Educational Wind Powered Charger

ECE 445 Design Document

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1 Introduction

1.1 Objective and Background

As more industrial companies turn to cleaner energy utilization, wind power has become one of the main power sources for energy supply. From an industry point of view, it would be a good idea to teach students how this technology is used in real-world applications. An exemplary application would be a bike-mounted wind electricity generator.

Lots of cyclists prefer to ride in wild areas, such as mountains, grasslands, and remote gravel tracks, where electricity is absent. A charging tool that can supply power to portable electronic devices would be beneficial. This product farms wind with a 3 blade rotor and convert the energy into electricity. When riding the bike, the coming wind would directly be converted into electricity, which ensures sustainable high wind speed for the power supply.

Although there are commercial products available, they are not operational when having a rest, not adjustable for wind speed, and expensive. This design intends to provide a relatively cheap, portable, self-support, ever-ready, and educational battery charger to customers.

1.2 High-Level Requirements

- **Portable blade and rotor system.** We want to farm energy and protect our rotor as much as possible. When the wind is too high(20 mph) for the rotor to rotate, the rider has choice to temporarily remove the rotor system and easily install it back.
- **The system is able to charge a phone.** The system should provide enough power output(5 watt) when rider is riding the bike with 13 mph. When charging a phone, the phone should show a charging status.
- **The entire system's width must not exceed 40 cm.** We do not want our wind turbine to be too large in diameter, which might disturb view of riders.

1.3 Visual Aid

Figure 1: Visual Diagram for the System.

Both the sensor and turbine itself will be mounted on the head tube of the bike. All the PCB hardware will be mounted on the down tube. When you ride the bike, the wind pushes the blade on turbine and make electricity. Anemometer is going to communicate with the microcontroller to assist calculating the maximum power point.

2 Design

2.1 Block Diagram

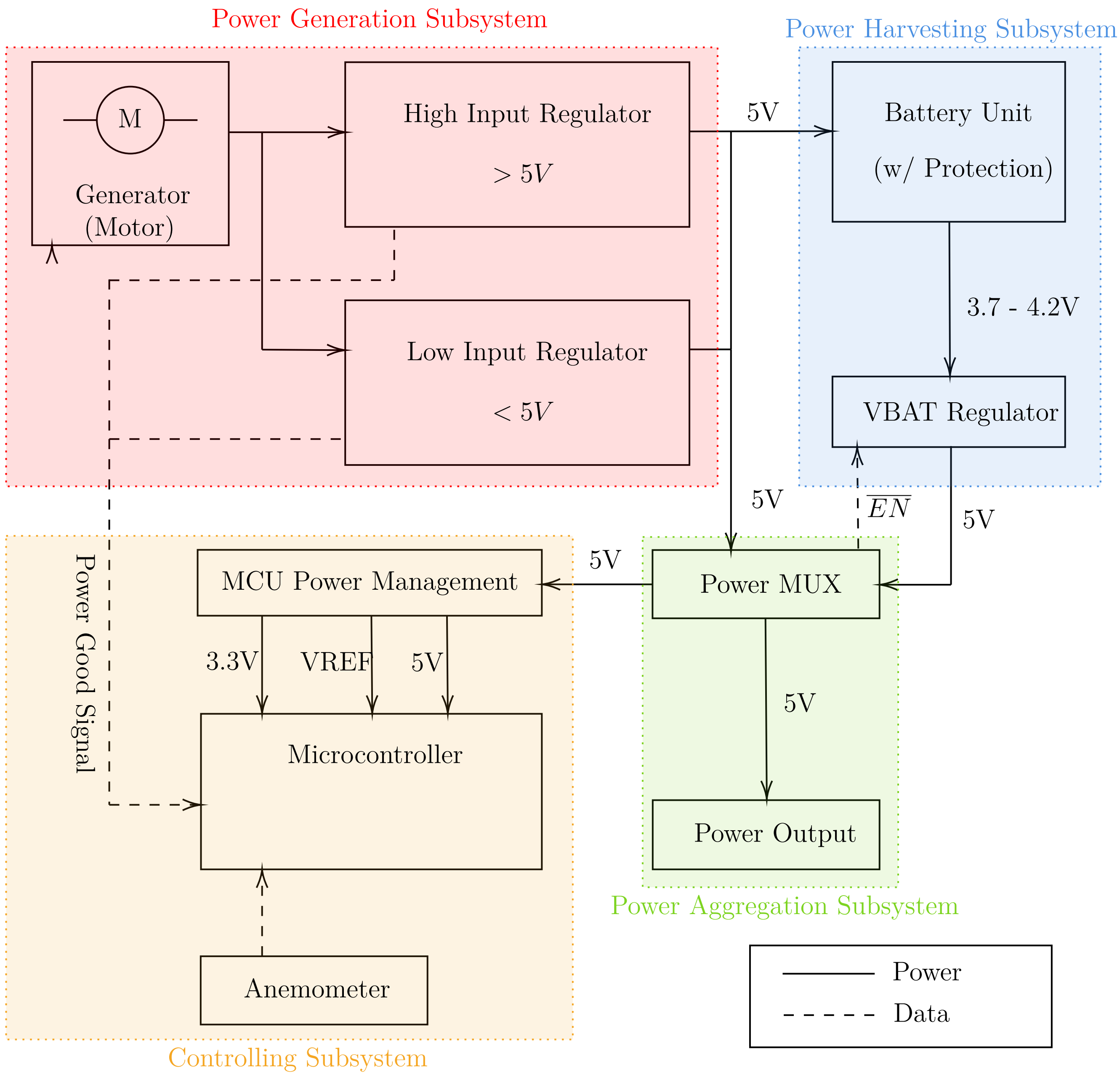

Figure 2: Block Diagram

The block diagram consist of four different subsystems: Power Generation, Power Harvesting, Power Aggregation and Controlling subsystems.

2.2 Subsystems

2.2.1 Power Generation Subsystem

This subsystem holds the wind turbine, AC/DC diode bridges, buffers, and regulators. It generates energy from wind power and provides an unstable 5V output. The current capability of this 5V output cannot be relied on.

The source voltage from the motor generator can be viewed as a high-impedance power source. When current is drawn from the motor, the current will generate an electromagnetic force in the motor in the reverse direction, causing it to slow down and reducing its output voltage.

This unit also outputs a `Power Good` signal indicating that the input voltage is within operational range. This signal will be consumed by the microcontroller.

Requirements	**Verification**
When the input voltage is higher than 3V, the system should be able to provide a 5V output. (Under 3V, either the wind speed is too low, or too much current is being drawn.)	Sweep the input voltage from 3V to 36V. The output voltage should be stable around $5V \pm 5\%$.
The module should not break when the input suddenly spike to voltages around 60 Volts. (A possible case for motor generators)	Hit the system input with 60V in the lab. It is acceptable for the system to provide no output in this situation. The system must not break after this stimuli is removed, and it should continue to function normally when input voltage returns to under 36 Volts.
The power good signal should be asserted only when the output is valid.	Sweep the input voltage from 0V to 36V, monitor output voltage and power good signal together with the oscilloscope. The 5V output should be synchronous with the Power Good signal.

Expectations of this subsystem: This system should provide a 5V output and a PG signal when there is enough wind power. When there is no wind power, there should be no PG signal, and no output is expected. The servo will turn smoothly based on the microcontroller's control signal simultaneously.

2.2.2 Power Harvesting System

This subsystem holds a battery and its *Maximum Power Point Tracking*(MPPT) charger. the MPPT charger will control the charging current of the battery in order to achieve the maximum power input. Such units are common on lots of renewable energies, such as solar panels and wind turbines. The VBAT regulator can also be disabled by signals from Power Aggregation Subsystem.

This subsystem has a 5V regulator output, which could be toggled on or off depending on the need. The regulator could supply up to 2A of current.

Expectations of this subsystem: This system should be able to charge from an unstable power supply and provide a stable 5V output when asked.

Requirements	**Verification**
The module should be able to draw current from the input within 100ms as the input rises to 4.75V.	The input current will be measured with a current probe. When a 5V signal is provided, the system should immediately start to try drawing current in 100ms.
When the input is absent, the system should still provide a 5V output.	Remove power from the input. The output should still be available.
When the battery is charging from the input and output is disabled, the charging efficiency should be at least 90%.	Measure the input voltage, input current, battery voltage and battery current. The difference in total input power and charging power should not exceed 10%.

2.2.3 Power Aggregation System

This subsystem chooses a power supply from either the generators or the battery, and delivers it to the Controlling Subsystem and the output. It serves to detect whether the 5V output from the Power Generation Subsystem is reliable and toggles the battery output accordingly. The Power MUX in this subsystem could also disable the VBAT regulator in Power Harvesting Subsystem.

It provides stable, reliable 5V output to the power outlet and the Controlling Subsystem.

Requirements	**Verification**
When both 5V from the generator and 5V from the battery is available, the MUX should send use 5V from the generators, and disable VBAT regulator.	Use the lab bench power supply to provide 5V to the MUX, and use the MUX to power another device. The MUX should assert the $\overline{EN}$ signal, draw current from the generator 5V line, and not draw current from the battery 5V line.
When generator input drops below 4.75V, the MUX should switch to battery output within 200ms and the supply to microcontroller unit should not fail during switching.	Supply both inputs and remove the generator input, connect a 100Ω resistor to the MCU output port. The enable signal should come up within 100ms, and the voltage on the MCU output port should not drop below 4.75V during switching.

Expectations of this subsystem: This system should provide a stable 5V output from the best available source.

2.2.4 Controlling Subsystem

This subsystem holds the sensor (anemometer) and the microcontroller unit. The microcontroller will monitor the wind speed and decide the Maximum Power Point for the wind turbine.

Requirements	Verification
The microcontroller should adjust the bias of the charging controller IC to meet the maximum power point. The algorithm is considered successful if the achieved power is at least 90% of maximum possible power.	In the lab, we can simulate different wind speeds, measure the maximum power point at each wind speed with programmable electronic loads, and hard code those data into the program.
The microcontroller should provide the user with LEDs, indicating whether the battery is currently charging or discharging.	The MCU will be provided with simulated Power Good, Float and Charging signals. The MCU should light up the corresponding LED indicators.

Expectations of this subsystem: It accurately detects the wind speed and performs dynamic MPPT analysis.

2.3 Tolerance analysis

No expectations was given to the power generation subsystem, since the output will vary wildly depending on the strength of the wind and the speed of the bike.

The power harvesting system has a wide input accepting range. It's output should follow the specifications of USB 5V, which is $5V \pm 5\%$, or 4.75V - 5.25V.

The microcontroller accepts a wide range of voltages. The microcontroller can run at 1.5-3.6V, here we chose 3.3V. VREF is a stable voltage voltage reference, which will be generated with an LDO. The more accurate VREF is, the more accurate the on-chip ADC data will be. The actual output of the LDO chip will be written into MCU software to compensate for error.

3 Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

Basing the calculation in the annual salary information based on electrical and computer engineering for a full-time employment, the average salary is $ 91,781. The average hours worked in a year are 2080, taking into account that and employee works 40 hours a weeks during 52 weeks. Therefore, the hourly income is approximately $ 44 per hour.

Taking into account that each team member should spend 10 hours a week on the project in a 16 weeks semester, this would be a total of 160 hours to complete the project.

Labor per member = 44 * 2.5 * 160 = $ 17,600

For the 3 members of the team: Total Labor = 3 * 5,280 = $ 52,800

3.1.2 Parts

The costs of the major components on the PCB are as follows:

Item	**Price**	Retrieval Date
LTC4000-1	$12.04	Feb. 20, 2022
STM32L433RCT6	$7.60	Feb. 20, 2022
TLV3691IDCKT	$1.57	Feb. 20, 2022
TPS63802DLAT	$2.16	Feb. 20, 2022
SI4401BDY-T1-E3	$2.08 each, 2 PCS	Feb. 20, 2022
Mini Wind Turbine Blade	$24.97[1],	Feb. 20, 2022
DC Wind Turbine Project Motor Generator	$24.97[2]	Feb. 20, 2022
Other cheap passive components.	Around 10$ - 15$ total.	/
Metal tube with Clamps.	Machine shop	/
Blades safety cover	Machine shop	/
Anemometer	$23.43	Mar 1. 2022/

Therefore, we expect the total cost of the components on the PCB to be 30$. The sensor would be 24$. The 3 blade in totol costs 25$ and motor generator costs 25$ as well.

3.1.3 Sum of total costs

We are assuming a cost of around $ 30 for additional unexpected costs The sum of the total cost would be: Total = total labor cost + PCB cost + Blades + Motor Generator + Clamps + Extra = 52,800 + 30 + 25 + 25 + 24 + 30 = $ 52,944

3.2 Schedule

Date	Zixi	Lingxiao	Maria
Feb 24 – March 2	PCB design	PCB design	PCB design
March 3 – 10	PCB redesign	Machine Shop Parts Ordering	Machine Shop Parts Ordering
March 11 – 17	Soldering and assembling	Test MPPT	Soldering and assembling
March 18 – 24	Testing (PCB redesign)	Assembling motor	Assembling blades
March 25 – 31	Test microcontroller	Test motors	Test microcontroller
April 1 – 7	Coding IC	Coding IC	Coding IC
April 8 – 13	Test PCB	Track MPPT	Soldering ne PCB is needed
April 14 – 20	Mock Presentation	Mock Presentation	Mock Presentation
April 21 – May 4	Finish Document	Finish Document	Finish Document

4 Discussion of Ethics and Safety

4.1 Ethics

Following the guidelines from the IEEE Code of Ethics, we are willing to develop this project to hold paramount the safety, health and welfare of the public(IEEE (Institute of Electrical and Electronics Engineers) Code of Ethics, 2015). Therefore, we will make sure that the mechanism is save to attach to a bicycle, to avoid any possible accidents due to a piece of our project falling off or distracting the rider.

To manage this, we will do lots of testing on different weather conditions and with the needed precautions to protect ourselves form injury, to make sure that we do not manufacture a dangerous object and make sure it is functional.

4.2 Safety

We are currently planning to mount the blade in the front of the bike. As a result, there is a safety issue if the rider's hand somehow touched the rotating blade, which could cause damage to both rider and the rotor itself. As a result, we are planning to make the blade as circular as possible to avoid any sharp edges on the blade. Plus, we would like to make the rotor be a certain distance away from the head tube. The rotor should be located 10 cm in the front of the head tube. Also, considering the possibility that the rotating blade might disturb the view of the rider, we will make the mounting position as low as possible on the head tube.

After carefully checking federal and state regulations, industry standards, and campus policy, we need to follow safety rules in the lab. As concerns for safety for working in the lab, we promise not to allow any group member to work alone in the lab session.

Instead, there should be at least another member or a TA working together. Plus, we will not bring any food into the lab and always clean the table to keep the working station clean. This behavior could prevent any accidental touching of electronic devices hidden under the messy table(ECE 445 p.3). The biggest safety concern for us is accidentally touching high voltage circuits without protection and misconduct during soldering. But if we are careful with our implementation, we should be able to do our job successfully.

5 Appendix: Schematics

We have completed the schematics of the generator regulator, battery charging and monitoring. The power MUX is now integrated with the charger IC (Q4A and !4B in Figure 4). We are still deciding on the exact SKU of microcontroller to use.

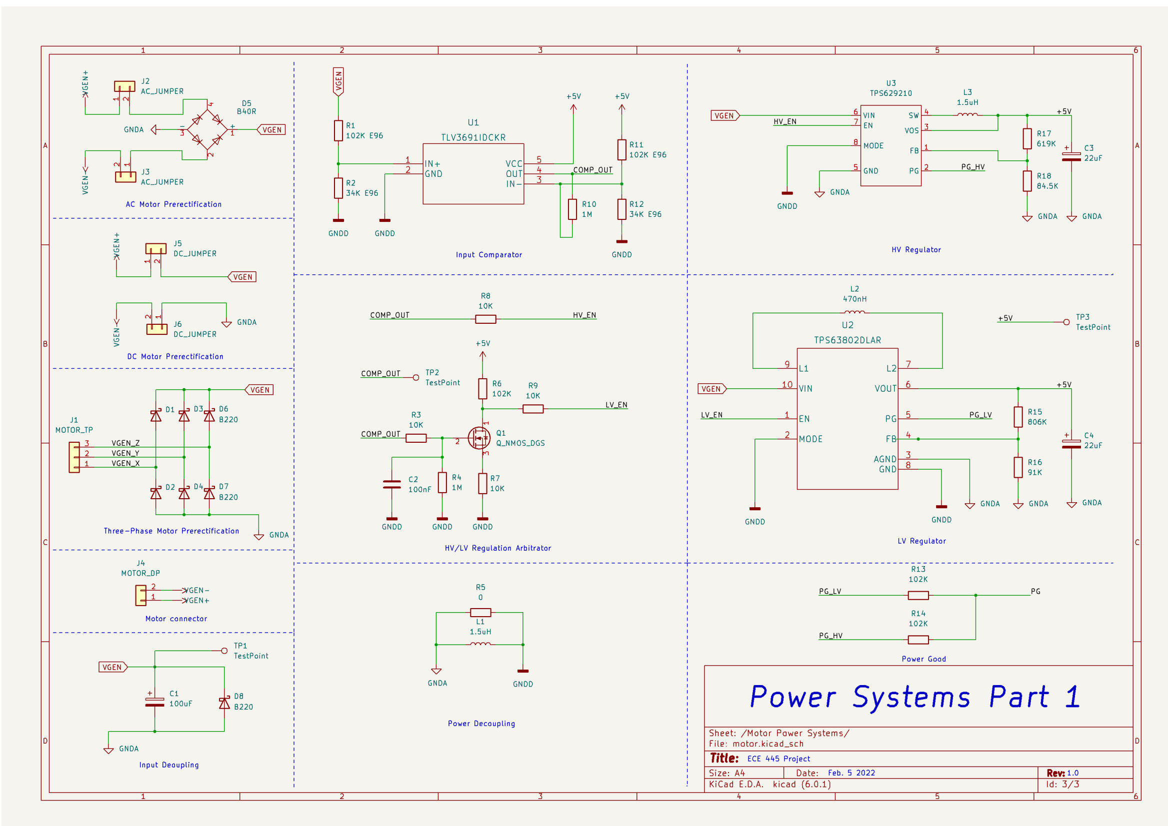

Figure 3: Power Generation Subsystem, including motor connectors.

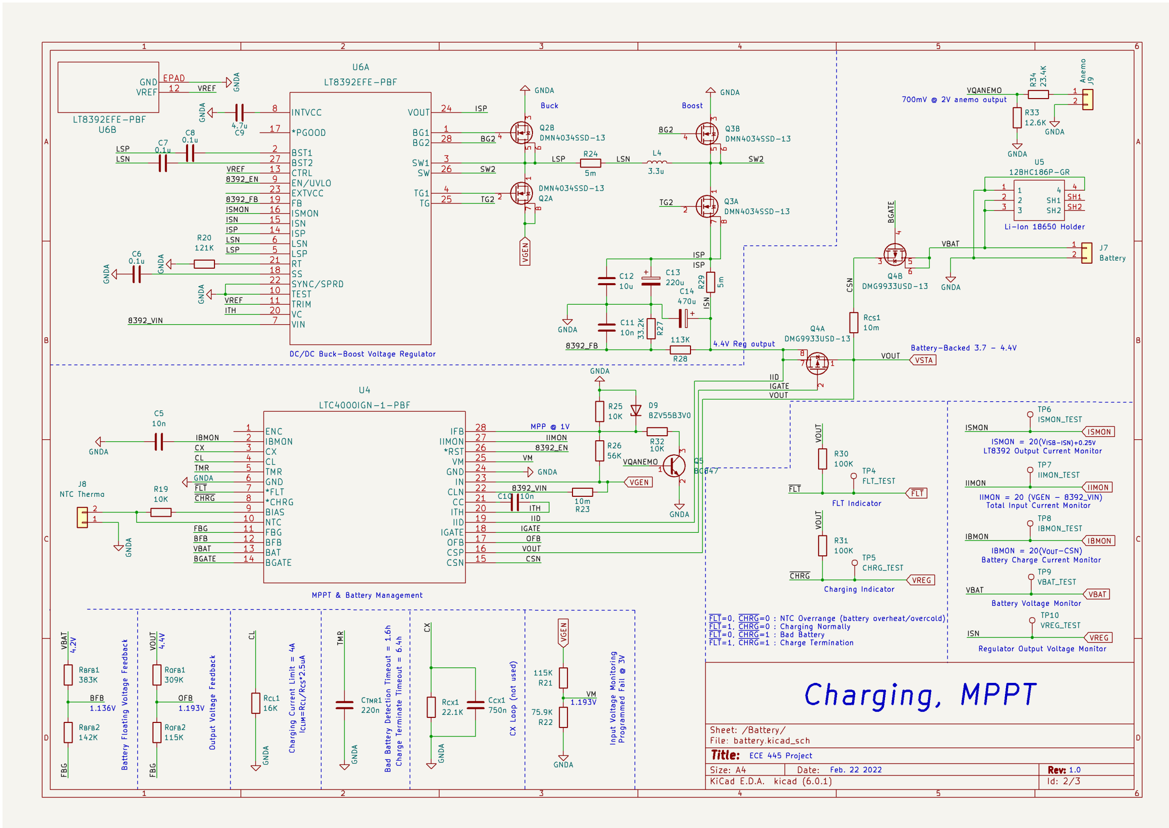

Figure 4: Battery charging and MPPT subsystem.

6 Reference

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