Educational Wind Powered Charger

ECE 445 Design Document

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Contents

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

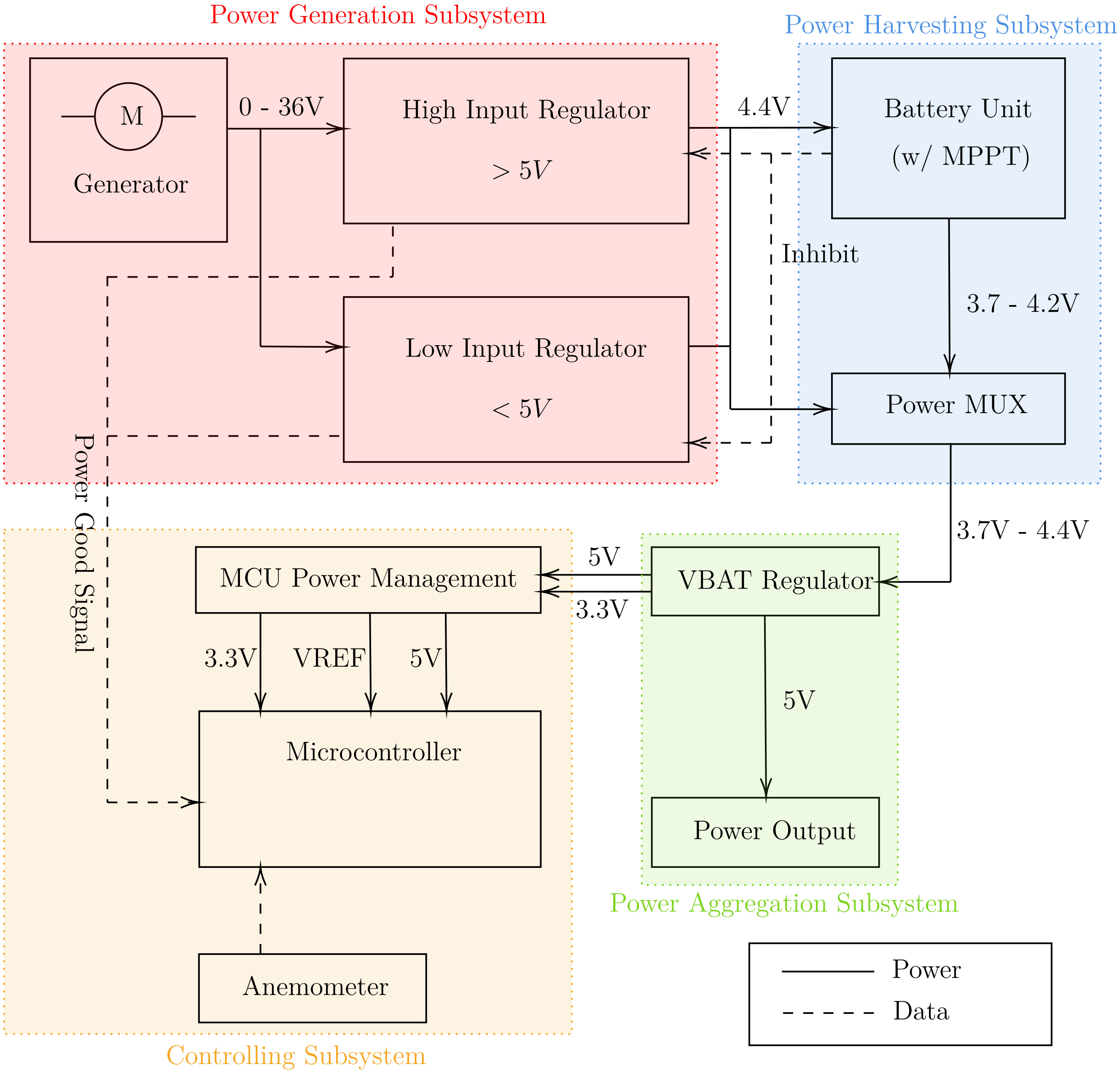

Figure 2: Block Diagram

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 4.4V output. The current capability of this 4.4V 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**
1. When the input voltage is higher than 3V, the system should be able to provide an output between 4.2V - 4.5V, the floating voltage for charging a Li-ion battery. 4.4V is most ideal. (Under 3V, either the wind speed is too low, or too much current is being drawn.)	i). Connect the input voltage to a function generator. Let the function generator generate a random voltage from 3-36V. Disconnect the battery unit. ii). Measure the output voltage. It should fluctuate around $4.2V - 4.5V$.
2.The module should not break when the input suddenly spike to voltages around 60 Volts. (A possible case for motor generators)	i) Set the DC power supply to 60V. Connect the output of the module to the oscilloscope. ii) Briefly connect the power supply output to the input for around 0.1 seconds. Make sure the circuit did not generate any sparks or burns. iii) Set the DC power supply to 12V and connect the output to digital voltmeter. Make sure the output voltage is between 4.2 - 4.4V.

3. The power good signal should be asserted only when the output is valid.	i). Connect the input voltage to a function generator. Let the function generator generate a sine voltage from 3-36V. Disconnect the battery unit. ii). Connect oscilloscope Channel 1 to output, and Channel 2 to Power Good signal. The Power Good signal should only be asserted when output is available. i.e. They should appear synchronous on the oscilloscope.

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 system contains a power MUX. When power is available from the generator, it will prioritize using the power from the regulators as its output. When the generator is not providing enough power, the MUX will utilize battery power. The output of the MUX depends on wind conditions and fluctuates due to the charge of the battery. Output range is 3.7 - 4.4V.

Expectations of this subsystem: This system should be able to charge from an unstable power supply and provide an always-available output voltage.

Requirements	**Verification**

1. The module should be able to draw current from the input within 100ms as the input rises to 4.2V.	i) Connect a lab power supply to input and Oscilloscope Channel 1. Connect the positive battery terminal to Channel 2. Turn lab power supply off. Set the oscilloscope to trigger on Channel 1 rising edge @ 2V. ii) Set lab power supply to 4.4V and turn on. The oscilloscope should trigger. Observe the time difference between the rising of Channel 1 and Channel 2. It should not exceed 100ms.
2. When the input is absent, the system should still provide a 3.7V - 4.4V output.	i) Connect a charged battery and remove power from the input. ii) Measure the output. It should still be available at around 3.7V - 4.2V
3. When the battery is charging from the input and output is disabled, the charging efficiency should be at least 90%.	i) Measure the input voltage, input current, battery voltage and battery current. ii) Check the difference in total input power and charging power should not exceed 10%
4. When generator input drops below 4.2V, the MUX should switch to battery output within 200ms and the supply to microcontroller unit should not fail during switching.	i) Connect a 100Ω resistor to the output line to simulate the power draw of the microcontroller. Connect a 4.4V lab power supply to the input. Connect Oscilloscope Channel 1 to input and Channel 2 to output, set the oscilloscope to trigger on the falling edge of Channel 1 @ 2V. ii) Turn off the lab power supply. The oscilloscope should trigger. Observe the output curve. It should stabilize within 200ms, and the voltage should not fall below 3.3V for more than 10ms.

2.2.3 Power Aggregation System

This subsystem takes the voltage from the battery unit, converts it into 3.3V and 5V, and delivers it to the Controlling Subsystem and the output.

It provides stable, reliable 5V and 3.3V output to the power outlet and the Controlling

Subsystem.

Requirements	**Verification**
1. The 5V line should provide 2A of current when power is available in the system.	i). Connect a 4.2V, 2.5A lab power supply to the input line. ii). Connect a 2.5Ω ceramic resistor onto the 5V output line. Ensure the voltage across the resistor is 5V.
2. The 3.3V line should provide 20mA of current when power is available in the system.	i). Connect a 4.2V, 2.5A lab power supply to the input line. ii). Connect a 165Ω resistor onto the 3.3V output line. Ensure the voltage across the resistor is 3.3V.
3. Shorting the 5V Power Output should not cause the MCU to fail, and should not permanently hurt the system.	i).Connect a battery and short the 5V output to make sure the 3.3V line not drop below 1.8V. ii). Measure the output when the shortage is resolved. 5V output should be available within 10 seconds.

Expectations of this subsystem: This system should provide a stable 5V and 3.3V output.

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**
1. The microcontroller should provide the user with LEDs, indicating whether the battery is currently charging or discharging.	i). Provide simulated Power Good, float and charging signals to MCU by manipulating wires into the test points. ii). The MCU should light up the corresponding LED indicators.

2. 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 80% of maximum possible power.	This verification could not be done individually on the unit. It must be tested with the whole system assembled. i) Calculate the theoretical power at 5mph, 10mph and 15mph. ii) Generate a wind of 5mph, 10mph and 15mph (possibly with a wind tunnel). Fine tune the feedback voltage to get the maximum power output of the system. Measure the motor output $VGEN$ and feedback voltage IFB iii) Hardcode the ratio of $VGEN$ and IFB into the microcontroller for each wind speed.

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 input will vary wildly depending on the strength of the wind and the speed of the bike. The tolerance of components here cannot help with efficiency or system robustness.

The power harvesting system contains voltage dividers for setting battery floating voltage, maximum charge voltage and output voltage. These resistors have to be very accurate for the unit to function correctly and safely. Therefore, the traces for these voltage dividers are as short as possible on the PCB, and the resistors are chosen as E192 resistors with at most 0.5% tolerance.

The power aggregation system accepts a wide range of input. However, the 5V line should follow the specifications of USB 5V, which is $5V \pm 5\%$, or 4.75V - 5.25V. The 3.3V line is only powering the microcontroller, and should be between 1.5V and 3.6V. Voltage dividers are also present in the system, but 1% tolerance parts suits the need.

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 a fixed-output 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	Quantity	Vendor	Price/unit	Total Price	Retrieval Date
LTC4000-1	1	Mouser	\$12.04	\$12.04	Feb. 20
STM32L433RCT6	1	Mouser	\$7.60	\$7.60	Feb. 20
TLV3691IDCKT	1	Mouser	\$1.57	\$1.57	Feb. 20
TPS63802DLAT	1	Mouser	\$2.16	\$2.16	Feb. 20
SI4401BDY-T1-E3	2	Mouser	\$2.08	\$4.16	Feb. 20
Mini Wind Turbine Blade	1	Amazon	\$24.97	\$24.97	Feb. 20
DC Wind Turbine Project Motor Generator	2	Amazon	\$24.97	\$49.94	Feb. 20
Other cheap passive components.	/	/	10\$ - 15\$	10\$ - 15\$	/
Metal tube with Clamps.	1	Machine shop	/	/	/
Blades safety cover	1	Machine shop	/	/	/
Anemometer	1	Moderndevice	\$23.43	\$23.43	Mar. 1

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.

Also, some criteria that we wanted to take into account in the project is the environmental aspect. Since we are making an educational project we thought we should teach also about environmental concern. For this reason, all the components we are using are RoHS compliant and we are using lead-free solder.

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

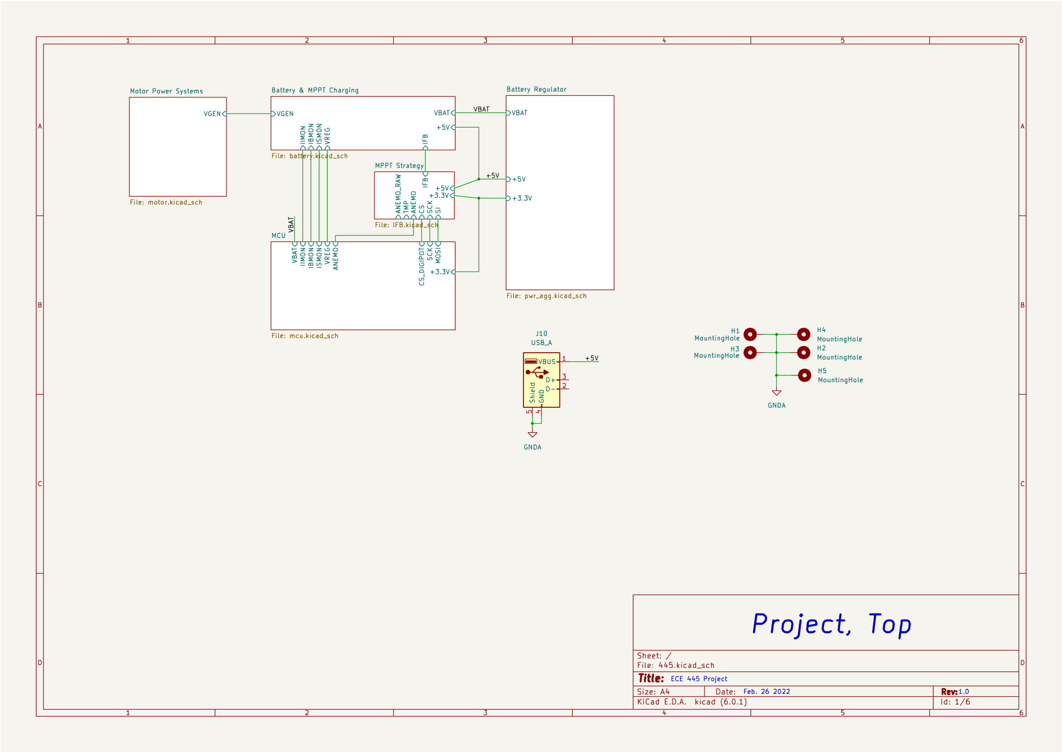

Figure 3: Top-Level schematic, shows connections between other sheets

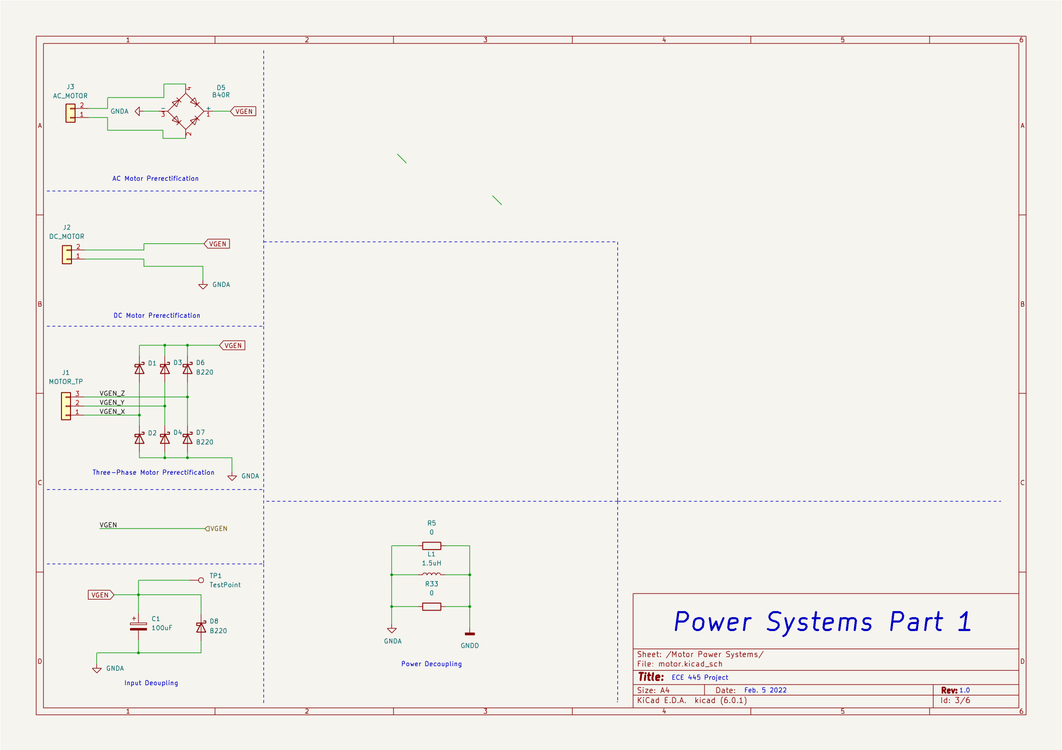

Figure 4: Motor connectors, rectifiers, buffer and protection

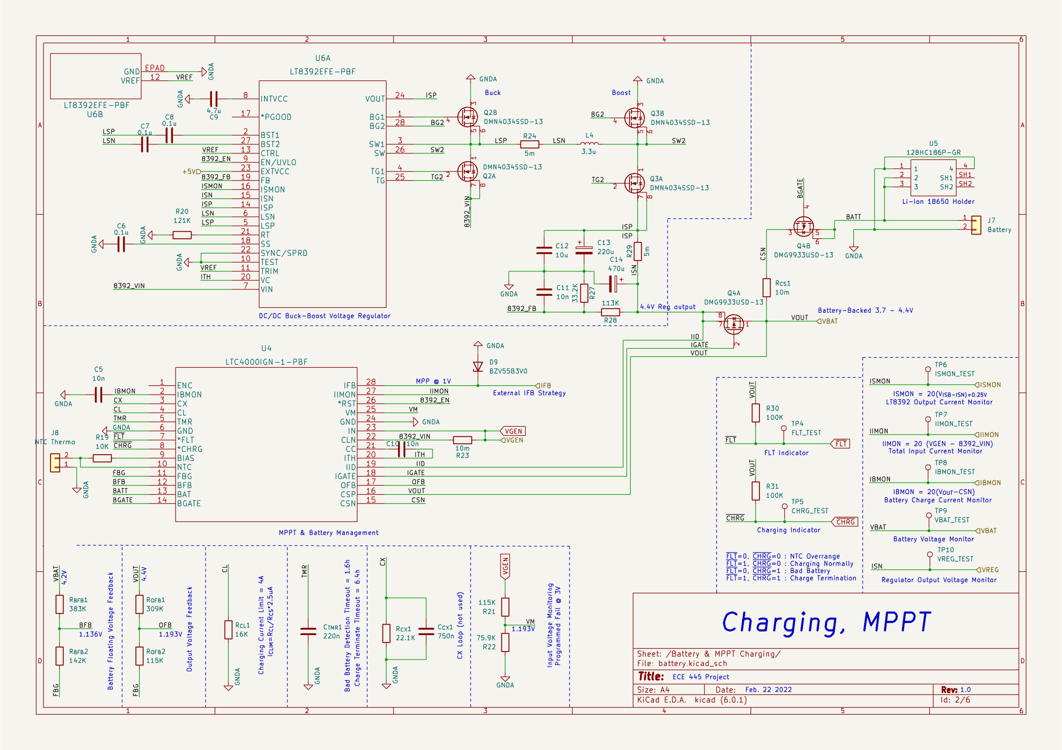

Figure 5: Battery charging and MPPT subsystem

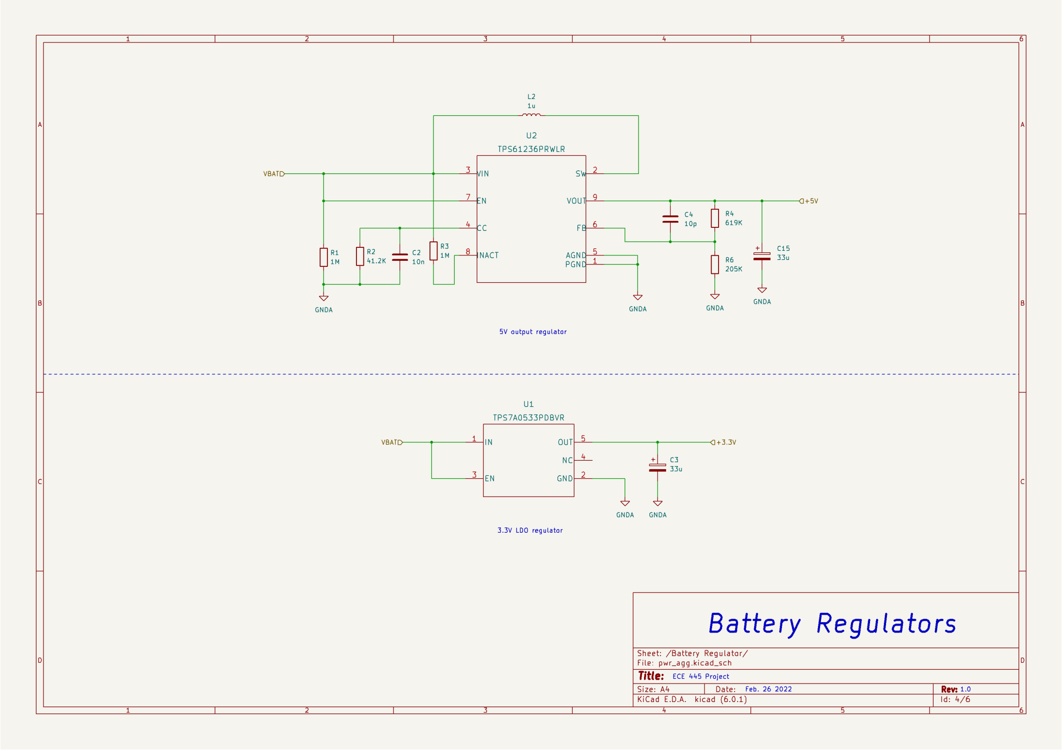

Figure 6: Power aggregation subsystem

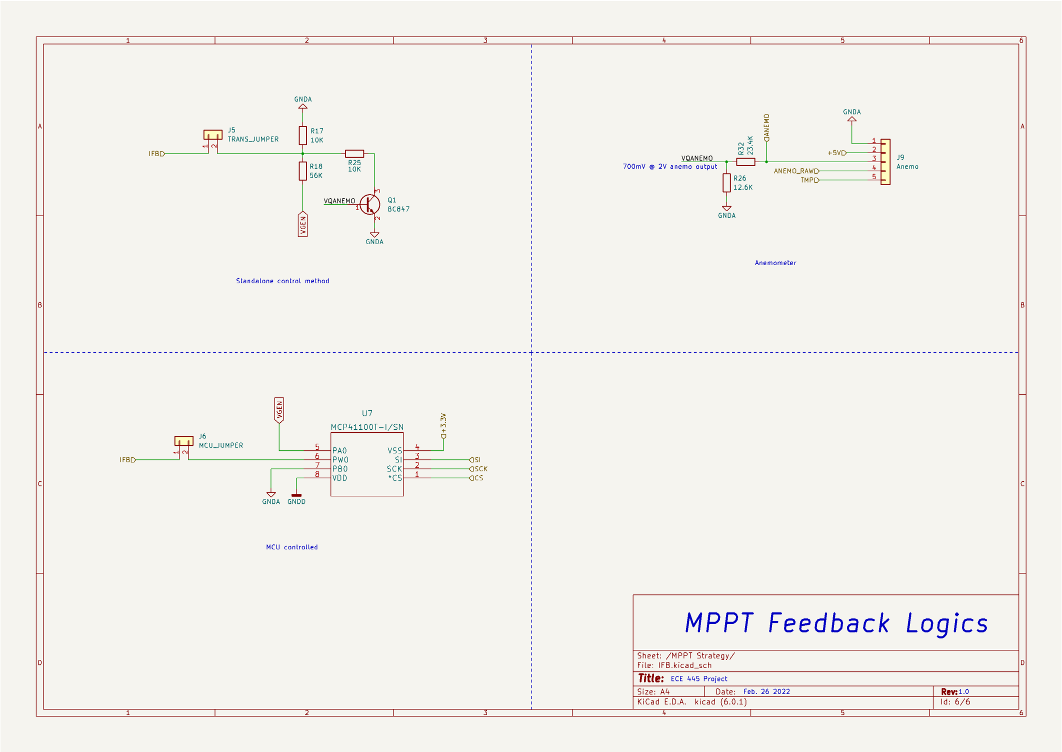

Figure 7: MPPT Feedback strategies

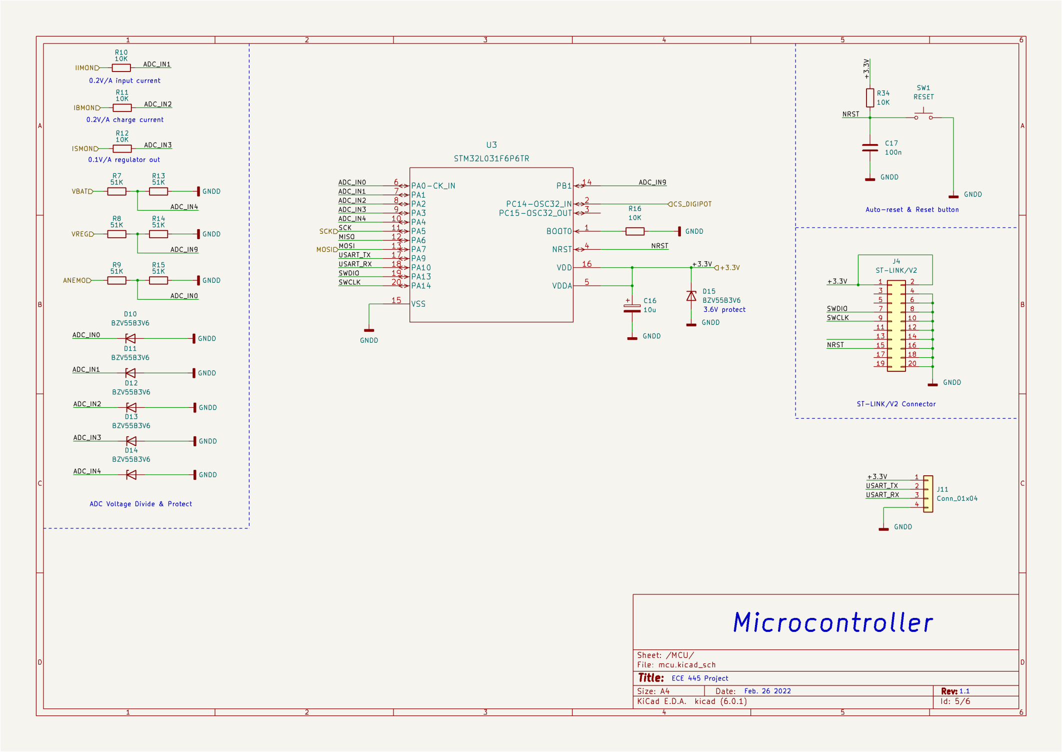

Figure 8: Microcontroller

6 Reference

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