns, we have to look at the available evidence which explicitly does not correlate playing video games and increased violence [7]. Thus, since there is no actual evidence linking the two together, we contend that enhancing the video game experience through our project does not provoke any ethical risk.

References

[1] Time. 2021. Don’t Feel Bad if Your Kids Are Gaming More Than Ever. [online] Available at: <https://time.com/5825214/video-games-screen-time-parenting-coronavirus/> [Accessed 19 February 2021].

[2] 2021. 11/30 Update: Verizon is prepared to serve customers during COVID-19 crisis. [online] Available at: <https://www.verizon.com/about/news/update-verizon-serve-customers-covid-19> [Accessed 19 February 2021].www.verizon.com/about/news/how-americans-are-spending-their-time-temporary-new-normal.

[3] BBC News. 2021. Netflix gets 16 million new sign-ups thanks to lockdown. [online] Available at: <https://www.bbc.com/news/business-52376022> [Accessed 19 February 2021].

[4] The NPD Group. 2021. Average Weekly Netflix Usage Rose 72% in the U.S. Since COVID-19 Pandemic Began. [online] Available at: <https://www.npd.com/wps/portal/npd/us/news/press-releases/2020/average-weekly-netflix-usage-rose-72-in-the-us-since-covid-19-pandemic-began-the-npd-group-says/> [Accessed 19 February 2021].

[5] Precision Microdrives, 2021.“What Vibration Frequency Is Best For Haptic Feedback?,” Precision Microdrives. [Online]. Available:https://www.precisionmicrodrives.com/content/what-vibration-frequency-is-best-for-haptic-feedback/. [Accessed: 02-Mar-2021].

[6] https://ece.dev.engr.illinois.edu/admissions/why-ece/salary-averages.asp

[7] Ieee.org. 2021. IEEE Code of Ethics. [online] Available at: <https://www.ieee.org/about/corporate/governance/p7-8.html> [Accessed 19 February 2021].