High Efficient Stand-alone Streetlamp

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ECE 445 Proposal - Fall 2017
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1 Introduction

1.1 Objective

Our goal is to design a stand alone streetlight that will power itself through sunlight (Solar Power) and store the energy for later use (at night). Lead acid batteries will power LED lights that can produce 3000+ lumen. Battery status and customization will be available through a mobile app on a bluetooth connected smartphone.

1.2 Background

In some area in the US/around the world it is difficult to have the access to the power grid. It would be inefficient to pull a power line across an entire region to power up a few street lights. Furthermore, during natural disasters, such as hurricanes, the power is often cut in a region, and essential streetlights will stop functioning at night. An independent, stand-alone streetlight that extracts and stores solar energy in a battery to power the light bulb will fix these problems.

1.3 High-level Requirements List

- Lead Acid Battery Capacity (>60Ah)
    - Needs to operate two consecutive nights without any input power
- Average daily input power from power panel at least (400Wh, 33.3Ah)
- LED lights produce 3000+ lumens for minimum 2 days on a full charge

2 Design

2.1 Diagrams

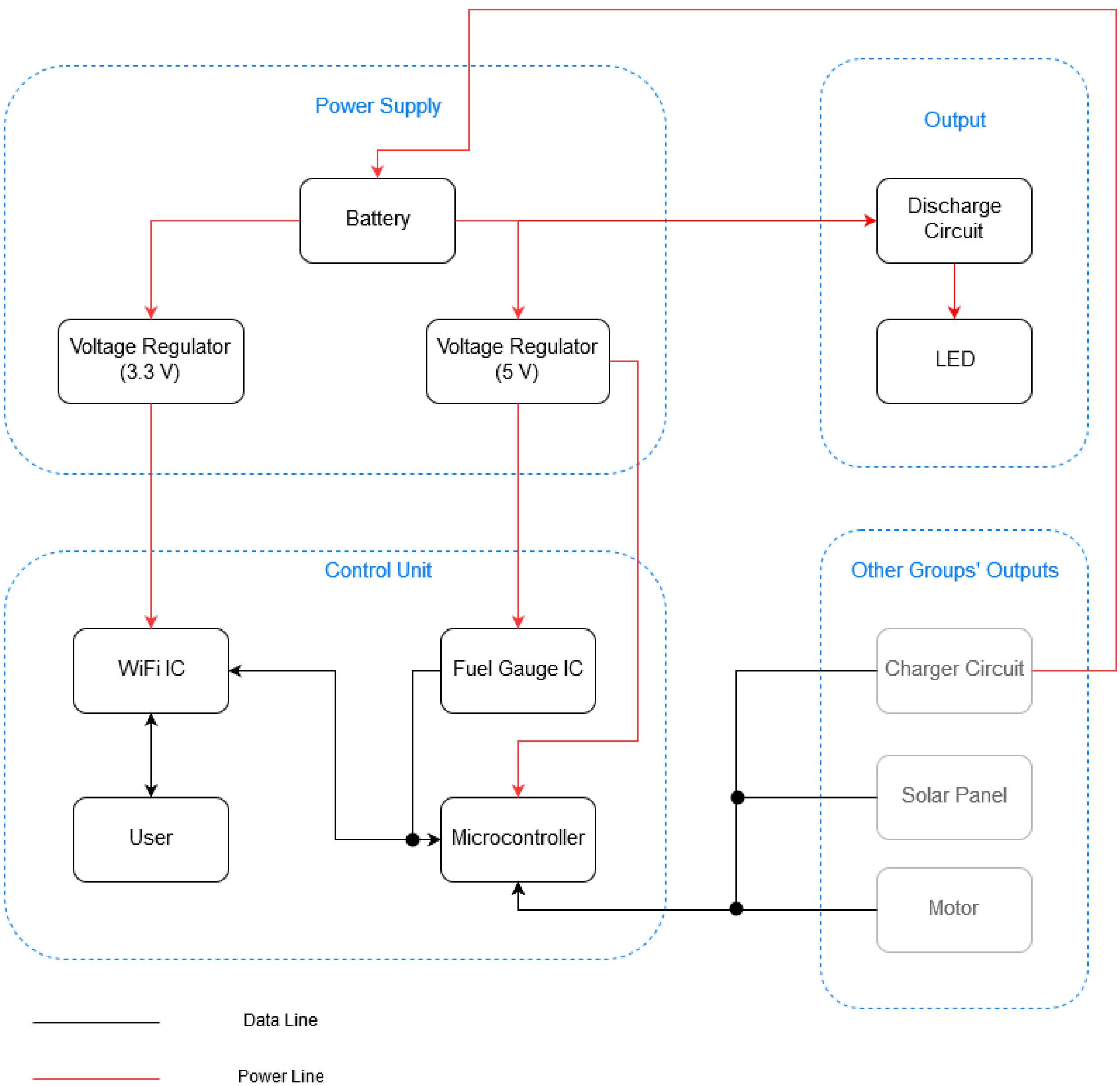

Figure 2.1 Block Diagram

2.2 Block Diagram Description

The battery will receive charge from a charging circuit another group is developing. The battery will then supply 12V to a discharge circuit that will power the LED light when the photoresistor senses the sunlight has lowered to a certain point. The battery will also supply power to a 5V voltage regulator to a microprocessor and fuel gauge and to a 3.3V voltage regulator to power the WiFi IC. The microcontroller will receive input from the fuel gauge and other groups outputs such as the charging circuit's voltage and current, solar panel output, and the motors current angle. The microcontroller will also send and receive signals to the WiFi IC to relay to the user the necessary data.

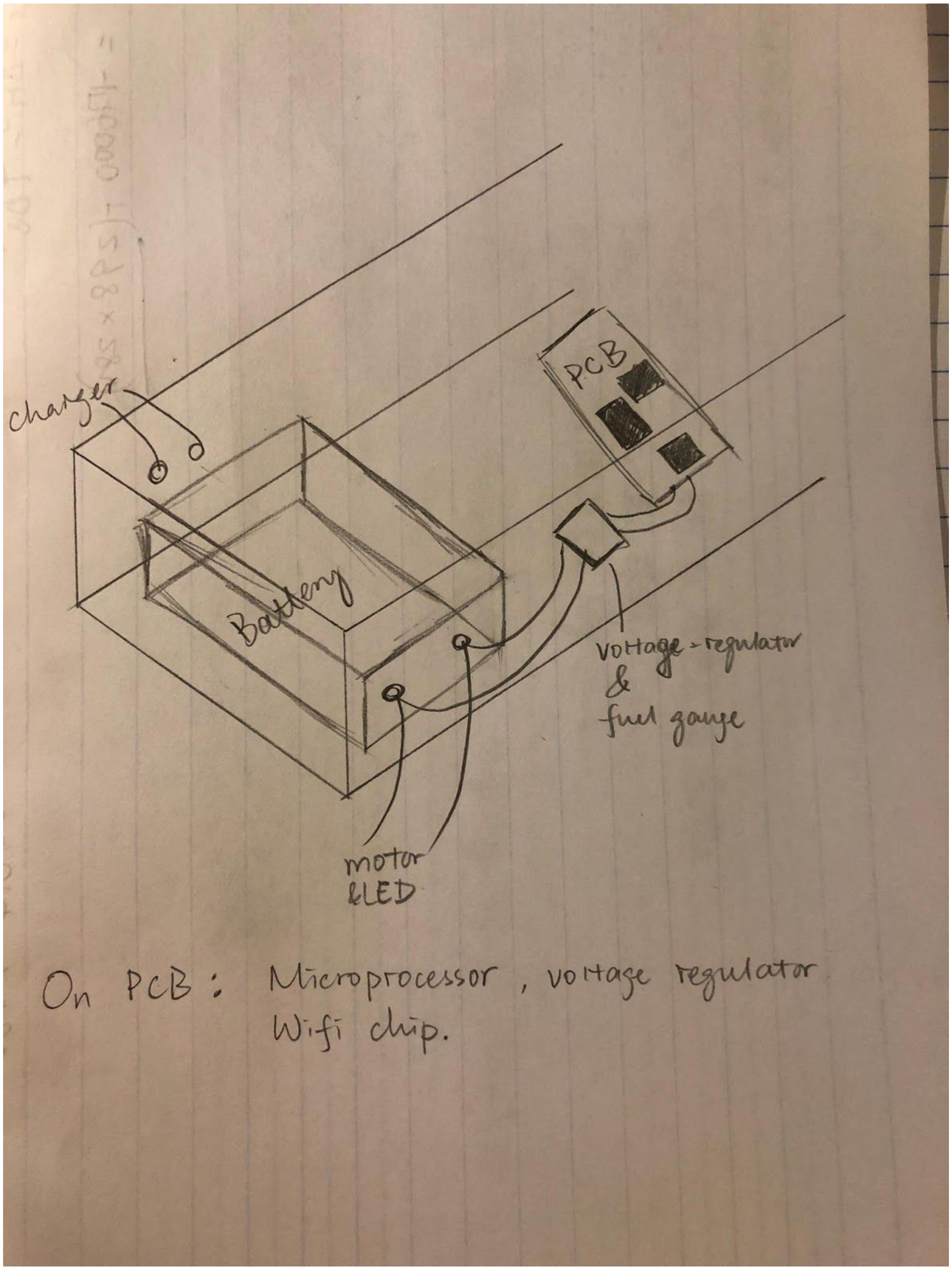

Figure 2.2 Physical Design Sketch

2.3 Power Supply

2.3.1 Lead-Acid Battery

Where the energy is stored and used for the LED and other components. The battery should have a nominal voltage of roughly 7.4V (2 cells) or 11.1V (3 cells). Battery capacity should be at least 60Ah, and maximum acceptable charging current should be roughly 0.25C.

With 33 W output and we want to operate 16 hours

$$P * t = 33W * 16h = 528Wh$$

The battery capacity should be at least 528Wh.

$$I = \frac{P}{V} = \frac{528Wh}{12V} = 44Ah$$

The battery should be larger than 44Ah considering the motor needed for adjust solar panel.

Requirements	Verifications and Cost
1. Capacity of 60 Ah+ 2. Maximum charging current to be 0.2C (12A) and equivalent discharging current	Found the battery that meets the requirements.

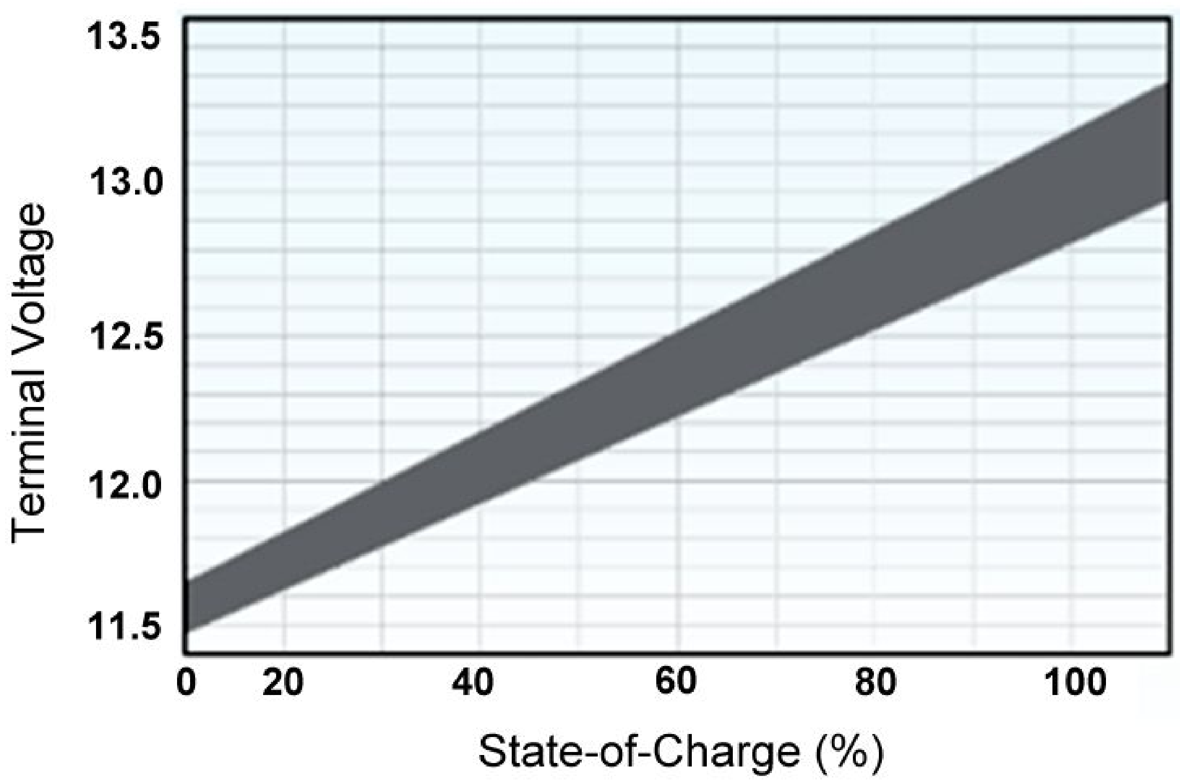

Figure 2.3 Voltage band of a 12V lead acid monoblock from fully discharged to fully charged [5]

This figure is a similar diagram, further detail needed to be corrected after doing the measurement using the battery.

2.3.4 Voltage-regulators (Buck converter)

The input voltage for the microcontroller and fuel gauge is 5V. We need the regulators to step-down to achieve 5V.

Requirements	Verifications and Cost
1. Input voltage range from 5-15V 2. Regulate voltage from battery voltage to 5V (buck converter)	Found the voltage regulator that meets the requirements.

The input voltage for the wifi module is 3.3V. We need the regulators to step-down to achieve 3.3V.

Requirements	Verifications and Cost
3. Input voltage range from 5-15V 4. Regulate voltage from battery voltage to 3.3V (buck converter)	Found the voltage regulator that meets the requirements.

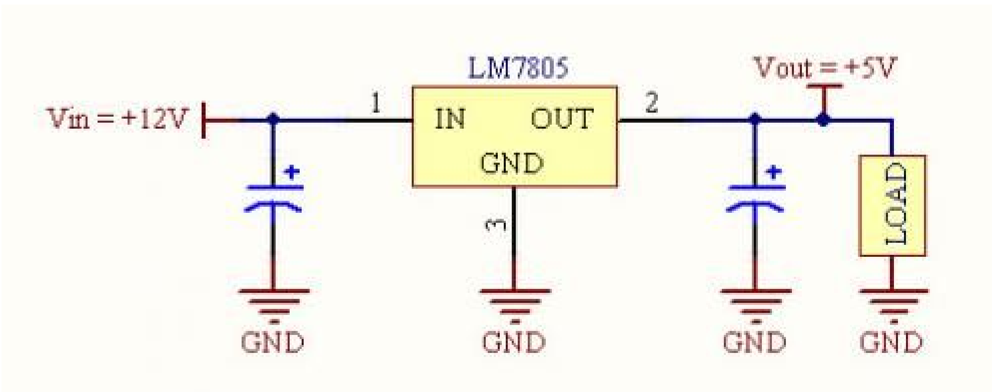

Figure 2.4 12 V to 5 V voltage regulator

2.3.5 fuel gauge

This module will monitor how much capacity left for the battery and transform to the microcontroller, which will further be displayed on mobile phone as percentage.

Requirements	Verifications
1. Minimize the inaccuracy to 1% 2. Should accept an input Voltage of 5V 3. Send battery capacity and other information status to the microprocessor through I2C or 1-Wire.	Obtain the I-V curve under different circumstances.

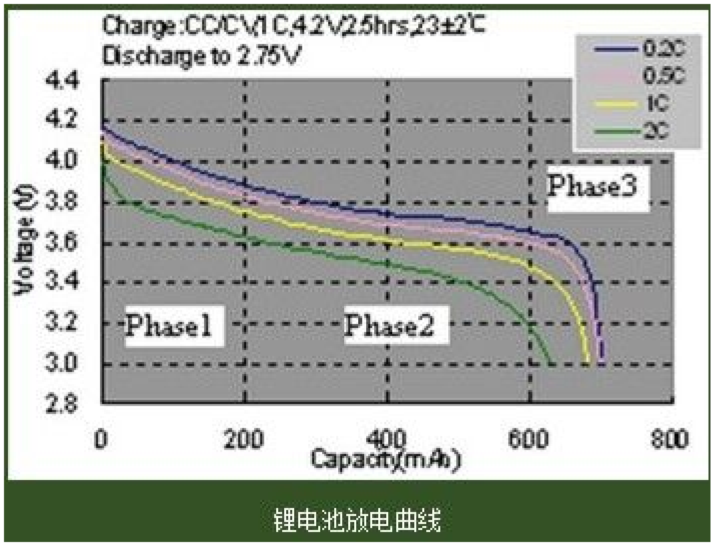

Figure 2.5

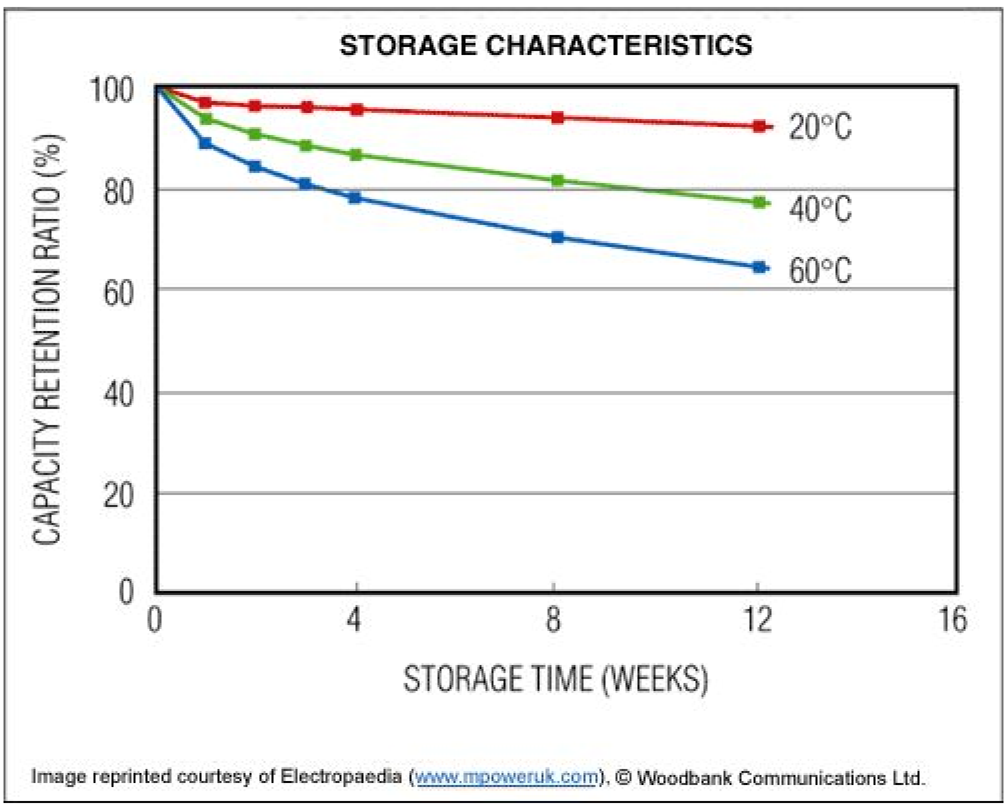

Figure 2.6 Temperature influencing the discharge of the battery

2.4 Output

2.4.1 LED (load)

Power consumption should be roughly 35-40 W; and needs to produce a minimum of 3000 lumens. Multiple LED could be used.

Requirements	Verifications and Cost
1. Output 3000+ lumen 2. Input Voltage of 12V, Power consumption 35-40 W 3. Either internal or external switch (togglable)	Found the LED that meets the requirements.

2.4.2 Discharging circuit (photoresistor)

This module will sense the light intensity and determine when to start discharging from the battery which is when to turn on the LEDs.

Requirements	Verifications and Cost
1. Discharge when light density is low	Experiment and set the range for photoresistor before use.

2.5 Control Unit

2.5.1 Microcontroller

The microcontroller will be powered by the battery; it will control/communicate with the wifi module. It will also read the data from the fuel gauge and input from other groups voltages and currents across modules to relay to the WiFi IC to show the user.

Requirements	Verifications
1. Enough GPIO to have communication with fuel gauge, Wifi-IC, relays for switches, etc. 2. At least 10 MB of internal flash to store temporary data.	

2.5.2 WiFi-module

Query and send the charging status of the battery, as well as the output of the solar panel, the current position of the motor, and the status of the charging circuit.

Requirements	Verifications
1. Send messages up to 50 +/- 5 meters 2. Receive messages up to 50 +/- 5 meters	1, 2 A. Measure 50 meters with a tape measurer. B. Send a message to get battery charge status and see if a message is sent back with the data.

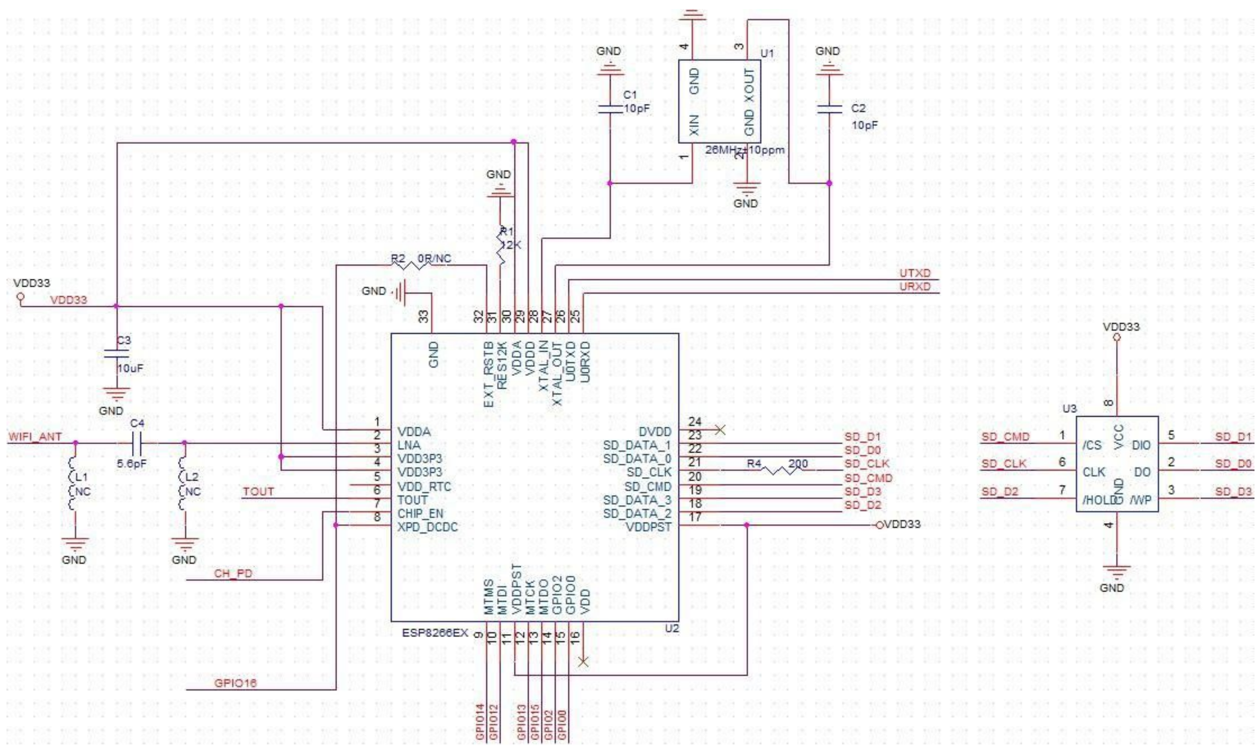

Figure 2.7 ESP8266 Wifi Module Schematic [4]

2.6 Tolerance Analysis

The most critical part of our design is the fuel gauge, due to all of the other components having a relatively large tolerance scale.

For the battery fuel gauge, all the calculations have relatively high error. As a result, we choose to test it for enough times and we can get a steady state of the battery and conclude into an equation which include the adjustments for the error that can represent how much capacity left for the battery.

Since these results are going to be displayed to the user, we will minimize the error to be within 5%.

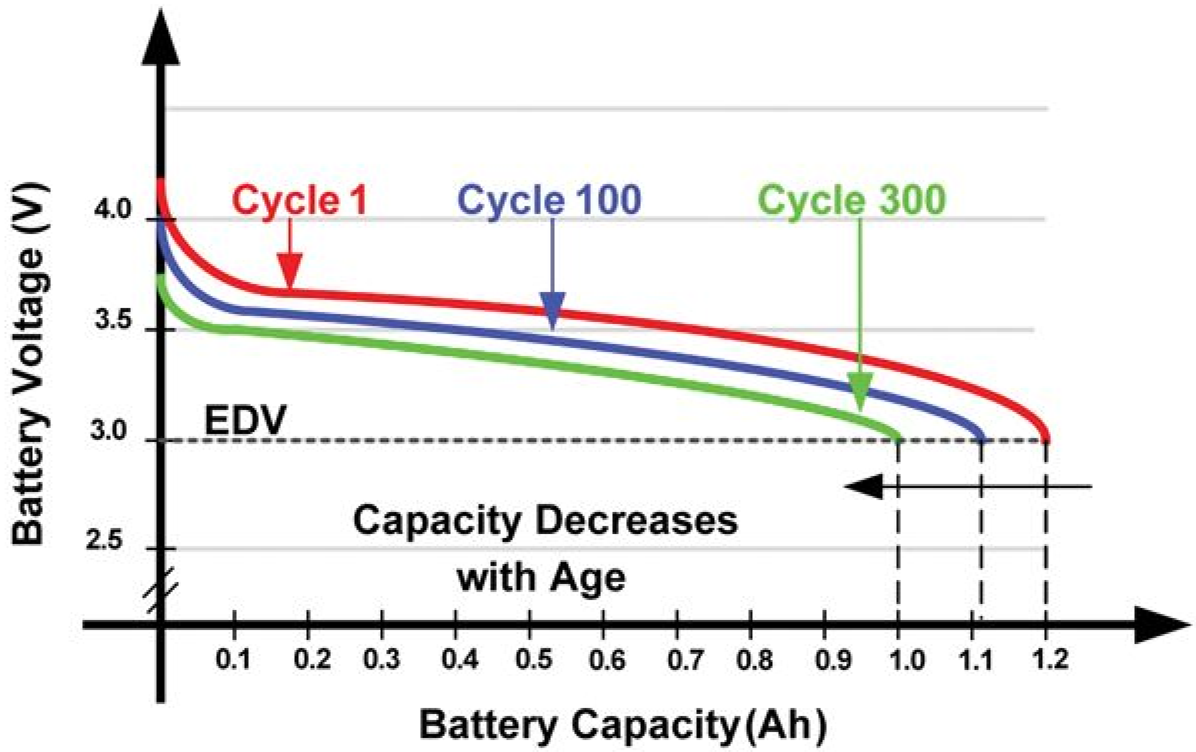

Figure 2.8 [6]

From the plot above, when the cycle becomes 300 times, the error is going to be:

$$\frac{4.25-3.75}{3.75} * 100\ \% = 13.33\%$$

This is unavoidable self-aging error.

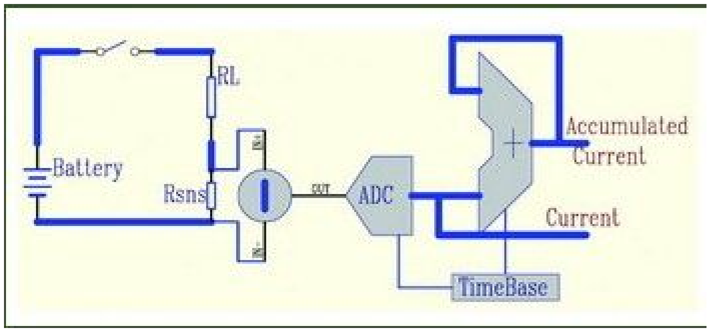

Figure 2.9

$$Q = \int_0^t I_O(t)\,dt = \int_0^t \frac{V_S(t)}{R_{SNS}}\,dt = \frac{1}{R_{SNS}}\int_0^t V_S(t)\,dt$$

By integrating the current of the discharging, we can get how many column is flowing out of the battery.

3. Costs

Our labor cost is $30 per hour for two people for the duration of 12 weeks:

$$2 * \frac{\$30}{hour} * \frac{8\ hours}{week} * 12\ weeks = \$5760$$

Part	Cost
WiFi: HiLetgo ESP8266 NodeMCU CP2102 ESP-12E (Amazon)	$8.79
Battery : 12 V 44Ah SLA Rechargeable Battery by Interstate Batteries (Amazon)	$180
Voltage regulator (5V) (Amazon)	$16
Voltage regulator (3.3V) (Amazon)	$ 9

Photoresistor (Amazon)	$10
PCB (PCBWay)	$5
Total	$222.79 + tax

Parts and labor together come to $5982.79 + tax

4. Schedule

Week	Collin	Xiaolou
10/8/17	Prototype WiFi connection	Test the battery and have the I-V curve
10/15/17	Create web server with dummy values	PCB designing
10/22/17	Read set values and display to web page	Calculations of the fuel gauge and verify
10/29/17	Fix bugs with web page	Discharging circuit and PCB
11/5/17	Read battery values and store average and recent values. Then display to webpage	Communicate with solar panel group and connect the photoresistor
11/12/17	Fix bugs with battery values	Debug the fuel gauge along with software displaying and modify the calculations of fuel gauge
11/19/17	Integrate other groups' values	Test discharging circuit and debug
11/26/17	Fix bugs with other group's values	Wrap up connecting
12/3/17	Work on presentation	Work on presentation

5 Ethics and Safety

5.1 Ethics

“1. to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;”[1]
With our project, we are charging and discharging a battery. This introduces a potential danger of the battery explosion or expelling acid. For this reason, we will show warnings for any danger and accept responsibility for our choices.

“3. to be honest and realistic in stating claims or estimates based on available data;”[1]
We will not over promise on our light output or how long the light can stay on.

“4. to reject bribery in all its forms;”[1]
We will not accept bribery from other groups working on the same problem to allow their projects to be better than ours.

“7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;”[1]
We will ask our TA for assistance whenever we are unsure to make sure we aren’t putting anyone at risk.

5.2 Safety

Our largest safety concern is with our battery. Batteries store large amount of chemical energy, especially in our project, a size of 60Ah can cause extreme heat which could cause fire if the battery is internally or externally shorted. We plan to use two series and multiple in parallel to achieve this capacity. Nominal voltage will be roughly 7.4 V, and shorting this voltage could generate a very high current.
Operational wise, we want to prevent damage to the battery and other potential hazards by stopping the charging or discharging of the battery when it is outside of the regulated temperatures. For lead acid batteries, this is between -20 to 50 degrees celsius for charging and discharging.[2]
User wise, our safety concern is making sure the final streetlight is bright enough to light up the ground as required and the ability to provide light throughout the night.
Due to lead acid batteries being volatile and very dangerous, we will look up the material data safety sheet before purchase and keep it on person at all times in lab.[3]

6 Citations and References

[1] *Ieee.org, "IEEE IEEE Code of Ethics", (2017). [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 19- Sept- 2017].*

[2] *“Charging at High and Low Temperatures”, (2017) [Online]. Available: http://batteryuniversity.com/learn/article/charging_at_high_and_low_temperatures. [Accessed: 19 - Sept - 2017].*

[3] *Safe Practice for Lead Acid and Lithium Batteries. (2016). [ebook] Champaign, pp.1-2. Available at: https://courses.engr.illinois.edu/ece445/documents/GeneralBatterySafety.pdf [Accessed 2 Oct. 2017].*

[4] *Itead.cc. (2016). ESP8266 Serial WIFI Module - ITEAD Wiki. [online] Available at: https://www.itead.cc/wiki/ESP8266_Serial_WIFI_Module [Accessed 2 Oct. 2017].*

[5] *Batteryuniversity.com. (2017). Measuring State-of-charge - Battery University. [online] Available at: http://batteryuniversity.com/learn/article/how_to_measure_state_of_charge [Accessed 2 Oct. 2017].*

[6] Kadirvel, K. (2017). *Cell Capacity*. [image] Available at: https://www.ecnmag.com/article/2012/11/fundamentals-battery-fuel-gauging [Accessed 8 Oct. 2017].

2.5 https://www.rs-online.com/designspark/content-333
2.6 https://www.maximintegrated.com/en/app-notes/index.mvp/id/3958