Stepper Machine Power Generation

ECE 445 Project Proposal

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1 Introduction

1.1 Problem

Exercise in our era is difficult to fit into our busy schedules. Even when we can find the time to exercise, sometimes we are unmotivated or it comes at an opportunity cost. The pandemic also increased the amount of people working remotely from their desks at their homes. Sitting around is just as much of a killer as smoking is. It has been found that people who sit for more than 13 hours a day are actually at a 200% higher risk of death when compared to people who sit for only 11 hours or less per day. Sometimes we are however forced to sit and it would be nice to get an exercise in while sitting and doing work.

1.2 Solution

A sitting exercise step machine that could generate electricity by an up and down movement of the legs would be a viable exercise in an office setting, because it leaves the arms free and you are able to do it without your hands. It also is not an intense exercise so you are not sweating while sitting or standing in an office. Finally this exercise machine can use that movement in order to generate some electricity, giving the user a sense of accomplishment.

The exercise machine we plan on creating is a step motion machine that can be used while sitting. The steps will be able to be converted into electrical energy by connecting to a DC motor. We plan on using this electrical energy to efficiently charge a phone (3.8V) battery. Charging a phone battery may not be enough incentive, so we also plan on connecting the machine to a smartwatch or computer to be able to remind the user to use the machine. This app will help the user space out their workouts during the day so they are forced to take breaks from sitting.

1.3 Visual Aid

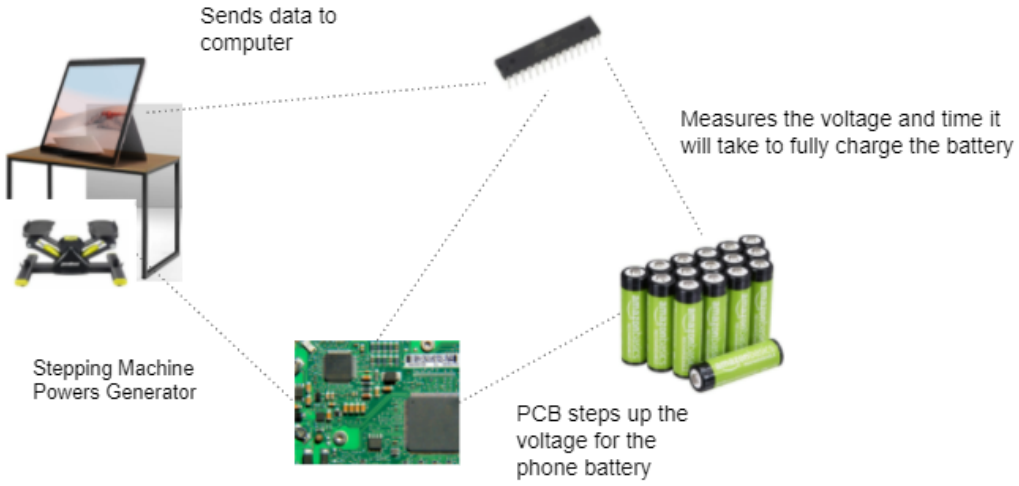


Figure 1: Visual aid of how the whole project is planned

1.4 High-level Requirements List

Electricity Generation

Demonstrate that stepmotion can produce usable energy and be able to convert the energy produced in step motion to charge phone batteries. This means that our power electronics need to be able to convert the electrical energy generated from the motor and stepper into a constant 3.8 V to charge the battery within about 1%.

Convenience Criteria

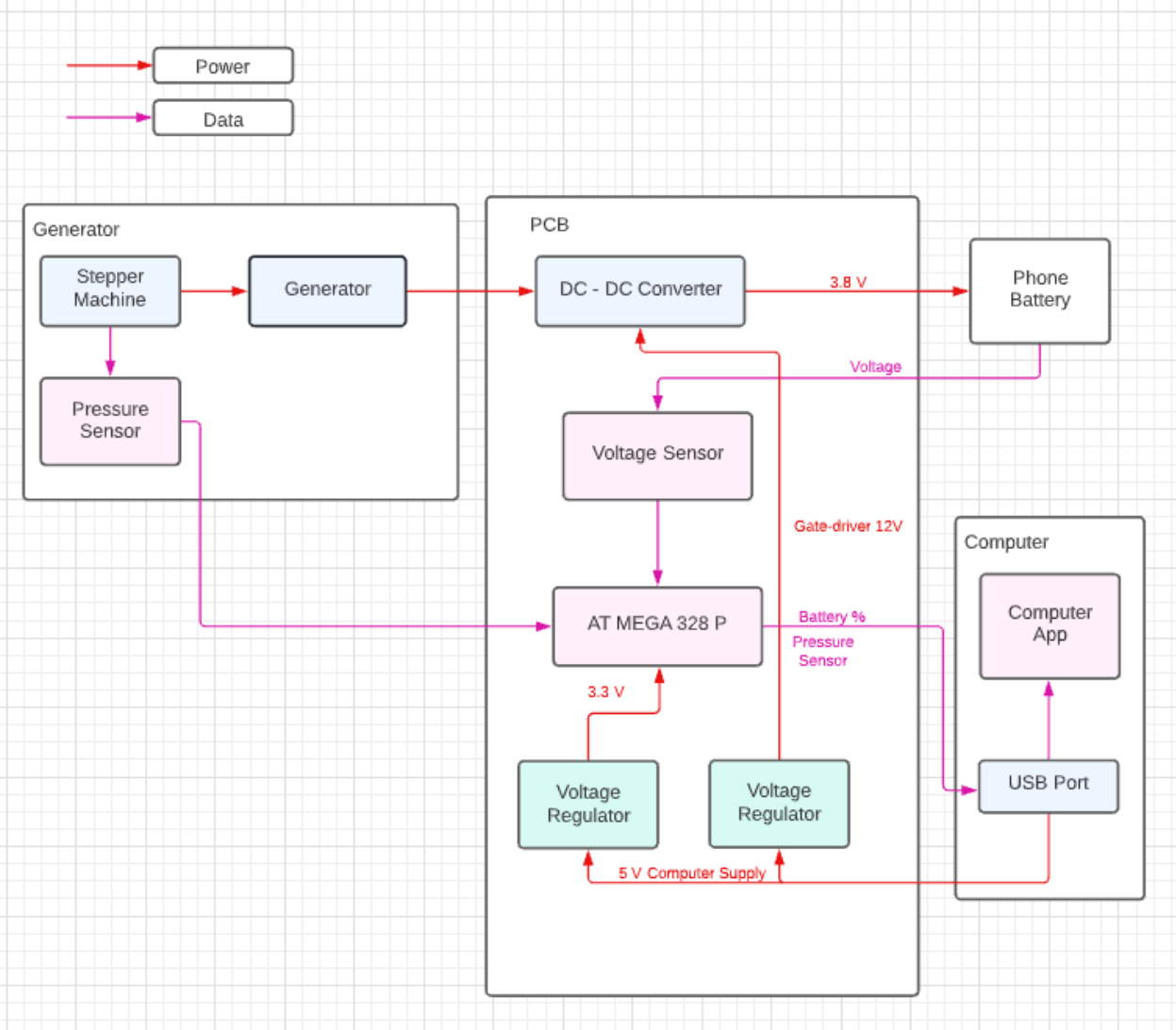
We want our machine to be able to be used while sitting or standing and we want the machine to be convenient to use while the user is working. Demonstrate that our step motion can perform as a workout machine by being able to use it while sitting, and make the step motion small enough so that it can fit under a desk. Common desk sizes are around 36 inches deep, around 30 inches tall, and usually have a minimum width for a person of around 24 inches. This means that our machine including the generator should be able to fit in that amount of space. Either to be used or stored under the desk.

Computer App Specifications

We need to demonstrate that the step machine can send notifications that can be turned off when the user uses the machine based on the daily goal. The application should be simple to use and it should be able to display the battery charge percentage. The computer app will have a minimum workout time that corresponds to how long the user needs to go to get some charge to the battery. We will be able to demonstrate this during a short amount of time by being able to set that the user wants to workout a lot and is able to set time in between workout sessions to be very short.

2 Design

2.1 Block Diagram



2.2 Subsystem Overview:

2.2.1 Mechanical System (Generator)

Stepper Machine

To be a generator, we need a mechanical system that can convert the step motion into electrical energy. We plan to produce mechanical energy with a generator connected to the step machine. If the user creates mechanical energy by moving legs, the motor will convert the mechanical energy to electricity. The electricity converted by the motor will be connected to the PCB board so that it can be converted to a voltage that can be safely put into the phone battery.
Requirement 1: The generator needs to be able to fit under the table.
Requirement 2: Needs to be able to convert mechanical motion of stepper to move generator.

Generator

We will be using a Minertia Motor P12-H in order to generate electricity. This is a relatively small motor which is perfect for our design as we are not going to be generating a lot of electricity and we are planning on making the whole thing fit under a desk. We are expecting around 30 watts of power and around 0-3 volts from the generator. Because the exercise is not strenuous and the stepper design inefficient, we expect the output of the generator to be low.
Requirement 1: Needs to be able to convert the mechanical energy from the stepper to a DC power.

Pressure Sensor

We are going to have pressure sensors on the step machine. In order for users to use the step machine, the user's weight will press down the pressure sensor and will send data to the user's computer. We are planning to use 'SEN-13879' as a pressure sensor.
Requirement 1: Needs to be able to hold the user's weight. If the user's weight is over or under the range pressure sensor can detect, it would cause problems to the whole system.
Requirement 2: Needs to be able to connect with PCB and computer to communicate datas.

2.2.2 PCB

DC-DC Converter

We want to be able to charge phone batteries with this machine. To do this, we will need a PCB that can step up the voltage generated by the machine into voltage that can be used to charge phone batteries. This will likely involve a DC-DC power converter that is able to handle low, inconsistent voltages. This will rely heavily on how much power we are actually able to create from our stepper generator as an input..
Requirement 1: Needs to be able to handle inconsistent DC values from the DC Motor.
Requirement 2: Needs to output 3.8 V to charge phone battery within 1% or 50mV.

Voltage Sensor

For the computer app part of our project we want to be able to display on the app how charged the battery is. To do this we need a voltage sensor to sense the voltage of the battery so we can tell how charged the battery is. This information will be passed to the microcontroller then to the computer app.
Requirement 1: Needs to be able to sense voltage within plus or minus 1%.

Voltage Regulators

The voltage regulators are to be used to supply both the microcontroller and the gate driver for the DC-DC converter. These will both be taking a 5 V supply from a USB port from a computer to convert the voltages to the specified amounts.
Microcontroller Requirement: Needs a 3.3 V supply with a tolerance of plus or minus 1V.
Gate Driver Requirement: Needs a 12 V supply with a tolerance of plus or minus 2V.

Microcontroller (ATMEGA328P)

The microcontroller we plan on using is the ATMEGA328P. This device is being used to take information from the pressure sensor and the voltage sensor and send it to the computer software so that the computer knows when to turn off the notification to work out and so the computer knows how charged the battery is.
Requirement 1: Must be able to collect data from both sensors and quickly send that information to the computer application.

2.2.3 Computer Connection

Computer Application for Device

We will use a simple app on the user's computer to notify them when the users should work out with step motion again based on the time intervals to promote activity throughout the day. The app should be able to set up a goal for the exercise and notify users periodically throughout the day to hit their exercise goals. The program will also be able to create a time for how long the user should use the machine at different times throughout the day to ensure sufficient charge of the battery. The app will also show how charged the battery is so that the user can see.

Requirement 1: Users can set how often they would like to workout during the day.
Requirement 2: The application will be able to take the user's workout plan to create a workout schedule and will notify the user when to workout.
Requirement 3: The notification will turn off when the microcontroller sends a signal that the machine is being used.
Requirement 4: Battery Percentage will be calculated based on the voltage sensor data received from the battery.

USB Port

The USB port of a computer will be used to supply 5 V to our voltage regulators to power our PCB elements and to be able to send information between the computer application and the microcontroller.

Requirement 1: Must be able to supply a constant 5 V source.
Requirement 2: Must have USB connection on board to transmit information from microcontroller to computer and for power supply uses.

2.4 Tolerance Analysis

Making a good PCB with a DC-DC converter will be a risk to successful completion of the project. In PCB, we have to take in smaller voltages and currents to produce larger voltages so that it matches the voltage of the phone charger (3.8 V). This will be hard to do because we need to be very close to the battery voltage (within 50mV) to ensure safe charging of the phone battery. This means our PCB will have to be very precise. We do think that through simulation and testing before connecting our machine to the battery we will be able to ensure that the output voltage of our DC-DC converter will be constant and within the tolerance of our phone battery.

3 Ethics and Safety

Since the project is worked as a team size, all the team members should have responsible behavior. Team members will respect each other and treat everyone fairly. Also, we will not engage in any kind of harassment and discriminate against each other.

Along with any other batteries, it is important to safely operate without exceeding the limits of the batteries. Taking battery safety into account we will have to pass the battery safety training and will test our output voltages before actually connecting to the phone battery.

When using and modifying a training machine, it is possible to get physically harmed while using the machine. It is important to make sure that there is no chance of users getting hurt while using the step machine. This will also apply when controlling PCB, so that no one gets hurt from electricity. We will ensure that the PCB is properly enclosed to prevent damage and will include safety warnings on the workout machine to ensure safe use.

4 References

[1] Yaskawa America *Minertia Motor P series (P09, P12) brochure*. Minertia Motor P series (P09, P12) Brochure. Retrieved February 10, 2022, from https://mobile.yaskawa.com/downloads/search-index/details?showType=details&docnum=CHA-C242-5.10B

[2] Randall, S., & Team, U. H. (2021, November 29). *Standard Desk Dimensions & Layout Guidelines (with photos)*. Standard Desk Dimensions & Layout Guidelines. Retrieved February 10, 2022, from https://upgradedhome.com/desk-dimensions/

[3] *IEEE Code of Ethics*. IEEE. Retrieved February 10, 2022, from https://www.ieee.org/about/corporate/governance/p7-8.html

[4] *The code affirms an obligation of computing professionals to use their skills for the benefit of society.* Code of Ethics. Retrieved February 10, 2022, from https://www.acm.org/code-of-ethics