Design Specifications

Green Breeze

Final Draft

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ECET 400
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1. Summary of Product

Green Breeze is a horizontal-axis wind turbine designed to be implemented within subway tunnels. Three sets of turbine blades are staggered one foot apart on a single shaft. The second and third set of blades rotated 40 and 80 degrees clockwise (respectively) in relation to the first set of blades. The turbine utilizes the residual wind energy produced by subway cars to create electricity by means of an alternator. The electricity generated is then sent through a regulator to control power output fluctuations. Electricity is then sent to the subway's grid system as well as to the device's battery. A second voltage regulator is utilized in order to power the device's microcontroller. The microcontroller is responsible for monitoring all sensors, activating switches, making calculations, as well as storing and relaying all pertinent data.

2. List of Requirements

2.1 Wind to electric energy conversion with stable 12v output to power electrical grid and charge device's battery

2.2 Power output from battery suitable for powering small devices, specifically the microcontroller, which requires a 5V 3A from a USB port

2.3 Ability to monitor temperature, infrared, and current, perform efficiency calculations, and store data onboard.

3. Requirements Specifications

3.1 Requirement #1:

The linear force provided by a moving vehicle must push diagonally upon the propeller blades and create torque on the connected shaft. This rotational energy must generate electricity sufficient to harness wasted energy but not dramatically increase vehicle drag. The result should create a net gain of electricity rather than a loss. (We have to follow page 15 of outline for this part)

3.2 Requirement #2:

3.2.1. General Description:

12v DC to 5v DC step down power converter module with USB port.

3.2.2. Power Requirements:

A. <u>Source</u>: Lead acid battery
B. <u>Voltage Requirements:</u> 6V-40V

3.2.3. Case Requirements:

A. <u>Description:</u> DC to DC Voltage Regulator Step Down Power Supply Buck Converter Module 6-40V to 5V 3A Dual USB Port Output
B. <u>Overall Size</u>: 59mm X 21mm X 17mm/2.32X0.83X0.67inch
C. <u>Material:</u> Silicon, plastic, capacitors (100μF and 1000μF), inductor (470mH), diode (SS34), step down voltage regulator (LM2596S), dual USB port

3.2.4. Technical Requirements:

A. <u>Inputs</u>: 6V-40V DC
B. <u>Outputs</u>: 5V / 3A (MAX)
C. <u>Ports</u>: Dual USB
D. <u>Switching frequency</u>: 150KHZ
E. <u>Working temperature</u>: -40 ℃ ~ 85 ℃

3.2.5. Cost and Schedule Requirements:

A. <u>Materials and cost should not exceed</u>: $11.00
B. <u>Development and costs should not exceed</u>: $10.00

3.3 Requirement #3:

3.3.1 Data Acquisition Requirements:

A. <u>Collect raw data from temperature and infrared sensors:</u>
    a. Implement I^2C protocol for getting temperature sensor data.
    b. Use digital inputs/ outputs for getting infrared sensor data.
    c. Use analog data to determine battery status.
B. <u>Determine battery data to prevent overcharging:</u>
    a. Using analog inputs/ outputs determine battery data such as current charge, battery capacity, etc.

3.3.2 Data Processing Requirements:

C. <u>Process and interpret raw data into meaningful and understandable formats:</u>
    a. Temperature data should be converted into the regional standard (C vs F)
    b. Infrared data determines turbine rotational speed in RPM (revolutions per minute).
    c. Battery data found via analog inputs and used to determine certain operations and procedures.

3.3.3 Display and Data Sharing Requirements:

D. <u>Display data real time using SSD1306 display:</u>
    a. Display also implements I^2C protocol for displaying data.
E. <u>Share data with the ESP8266 wifi module:</u>
    a. Wirelessly transfer data for remote data monitoring.

4. Top-Level Block Diagram

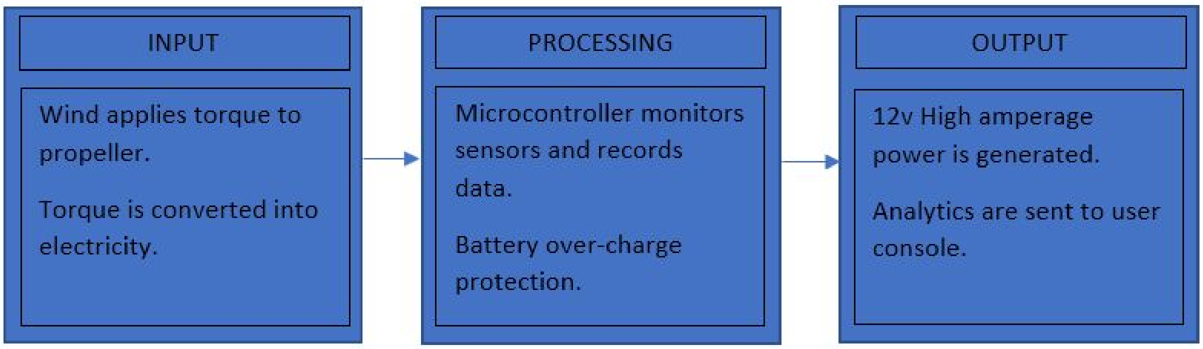

Fig 1.1

4.1. Section 1: Input

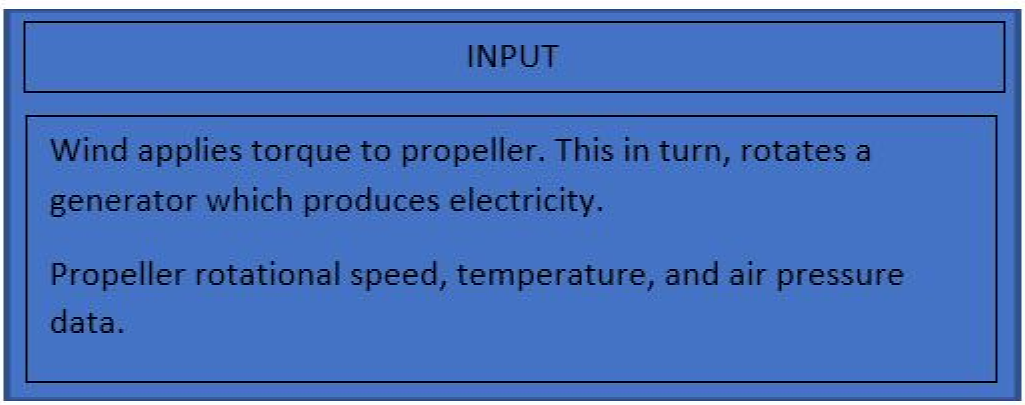

Fig 2.1

4.2. Section 2: Processing

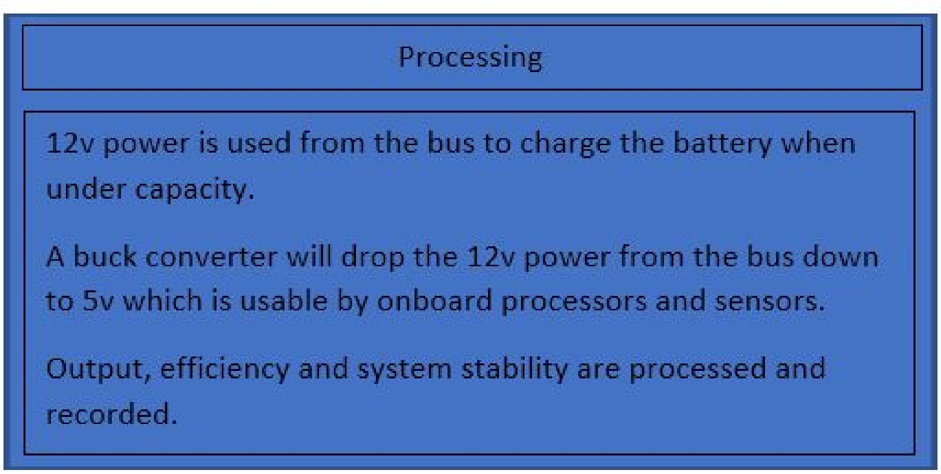

Fig 2.2

4.3. Section 3: Output

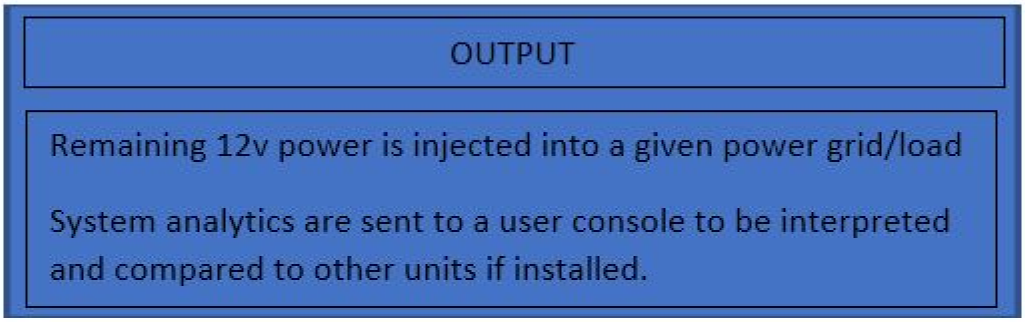

Fig 2.3

5. Explanation of Block Diagrams

5.1. Section 1:

Describes energy and data that enter and or exit the Green Breeze. The turbine includes the rotary blades and shaft that are responsible for capturing the kinetic wind energy and transforming it into mechanical energy. The mechanical energy is then used to turn a rotor within the alternator, at first generating alternating current. This alternating current is then sent through a voltage rectifier, responsible for converting the alternating current (AC) to direct current (DC). The regulator then maintains a steady 12v DC output. This 12V DC is then sent to a lead acid battery where it will be stored until it is needed by other components on the device. When electricity is drawn from the battery or bus, it must first pass through a buck converter. The buck converter decreases and stabilizes the power that is output from the battery, making it safe for small devices. Once passing through the buck converter a steady 5V is output. This 5V then reaches the microcontroller, the brain of the entire device.

5.2. Section 2:

The Atmega 328 microcontroller will allow us to monitor our sensors to ensure safe operation and strong system health. At this stage, the data gathered by the sensors is interpreted by the microcontroller and stored on board.

Battery charging is maintained to prevent overcharging and potentially battery degradation. The output power can also be cut by the microcontroller in the event of a power surge or malfunction.

5.3. Section 3:

System data processed by the microcontroller is sent to a user console to be interpreted in real time.

Remaining output power is sent to a desired load.

6. Second-Level Block Diagram

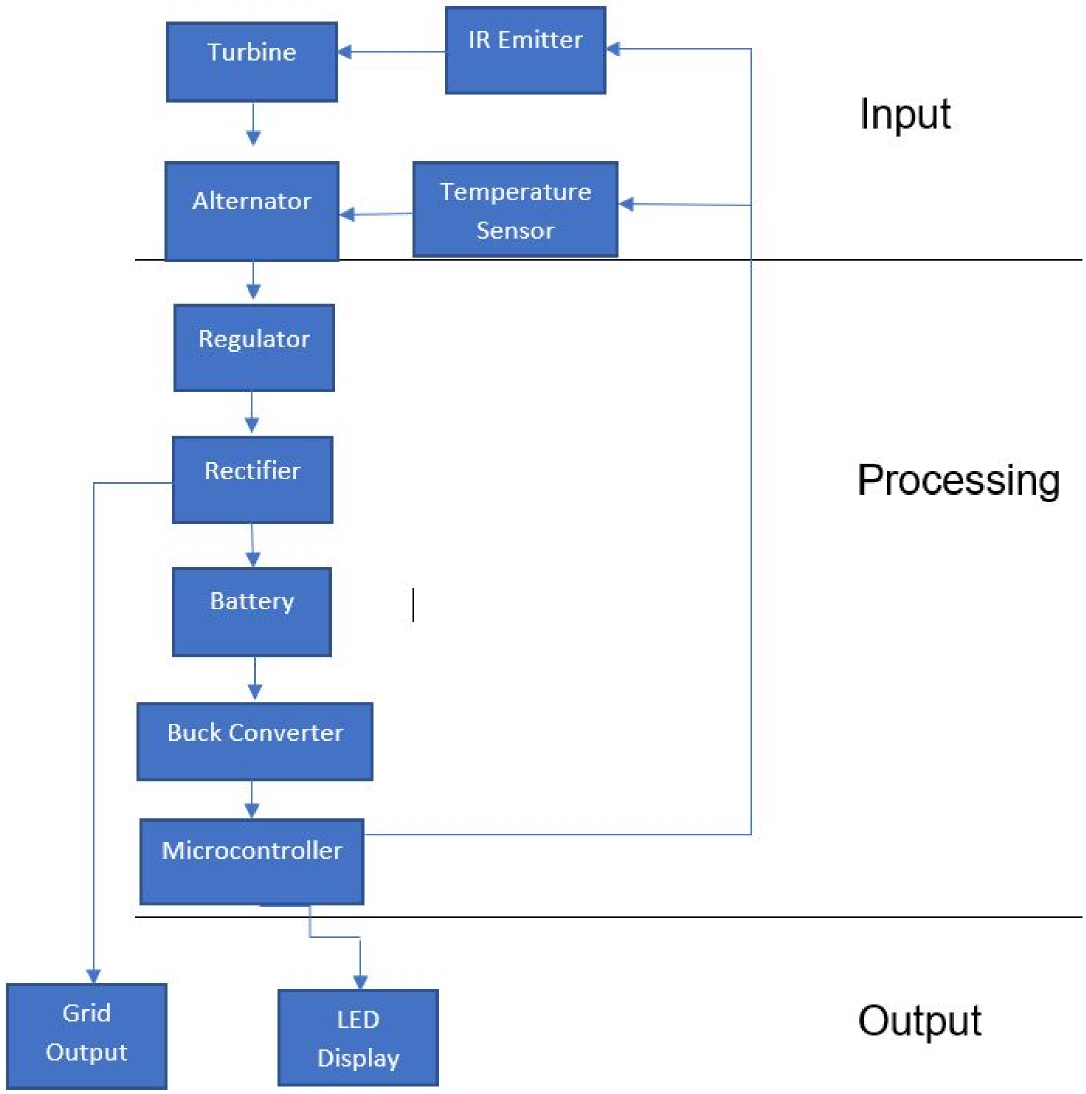

Fig 3.1

Charge/Output Power Schematic

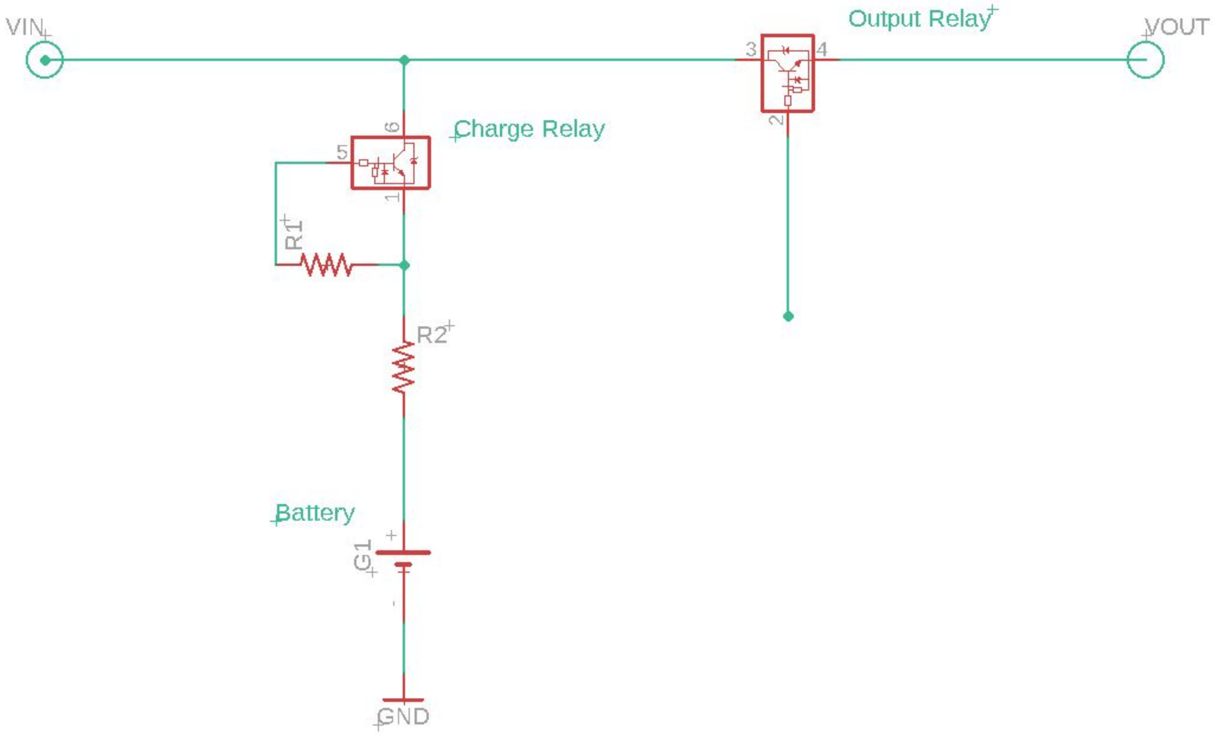

Fig 3.2

Useful Notes

Voltage divider for R1 and R2 must produce a voltage rated to open the relay once battery is charged fully.

The output relay is controlled by the microcontoller.

Charge relay will be normally open whereas the output relay is normally closed.

7. Flowchart of the Program

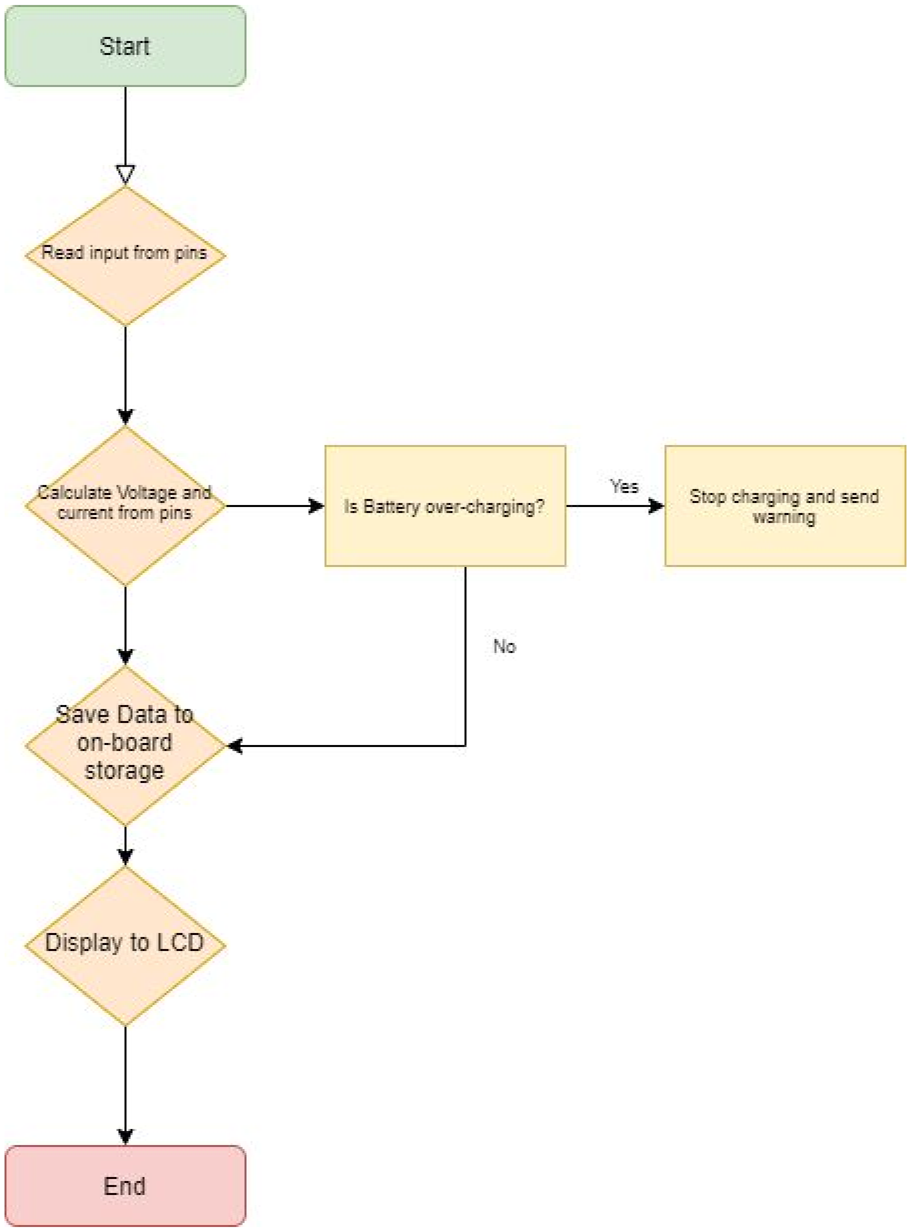

Fig 4.1

8. Part list and Bill of Materials

All component costs are from October 2020 and subject to change

Type	Model	Quantity	Individual Cost	Total Cost:	$331.46
Propeller					
Blade	2' length x 2" radius PVC Pipe	5.00	$5.00		
Shaft	3' x 2" OD Steel Tubing	1.00	$20.00		
Upper/Lower Discs	6" Radius 1/2" Thick Plexiglass	2.00	$10.00		
Base					
Generator Mount	2x2' 1/4" Thick Steel Plate	1.00	$5.00		
Gearing	Bicycle Gears	3.00	$5.00		
Outer Casing	6" Radius PVC Pipe	1.00	$10.00		
Chassis					
Electrical					
Microcontroller	Atmega 328	1.00	$1.90		
Charge Relay	IDEC Corporation RH1B-UDC12V	1.00	$11.48		
Output Relay	Grainger 5RLU7	1.00	$4.58		
Buck Converter	Oiyagai 5V 3A Dual USB Output	1.00	$8.50		
Battery	Interstate Batteries MTP-124R	1.00	$172.95		
Diodes					
SS 34 Diode	Chanzon SMD Fast Switching/Schottky/F	1.00	$0.10		
10 K Ω Resistor	CFR-12JB-52-10K	7.00	$0.10		
22 pF Capacitor	COM-08571	2.00	$0.25		
10 μF Capacitor	T322B106K006AT	2.00	$1.48		
100 μF	T598B107M006ATE045	2.00	$1.74		
1000 μF Capacitor	BOJACK BJ612	1.00	$0.60		
1000 Ω Resistor	PRT-14492	3.00	$0.05	(Minimun: 20Pcs)	
600 Ω Resistor	NS02B600R0FE12	1.00	$2.66		
Variable Resistor	3362P-1-105LF	1.00	$1.02		
100 Resistor	PRT-14493	1.00	$0.06	(Minimun: 20Pcs)	
330 Resistor	PRT-14490	1.00	$0.05	(Minimun: 20Pcs)	
470μH Inductor	MOONLIGHT IND60	1.00	$1.33		
Voltage Regulator	LD1117	1.00	$1.25		
Step-Down Voltage Re	LM2596	1.00			
16 MHz Crystal	COM-00536	1.00	$0.95		
Current Clamp	CR8401	1.00	$8.79		
Sensors					
Temerature Sensor	MCP9808	1.00	$10.70		
IR Emmiter	IR333-A	1.00	$0.50		
IR Reciever	PD333-3B/H0/L2	1.00	$0.50		
OP-Amp	LM538	1.00	$0.15		
Accessories					
Display	SSD1306	1.00	$17.50		
Push Buttons	Parts Express 060-632	5.00	$1.09		
Wifi Module	ESP8266	1.00	$9.43		

Fig 5.1

9. Appendices

9.1. Appendix A - Circuit Diagrams

9.1.1. Buck Converter:

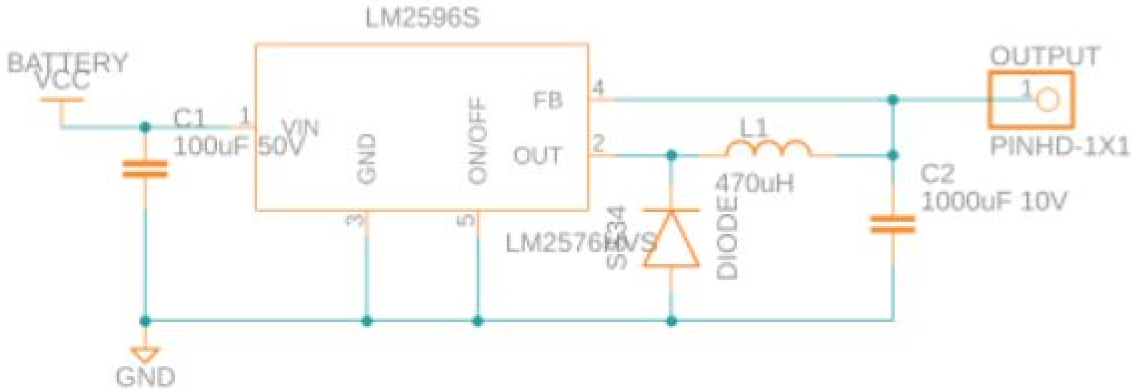

Fig 6.1

9.1.2 3.3v Regulator, Micro-Controller,Temp sensor, IR sensor, Display, and Wifi Module:

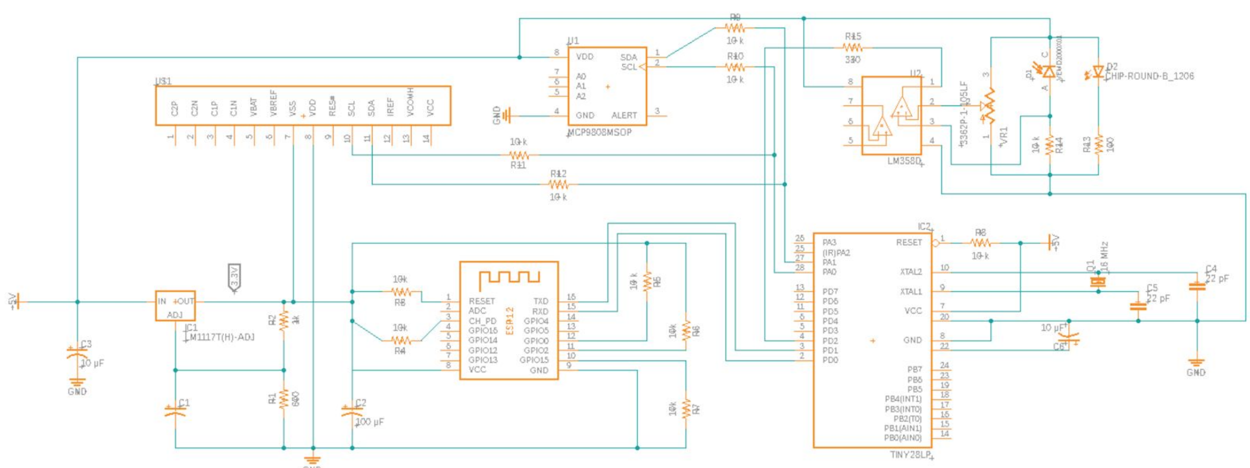

Fig 6.2

9.2. Appendix B - Coding with Comments

9.3. Appendix C - Potential Problems and Obstacles

9.3.1. <u>Turbulent Airflow</u>: When 15 miles within a 35 mile tunnel, a train passing through is within a more closed system than it would be traveling above ground. The sharp increase in air pressure and velocity deep within a tunnel system can have a chaotic affect on the uniformity of airflow that is produced. Turbulent airflow can lead to a much lower turbine efficiency.

9.3.2 <u>Poor Turbine Efficiency</u>: The wind turbine will need to be as efficient as possible in order to produce the most power out of the wind in the tunnel. Most wind turbines on the market today are between 35-45%. In order to make the device as efficient as possible the team will have to come up with an optimal blade design, find optimal places to install the device, minimize the turbulent airflow around the device, and minimize any losses created by moving parts.

9.3.3 <u>Poor Equipment</u>: Devices will have to be able to withstand and fully utilize immense amounts of wind energy over a lifespan of at least ten years. In order to do so, equipment will have to be able to endure high amounts of force and still maintain reasonable levels of efficiency. The locations where devices are to be installed are remote and therefore make repair costs much more expensive.

9.4. Appendix D - Component Explinantions

9.4.1 **Battery:**

Type: Interstate Batteries MTP-124R

Explanation: An MTP-124R lead-acid battery was chosen for several reasons. One, it is relatively cheap compared to other options. Two, lead-acid batteries are able to deal with high currents, something suitable for a rapidly fluctuating high current alternator. And three, It is a large sized battery and should have a reliable lifespan of at least 5 years.

9.4.2 **Relays:**

<u>Charge Relay:</u>
Type: IDEC Corporation RH1B-UDC12V
Explanation:

<u>Output Relay:</u>
Type: Grainger 5RLU7
Explanation:

9.4.3 **Buck Converter:**

Type: Oiyagai DC to DC Voltage Regulator Step Down Power Supply Buck Converter Module 6-40V to 5V 3A Dual USB Port Output

Explanation: A Oiyagai DC to DC Voltage Regulator Step Down Power Supply Buck Converter is used because this one device is able to perform two essential functions. It is able to step down the voltage output from the battery while at the same time providing a stable voltage and current output suitable for small devices (the microcontroller). The device also already comes equipped with all the ports that are required.

9.4.4 **3.3 Voltage Regulator:**
Type: LM1117

Explanation: A low dropout voltage regulator with a dropout of 1.2 V at 800 mA of load current. Used here for a constant 3.3v power supply.

9.4.5 **Wifi Module:**
Type: Esp8266

Explanation: The smallest 802.11b/g/n Wi-Fi SOC module, utilizes I^2C interface and enables wireless communication with any network device.

9.4.6 **MicroController:**
Type: Atmega 328

Explanation: A low power, CMOS 8-bit microcontroller, with a CPU throughput approaching one million instructions per second (MIPS) per megahertz. Open source software also enables easy troubleshooting and interfacing.

9.4.7 **Temperature Sensor:**
Type: MCP98083

Explanation: A high precision temperature module that can utilize I^2C interface for easy data gathering.

9.4.8 **IR sensor:**
<u>IR Emitter:</u>
Type: IR333-A

Explanation: A simple IR LED that can be detected by almost any photodiode

<u>IR Receiver:</u>
Type: PD333-3B/H0/L2

Explanation: A simple photodiode that detects IR signals from an IR LED

<u>Operational Amplifier:</u>
Type: LM358

Explanation: An op-amp integrated circuit from texas instruments that allows up to output a square wave based on IR emitter and receiver data.

9.4.9 **Display:**

Type: SSD1306

Explanation: A small monochrome matrix type display that uses I^2C interface

9.4.10 **Current Clamp:**

Type: CR8401 - Wire Lead Current Transformer - Measures Amperage

Explanation:

9.5. Appendix E - Calculations

9.5.1 Power Production

Assumptions:

- Device installed in 10% of the Gotthard Base Tunnel system
- Passenger trains produce maximum output
- Freight trains produce 75% maximum output
- Turbines move 100% of time train is passing and 0% all other times

Required Data:

- Gotthard Base Tunnel system consists of two 57km long tunnels
- System's required capacity: 2 passenger trains and 6 freight trains per hour in each direction
- 50 passenger trains pass through tunnel system each day
- Passenger train length = 200m
- Passenger train average speed in tunnel = 200km/h = 55.56 m/s
- Freight train average length = 700m
- Freight train average speed in tunnel = 120 km/h = 33.33 m/s
- Device's maximum output = 1140 W

Calculations:

Total distance of tunnel system = 57km * 2 tunnels = 114 km
Total distance of devices installed = 114km * 10% = 11.4 km
Number of passes freight trains make a day:

Ratio of freight trains to passenger trains = 3:1
Number of freight train passes = (50 passenger trains a day) * 3 = 150 passes

Passenger Train:

Time it takes for entire train to pass one point = 200m / (55.56m/s) = 3.6 s
Time it takes for front of train to pass all devices = 11.4km / (55.56m/s) = 205.2s
Time it takes for entire train to pass all devices = 205.2s + 3.6s = 208.8s
Time it takes for all trains to pass all devices in one day = 208.8s * 50 = 10440s

= 174 minutes = 2.9 hours
Daily power generated = 1140W * 2.9hours = 3306 Wh
Power generated yearly = 3306Wh * 365 days = 1.207 MWh

Freight Train:
Time it takes for entire train to pass one point = 700m / (33.33m/s) = 21 s
Time it takes for front of train to pass all devices = 11.4km / (33.33m/s) = 342 s
Time it takes for entire train to pass all devices = 342s + 21s = 363 s
Time it takes for all trains to pass all devices in one day = 363s * 150 = 54450s
= 907.5 minutes = 15.125 hours
Daily power generated = 1140W * 75% * 15.125hours = 12.93 kWh
Power generated yearly = 12.93kWh * 365 days = 4.72 MWh

Total power produced a year = 4.72MWh + 1.207MWh = **5.927 MWh**

$$RPM \times Current\ Variable = Output\ Current\ (Ao)$$
$$Drag\ /\ (Area * .5 * r * V\hat{}2) = Drag\ Coefficient\ (Cd)$$

Vo = 1.25 (1 - R_2 / R_1)

9.6. Appendix F - Datasheets

9.6.1. **LM1117 voltage regulator :**
https://www.ti.com/lit/ds/symlink/lm1117.pdf?ts=1601864449147&ref_url=https%253A%252F%252Fwww.google.com%252F

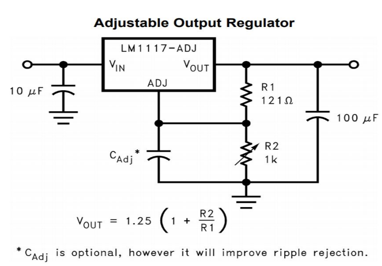

Fig 6.3

9.6.2. **ESP 8266 - 12 Wifi module info:**
https://www.mouser.com/datasheet/2/975/1513856197DS-ESP-12S-1589038.pdf

9.6.3. **ATMEGA-328 MicroController:**

http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061B.pdf

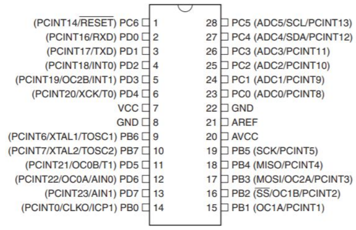

Fig 6.4

9.6.4. **Interstate Batteries MTP-124R:**

Part Number	MTP-124R	**Termination Code**	Common Code A
Group Size	124R	**Voltage**	12
Cold Cranking Amps	700	**Wet/Dry**	W
Cranking Amps	875	**Footnotes**	
(RC) Min @ 25 Amp	120		
Length	10 3/8		
Width	7		
Height	8 5/8		
Weight	40		

Fig 6.5

9.6.5. **LM2596**:

https://www.ti.com/lit/ds/symlink/lm2596.pdf

9.6.6. **Oiyagai DC to DC Voltage Regulator Step Down Power Supply Buck Converter:**

Specifications:

Input: 6V-40V
Output: 5V / 3A (MAX)
Converting Efficiency: 92% (MAX)
Switching frequency: 150KHZ
Load capacity: Maximum output 3A
Working temperature: -40 °C ~ 85 °C
Module Size: 59mm x 21mm x 17mm/2.32X0.83X0.67inch(L*W*H)

9.6.7 **MCP9808 High Accuracy I2C Temperature Sensor**

https://cdn-shop.adafruit.com/datasheets/MCP9808.pdf

9.6.8. **SSD1306 Monochrome OLED**
https://cdn-shop.adafruit.com/datasheets/SSD1306.pdf

9.6.9. **IR333-A IR Emitter**
https://cdn-shop.adafruit.com/datasheets/IR333_A_datasheet.pdf

9.6.10 **PD333-3B/H0/L2 IR Photodiode**
https://www.everlight.com/file/ProductFile/PD333-3B-H0-L2.pdf

9.6.11 **LM358 Operational Amplifier**
https://www.ti.com/lit/ds/symlink/lm158-n.pdf

9.6.12 **3362P-1-105LF Variable Resistor**
https://www.bourns.com/docs/Product-Datasheets/3362.pdf

9.6.13 **16MHz Crystal Oscillator**
https://www.nxp.com/docs/en/application-note/AN2500.pdf