Wind Turbine Phone Charger

ECE 445 - Spring 2018
Mock Design Review

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Diagrams

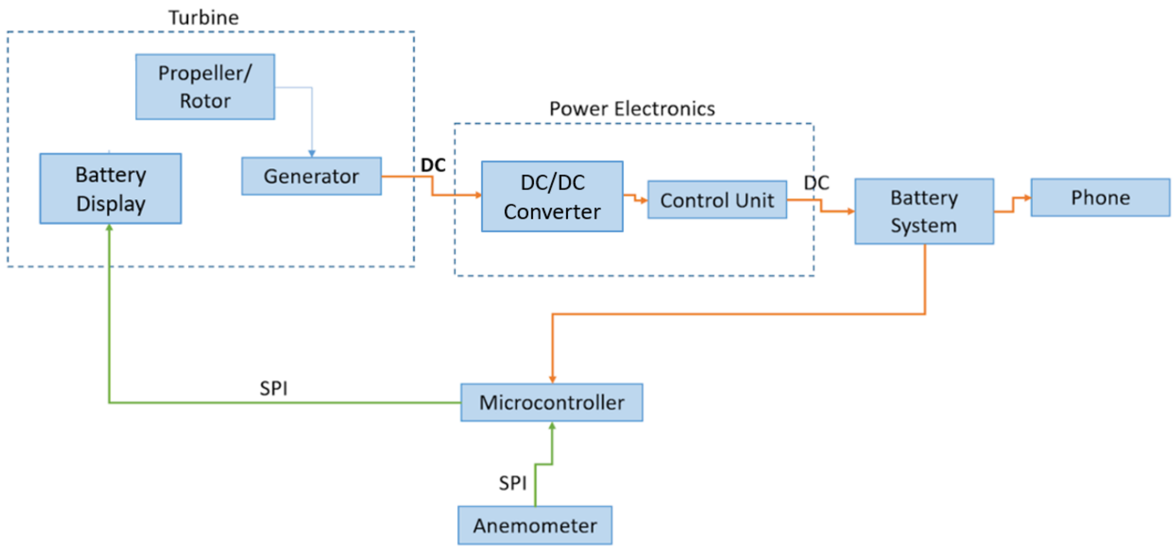

Figure 1: Block Diagram #1

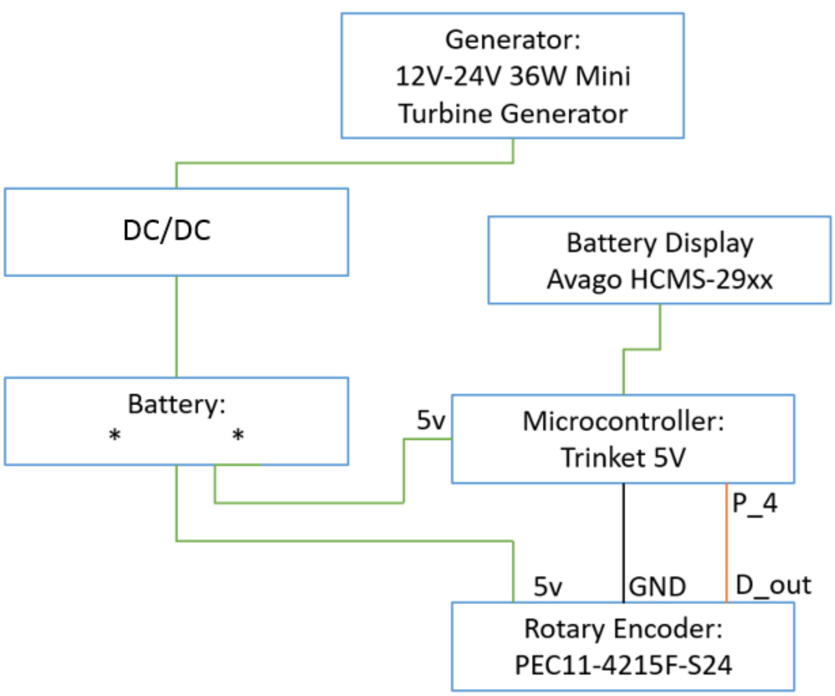

Figure 2: Block Diagram #2

Mechanical Design

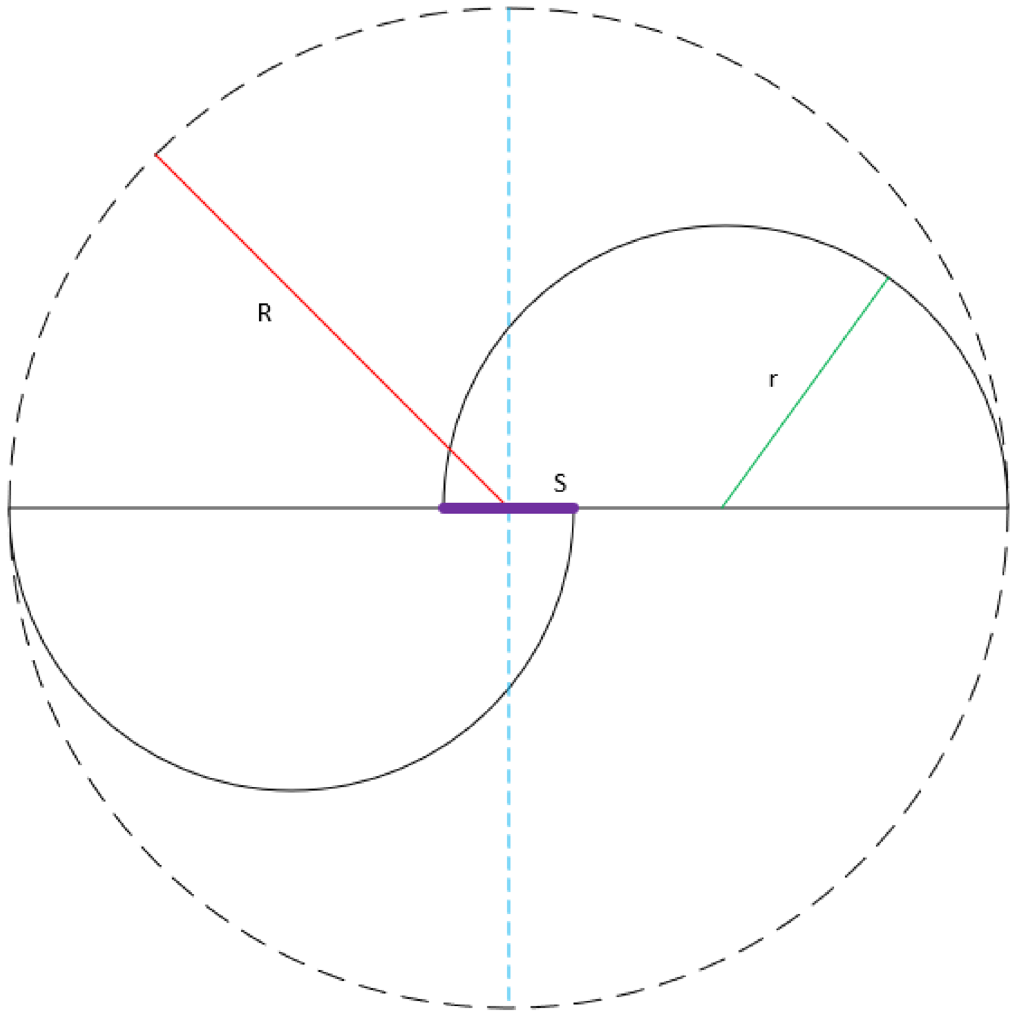

Figure 3: Two-bucket Savonius Design - Bird’s-eye view

Circuit schematics

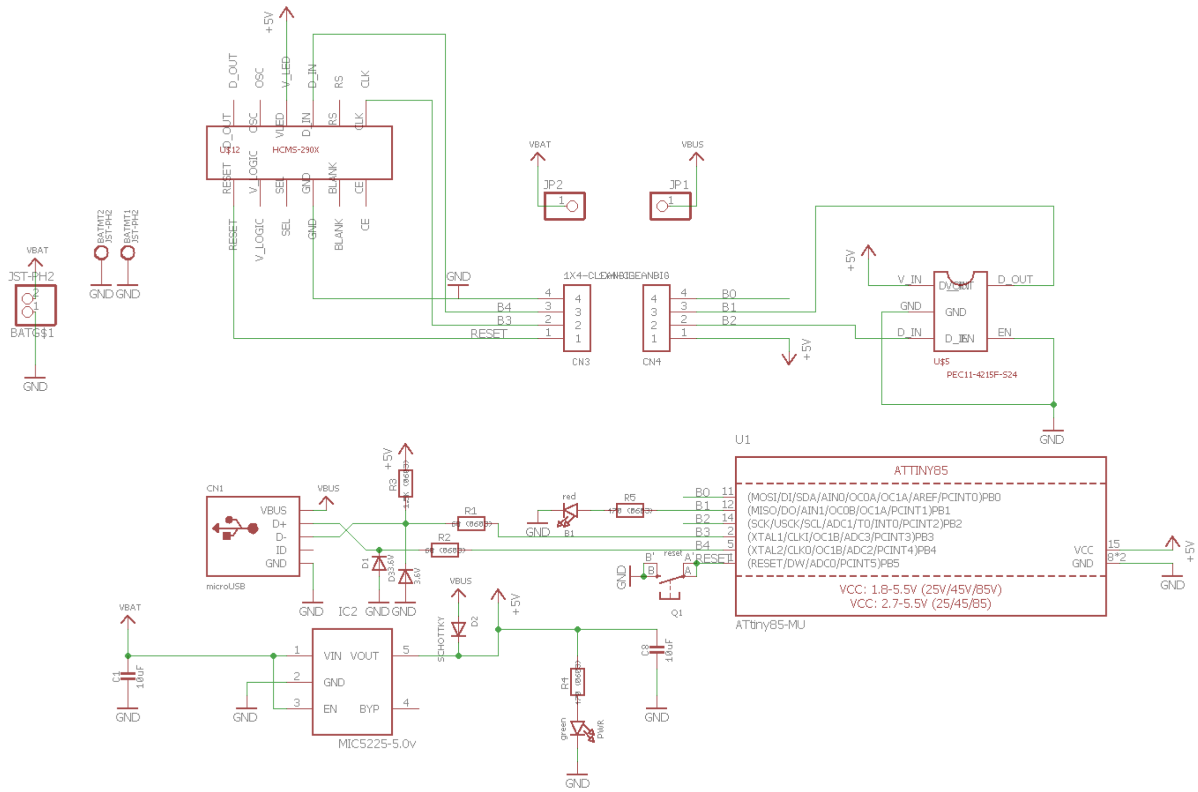

Figure 4: Circuit schematic for Microcontroller based on Trinket 5V

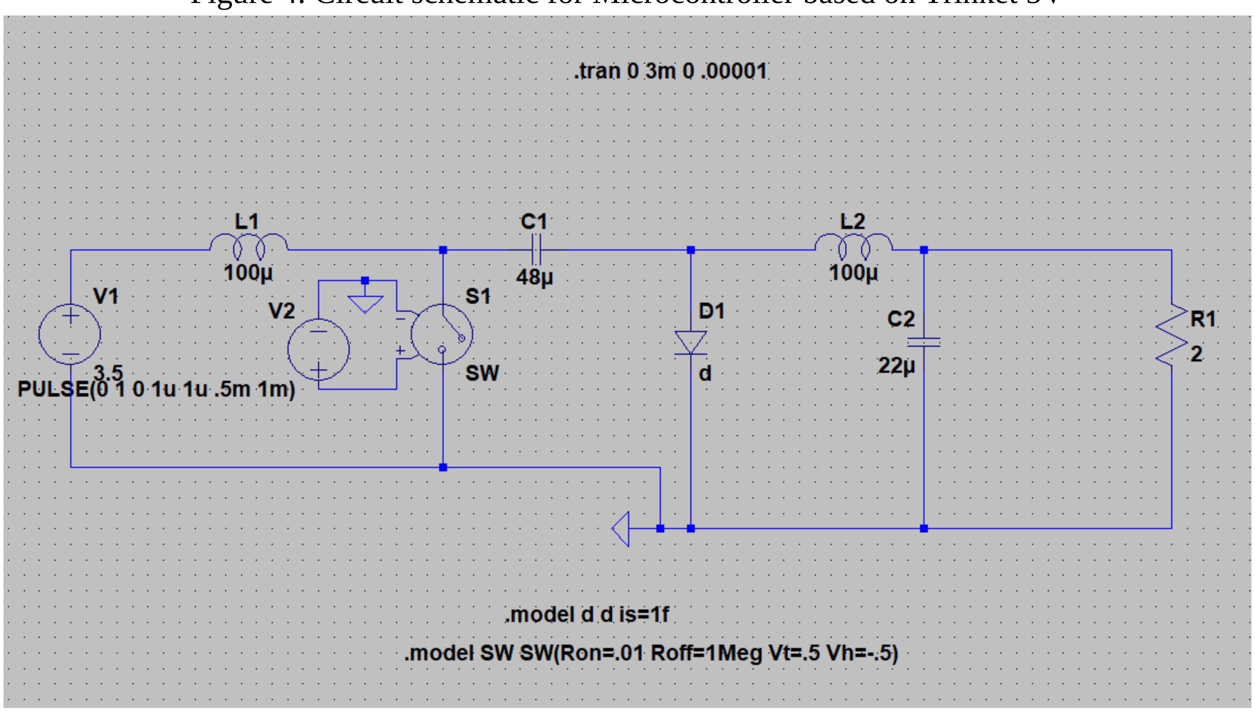

Figure 5: Cuk converter

Calculations

Betz Formula: Pmax = $\frac{16}{27}\rho S v^3$
where S is the swept area, ρ is the air density and v provides the wind speed.
To find the electrical power produced by the system, we must also consider the inefficiencies due to the gearbox transmission, electrical generator and the wind turbine. We may therefore consider a lower bound for the power produced by our system.
Our swept area can be defined as S=h*r , where h=.5m and r=.15m
Assuming a lower bound coefficient of 20%, an air density of ρ = 1.25 kg/m^3 , and a wind speed v = 11 m/s
Pmax =0.2*1.25*(11^3)*(0.5)*(0.15)=25 W

Parts

1x : PEC11-4215F-S24
1x: Adafruit Trinket - Mini Microcontroller - 5V Logic
1x: Avago HCMS-29xx LED display or Adafruit Accessories NeoPixel Ring RGB LED 12 x WS2812
1x: USB-C 5V 3A input battery w/ 2 outputs
1x: 36W Permanent Magnet DC motor/generator

Requirements and Validation Plans

1) Turbine: As illustrated in the block diagram, the turbine has several subcomponents.

   (a) Propeller/Rotor: This is the main exterior component that will provide the torque necessary to power our generator. They will most likely be some sort of plastic blades that will be aerodynamically feasible as well as portable.
      (i) Requirement: Able to rotate at low wind speeds and up to 15 m/s

   (b) Generator: Taking its input from the propeller, the generator will provide the conversion of the mechanical motion of the blades to electrical power. This may be created by converting an existing motor to a generator.
      (i) Requirement: When rotated produce DC power

   (c) Braking Mechanism: The braking mechanism will ensure that the turbine is not damaged at very high speeds. It will stop the turbine operation if the anemometer readings state an undesired wind speed.

(i) Requirement: Upon receiving a signal from the microcontroller the mechanism must be able to stop the turbine and release when the wind speed decreases

2) Power Electronics:

- DC/DC Converter: The generator will output unregulated DC, which must be regulated through the converter to a suitable output voltage for the battery bank. The DC will pass through an input filter first. Then, the converter will behave as a buck or a boost depending on if the input voltage is higher or lower than what the output should be.

Requirement: Able to convert a wide range of voltages to a fixed DC voltage output

Requirement: Above 80% efficiency

-Control Unit: The main function of the control unit will be to certify that our voltage output will not exceed what the battery is rated for. It's a fundamental feature that will safeguard a sensitive component, the battery. Since we may have voltages lower or higher than the required output the control will change the duty ratio fed into the gate of the MOSFET which is our switch for the buck/boost converter.

Requirement: Upon seeing a current or voltage greater than what the battery can handle the control will change the switching pattern to reduce the voltage and current

3) Battery System: This will be an off the shelf purchase. It will be rated for approximately 30W. This will allow us to charge our device. It will be powered through the output of our AC/DC converter. This will power the phone and microcontroller

4) Phone: The battery system will feed the user phone with electricity to charge and/or power their device. The user will connect their device through a USB into the battery system.

5) Anemometer: The anemometer is one of the most critical components for this design, in addition to playing a large role in risk analysis, it allows us to safely operate our wind turbine. It measures the speeds recorded by the turbine, and may provide the information that will cause the system to brake.

6) Microcontroller: This will be a custom built microcontroller that will mimic/clone a basic arduino. The main function will be to take the input from the anemometer and measure the output of the power electrons as well as communicate with the phone app and the braking mechanism.

Requirement: Take in input from the anemometer and send a signal to the brake and info to the phone app.

Requirement: Successfully read the voltage and current output and send the info to the phone app

7) Phone App: A phone app may provide essential information output by the turbine. It could for example provide the power output by the generator. Communicates via bluetooth since many use cases will be away from WiFi signals.

Safety statements

The user of our Wind Turbine will be directly involved with the operation of the device; thus, it is important that we ensure a safe and reliable product. There must be safeguards in place to protect both the product and the user.

There are several components in our product that may be potential safety hazards for the user if mishandled or incorrectly designed. The main components to consider is the battery, the rotor blades and the electrical circuitry.

Batteries always pose a risk since they can leak or explode. Proper handling will minimize the risks associated from damaging the battery due to impact. In order to prevent an explosion, it's important to monitor the temperature of the device, as well as the power input into the battery. Since the input of the battery is through the output of the power electronics, there is always an underlying risk of unstable power being fed. The monitor of the output through the phone app, as well as a meticulous power electronics design will lessen the risks related to the battery.

Another component to consider are the blades that will be spinning when the wind turbine is in motion. The responsibility is on the user side mostly, users should always approach these machines with the knowledge that they will have moving parts which should be handled with care. The blades will be made from a plastic-like material which at high speeds may be dangerous if direct contact is made. As the designer, there is a responsibility to make these blades safe to operate and through the use of tools such as brakes have the required automated oversight.

The wind turbine is expected to portable and may be chosen to be brought along on hiking trips or other strenuous outdoor activities. Such activities may lead to occasional impacts, however, it is not the normal mode of operation and therefore it should ideally be handled with care. There are many electrical elements within the structure, and a strong exterior will provide the necessary protection for the fragile interior. Different weather conditions in which the turbine will operate must also be considered when designing the exterior and choosing the materials.
In addition to the portability and the conditions in which the turbine will be carried through, we must also consider the operating conditions. At high speeds there may be vibration and temperature variations that we have to account for. Ideally, the material and structure of our turbine should withstand these effects. The consideration of a secure mount also holds paramount importance in this aspect, as it may help to minimize these factors.

Most products assume that the user will behave such that they do not put themselves or others at risk. This wind turbine is no exception and it assumes that the user will act responsibly. We as the designers must ensure that all the necessary steps are taken in order to mitigate the risks.

In compliance with the IEEE Code of Ethics[5], we must consider that our product will be available to everyone, and that "to treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression", thus adhering to #8 of the IEEE Code of Ethics. Additionally, we must follow the guidelines underlined in

#1, “to hold paramount the safety, health, and welfare of the public…” and in #3, “to be honest and realistic in stating claims…” We must make sure that our wind turbine operates in a way that is safe for the environment and surroundings. The output data that we provide in our phone application must reflect what is measured in our devices.

Citations

Ben F. Blackwell, Robert E. Sheldahl, Louis V. Feltz “Wind Tunnel Performance Data for Two- and Three-Bucket Savonius Rotors”, Sandia Laboratories, Albuquerque, NM, July 1977.

Gabriel Benavides “NPRE 498 Class Wind Turbine Project”, May 2009

http://www.instructables.com/id/Displaying-Battery-Life-on-a-Liquid-Crystal-Displa/

http://www.electric-skateboard.builders/t/arduino-project-percentage-based-voltage-display-using-16-x-2-lcd/16067