Mock Design Review

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Introduction

According to the American Chiropractic Association, 31 million americans experience low-back pain at any given time[1]. Lower back pain is the single leading cause of disability worldwide,and back pain is the second most common reason for visits to the doctor's visits, outnumbered only by upper-respiratory infections. Furthermore, Americans spend at least $50 billion each year on back pain. A study done by the Agency for Healthcare Research and Quality showed that most cases of back pain are mechanical or non-organic, meaning they are not caused by some major illness. National Center for Biotechnology Information states that acute episodes of back pain are associated with muscle strain.

A major player in back pain is poor posture, something many who work a desk job can relate to. The typical method of fixing/correcting posture is just "remembering to sit up straight". However, until muscle memory has been formed, this is difficult and as a result, many never "learn" proper posture, potentially resulting in injury.

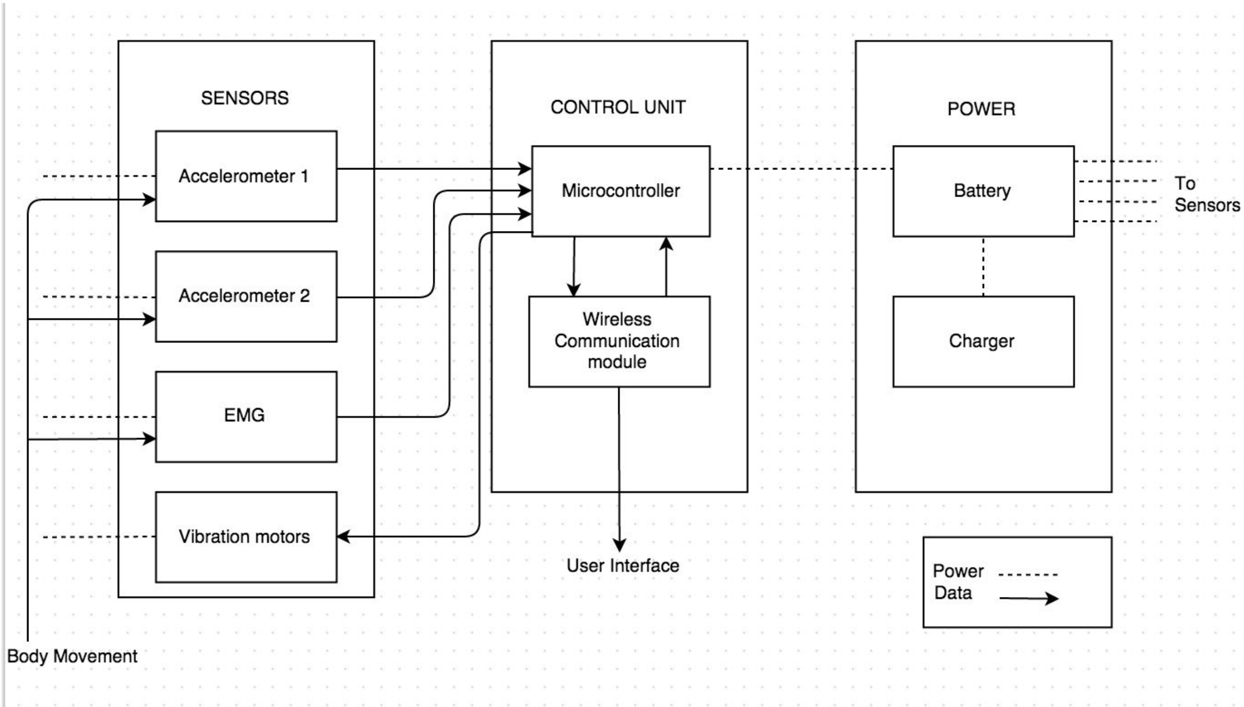
The 'Slouch Detector/Posture detector' was a ECE 398/445 project[2], using two accelerometers attached to the back; one near the base of the spinal curve and one near the top to measure the posture. We will be adding features to the project, giving more functionality to the user and solve the problems faced in previous semesters such as perfecting the method of mounting the device, designing a product which can be comfortably worn and improving the accuracy of bad posture detection. We will also try to add sensors to cover the horizontal axis, and measure muscle flexity to see how these factors affect posture in totality.

We will be giving users a more flexible choice in calibrating the way they want it. This flexibility for users means that the product would be perfectly able to understand the user's physical posture and give very accurate and personalised corrective feedback. Also we want to check the tension in the muscles which are normally affected by posture problems and want to alert the user about this. This gives us a stronger hold over the position of the user and makes sure that the user's posture is maintained.

We selected this project as we thought that there is a very dire need for such a product in the market. There is only one other such thing in the market, 'Lumo Lift' and that too does not seem to give very precise results and does not have too much that it monitors. It also has a different approach to the measurement of posture including the use of a gyroscope. We are sure that with the growth in a sedentary lifestyle, more and more people will be affected by posture problems.

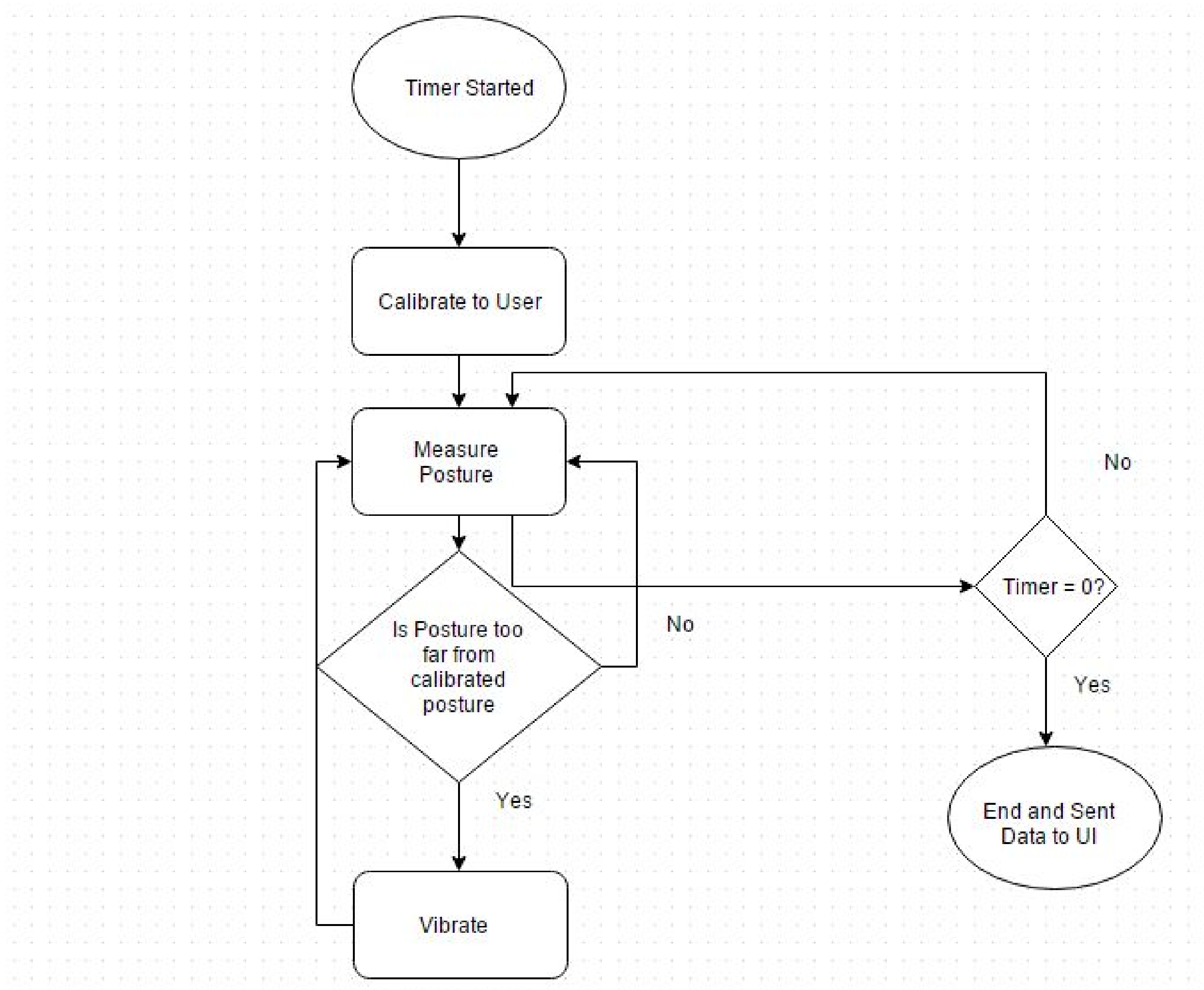
Design:

Block Diagram:



Dotted lines	Power going out from battery. Charger sends power to battery
Arrows	Shows direction of flow of logic/signal. Body movements signals are picked up by the sensors. Wireless module will send data to computer/phone.

Finite State Machine:



Block Descriptions
Sensors

Muscle Flex Sensor (EMG) [3]:

- Movement/tension in muscles will send an input signal which will be picked up by the EMG
- Checks whether the muscle is tightened or loosened.
- Sends a high or low signal corresponding to the muscle tightened or loosened.

Accelerometer[4]:

- Movement in the body, and changes in posture will change angles measured by the accelerometer. Thus, body movement will act as input to accelerometers.
- Measures the acceleration at the base of the curve of the spine and the top of the curve of the spine. Thus, calculate the angle by which the person is bending and check if threshold is crossed.
- These values are sent directly to the microcontroller which can be used to calculate the angle differential.

Vibration Motor[5]:

- Takes a high or low from the microcontroller
- Vibrates if it is high and indicates to the user that they are not in a position that has acceptable posture.
- The output is the vibration and we will have a regulator to control the duration and signature of vibration so that this is a comfortable signal for the person using this device.

Control Unit
Microcontroller:

- Receives data from the sensors and also the wireless communication module.
- Computes the angle of the back through the accelerometer data and also sees if the muscles are flexed. If any of these values cross the specified threshold values; then it knows if has to signal one or more motors.
- Depending on the settings the microcontroller sends a signal to the vibration motor(s) if the posture is not acceptable.

Wireless Communication Module[6]:

- Takes the angles and muscle flex data from the microcontroller and relays them to a computer.
- If there is a change in the setting, relays back the new parameters.
- We will try to have a smart algorithm here that uses minimum energy to transfer data. The output can be seen on a computer in form of a graph maybe.

Power:
- The only input will be a charger[7] such the battery pack[8] can be recharged. Given time, we would like to implement a charger module as well.
- The output would be controller current and voltage for which a regulator can be used.
- We can simply power the device with small and portable batteries (2 AA).

Circuit Schematic
Our final product will comprise of different circuit schematics. They are:
a. Rechargeable battery pack (preferably a Polymer Lithium ion battery pack).
b. Motor design to vibrate when required so by the pcb.
c. Accelerometer and Gyroscope as per requirement. We can have 2 accelerometers but trade off portability. We can also use 1 accelerometer and 1 gyroscope to achieve a similar functionality.
d. Pcb design with a microcontroller to work out the calculations by the accelerometer and gyroscope. We can have onboard memory to store some data.
e. A wireless communication module to send the stored/calculated data to a server/phone/computer over low power bluetooth

(b) Vibration Motor:

Vibration motor expected to be a physical indicator without notifying anyone but the user.
- Low powered
- Energy efficient
- As small / flat as possible to be a wearable.

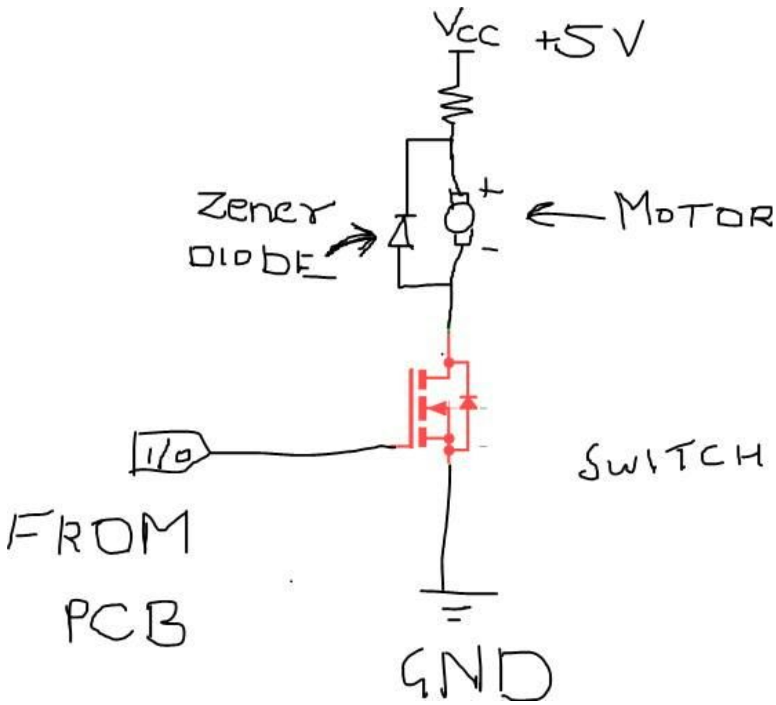

Specifications of motor[5]:
- 10mm frame diameter
- 3.4 mm height
- weight 1.2grams
- 3V (2.5V to 3.8V)
- Rated current - 75 mA

- Start current - 85 mA
- Rated speed - 12000 rpm
- Terminal Resistance - 75 Ohms
- Vibration Amplitude - 0.8G

All these specific details have been taken from Sparkfun.com.

Circuit diagram for vibration motor

VERSION 1



The switch can be placed above the resistor.

We can also attach a linear voltage regulator like LM7805, LM317, or LD1117 in series with the motor[9].

Alternatively. Lilypad shown below has incorporated this same circuit; however it seems to waste too much space.

VERSION 2

This has the same circuit above and operates at 5V.

We can also completely get rid of the voltage regulator as we do not expect much variation in voltage and current and these voltage regulators might waste a lot of power.

As an example. if we have a 7V supply, and have to provide 3V, 0.08 Amps to motor, we will be wasting
(7-3) * (0.08) = 0.32 W.

This is not too bad for power losses but can still be a significant amount of wasted energy[10].

Please note: We intend to reduce the size of this motor further; or rather want to make it flatter so that our final wearable device does not have to be restrained by the thickness of this. As of now this is the smallest vibration motor we could find.

We can also consider using the voltage regulator that we made for eagle assignment if it is low power consuming.

(a) The battery circuit schematic:

Module to recharge lithium ion battery[7].

- Charge using a micro usb.
- Status LED to show when the battery is charged.
- Voltage Regulator options: 4.20V, 4.35V, 4.40V, 4.50V
- Programmable charge current: 15mA to 500mA

All diagrams below; refer to [7]

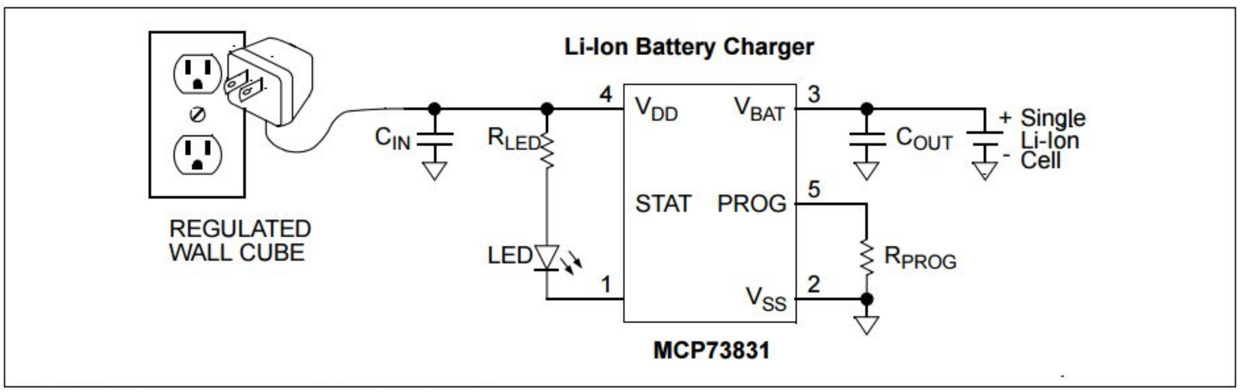
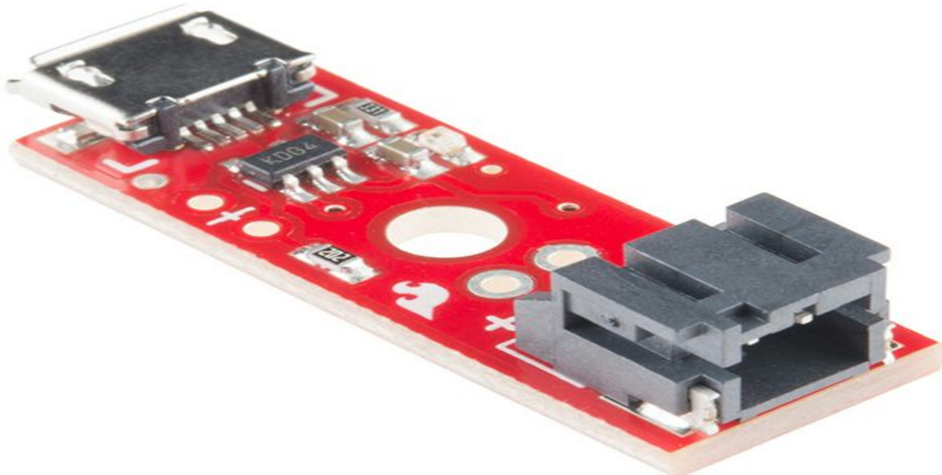
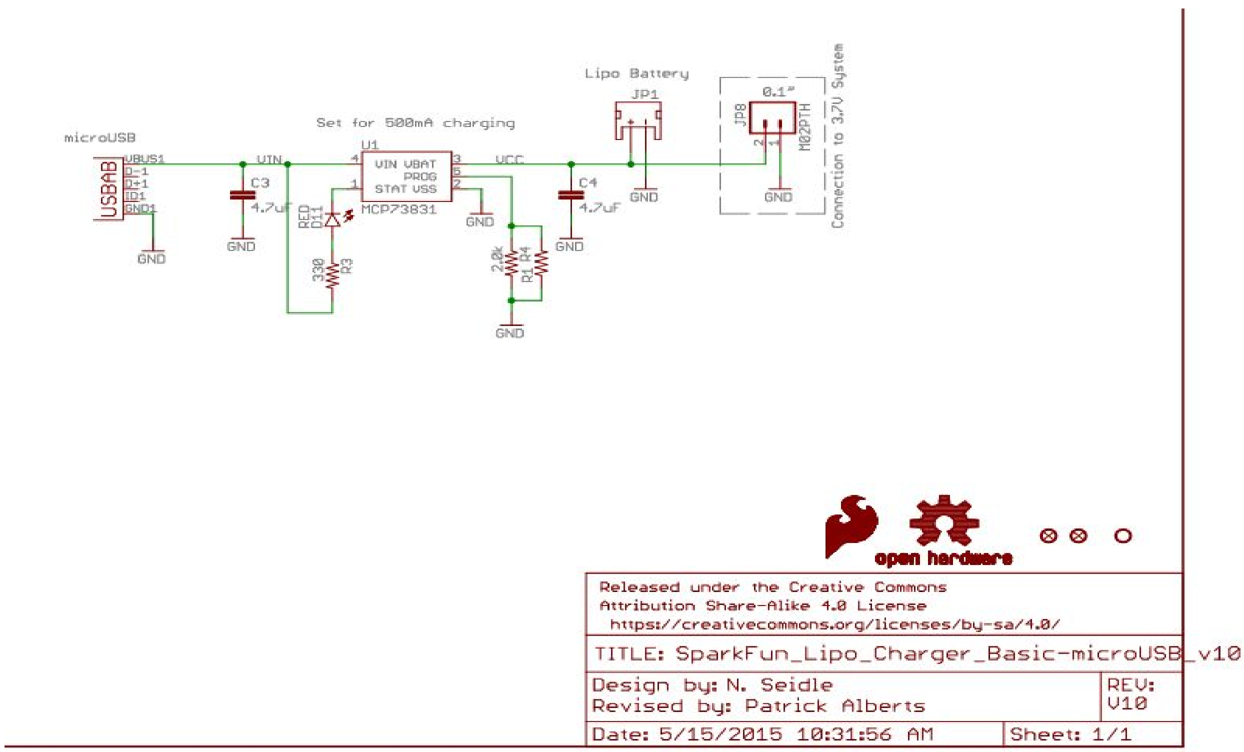


FIGURE 6-1: *Typical Application Circuit.*





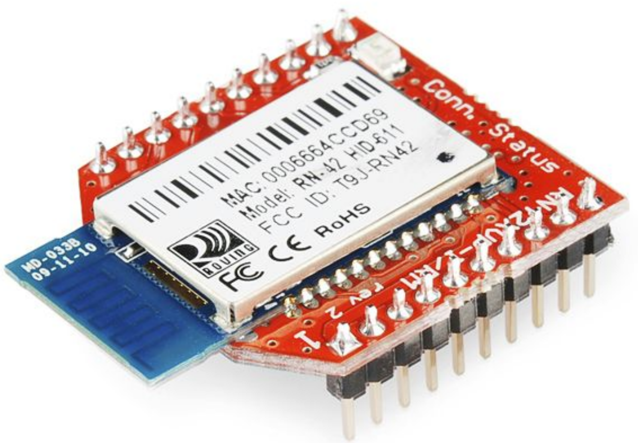
Schematic for recharging battery[7]

(e) The communication module:

Bluetooth module to connect to our pcb which will be capable of sending data[6].

- Low Powered bluetooth.
- Version 2.1 and backward compatible with version 2.0, 1.2, 1.1

- Can transfer 3Mbps data rate for distances upto 20 meters.
- Power consumption is 26uA sleep, 3mA connected, 30mA transmit.
- Secure communications, 128 bit encryption.
- 3V DC supply voltage (max 3.6V and avg 3.3V).
- We will separately need a voltage regulator to give it a 3.3 V continuous supply.



Calculations:

- **For vibration motor (DC shaftless motor)**

If we observe, this motor has a higher starting current than when running continuously. DC motors unlike other motors have a very high starting current that has the potential of damaging the internal circuit.

Let us further explore why we need that extra current. The basic operational voltage equation of the dc motor is given by,

$$E = E_b + I_a R_a$$

E = supply
Ia = armature current
Ra = armature resistance
Eb = back emf

The back emf is produced by the rotational motion of the current carrying armature conductor in presence of the field.

$$E_b = \frac{P.\phi.Z.N}{60A}$$

So, we can see that back emf depends on the speed of the motor (N). Since, N = 0 at the time the motor starts, $E_b = 0$.

Our final operational voltage equation becomes $E = 0 + I_a R_a$.

Thus, $I_a = \frac{E}{R_a}$.

This is why we have a very high starting current; and a result high starting torque.

This is why we use a starter to limit this current. This starter is basically a variable resistor (R_{ext}) connected in series to the ‘armature winding’ so as to limit the starting current of this motor to a desired optimum value.

Therefore, $I_a = \frac{E}{R_a + R_{ext}}$

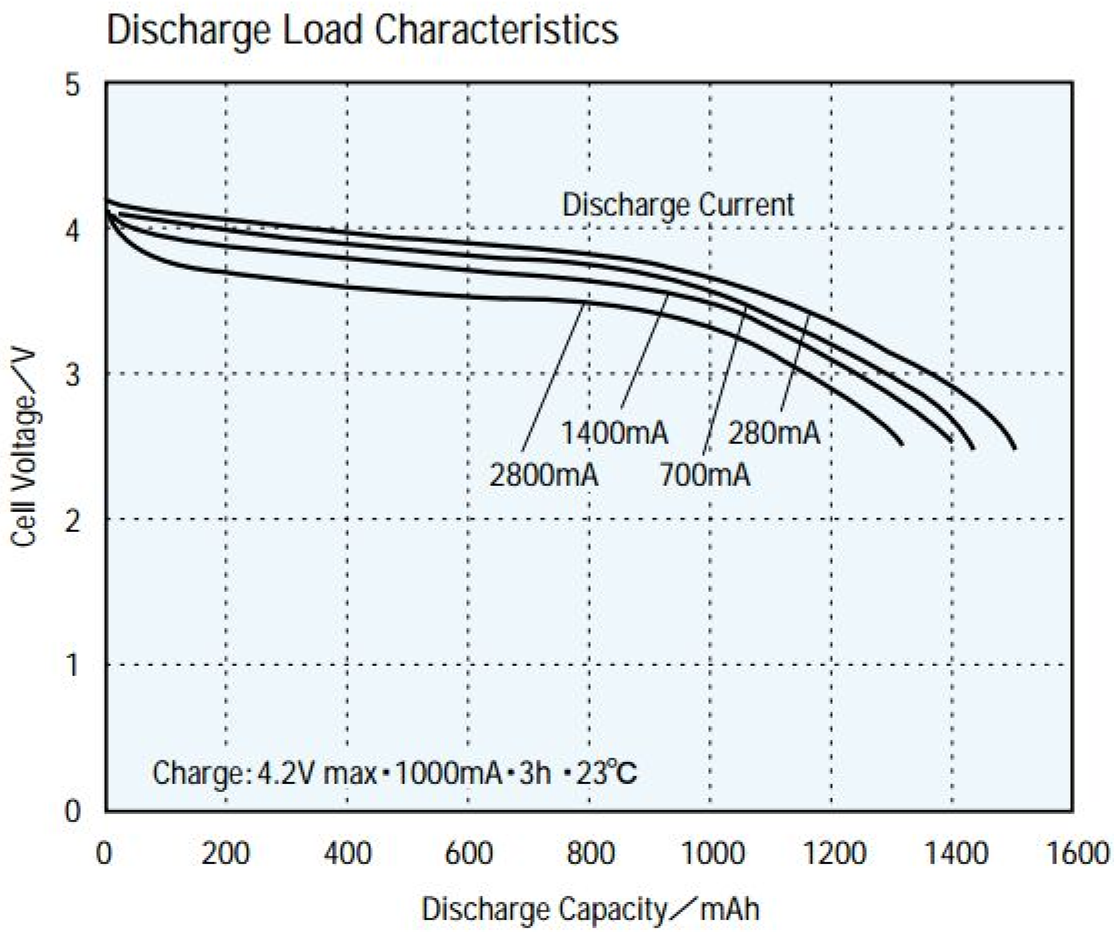
Now as the motor continues to run and gather speed, the back emf successively develops and increases, countering the supply voltage, resulting in the decrease of the net working voltage. Thus now,

Therefore, $I_a = \frac{E - E_b}{R_a + R_{ext}}$

At this moment to maintain the armature current to its rated value, R_{ext} is progressively decreased unless it's made zero, when the back emf produced is at its maximum. The regulation of the external resistance in case of the starting of dc motor is facilitated by means of the starter.

- **Plot (simulation or experiment) for vibration motors**

This would be any kind of data that you acquired in the course of your design



Polymer Lithium Ion DataSheet[11]

Block Level Requirements and Verification

Module	Requirement	Verification
Vibration motor	The max peak of the current sunk into the motor should not be greater than 95mA The motor and switch should accept high frequency PWM pulses demonstrating good feedback	Connect the motor to a battery and measure the current with an ammeter. The current peaks cannot exceed 95mA. Send PWM pulses under different frequency and duty cycles to find ideal frequency.
Battery/Voltage Regulation	The voltage supplied has to be greater than 3.0V regardless of spikes from the vibration motor. No liquid such as water or liquid goes through the case containing the battery and affects the functionality.	Connect the PCB, accelerometers, vibration motor, EMG and check for voltage drop with multimeter. Spray water lightly along the case and see whether the functionality is affected.

Safety Statement:
Since we are making a wearable, we will have to make sure that even if something fails, it either recovers gracefully; else stays intact and limited to the device such that the user has no physical signs of the device being broken.

Some of the things to keep in mind are:
- The battery has to be properly packed. Has to be surge protected and properly packed to prevent any leakage..
- We need to understand that a short is possible in case the device is managed roughly. We have to isolate all the components as much as possible to prevent this; and also have to incorporate a circuit breaker.
- Something to consider would be the heat of the board, if it is run for a very long time, there is a chance that the heat from the board could be harmful to the user or the surrounding parts.

Citations:

[1] Getting facts about back pain
http://www.acatoday.org/Patients/Health-Wellness-Information/Back-Pain-Facts-and-Statistics

[2] previous projects done by students used as a reference
https://courses.engr.illinois.edu/ece445/getfile.asp?id=6910

[3] Got the idea for using an EMG from here. We might give sockets to add these to final product
http://www.instructables.com/id/Muscle-EMG-Sensor-for-a-Microcontroller/

[4] We will use this when making the circuit for accelerometers
http://www.dimensionengineering.com/info/accelerometers

[5] The first one is lilypad and the second one is button vibration motor.
Also refer to the data sheet for both these products on the website below
https://www.sparkfun.com/products/11008
https://www.sparkfun.com/products/8449

[6] bluetooth module
https://www.sparkfun.com/products/11601

[7] battery charger from micro usb
https://www.sparkfun.com/products/10217

[8] lithium ion battery
https://www.sparkfun.com/products/10718

[9] Check out which linear voltage regulator is needed from this page
http://www.mouser.com/Semiconductors/Power-Management-ICs/Linear-Voltage-Regulators/_/N-5cg9g

[10] Calculation for power loss to heat
https://www.dimensionengineering.com/info/switching-regulators

[11] Lithium Ion Battery- Discharge Characteristics
http://cdn.sparkfun.com/datasheets/Prototyping/Lithium%20Ion%20Battery%20MSDS.pdf

Suggested websites to see:

Below are couple of suggested motors that can be used:
https://www.sparkfun.com/products/11008
https://www.sparkfun.com/products/8449
http://www.precisionmicrodrives.com/vibrating-vibrator-vibration-motors/pancake-shaftless-coin-vibration-motors/design-considerations

The following links to get a lithium ion battery and recharge it using a micro usb.
https://www.sparkfun.com/products/10217
https://www.sparkfun.com/products/10718

Following link for a bluetooth module
https://www.sparkfun.com/products/11601

Calculations for high starting current for vibration motor
http://www.electrical4u.com/starting-methods-to-limit-starting-current-torque-of-dc-motor/